IXODID TICKS OF DOMESTIC AND WILD ANIMALS IN SOUTH AFRICA AND SOME NEIGHBOURING COUNTRIES

by

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This treatise is dedicated to the memory of my father,
Izak Gerhardus Horak (1904-1988)

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My most sincere thanks go to my wife, Petra, for her patience and understanding, particularly during the days and weeks that I was away from home on field trips, and also during the evenings, when I was at home, but working on the manuscripts that catalogue my findings.

Much of my research would not have been possible without generous financial support. For this I am greatly indebted to the organisations then known as the Meat Board, the Mohair Board, and the Wool Board, also to the Department of Agriculture, Rhodes University, Pretoria University, Free State University, the National Research Foundation, and the pharmaceutical companies Bayer Animal Health and Pfizer Animal Health.

My gratitude too goes to the South African National Parks and to various provincial nature conservation authorities for placing the hosts, and their associated parasites, both of which they are mandated to conserve, at my disposal. I am also most grateful for the use of their facilities and for the assistance given to me by their staff. My thanks go to various gun-bearers who, for my protection, walked many kilometres with me while I was collecting questing ticks from the vegetation in the Kruger National Park. Dr V. de Vos and Dr L.E.O. Braack and Mr A.L.F. Potgieter facilitated my research in the Kruger National Park and several of the other national parks. I have been similarly privileged to work with a number of private landowners amongst whom Mr and Mrs W.A. Phillips of the farm 'Bucklands', Messrs John and Simon Matthews of the farm 'Glendye', Mr J. van Niekerk of the farm 'Preezfontein', and the members of the Sidbury Farmers' Study Group. My thanks too to my numerous co-workers, most notably Prof J. Boomker, Dr V. de Vos, Prof L.J. Fourie, Mr A.M. Spickett, Dr L.E.O. Braack, Dr J.B. Walker and Dr J.G. Gallivan.

I could not have identified nor counted the enormous numbers of ticks that underpin the contents of this treatise had I not had the assistance of a number of people with processing the skins and hides of animals for tick recovery, and thereafter with

separating the ticks from the rather bulky processed material. Here I must make particular mention of Johan Sithole, Eddie Williams, Michael Knight, Santa Meyer, Louise Horak, André Uys and Renadè Bartlett.

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PREAMBLE

The past 47 years of my working-life have been spent in the discipline of Veterinary Parasitology, first in Helminthology and subsequently also in Entomology and Acarology. My particular pleasures have been fourfold, firstly the trematode *Calicophoron microbothrium* (then known as *Paramphistomum microbothrium*), a parasite of domestic sheep, goats and cattle, secondly the nematodes that infect domestic and wild bovids and suids, thirdly the larvae of a variety of oestrid flies that infest both domestic and wild ungulates, and finally the ixodid ticks that infest nearly all mammals and some birds. The research on *C. microbothrium*, the surveys on helminths of pigs, sheep cattle, impalas and blesbok in the province then known as Transvaal, and the subsequent surveys on helminth and arthropod parasites of domestic and wild animals in southern Africa have constituted the fabric of three previous doctoral theses, namely:

Horak, I.G. 1967. Host-parasite relationships of *Paramphistomum microbothrium* Fischoeder, 1901, in experimentally infested ruminants, with particular reference to sheep. DVSc thesis: Department of Parasitology, Faculty of Veterinary Science. University of Pretoria, 85 + xxxi pp.

Horak, I.G. 1980. The incidence of helminths in pigs, sheep, cattle, impala and blesbok in the Transvaal. PhD thesis: Department of Zoology, University of Natal, Pietermaritzburg, 201 + xvii pp.

Horak, I.G. 1989. Studies on helminth and arthropod parasites of some domestic and wild animals in southern Africa. DVSc thesis (based on published findings), Department of Parasitology, Faculty of Veterinary Science, University of Pretoria, 671 + xiv pp.

The present dissertation is devoted to ixodid ticks, and has been compiled from research published since 1988 on free-living questing ticks, and on the ticks infesting humans, cattle, sheep, goats, dogs and a number of wildlife species, including rodents and birds, at various localities in southern Africa. Many of these publications contain data on other ectoparasites and some also on helminths. The latter data are not the subject of this

treatise, but have unavoidably been included because of their incorporation in the publications comprising the body of the thesis.

OUTLINE OF THESIS

I have chosen to divide the dissertation into chapters, some of them with subsections, each covering a specific topic. The sequence in which the various chapters have been arranged is as follows: taxonomy (of the parasites), morphometrics (of the hosts), geographic distribution (of the ticks), free-living questing ticks, ticks infesting humans, followed by a chapter on the ticks infesting domestic livestock with subsections on the ticks of cattle, sheep, goats, sympatric cattle and goats, and dogs, then by a similar chapter on the ticks of wildlife, with subsections on the ticks of wild ruminants, suids and rhinoceroses, carnivores, leporids, small mammals, birds, reptiles, and sympatric wildlife species, followed by chapters dedicated to control and to review articles. These are succeeded by a chapter appraising my studies, and finally by a section that lists the products that have emanated from my work.

Each chapter, or its subsections, are treated as an entity and the names of all the authors of each publication are listed the first time that the publication is referred to in the chapter or its subsections. A similar protocol applies to the scientific names of the various tick species in that they are supplied in full on the first occasion that they are used in a chapter or its subsections. The common names of the various host species have been used throughout, and are accompanied by their scientific names the fist time that they are used in a chapter or subsection thereof. The references supplied at the conclusion of each chapter or subsection, have been listed in chronological order, irrespective of the author, as this in some degree reflects the progression of my research. Where more than one publication has appeared in the same year, the year of publication is suffixed by the letters a, b, c, d etc., according to the overall chronology of all my publications irrespective of the chapter or its subsection in which it has been included. The bound publications germane to each chapter or subsection thereof follow the same chronological sequence as the references. In the text of some of the chapters, I may refer to some of my own work that is relevant to this treatise, but which does not comprise an integral part of it, or that was incorporated in an earlier thesis. The latter references are included in the list of references at the end of each chapter with the postscript (Reference only). In Chapter 10 the references are treated as in any research publication.

CHAPTER 1

TAXONOMY

Two of my contributions in the field of taxonomy are of particular significance. The first is my participation as a co-author of the book by Jane B. Walker, formerly of the Onderstepoort Veterinary Institute, and James E. Keirans, erstwhile Curator of the United States National Tick Collection and Ivan G. Horak, Emeritus Professor of Parasitology, devoted to the genus *Rhipicephalus*, or brown ticks, of the world (Walker, Horak & Keirans 2000). Although the taxonomy of the majority of species belonging to other ixodid tick genera had been addressed in mono-generic or multi-generic monographs, published in the first half, or early in the second half of the 20th century, most authors had avoided tackling this important, but complex genus. In our book we attempt to cover not only the taxonomy of the adult ticks, but also that of their immature stages, where these are known. In addition we list the host records of both the adult and immature stages, and where possible their sites of attachment, life cycles, seasonal occurrence, geographic distribution and role as vectors of disease. My contribution is confined to aspects of the morphology, host preference, seasonal abundance, geographic distribution and vector status of those species occurring in southern Africa and to the latter four facets of some of the other species occurring in Africa. Jane Walker and I also describe two new species in this book, namely *Rhipicephalus oreotragi* Walker & Horak 2000, and *Rhipicephalus warburtoni* Walker & Horak 2000. This book already serves as a major reference source for other authors and will continue to do so not only in the foreseeable future but also for generations of researchers to come.

The second contribution of significance is the compilation of a list of valid tick names for the argasid and ixodid ticks of the world (Horak, Camicas & Keirans 2002b). This list was compiled with the benefit of three previous lists and by the inclusion of taxa described subsequent to the compilation of those lists. The list has been a source of controversy since its publication, in that in it one of the best known ticks in the world, namely *Boophilus microplus* and its nearly equally well known African counterpart,

Boophilus decoloratus, as well as the other three ticks in this genus, were placed in the subgenus *Boophilus* within the genus *Rhipicephalus.*

In addition to the aforementioned I supplied much of the biological data in support of the description of *Rhipicephalus exopthalmos* Keirans & Walker 2000, a tick infesting scrub hares, *Lepus saxatilis*, and ruminants, and of the redescription of *Rhipicephalus oculatus*, a tick infesting Cape hares, *Lepus capensis*, and scrub hares (Keirans, Walker, Horak & Heyne 1993).

D.A. Apanaskavich, of the Russian Academy of Sciences, St Petersburg, and currently Assistant Curator of the United States National Tick Collection, joined me in 2005 and spent nearly two years in my laboratory as a postdoctoral fellow. He, as senior author, and I, as co-author, collaborated in taxonomic revisions of ticks of the genera *Hyalomma* (Apanaskevich & Horak 2006) and *Haemaphysalis* (Apanaskevich, Horak & Camicas 2007). During the course of these studies we demonstrated that the tick, previously known in South Africa as *Hyalomma marginatum turanicum*, was an old taxon, *Hyalomma glabrum*, and that it is the only species of the genus *Hyalomma* that occurs solely in the southern hemisphere. We also proved that the tick, hitherto known in South Africa as *Haemaphysalis leachi*, was also an old taxon, *Haemaphysalis elliptica*, described by Koch from the Cape of Good Hope in 1844. It is this tick that transmits *Babesia canis rossi*, the cause of virulent babesiosis in domestic dogs, and not true *H. leachi*, which occurs further north in Africa.

Keirans, J.E., Walker, Jane B., Horak, I.G. & Heyne, Heloise, 1993. *Rhipicephalus exophthalmos* sp. nov., a new tick species from southern Africa, and redescription of *Rhipicephalus oculatus* Neumann, 1901, with which it has hitherto been confused (Acari: Ixodida: Ixodidae). *Onderstepoort Journal of Veterinary Research*, 60: 229-246.

Walker, Jane B. & Horak, I.G. 2000. *Rhipicephalus oreotragi* Walker & Horak, 2000, sp. nov. In *The genus* Rhipicephalus *(Acari, Ixodidae): a guide to the brown ticks of the World.* Walker, Jane B., Keirans, J.E. & Horak, I.G. Cambridge University Press: Cambridge: 330-333.

Walker, Jane B. & Horak, I.G. 2000. *Rhipicephalus warburtoni* Walker & Horak, 2000, sp. nov. In *The genus* Rhipicephalus *(Acari, Ixodidae): a guide to the brown ticks of the World.* Walker, Jane B., Keirans, J.E. & Horak, I.G. Cambridge University Press: Cambridge: 463-470.

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Horak, I.G., Camicas, J.-L. & Keirans, J.E. 2002b. The Ixodidae, Amblyommidae and Nuttalliellidae (Acari: Ixodida): a world list of valid tick names. *Experimental and Applied Acarology*, 28: 27-54.

Apanaskevich, D.A. & Horak, I.G. 2006. The genus *Hyalomma* Koch, 1844. I. Reinstatement of *Hyalomma* (*Euhyalomma*) *glabrum* Delpy, 1949 (Acari, Ixodidae) as a valid species with a redescription of the adults, the first description of its immature stages and notes on its biology. *Onderstepoort Journal of Veterinary Research*, 73: 1-12.

Apanaskevich, D.A., Horak, I.G. & Camicas, J.-L. 2007. Redescription of *Haemaphysalis* (*Rhipistoma*) *elliptica* (Koch, 1844), an old taxon of the *Haemaphysalis* (*Rhipistoma*) *leachi* group from East and southern Africa, and of *Haemaphysalis* (*Rhipistoma*) *leachi* (Audouin, 1826) (Ixodida, Ixodidae). *Onderstepoort Journal of Veterinary Research*, 74: 181-207.

Onderstepoort Journal of Veterinary Research, 60:229–246 (1993)

Rhipicephalus exophthalmos sp. nov., a new tick species from southern Africa, and redescription of *Rhipicephalus oculatus* Neumann, 1901, with which it has hitherto been confused (Acari: Ixodida: Ixodidae)

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ABSTRACT

KEIRANS, J.E., WALKER, JANE B., HORAK, I.G. & HEYNE, HELOISE 1993. *Rhipicephalus exophthalmos* sp. nov., a new tick species from southern Africa, and redescription of *Rhipicephalus oculatus* Neumann, 1901, with which it has hitherto been confused (Acari: Ixodida: Ixodidae). *Onderstepoort Journal of Veterinary Research*, 60: 229–246

Rhipicephalus exophthalmos sp. nov., a species which has in the past been confused with *Rhipicephalus oculatus* Neumann, 1901, is described and illustrated from laboratory-reared specimens. Preferred hosts for the adults of this tick are various domestic and wild ungulates and hares. It is widely distributed in Namibia and in the south-eastern Cape Province, South Africa, with only scattered records from elsewhere.

The adults of *R. oculatus* are redescribed and illustrated, and the immature stages are described and illustrated for the first time. All stages feed virtually exclusively on leporids. It is common in parts of the eastern and southern Cape Province, with few records as yet from other parts of South Africa and Namibia.

INTRODUCTION

Neumann (1901) described *Rhipicephalus oculatus* from two males, two females collected from *Lepus timidus* in Damaraland, D.S.W. Afrika (Namibia), by Borchmann, plus one female from a bovine at Kilossa (= Kilosa, Tanzania), collected by the "K(ais). Gesundheitsamt de Berlin" (presumably a member of the Kaiser's Health Department of Berlin). Of these specimens only one male, one female (Zoological Museum, Berlin 17613, 17614) are now known to exist (Moritz & Fischer 1981) and they have been re-examined by the senior author. Studies by Yeoman & Walker (1967) in Tanzania and by Walker (1974) in Kenya demonstrated that *R. oculatus* does not occur in eastern Africa. Although now lost, the Kilosa specimen was, in all likelihood, *R. pravus*. The host, *Lepus timidus*, was most probably *Lepus capensis*, although it may have been *Lepus saxatilis*, since both these species of hares occur in Damaraland (R.H.N. Smithers, personal communication to J.B. Walker, Pretoria, *c.* 1985).

Zumpt (1942), in a comparison of *Rhipicephalus evertsi* and *R. oculatus*, observed (translated from the German): "*R. oculatus*, however, is more extensively, and sometimes more irregularly, punctate.

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Then there are finer punctations among larger ones, which probably caused this species to be confused with *pravus*. Also, in the male the central festoon can be protruded, which is never the case in *evertsi*. The female has pronounced scutolateral grooves, which are also lacking in *evertsi*." Judging by these statements, Zumpt was probably describing what we consider to be *Rhipicephalus exophthalmos* sp. nov. rather than true *R. oculatus*. Subsequently, Zumpt (1949) published a key to adult *Rhipicephalus* spp. in which he included, and illustrated, a species he thought to be *R. oculatus*, but in reality his diagnosis and illustrations clearly refer to what is now regarded as *R. exophthalmos*.

Sousa Dias (1950) described and illustrated what is probably *R. exophthalmos* from Angola, and Santos Dias (1983a, b) later recorded collections of *R. oculatus sensu lato* from several areas there. Theiler & Robinson (1953) redescribed what they thought to be *R. oculatus*, including first descriptions of the nymph and larva, but these specimens (Onderstepoort Tick Collection 2810), reared from a female collected at Omandumba, Omaruru, Namibia, are definitely *R. exophthalmos*. Theiler & Robinson (1953) also recorded *R. oculatus* from Bulawayo and "Sitalika (Barotseland)" in Southern Rhodesia (= Zimbabwe). Subsequently, Theiler (1962) correctly relocated Barotseland in Northern Rhodesia (= Western Province, Zambia), from which she listed Sitaleka and Sesheke. The source of these records is unknown, and we ourselves have seen no specimens of either *R. oculatus* or *R. exophthalmos* from Zambia. Norval (1985) did not list *R. oculatus* in his survey of lesser known *Rhipicephalus* species in Zimbabwe, and said there was no evidence that it was established there. Theiler & Robinson (1953) reported *R. oculatus* from Palapye and Nokanen in Bechuanaland (= Botswana), as did Zumpt (1958), who recorded it from Palapye, Debeete (= Dibete) and Tsessebe (= Tshesebe). From the information provided by these authors, these collections were possibly a mixture of *R. oculatus* and *R. exophthalmos*.

Clifford & Anastos (1960) examined larvae listed as *R. oculatus* for their seminal paper on the use of chaetotaxy in the identification of ixodid ticks. These larvae were provided by Dr G. Theiler but, from the data available to us, we cannot say whether or not they were from OP 2810, i.e. the series originating from Namibia used by Theiler & Robinson (1953).

DESCRIPTIONS

In the following descriptions, measurements are in millimeters. Chaetotaxic terminology is according to Clifford & Anastos (1960).

Rhipicephalus exophthalmos Keirans & Walker, sp. nov.

HOLOTYPE. ♂, laboratory reared, F_2 generation from ♀ collected on farm "Kosos 11", Karas region (formerly Bethanien), Namibia, on *c.* 10 March 1970; host not recorded (Series no. WON 3396). Deposited in the Onderstepoort Tick Collection 3144.

ALLOTYPE. ♀, data as above.

PARATYPES. ♂♂, ♀♀, nymphs and larvae, data as above, deposited in the Onderstepoort Tick Collection 3144. Five ♂♂, five ♀♀, nymphs and larvae, data as above, deposited in the U.S. National Tick Collection, RML 65729; five ♂♂, five ♀♀, nymphs and larvae deposited in the Natural History Museum, London.

MALE (Fig. 1, 3–5)

Inornate, typically both scutum and lateral idiosomal area light brown; legs uniformly light brown.

CAPITULUM (Fig. 3). Approximately as broad as long, the length (including cornua) x breadth varying from 0,737 x 0,759–0,531 x 0,556.

BASIS CAPITULI. Length from palpal insertion to cornual apices varying from 0,428–0,287. Anterolateral margins straight, diverging posterolaterally; posterolateral margins concave, extending anteriorly over the apical processes of coxa I. Cornua triangular, bluntly rounded, about as long as wide. Dorsal setae of basis capituli as in Fig. 3.

PALPS (Fig. 3). Article I visible dorsally; article II longer than article III; both broader than long.

BODY (Fig. 1). Length (from scapular apices to posterior body margin) x breadth varying from 3,346 x 2,075–2,247 x 1,445, broadest at level of spiracular plates, broadly rounded posteriorly. In engorged specimens the idiosomal wall bulges laterally and an elongate caudal process protrudes posteromedially.

CONSCUTUM (Fig. 1). Eyes submarginal, bulging, deeply orbited. The orbit in some specimens round as in this illustration; in others the orbit is extended somewhat anteriorly or posteriorly, giving it a slightly elongate appearance. Cervical pits relatively deep; internal cervical margins shallow, converging initially then diverging posterolaterally; cervical fields shallow, external cervical margins usually marked by a few punctations. Marginal lines well developed, deep, punctate; extending posteriorly from just behind eyes to festoon one, which is occasionally delimited by the marginal line. Posteromedian and posterolateral grooves well developed; posteromedian broad posteriorly, narrowing anteriorly, posterolaterals ovoid, deep. Punctations generally as illustrated (Fig. 1), but in some specimens large, deep punctations vary in number and intensity.

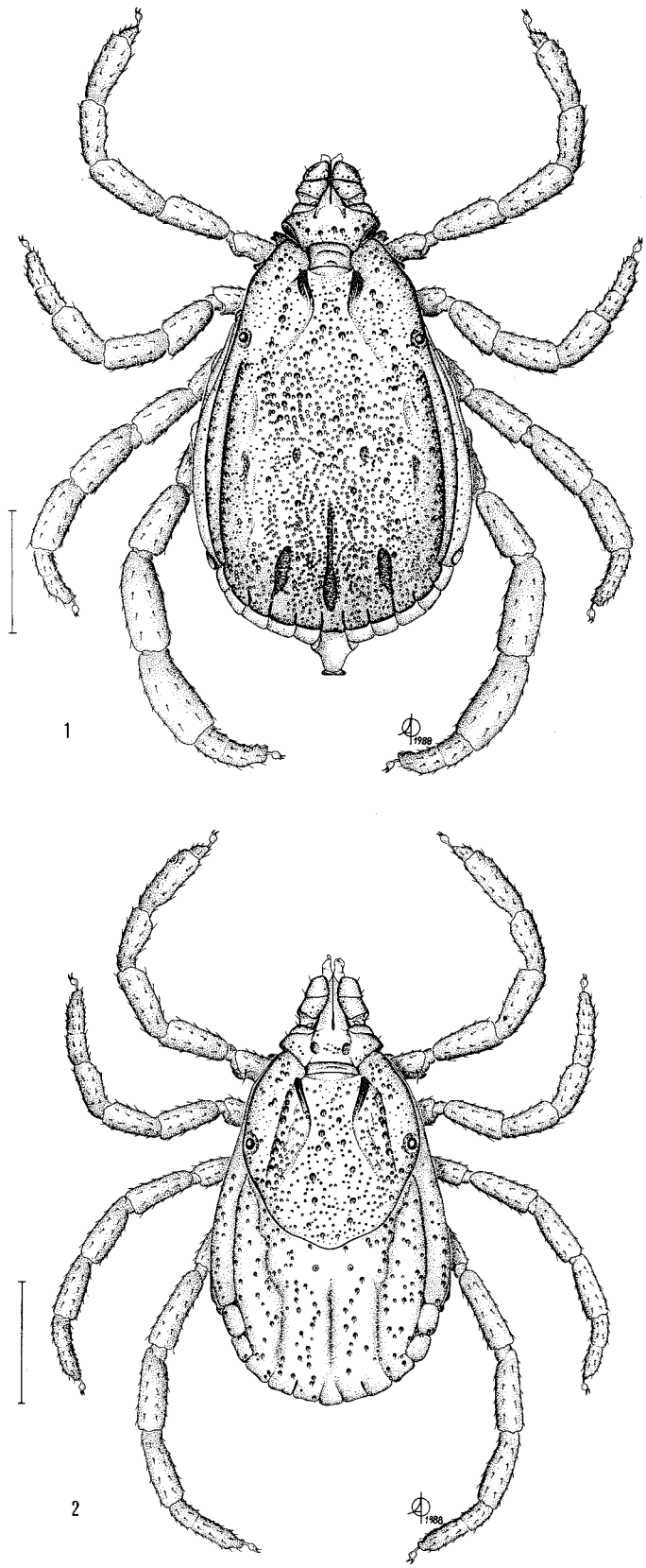

FIG. 1–2 *Rhipicephalus exophthalmos* sp. nov. (from Onderstepoort Tick Collection 3144). 1. Male, dorsal view. 2. Female, dorsal view. A. Olwage *del*. Scales represent 1 mm

LEGS (Fig. 1). Increasing slightly in size from I–IV. Anterior projection of coxa I sharp, easily visible dorsally.

VENTRAL SURFACE: SPIRACLE (Fig. 5). Narrowly elongate with a long tail that can often be seen from the dorsal surface.

ADANAL PLATES (Fig. 4). With external margin mildly convex; posterior margin broad and slightly convex; internal margin nearly straight and, in almost all specimens examined, leading posteriorly to a small medially directed point as illustrated.

FEMALE (Fig. 2, 6–8)

CAPITULUM (Fig. 6). Slightly broader than long, the length x breadth varying from 0,746 x 0,830–0,670 x 0,778.

BASIS CAPITULI (Fig. 6). Length from palpal insertion to cornual apices varying from 0,370 x 0,305, porose areas small, subcircular.

PALPS (Fig. 6). Article I short, but visible from the dorsal surface. Article II longer than article III.

BODY (Fig. 2). Length (from scapular apices to posterior body margin) x breadth varying from 3,220 x 1,948–2,720 x 1,775. Dorsally the marginal line extends posteriorly from the scutum and usually delimits the first two festoons.

SCUTUM (Fig. 2, 7). Outline as illustrated. Length x breadth varying from 1,535 x 1,477–1,409 x 1,328, broadest at eye level. Eyes submarginal, bulging, deeply orbited. The orbit either round (Fig. 2) or often slightly extended anteriorly and/or posteriorly (Fig. 7). Cervical pits (Fig. 7) deep; internal cervical margins converging as sharp declinations, then diverging as shallow ridges; cervical fields scalpel-shaped, often with irregular ridges centrally (Fig. 2), but sometimes quite smooth (Fig. 7); external cervical margins usually ridge-like and often well delineated with somewhat larger punctations containing small white setae. Scutal punctations as illustrated.

LEGS (Fig. 2). Uniform in size, light brown.

VENTRAL SURFACE: GENITAL APERTURE (Fig. 8). Situated between coxae II, a broadly rounded U in shape, the area within the opening bulging.

SPIRACLE. Short, rounded, with a small dorsal prolongation.

NYMPH (Fig. 9–12)

CAPITULUM (Fig. 9, 10). Length (measured from tip of hypostome to posterior border of basis capituli) x breadth varying from 0,257 x 0,316–0,198 x 0,287, much broader than long.

BASIS CAPITULI (Fig. 9, 10). Length from palpal insertion to posterior margin of basis varying from 0,111–0,086. Posterolateral margins straight, diverging anteriorly over scapulae and apical processes of coxa I. Ventrally broadly rounded posteriorly, without posterolateral spurs, with two pairs of setae, one pair posthypostomal and one pair postpalpal.

PALPS (Fig. 9, 10). Article I visible from dorsal surface, article II longer than III. Broadest basally, narrowing appreciably to the apices.

BODY. Length (from scapular apices to posterior body margin) x breadth varying from 1,080 x 0,655–0,840 x 0,532, broadest at level of coxa IV. Marginal line extends posteriorly from scutum to 1st festoon. Posteromedian and posterolateral grooves extending anteriorly from festoons to body midlength.

SCUTUM (Fig. 11). Length x breadth varying from 0,581 x 0,552–0,496 x 0,485. Scapulae bluntly rounded. Eyes as prominent bulges, partially orbited, situated on the lateral border immediately anterior to the posterolateral scutal angle. External cervical margin ridge-like, extending from junction with the internal cervical margin almost to posterior scutal margin; internal cervical margin shallow and short, not reaching scutal midlength. Cervical and median fields shagreened; raised lateral border smooth except around eyes. Setae fine, short, about the same length as dorsal body setae.

VENTRAL SURFACE: LEGS (Fig. 12). Coxa I with an elongate triangular external spur and a short triangular internal spur; coxae II-IV each with a small triangular external spur; internal spurs absent. Legs I–IV equal in size.

SPIRACLE. Subcircular.

LARVA (Fig. 13–16)

CAPITULUM (Fig. 13, 14). Slightly longer than broad, the length x breadth varying from 0,129 x 0,125–0,109 x 0,121.

BASIS CAPITULI (Fig. 13, 14). Length (from base of cheliceral sheaths to posterior margin of basis) x breadth varying from 0,051 x 0,125–0,043 x 0,121, dorsally with posterior margin straight, cornua absent. Ventrally with posterior margin broadly rounded; posthypostomal setae one pair.

PALPS. Broad proximally, tapering gently to bluntly rounded apices, suture between segments two and three only faintly indicated (Fig. 13, 14); palpal setae, segment two with three dorsal and three ventral, segment three with four dorsal and two ventral, segment four with about 12.

BODY. Ovoid, broadest posterior to coxa III. Length (from scapulae to posterior body margin) x breadth varying from 0,663 x 0,523–0,624 x 0,468. Dorsal body setae number ten pairs; two pairs central dorsals and eight pairs marginal dorsals. Ventral setae number 14 pairs plus one pair on anal valves; three pairs sternals, two pairs preanals, four pairs premarginals, five pairs marginal ventrals.

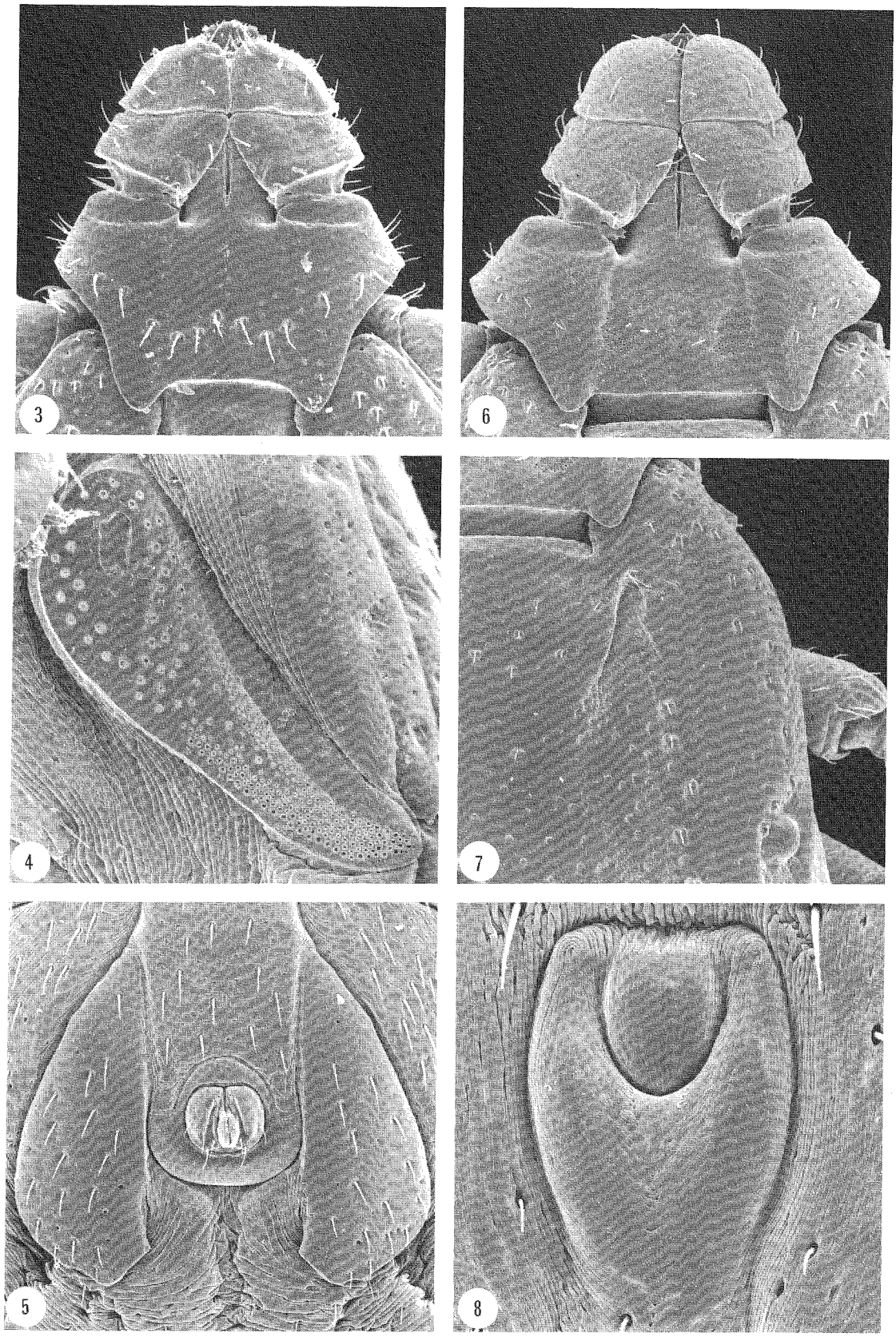

FIG. 3–8 *Rhipicephalus exophthalmos* sp. nov. (from Onderstepoort Tick Collection 3144). Male: 3. Capitulum, dorsal. 4. Spiracle. 5. Adanal plates. Female: 6. Capitulum, dorsal. 7. Scapular area. 8. Genital aperture. SEMs by M.D. Corwin

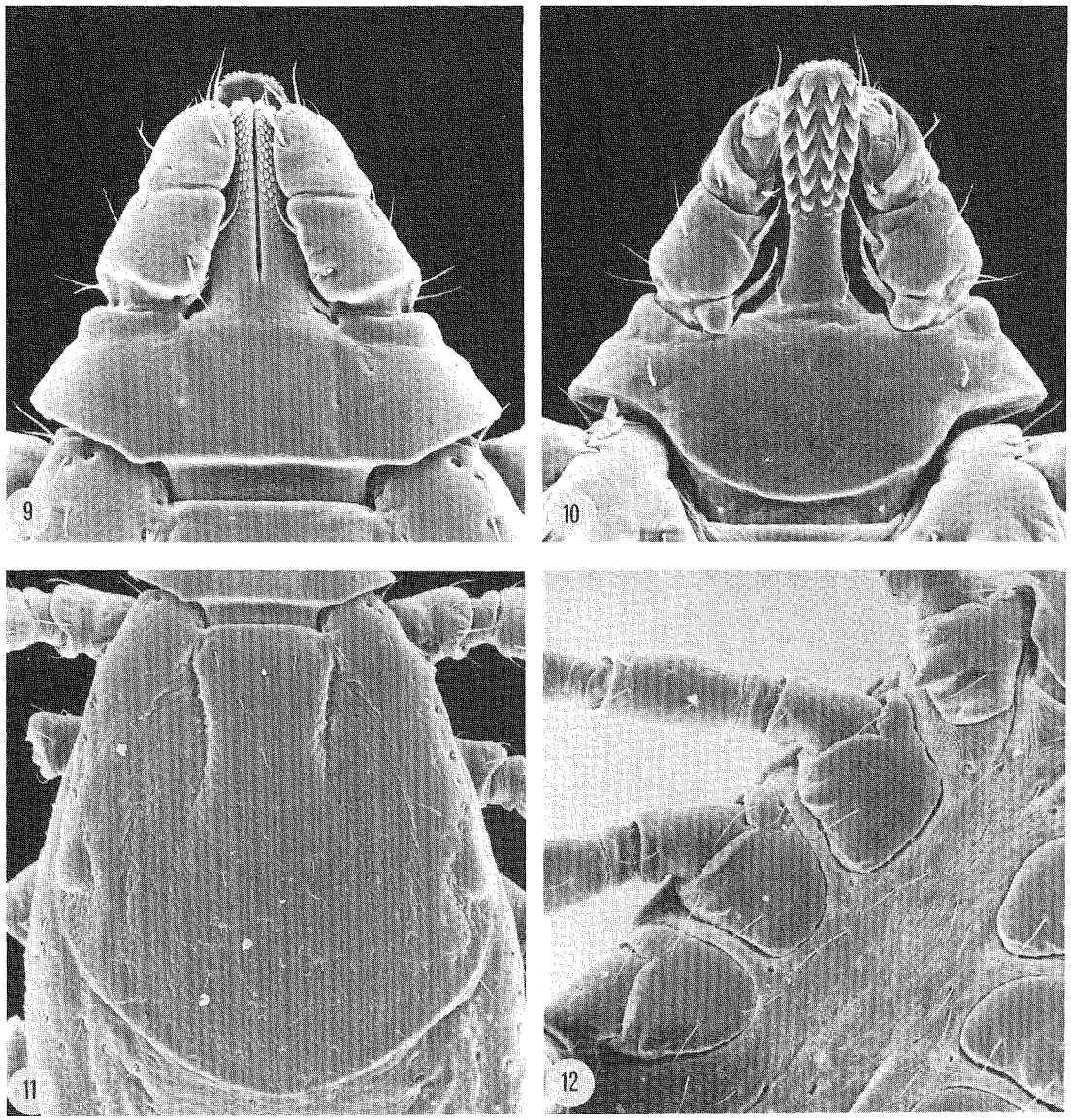

FIG. 9–12 *Rhipicephalus exophthalmos* sp. nov. (from Onderstepoort Tick Collection 3144). Nymph: 9. Capitulum, dorsal. 10. Capitulum, ventral. 11. Scutum. 12. Coxae. SEMs by M.D. Corwin

SCUTUM (Fig. 15). Length x breadth varying from 0,308 x 0,109–0,293 x 0,102; anterolateral borders smoothly curved, posterior border a smooth, relatively shallow curve; internal cervical margins short, moderately deep, posteriorly directed; external cervical margins absent; eyes at posterolateral angles of scutum, large, bulging, rounded, slightly orbited; scutal setae three pairs.

VENTRAL SURFACE: LEGS (Fig. 16). Coxa I with moderately large, triangular, pointed internal spur; coxa II lacks an internal spur, but a noticeable internal bulge is present; coxa III with a very small triangular internal spur; external spurs absent on all coxae. Coxal setae, three on I, two on II and on III.

LIFE CYCLE

Rhipicephalus exophthalmos is a three-host tick (Table 1). Theiler & Robinson (1953) did not state what hosts were used to rear this species in the laboratory. The survival periods recorded for the adults were extremely short, suggesting that the conditions under which they had been kept were far from ideal. Subsequently, this species was reared again on rabbits by W.O. Neitz & J. de V. Hoffman (unpublished data 1970-1972) and by Rechav & Knight (1983) (Table 1). The latter authors mistook this tick for *R. oculatus*, but examination of their material, plus the fact that they collected their original adult stock from Angora goats, indicate that it is *R. exophthalmos*.

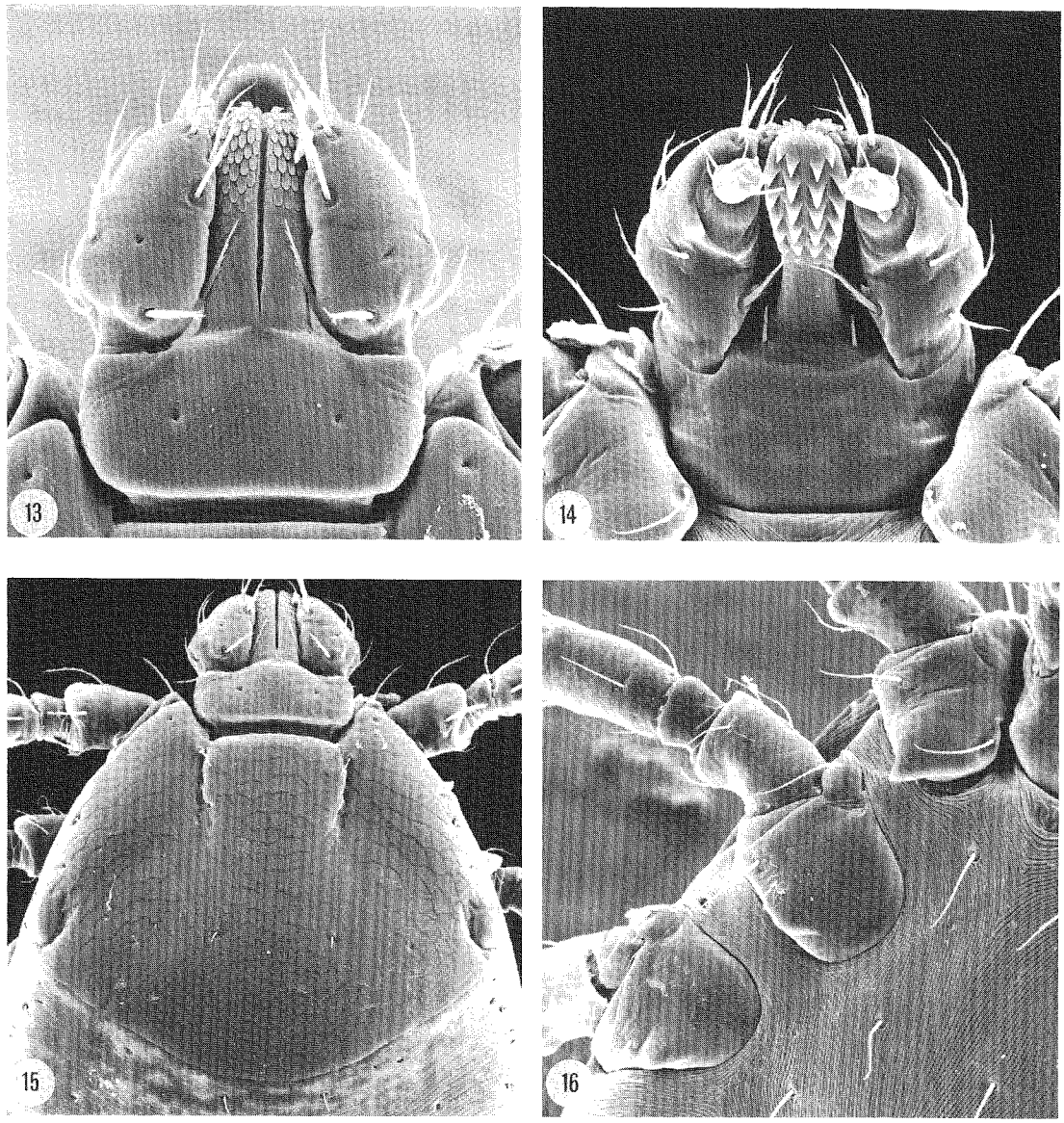

FIG. 13–16 *Rhipicephalus exophthalmos* sp. nov. (from Onderstepoort Tick Collection 3144). Larva: 13. Capitulum, dorsal. 14. Capitulum, ventral. 15. Scutum. 16. Coxae. SEMs by M.D. Corwin

BIOLOGY IN THE FIELD

The records of *R. exophthalmos* listed below represent collections that we have identified ourselves.

Hosts

Rhipicephalus exophthalmos adults commonly parasitize cattle and sheep, sometimes goats, but rarely other domestic animals (Table 2). Their wild animal hosts are almost exclusively members of the families Artiodactyla and Leporidae. Among the artiodactyls both small antelopes, such as the springbuck and large species, such as the gemsbok and greater kudu, are frequently infested. The scrub hare is the favourite leporid host of the adults, and the only animal from which nymphs have as yet been recorded.

During a 2-year survey of ticks on a farm and an adjacent game reserve in the eastern Cape Province, *R. exophthalmos* [then referred to as *Rhipicephalus* sp. (near *R. oculatus*)] was recovered from Dorper sheep (Horak, Williams & Van Schalkwyk 1991a), Angora goats (Horak, Knight & Williams 1991d), scrub hares (Horak & Fourie 1991), kudus (Horak, Boomker, Spickett & De Vos 1992b) and cattle. The burdens of these animals are summarized in Table 3.

Although a greater proportion of kudus than any other host were infested, cattle harboured the largest

TABLE 1 Life cycle and survival periods of *Rhipicephalus exophthalmos* in the laboratory

Developmental stages	Developmental periods (days)		
	OP 2810 [a]	WON 3348 & 3396 [b]	Rechav & Knight (1983)
Pre-oviposition	13–15	5–6	6,0
Eggs hatch	13–17	32–33	26,8
Larvae feed	2–8	4	6,6
Larvae moult	8–16	11	8,0
Nymphs harden	3		
Nymphs feed	4–10	5	8,3
Nymphs moult	13	17–19	14,6
Adults harden	No data	No data	No data
Adults feed	8–14	8	7,2
Survival periods	Months	No data available	
Unengorged larvae	3		
Unengorged nymphs	5		
Unengorged adults	2–2½		

[a] Theiler & Robinson (1953)
[b] W.O. Neitz & J. de V. Hoffman (unpublished data 1970–1972)

TABLE 2 Host records of *Rhipicephalus exophthalmos* sp. nov.

Hosts	No. of collections
Domestic animals	
Cattle	37
Sheep [a]	38
Goats [b]	14
Pig	1
Horses	2
Donkey	1
Dogs	2
Wild animals	
Lion (*Panthera leo*)	1
Burchell's zebra (*Equus burchelli*)	1
Warthog (*Phacochoerus aethiopicus*)	8
Springbuck (*Antidorcas marsupialis*)	19
Steenbok (*Raphicerus campestris*)	5
Impala (*Aepyceros melampus*)	1
Grey rhebok (*Pelea capreolus*)	1
Gemsbok (*Oryx gazella*)	22
Greater kudu (*Tragelaphus strepsiceros*)	30
Eland (*Taurotragus oryx*)	4
Mountain reedbuck (*Redunca fulvorufula*)	2
Cape hare (*Lepus capensis*)	1
Scrub hare (*Lepus saxatilis*)	32
"Hare" (*Lepus* sp.)	17
Namaqua rock mouse (*Aethomys namaquensis*)	1

[a] Sheep include Dorpers, Black-headed Persians and Karakuls; in many cases the breed was not specified
[b] Goats include Boer goats and Angoras; in many cases the breed was not specified

TABLE 3 The relative abundance [a] of *Rhipicephalus exophthalmos* on cattle, sheep, goats, kudus and scrub hares on a farm and adjacent nature reserve in the eastern Cape Province [b]

Hosts	Number examined	Number infested	Number of ticks recovered				
			Larvae	Nymphs	♂	♀	Total
"Bucklands"							
Cattle	46	19	0	0	223	75	298
Sheep	48	1	0	0	2	0	2
Goats	48	3	0	0	6	2	8
Scrub hares	45	15	11	8	21	6	46
Kudus	9	6	0	0	30	13	43
Andries Vosloo Kudu Reserve							
Scrub hares	42	14	28	4	18	12	62
Kudus	16	13	0	0	104	41	145

[a] Tick counts according to the methods of Horak & Fourie (1991) and Horak *et al.* (1992b)
[b] 76 helmeted guineafowls examined on the two properties were free of infestation

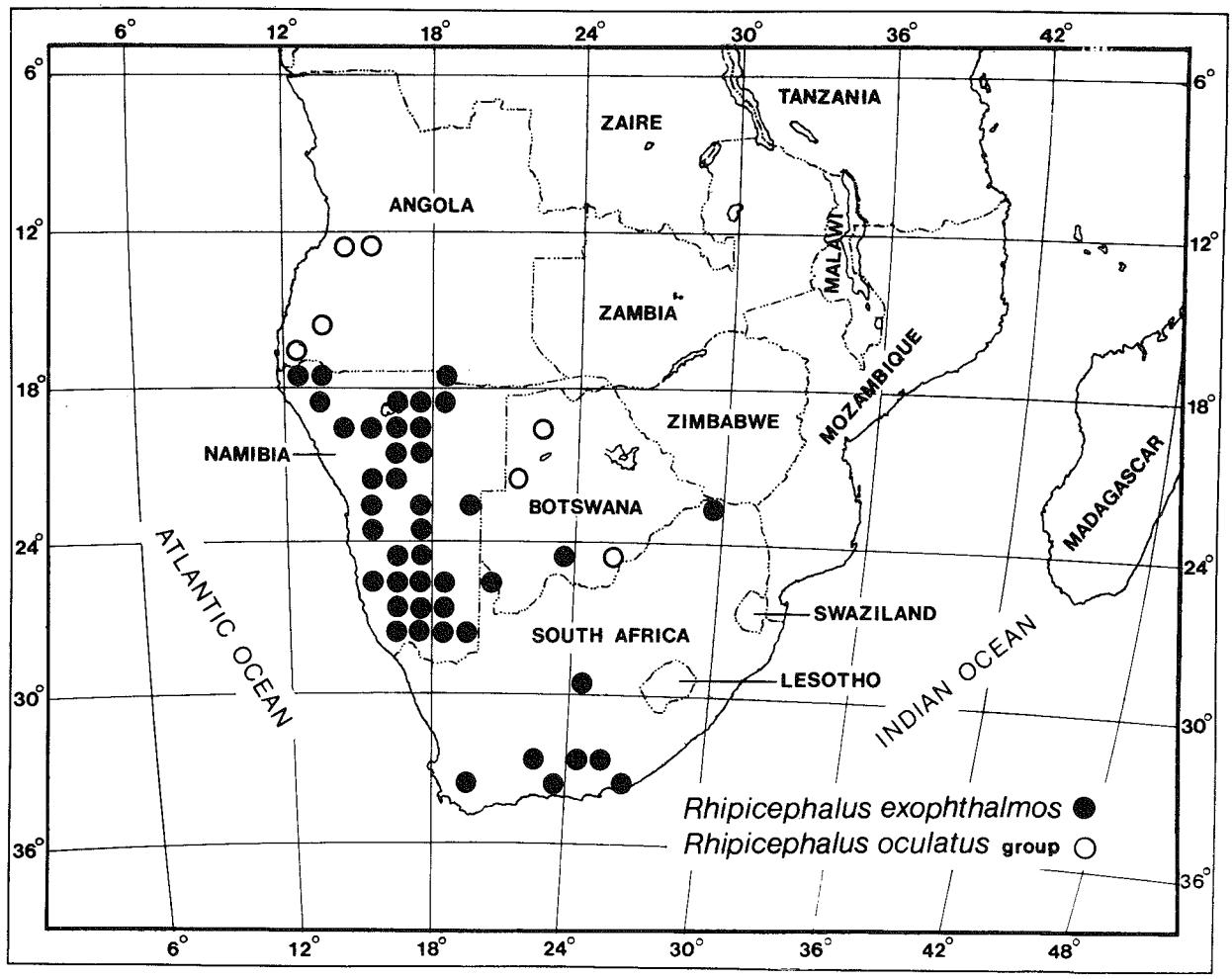

FIG. 17 *Rhipicephalus exophthalmos* sp. nov.: distribution

individual burdens. No ticks were found during May, but they were recovered during every other month. The largest numbers were recovered and all mammal host species were infested in January.

A 13-month survey conducted on gemsbok in southern Namibia revealed that all animals examined during the period November to March were infested. The largest burdens were present during November (Horak, Anthonissen, Krecek & Boomker 1992a).

Zoogeography

To date, *R. exophthalmos* has been recorded most frequently in Namibia, especially in the central and southern parts of the country (Fig. 15). In South Africa the majority of our records come from the south-eastern Cape Province, with few from elsewhere in the country. The record in Horak, Boomker & Flamand (1991e) of *R. exophthalmos* [then identified as *Rhipicephalus* sp. (near *R. oculatus*)] from a red duiker in north-eastern Natal has, upon subsequent re-examination, proved to be *Rhipicephalus evertsi evertsi* Neumann, 1897. In Botswana there is one confirmed record only, from Sekoma Pan in the south. In Angola Sousa Dias (1950) recorded what is probably this species from Bocaio. Collections from Angola that can be designated only as belonging to the *R. oculatus* group have been recorded from Nova Lisboa (= Huambo) (G. Theiler, unpublished data) and Luapasso, Espinheira and Hunguéria (= Onguéria) (Santos Dias 1983a, b).

The vegetation in many of the areas in which *R. exophthalmos* occurs is semi-desert, bushy Karoo-Namib shrubland or dry wooded grassland and bushland (White 1983). In the south-eastern Cape it is common in the evergreen and semi-evergreen bushland and thicket referred to locally as Fish River bush.

TABLE 4 Course of paralysis in a rabbit caused by *Rhipicephalus exophthalmos* (W.O. Neitz, unpublished data 1970)

Day of observation	Degree of paralysis of rabbit	No. of engorged ♀ ticks collected	Notes
1			Ticks placed on rabbit's ears
7	++++		Rabbit not feeding well. Ascending paralysis developing
8	++++++		Rabbit neither feeding nor drinking
9	++++++	9	Rabbit neither feeding nor drinking
10	++++++	10	Rabbit neither feeding nor drinking
11	++++++	0	Rabbit neither feeding nor drinking
12	++++	2	Rabbit neither feeding nor drinking
13	++++	0	Rabbit feeding and drinking water again
14	++	1	Rabbit feeding and drinking water again
15		0	Rabbit feeding and drinking water again
Total no. of engorged ♀ ticks collected		22	

DISEASE RELATIONSHIPS

W.O. Neitz (unpublished data 1970) reported that a rabbit on which *R. exophthalmos* adults were fed became completely paralysed while the female ticks were feeding, but subsequently recovered (Table 4). Two rabbits on which F_2 generation adults of the same strain of this species were fed also became paralysed. Of these rabbits one recovered but the other died.

Rhipicephalus oculatus Neumann, 1901

MALE (Fig. 18, 20–22)

Inornate; scutum brown to very dark brown in large, heavily punctate specimens and lateral idiosomal area light to dark brown; legs uniformly brown.

CAPITULUM (Fig. 20). Broader than long, the length (including cornua) x breadth varying from 0,632 x 0,641–0,521 x 0,539.

BASIS CAPITULI (Fig. 20). Length from palpal insertion to cornual apices varying from 0,344–0,293. Anterolateral margins straight, diverging posterolaterally; posterolateral margins slightly concave, extending anterolaterally over the apical processes of coxa I. Cornua triangular, bluntly rounded, slightly broader than long. Dorsal setae of basis capituli as in Fig. 20.

PALPS (Fig. 20). Article I visible dorsally; article II longer than III; both broader than long.

BODY (Fig. 18). Length (from scapular apices to posterior body margin) x breadth varying from 2,905 x 1,982–2,355 x 1,528. In unengorged specimens, broadest at level of coxa IV and broadly rounded posteriorly. In engorged specimens the lateral idiosomal wall bulges significantly just anterior to the spiracular plates, and a very small, pointed caudal process protrudes posteromedially.

CONSCUTUM (Fig. 18). Eyes submarginal, round, bulging, deeply orbited. The orbit is usually round without anterior or posterior extensions. Cervical pits deep, internal cervical margins shallow, converging initially then diverging posterolaterally. In some specimens the internal cervical margins and cervical fields are inapparent. External cervical margins slightly raised from cervical fields and often indicated by a few punctations. Marginal lines well developed, deep, punctate; extending anteriorly from just behind eyes to 1st festoon. Posteromedian and posterolateral grooves well developed; posteromedian narrows abruptly as it extends anteriorly from festoon 6; posterolaterals oval, deep, the scutal areas anterior to posterolaterals often broadly indented. Scutal punctations generally as illustrated (Fig. 18), but some specimens may have slightly smaller punctations centrally.

LEGS (Fig. 18). Increasing slightly in size from I–IV. Anterior projection of coxa I visible dorsally.

VENTRAL SURFACE: SPIRACLE (Fig. 21). Narrowly elongate with long tail projecting dorsalwards.

ADANAL PLATES (Fig. 22). Broadly triangular in general shape, with bluntly rounded apex and mildly concave internal margin; external margin slightly convex; posterior margin almost straight, characteristically somewhat crenellated.

FEMALE (Fig. 19, 23–25)

CAPITULUM (Fig. 23). Broader than long, the length x breadth varying from 0,683 x 0,765–0,661 x 0,762.

BASIS CAPITULI (Fig. 23). Length from palpal insertion to cornual apices varying from 0,360–0,307; porose areas small, subcircular.

PALPS (Fig. 23). Article I short but visible from the dorsal surface; article II longer than article III.

BODY (Fig. 19). Length (from scapular apices to posterior body margin) x breadth varying from 2,849 x 1,755–2,773 x 1,674. Dorsally marginal line extends posteriorly from the scutum and usually delimits the first two festoons.

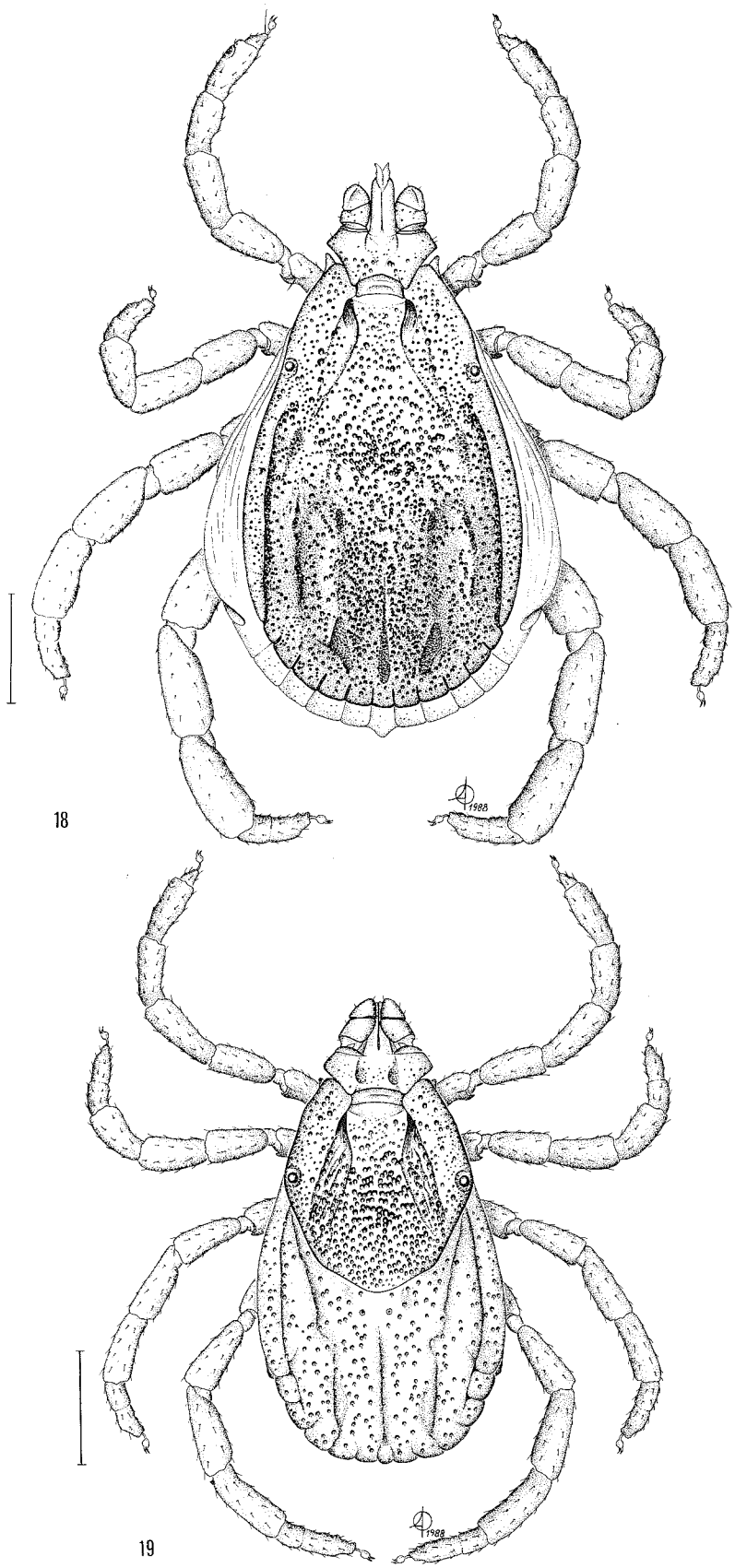

FIG. 18–19 *Rhipicephalus oculatus* [from scrub hare (H39), Andries Vosloo Kudu Reserve, Grahamstown, 24 Nov. 1986, I.G. Horak]. 18. Male, dorsal view. 19. Female, dorsal view. A. Olwage *del*. Scales represent 1 mm

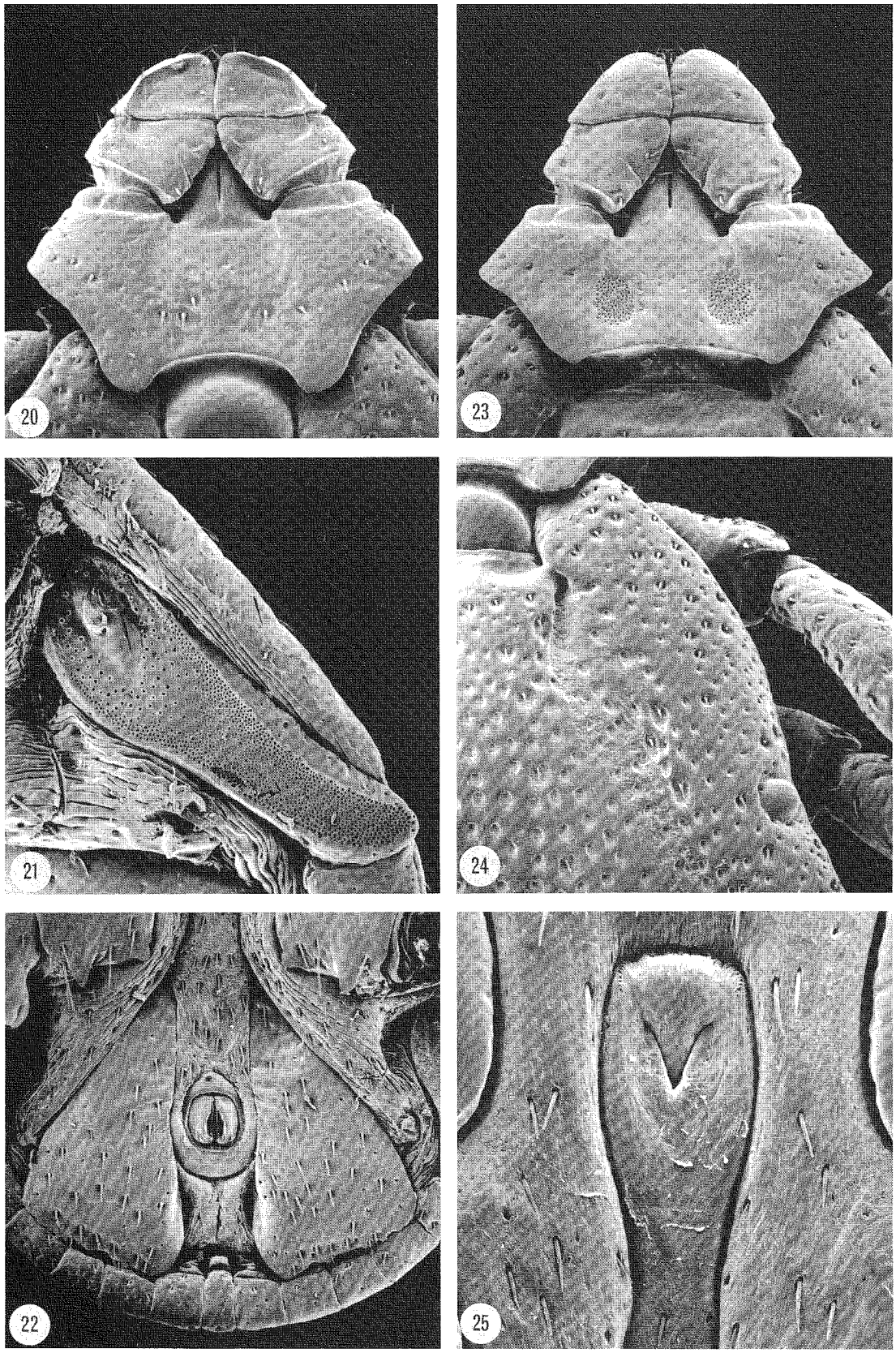

FIG. 20–25 *Rhipicephalus oculatus* [from scrub hare (H12), Andries Vosloo Kudu Reserve, Grahamstown, 18 Aug. 1985, I.G. Horak]. Male: 20. Capitulum, dorsal. 21. Spiracle. 22. Adanal plates. Female: 23. Capitulum, dorsal. 24. Scapular area. 25. Genital aperture. SEMs by J.F. Putterill

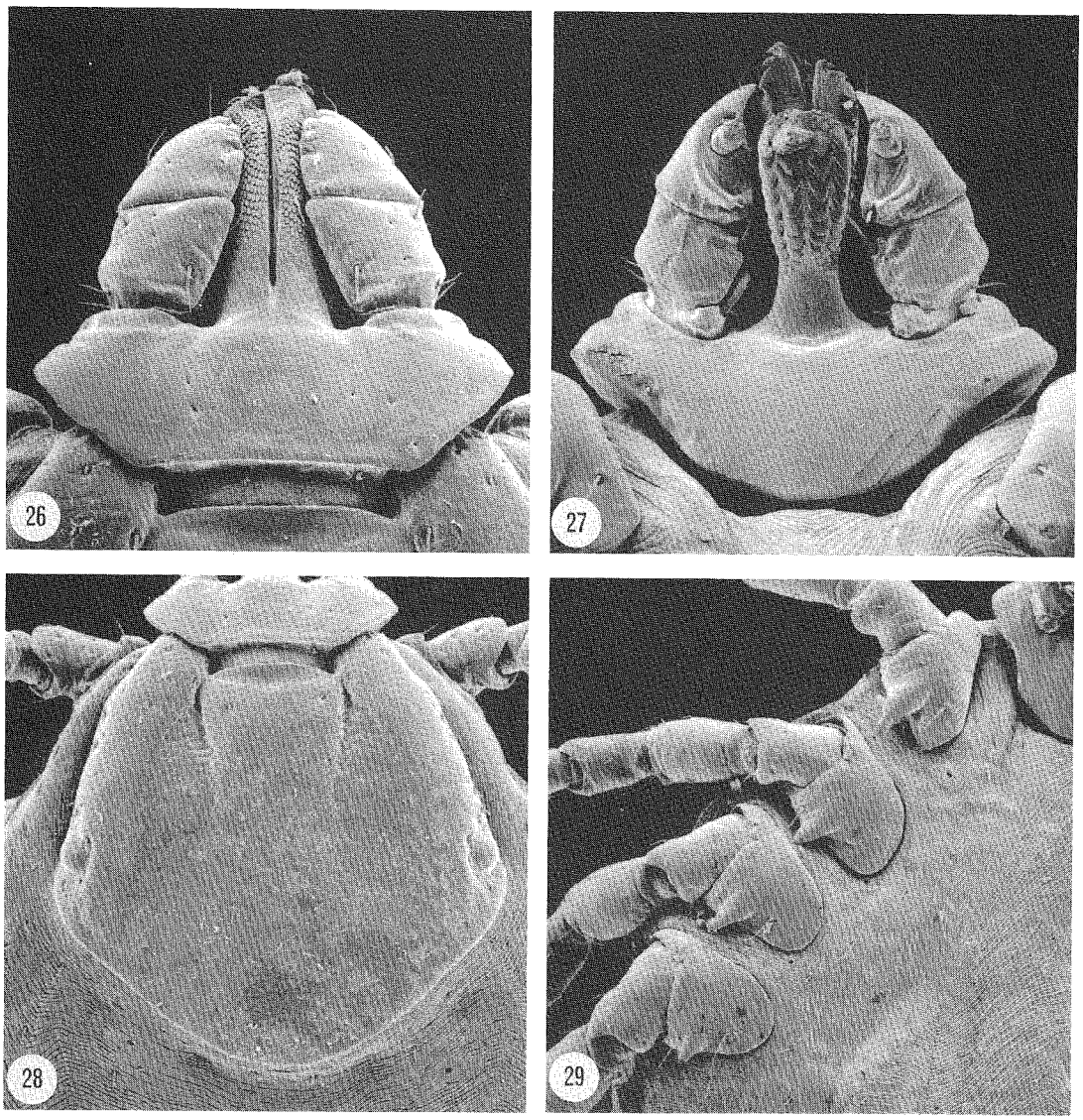

FIG. 26–29 *Rhipicephalus oculatus* [from scrub hare (H28), Andries Vosloo Kudu Reserve, Grahamstown, 19 June 1986, I.G. Horak]. Nymph: 26. Capitulum, dorsal. 27. Capitulum, ventral. 28. Scutum. 29. Coxae. SEMs by J.F. Putterill

SCUTUM (Fig. 19, 24). Outline as illustrated. Length x breadth varying from 1,500 x 1,313–1,447 x 1,248, broadest at eye level. Eyes submarginal, bulging, hemispherical, deeply orbited; the orbit round, typically without an anterior or posterior extension. Cervical pits deep; internal cervical margins converging, then diverging as roughened extensions, or fading into numerous punctations. Cervical fields narrow, external and internal edges almost parallel. External cervical margins ridge-like and well delineated, often outlined with punctations. Scutal punctations as illustrated, with fewer, smaller punctations on the raised lateral areas.

LEGS (Fig. 19). Uniform in size, brown.

VENTRAL SURFACE: GENITAL APERTURE (Fig. 25). Situated between coxae II, a narrow V in shape, bluntly rounded posteriorly, the area within the opening depressed.

SPIRACULAR PLATE. Short, rounded, with a short tail.

NYMPH (Fig. 26–29)

CAPITULUM (Fig. 26, 27). Length (measured from tip of hypostome to posterior border of basis capituli) x breadth varying from 0,253 x 0,364–0,211 x 0,262, much broader than long.

BASIS CAPITULI (Fig. 26, 27). Length from palpal insertion to posterior margin of basis varying from 0,108–0,106; posterolateral margins straight to very slightly curved, diverging anteriorly over scapulae and apical process of coxa I, lateral angles relatively anterior in position. Ventrally broadly rounded posteriorly, without posterolateral spurs; two pairs of

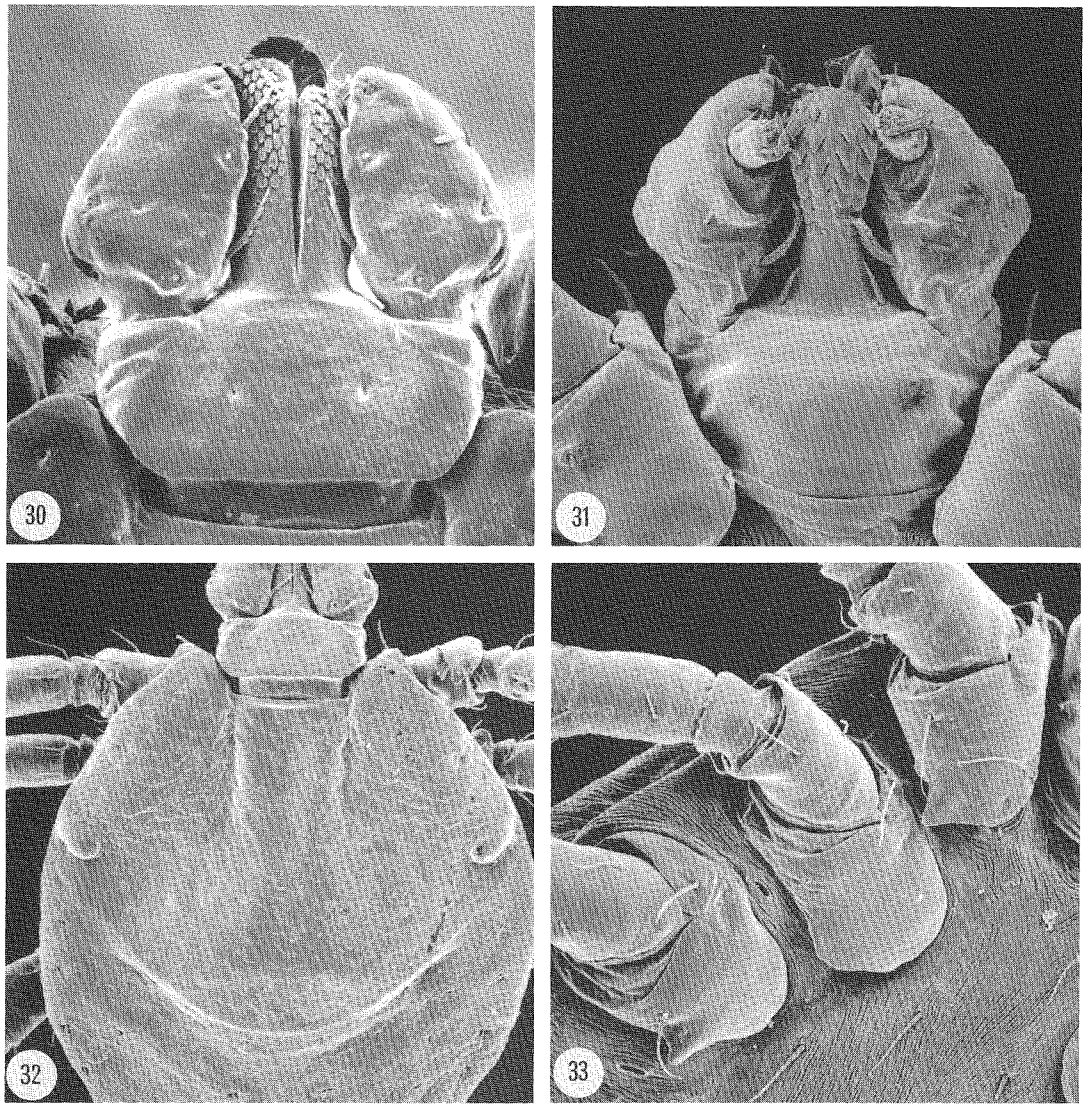

FIG. 30–33 *Rhipicephalus oculatus* [from scrub hare (H28), Andries Vosloo Kudu Reserve, Grahamstown, 19 June 1986, I.G. Horak]. Larva: 30. Capitulum, dorsal. 31. Capitulum, ventral. 32. Scutum. 33. Coxae. SEMs by J.F. Putterill

setae, one pair posthypostomal and one pair postpalpal.

PALPS (Fig. 26, 27). Article I visible from dorsal surface, article II longer than III. Broadest basally, apices broadly rounded.

BODY. Length (from scapular apices to posterior body margin) x breadth varying from 1,150 x 0,800–0,849 x 0,496, broadest just posterior to coxa IV. Marginal line extends posteriorly from scutal margin to first festoon. Posteromedian and posterolateral grooves extending anteriorly from festoons to body midlength.

SCUTUM (Fig. 28). Length x breadth varying from 0,525 x 0,638–0,514 x 0,462. Scapulae bluntly rounded. Eyes orbited, prominent, bulging, situated immediately anterior to posterolateral scutal angle. External cervical margin ridge-like, extending posteriorly from junction with the internal cervical margin to or nearly to posterior scutal margin. Internal cervical margins shallow, reaching approximately to eye level. Cervical and median fields shagreened; raised lateral border smooth. Setae numerous, short, about the same length as dorsal body setae.

VENTRAL SURFACE: LEGS (Fig. 29). Coxa I with a long, pointed external spur and a stout, triangular internal spur; coxa II–IV with a long, pointed external spur, slightly decreasing in size from II–IV; internal spurs absent. Legs I–IV equal in size.

SPIRACLE. Subcircular, macula located anteriorly.

LARVA (Fig. 30–33)

CAPITULUM (Fig. 30, 31). Approximately as long as broad; the length x breadth varying from 0,136 x 0,140–0,109 x 0,133.

BASIS CAPITULI (Fig. 30, 31). Length (from base of cheliceral sheaths to posterior margin of basis) x breadth varying from 0,585 x 0,140–0,429 x 0,133. Dorsally with posterior margin straight, cornua absent. Ventrally posterior margin broadly rounded, posthypostomal setae one pair.

PALPS (Fig. 30). Bulbous proximally, tapering to broadly rounded apices, suture between segments two and three inapparent; palpal setae, segment two with three dorsal and three ventral, segment three with four dorsal and two ventral, segment four with about ten.

BODY: Ovoid. Widest posterior to coxa III. Length (from scapulae to posterior body margin) x breadth varying from 0,741 x 0,636–0,538 x 0,468. Dorsal body setae number ten pairs; two pairs central dorsals and eight pairs marginal dorsals. Ventral setae number 14 pairs plus one pair on anal valves; three pairs sternals, two pairs preanals, four pairs premarginals, five pairs marginal ventrals.

SCUTUM (Fig. 32). Length x breadth varying from 0,331 x 0,448–0,277 x 0,394; anterolateral borders slightly curved, posterior border a broad, smooth curve; internal cervical margins short, moderately deep, posteriorly directed; external cervical margins absent; eyes immediately anterior to posterolateral scutal angle, large, transversely ovoid, inner sides bulging markedly, partially orbited; setae three pairs (pair two broken off in Fig. 32).

VENTRAL SURFACE: LEGS (Fig. 33). Coxae all much broader than long. Coxa I with a large, broadly triangular internal spur; coxa II without spurs; coxa III with a moderately long, pointed internal spur; external spurs absent on all coxae. Coxal setae, three on I, two on II and on III.

TABLE 5 Host records of *Rhipicephalus oculatus*

Hosts	No. of collections
Wild animals	
"Duiker" (species unknown)	1
Mountain reedbuck (*Redunca fulvorufula*)	1
Springhare (*Pedetes capensis*)	2
Cape hare (*Lepus capensis*)	8
Scrub hare (*Lepus saxatilis*)	65
Smith's red rock rabbit (*Pronolagus rupestris*)	1
Helmeted guineafowl (*Numida meleagris*)	4

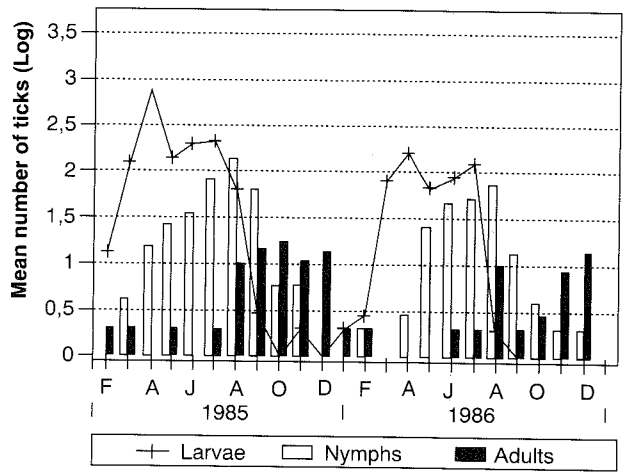

FIG. 34 The seasonal abundance of *Rhipicephalus oculatus* on scrub hares on the farm "Bucklands" and in the Andries Vosloo Kudu Reserve, eastern Cape Province (from Horak & Fourie, 1991)

LIFE CYCLE

Unknown.

BIOLOGY IN THE FIELD

The records of *R. oculatus* listed below represent collections that we ourselves have identified.

Hosts

Undoubtedly the primary hosts of all stages of *R. oculatus* are members of the Leporidae, particularly the scrub hare (Table 5). In our experience, occasional infestations of this tick on other hosts have always been small and are probably accidental.

With the exception of helmeted guineafowls, which harboured a few larvae and nymphs (Horak, Spickett, Braack & Williams 1991c), only the scrub hares examined in the 2-year survey mentioned under *R. exophthalmos* were infested with *R. oculatus* (Table 6). The largest numbers of larvae were recovered from the latter animals from March to July or August, nymphs from May to August or September, and adults from August to December (Fig. 34). In a survey conducted in the Mountain Zebra National Park in the eastern Karoo, the scrub hares were found to be heavily infested, but a Smith's red rock rabbit, two springhares and a mountain reedbuck harboured just a few ticks (Table 6). At this locality the periods of seasonal activity were March to August for the larvae, June to October for the nymphs and August to November for the adults (Horak, Fourie, Novellie & Williams 1991b). This pattern of seasonal abundance indicates that only a single life cycle will be completed annually.

Zoogeography

As far as we know, *R. oculatus* is confined to parts of southern Africa (Fig. 35). It has been found most

TABLE 6 The relative abundance [a] of *Rhipicephalus oculatus* on scrub hares on a farm and two nature reserves in the eastern Cape Province

Hosts	Number examined	Number infested	Number of ticks recovered				
			Larvae	Nymphs	♂	♀	Total
"Bucklands"							
Scrub hares	45	41	6010	1397	97	80	7584
Helmeted guineafowls	37	4	3	4	0	0	7
Andries Vosloo Kudu Reserve							
Scrub hares	42	37	1196	839	118	70	2223
Helmeted guineafowls	39	0	0	0	0	0	0
Mountain Zebra National Park							
Scrub hares	26	19	957	306	21	23	1307
Smith's red rock rabbits	28	1	0	0	2	1	3
Springhares	17	2	2	0	0	0	2
Mountain reedbuck	18	1	4	0	0	0	4
Helmeted guineafowls	16	0	0	0	0	0	0

* Tick counts according to the method of Horak & Fourie (1991)

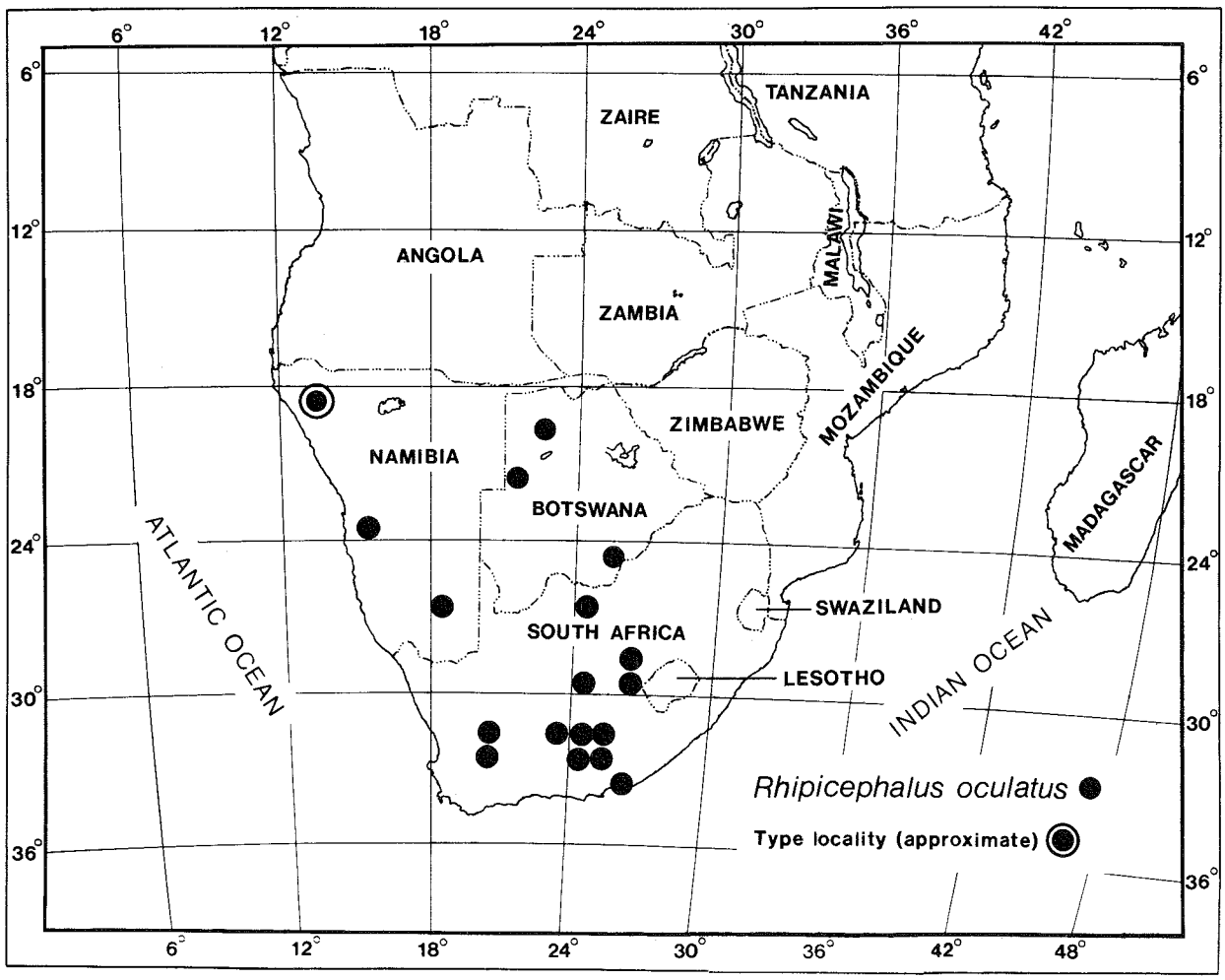

FIG. 35 *Rhipicephalus oculatus*: distribution

commonly in South Africa in the south-eastern Cape Province, where its distribution sometimes overlaps that of *R. exophthalmos*. There are also scattered records from the northern and western Cape Province, and from the Orange Free State, from the vicinity of Glen and Bloemfontein. The type specimens, though, were collected in Namibia, at an unspecified location in Damaraland. The only other places in Namibia where the species has been found are the Namib Desert, west of the Kuiseb Canyon, and Keetmanshoop.

Judging from these localities, it is apparent that *R. oculatus* can survive various extremes of climate: great summer heat (as in Keetmanshoop and parts of the eastern Cape Province); severe winter cold (as in Sutherland in the western Cape), and dryness (as in the Namib Desert). The vegetation in these areas ranges from the evergreen and semi-evergreen bushland and thicket (Fish River bush) of the eastern Cape Province, through semi-desert types of montane, grassy, bushy and dwarf Karoo shrubland, to the Namib Desert itself.

ACKNOWLEDGEMENTS

We thank Dr Anne Baker, Natural History Museum, London, who suggested the name *exophthalmos*, meaning "bulging eyes", for our new species.

We also sincerely thank Dr M. Moritz, Museum für Naturkunde, Berlin, for the loan of the types of *R. oculatus*.

We are grateful to Mr A. Olwage for the line drawings of the *R. exophthalmos* and *R. oculatus* adults, and to Messrs M.D. Corwin and J.F. Putterill for the scanning electron micrographs.

R. exophthalmos (Serial Nos. WON 3260, 3348, 3396) was reared at Onderstepoort by the late Dr W.O. Neitz and Mr J. de V. Hoffman.

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RHIPICEPHALUS OREOTRAGI WALKER & HORAK, *SP. NOV.*

This species is named after the only host from which it has been collected thus far, the klipspringer (*Oreotragus oreotragus*).

Diagnosis

A small lightly punctate yellowish-brown tick; females with a characteristically long narrow scutum. Punctations always discrete.

Male (Figs 151(a), 152(a) to (c))

Capitulum slightly broader than long, length × breadth ranging from 0.44 mm × 0.45 mm to 0.54 mm × 0.55 mm. Basis capituli with short acute lateral angles at anterior third of its length. Palps short, broad, almost flat apically. Conscutum length × breadth ranging from 2.02 mm × 1.25 mm to 2.61 mm × 1.62 mm; anterior process of coxae I fairly small but well sclerotized. Eyes slightly convex, delimited dorsally by a few medium-sized setiferous punctations. Cervical pits deep, discrete. External margins of cervical fields indicated by rows of large discrete setiferous punctations that continue past the eyes and mark the positions of the marginal lines. Posteromedian groove short, somewhat spindle-shaped; posterolateral grooves small, round. A few medium-sized setiferous punctations scattered on scapulae and anteromedially on the conscutum, becoming larger and more numerous towards the posterior end of the conscutum, where they encircle the posterior grooves. A few minute punctations scattered among the larger elements but in general the conscutum looks smooth and shiny. Ventrally spiracles broad, tapering rather abruptly to a short gently-curved dorsal prolongation. Adanal plates broad, their external margins slightly curved, their internal margins scooped out just posterior to the anus, their posterior margins smoothly rounded; accessory adanal plates large, pointed, well sclerotized.

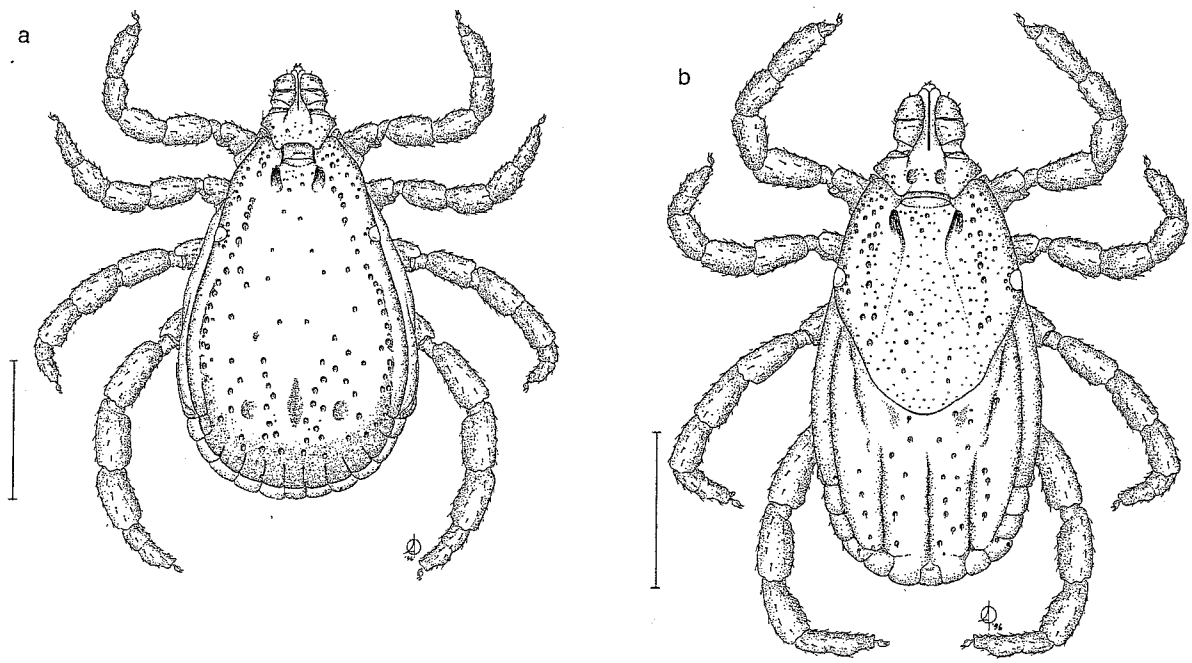
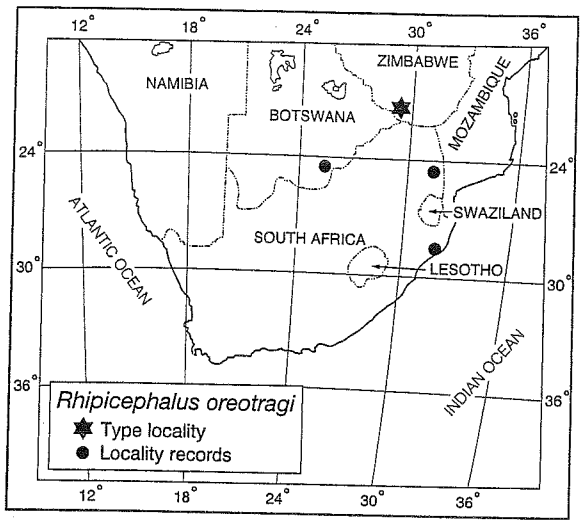


Figure 151. *Rhipicephalus oreotragi* Walker & Horak, *sp. nov.* [Onderstepoort Tick Collection 3145ii, paratypes, collected from klipspringer (*Oreotragus oreotragus*), Sentinel Ranch, 70 km W. of Beit Bridge, Zimbabwe, on 4 July 1992]. (a) Male, dorsal; (b) female, dorsal. Scale bars represent 1 mm. A. Olwage *del.*



Map 44. *Rhipicephalus oreotragi* Walker & Horak, *sp. nov.*: distribution.

Female (Figs 151(b), 152(d) to (f))

Capitulum broader than long, length × breadth ranging from 0.50 mm × 0.56 mm to 0.67 mm × 0.73 mm. Basis capituli with long acutely-pointed lateral angles just anterior to mid-length; porose areas small, oval, three times their own diameter apart. Palps longer than those of the male, with article III more-or-less wedge-shaped. Scutum longer than broad, length × breadth ranging from 1.04 mm × 0.91 mm to 1.52 mm × 1.30 mm; posterior margin a deep slightly sinuous curve. Eyes at about mid-length, slightly convex, delimited dorsally by a few medium-sized setiferous punctations. Cervical pits long, convergent; cervical fields long, their internal margins inconspicuous, their external margins indicated by long rows of large discrete setiferous punctations. A few medium-sized setiferous punctations scattered on scapulae and medially on scutum, interspersed with numerous very fine punctations. Ventrally genital aperture broadly U-shaped.

Nymph and larva

Unknown.

Holotype

♂ collected from klipspringer (*Oreotragus oreotragus*), Sentinel Ranch, 70 km west of Beit Bridge, Zimbabwe, on 4 July 1992, deposited in Onderstepoort Tick Collection 3145i.

Allotype

♀, data as above.

Paratypes

♂♂, ♀♀ data as above, deposited in Onderstepoort Tick Collection 3145ii; 2 ♂♂, 2 ♀♀, data as above, deposited in the United States National Tick Collection, RML 122748; 2 ♂♂, 2 ♀♀, data as above, deposited in The Natural History Museum, London.

Notes on identification

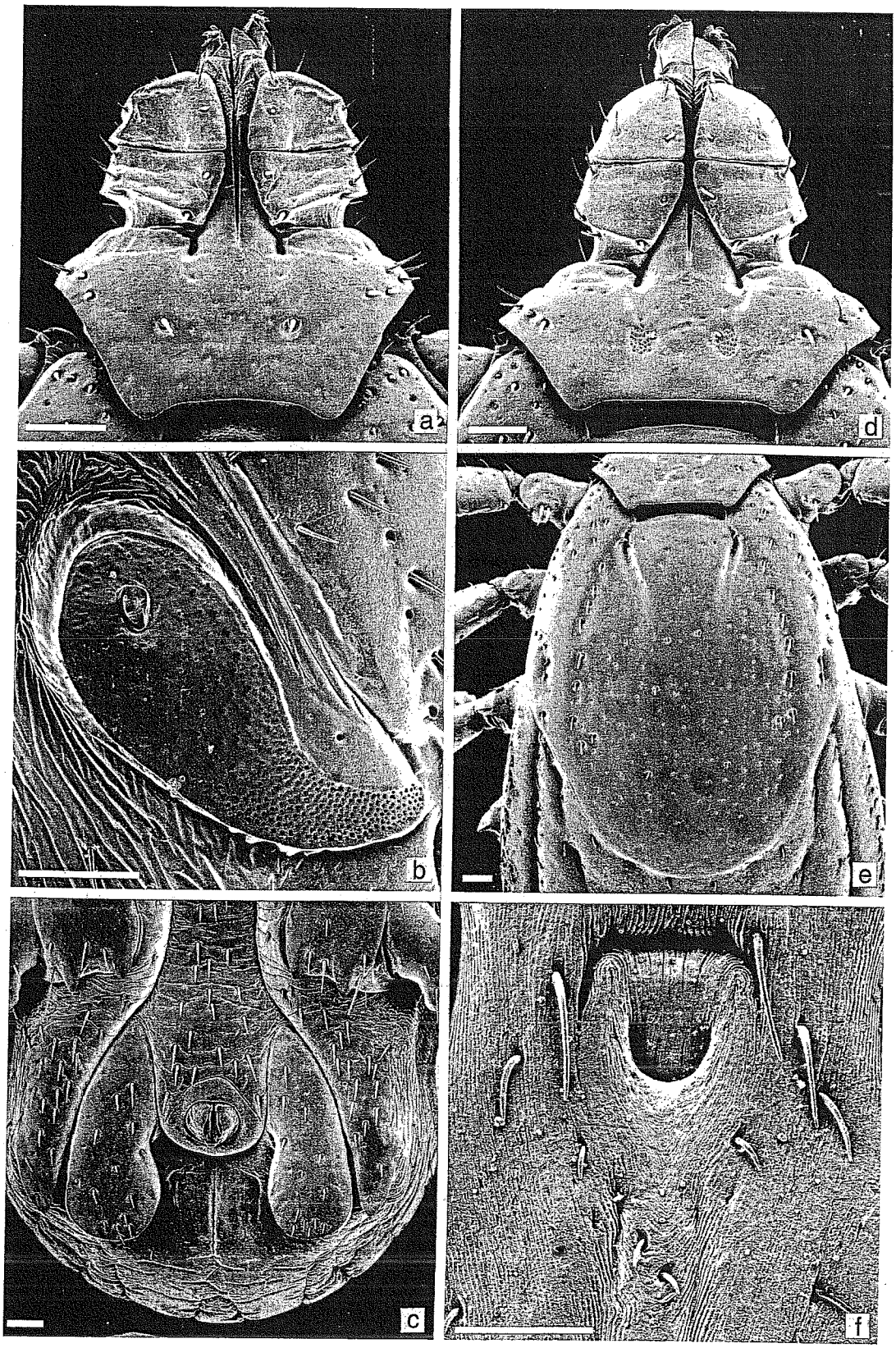
After examining the ticks collected by Dr F. Zumpt during December 1957 from a klipspringer in Botswana, Gertrud Theiler (unpublished data) noted that these were '*R. simus* (with a difference)'. Later Baker & Keep (1970) identified ticks that they had taken from a klipspringer in KwaZulu-Natal as *R. simpsoni*. Walker (1991) thought the latter ticks could be *R. distinctus*, but we now think that they are *R. oreotragi* (see above under *R. distinctus*, p. 138).

Hosts

Life cycle undetermined but it is assumed to be a three-host species. The only animals from which adult ticks have been collected are klipspringer. Collections for which the dates were recorded were made during April, July, September and December.

Zoogeography

Collections have been made in Zimbabwe and Botswana as well as in the Mpumalanga and KwaZulu-Natal Provinces of South Africa (Map 44). As klipspringer appear to be the only hosts of adult *R. oreotragi* its distribution is likely to be the same as that of this animal. It will thus be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discontinuous and associated with rocky hills or outcrops, gorges with rocky sides or mountainous areas with krantzes, all habitats favoured by klipspringer (Skinner & Smithers, 1990).

Disease relationships

Unknown.

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Figure 152 (*opposite*). *Rhipicephalus oreotragi* Walker & Horak, *sp. nov.* [Onderstepoort Tick Collection 3145ii, collected from klipspringer (*Oreotragus oreotragus*), Sentinel Ranch, 70 km W. of Beit Bridge, Zimbabwe, on 4 July 1992]. Male: (a) capitulum, dorsal; (b) spiracle; (c) adanal plates. Female: (d) capitulum, dorsal; (e) scutum; (f) genital aperture. Scale bars represent 0.10 mm. SEMs by J.F. Putterill.

RHIPICEPHALUS WARBURTONI WALKER & HORAK, *SP. NOV.*

This species is named in honour of Cecil Warburton (1854–1958), in recognition of his remarkable understanding of the difficult taxonomic problems in the genus *Rhipicephalus*. The analysis of morphological variations seen in individual species that he wrote in 1912 is still worthy of careful study by students of this genus today.

Diagnosis

A medium-sized dark brown species.

Male (Figs 216(a), 217(a) to (c))

Capitulum about as broad as long, length × breadth ranging from 0.59 mm × 0.61 mm to 0.79 mm × 0.78 mm. Basis capituli with short acute lateral angles at anterior third of its length. Palps short, broad, article III almost wedge-shaped. Conscutum length × breadth ranging from 2.59 mm × 1.52 mm to 3.46 mm × 2.13 mm; anterior process of coxae I prominent, well sclerotized. In engorged specimens body wall expanded somewhat laterally

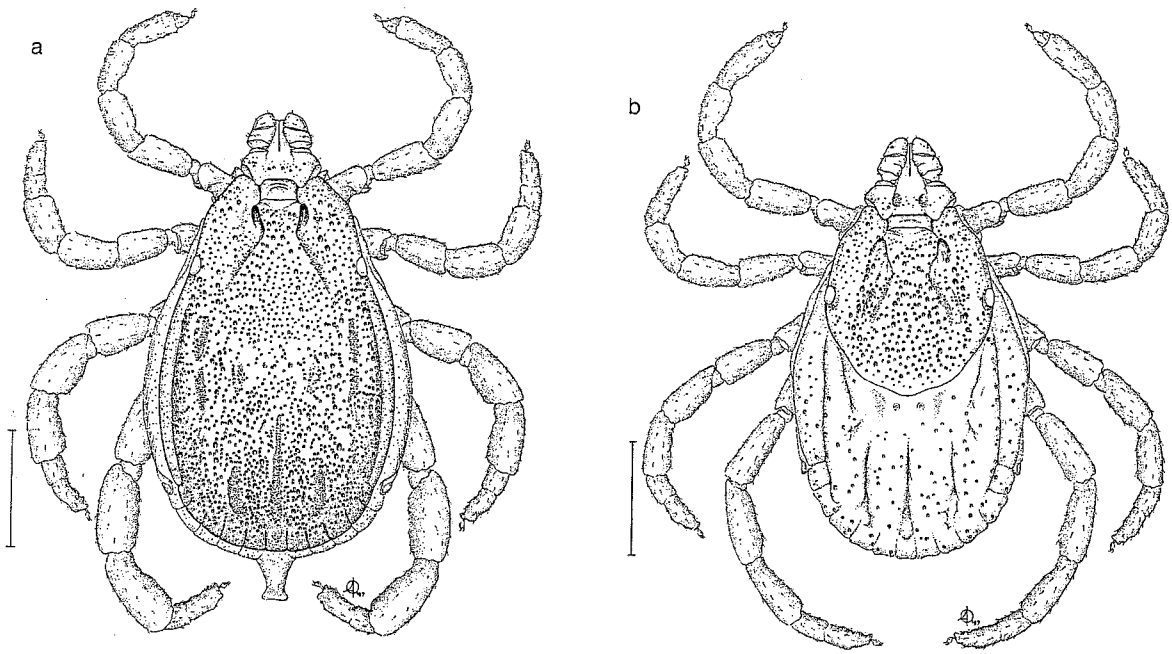
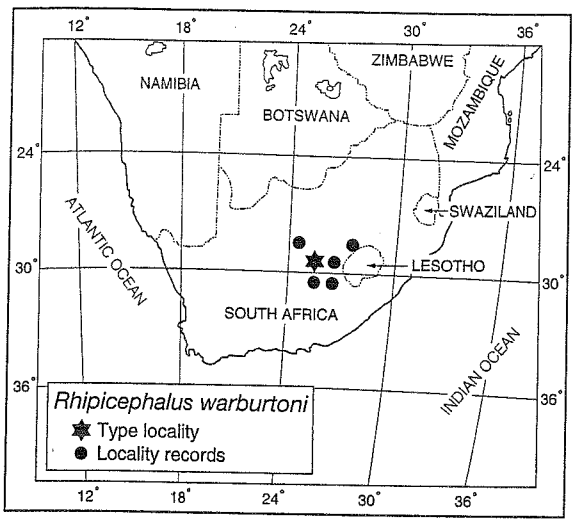


Figure 216. *Rhipicephalus warburtoni* Walker & Horak, *sp. nov.* [Onderstepoort Tick Collection 3146ii, paratypes, laboratory reared, originating from ♀ collected from Dorper sheep (D77), Preezfontein, Free State, South Africa, on 14 October 1993 by L.J. Fourie]. (a) Male, dorsal; (b) female, dorsal. Scale bars represent 1 mm. A. Olwage *del.*

Table 57. *Host records of* Rhipicephalus warburtoni

Hosts	Number of records
Domestic animals	
Cattle	26
Sheep	61
Goats	62
Dogs	2
Wild animals	
African wild cat (*Felis lybica*)	1
Gemsbok (*Oryx gazella*)	6
Namaqua rock mouse (*Aethomys namaquensis*)	69 (immatures)
Spring hare (*Pedetes capensis*)	14 (nymphs)
Cape hare (*Lepus capensis*)	12 (including immatures)
Scrub hare (*Lepus saxatilis*)	64 (including immatures)
Smith's red rock rabbit (*Pronolagus rupestris*)	7 (immatures)
Rock elephant shrew (*Elephantulus myurus*)	282 (immatures)



Map 61. *Rhipicephalus warburtoni* Walker & Horak, *sp. nov.*: distribution.

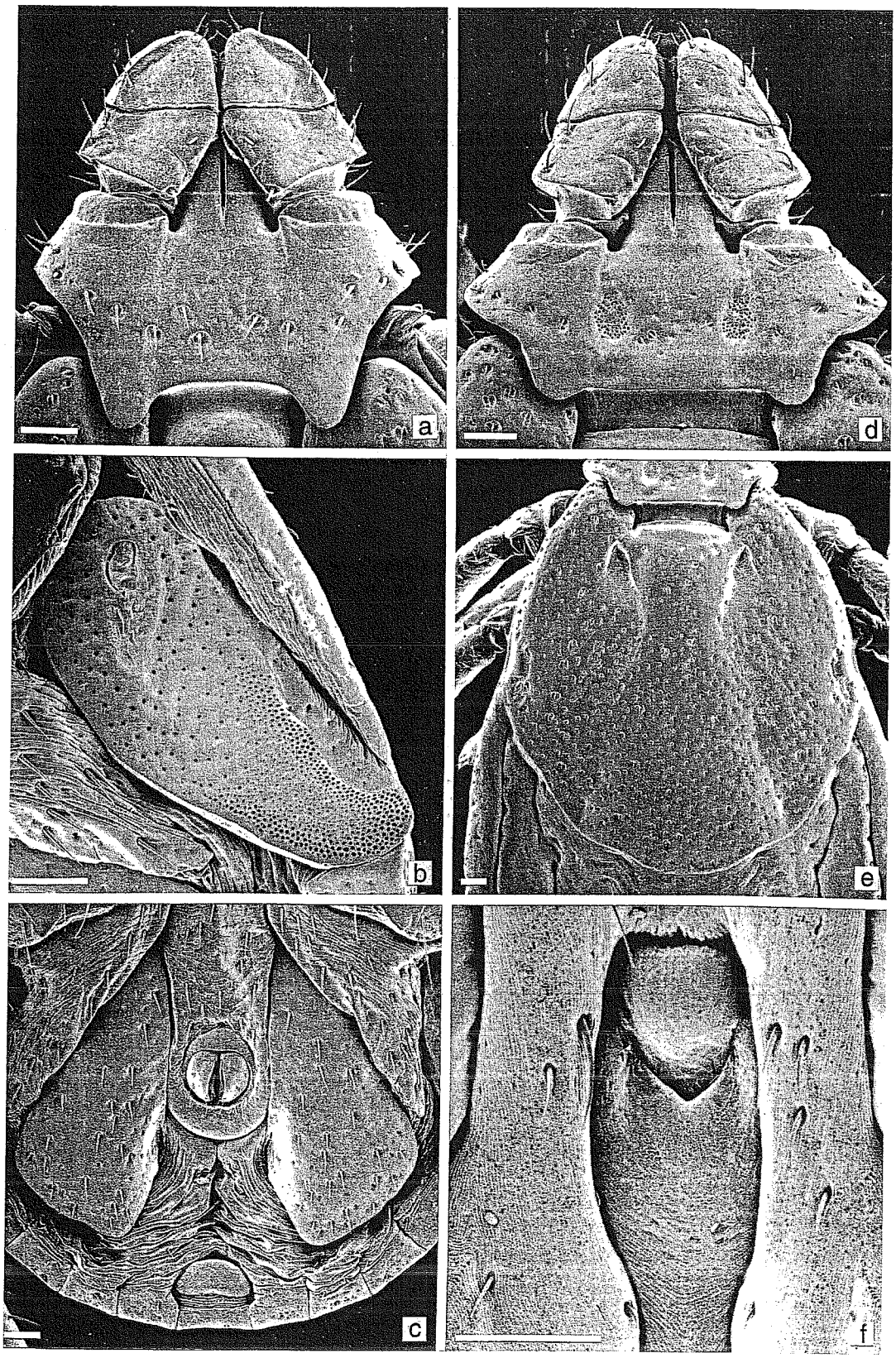
and posteriorly and forming a long tail-like caudal process posteromedially. Eyes convex, delimited dorsally by punctate grooves. Cervical pits deep, convergent; cervical fields divergent, tapering to points posterior to eyes, their external margins delimited by irregular rows of a few large discrete setiferous punctations. Marginal lines well developed, extending anteriorly almost to eye level, punctate. Posterior grooves conspicuous; posteromedian groove long and narrow, posterolaterals shorter and broader. A few large conspicuous setiferous punctations present on the scapulae and scattered medially on the conscutum, increasing in size and number towards the posterior end of the conscutum, interspersed with a dense pattern of discrete smaller punctations that also increase in size posteriorly. Small shagreened areas visible laterally on the conscutum, parallel to the marginal lines, and sometimes medially. Ventrally spiracles broad with a fairly short dorsal prolongation that curves slightly just at its tip. Adanal plates broad, their internal margins almost parallel anteriorly, becoming slightly divergent posterior to the anus; their posterointernal and posteroexternal margins smoothly rounded; accessory adanal plates indicated by small sclerotized points only.

Female (Figs 216(b), 217(d) to (f))

Capitulum broader than long, length × breadth ranging from 0.52 mm × 0.59 mm to 0.75 mm × 0.82 mm. Basis capituli with broad acute lateral angles just anterior to mid-length; porose areas small, oval, almost three times their own diameter apart. Palps longer and narrower than those of the male, their apices smoothly rounded. Scutum longer than broad, length × breadth ranging from 1.08 mm × 0.96 mm to 1.55 mm × 1.50 mm; posterior margin sinuous. Eyes at about mid-length, convex, delimited dorsally by punctate grooves. Cervical pits convergent; cervical fields broad, divergent, slightly depressed, their internal margins sometimes just reaching posterolateral margins of scutum, their external margins delimited by large setiferous punctations. A few medium-sized setiferous punctations scattered on scapulae and medially on scutum, interspersed with numerous discrete smaller punctations that are finest anterior to the eyes but larger between the cervical fields. Ventrally genital aperture broadly V-shaped.

Nymph (Fig. 218)

Capitulum much broader than long, length × breadth ranging from 0.21 mm × 0.27 mm to 0.22 mm × 0.29 mm. Basis capituli over three times as broad as long, lateral angles at about mid-length, very broad and overlapping scapulae, posterior margin concave. Palps narrow proximally, then widening, with article III tapering to narrowly-rounded apices, inclined inwards. Scutum slightly longer than broad, length × breadth ranging from 0.50 mm × 0.48 mm to 0.56 mm × 0.54 mm; posterior margin broadly curved. Eyes just anterior to widest point, well over halfway back, slightly convex, delimited dorsally by grooves. Cervical fields long, narrow, divergent, slightly depressed. Ventrally coxae I each with a short broad internal spur and a longer narrower external spur; coxae II to IV each with an external spur only, decreasing progressively in size.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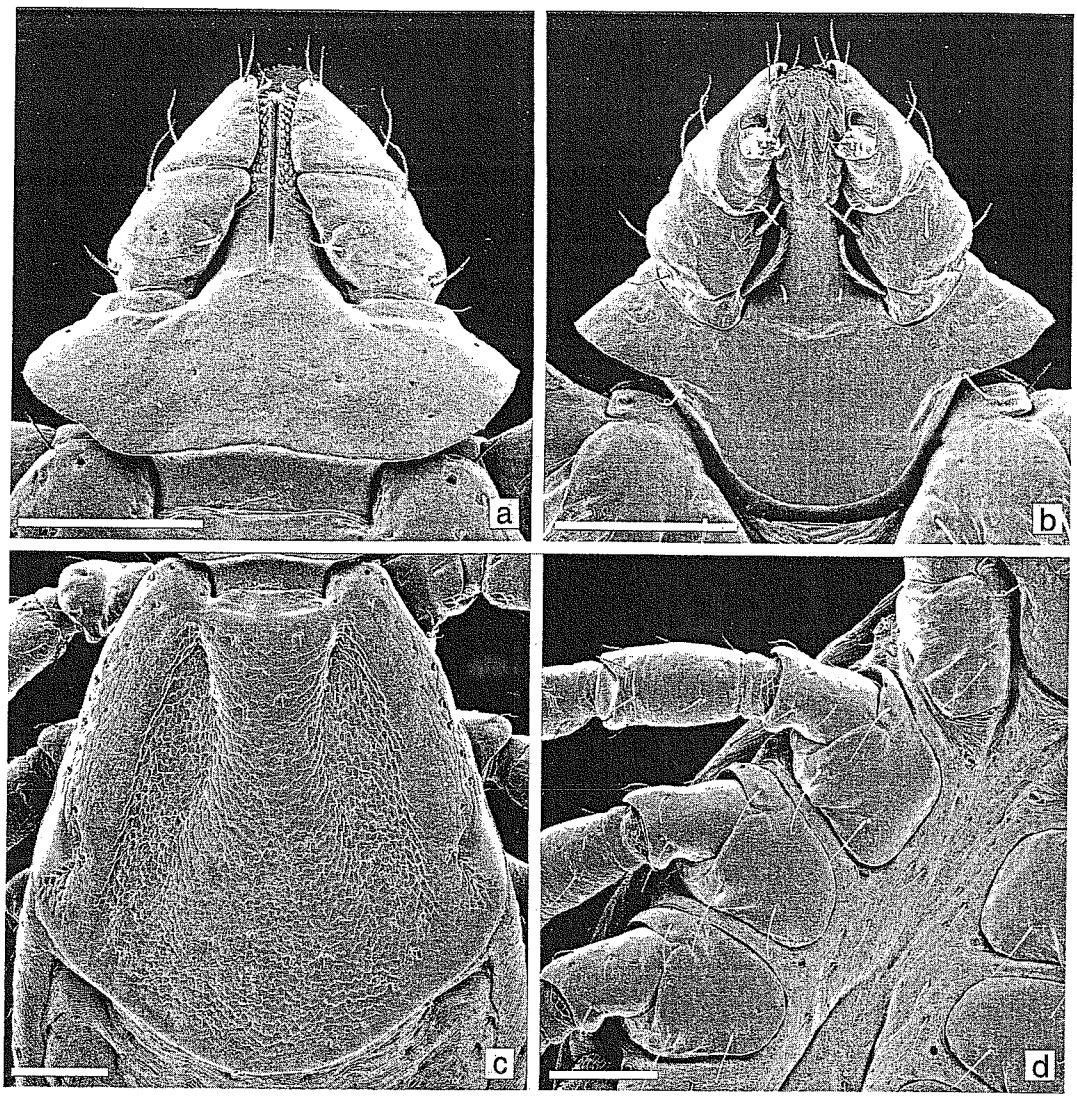

Figure 218 (*above*). *Rhipicephalus warburtoni* Walker & Horak, *sp. nov.* [laboratory reared, originating from ♀ collected from Dorper sheep (D77), Preezfontein, Free State, South Africa, on 14 October 1993 by L.J. Fourie]. Nymph: (a) capitulum, dorsal; (b) capitulum, ventral; (c) scutum; (d) coxae. Scale bars represent 0.10 mm. SEMs by J.F. Putterill.

Figure 217 (*opposite*). *Rhipicephalus warburtoni* Walker & Horak, *sp. nov.* [laboratory reared, originating from ♀ collected from Dorper sheep (D77), Preezfontein, Free State, South Africa, on 14 October 1993 by L.J. Fourie]. Male: (a) capitulum, dorsal; (b) spiracle; (c) adanal plates. Female: (d) capitulum, dorsal; (e) scutum; (f) genital aperture. Scale bars represent 0.10 mm. SEMs by J.F. Putterill.

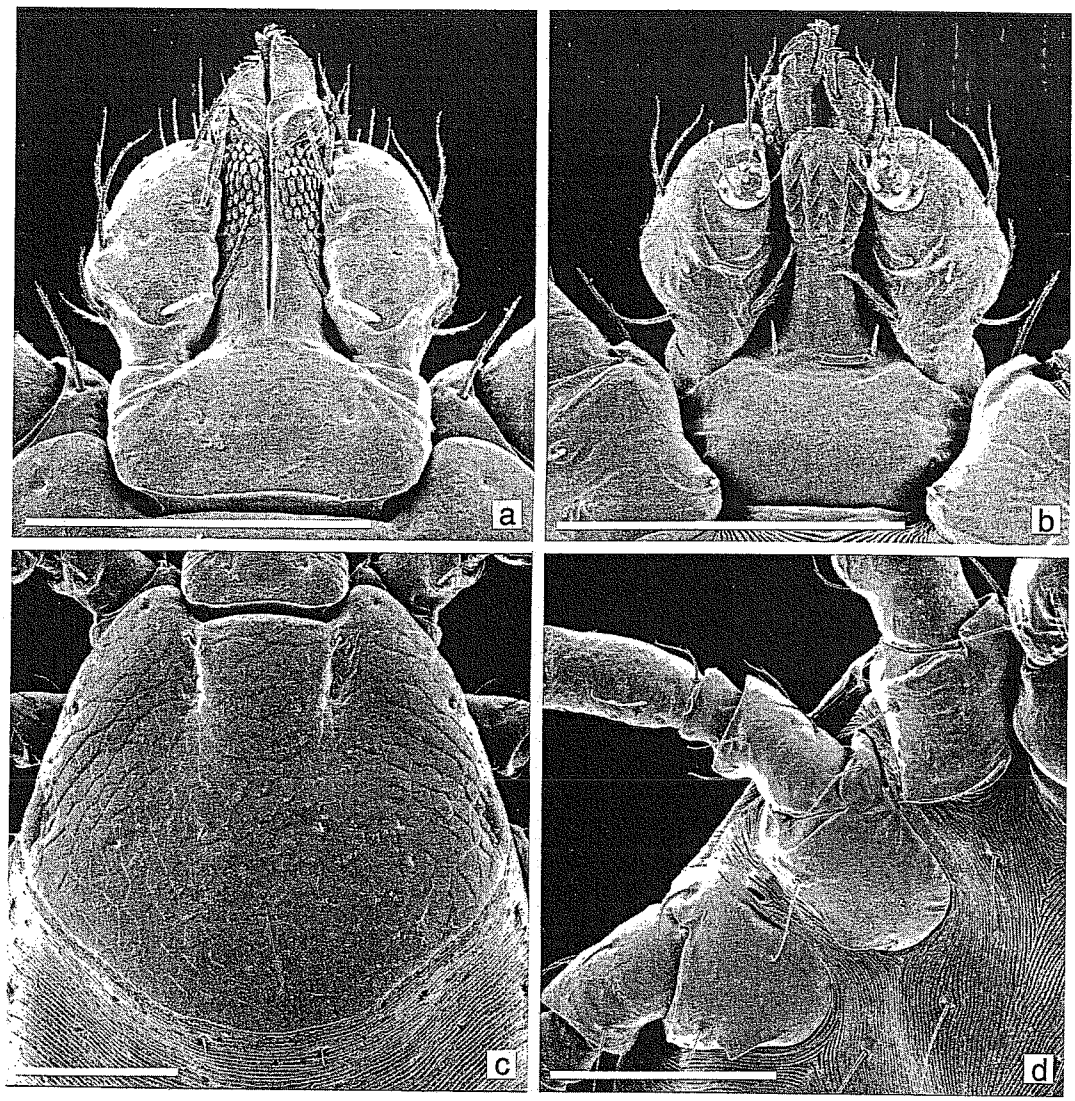

Figure 219. *Rhipicephalus warburtoni* Walker & Horak, *sp. nov.* [laboratory reared, originating from ♀ collected from Dorper sheep (D77), Preezfontein, Free State, South Africa, on 14 October 1993 by L.J. Fourie]. Larva: (a) capitulum, dorsal; (b) capitulum, ventral; (c) scutum; (d) coxae. Scale bars represent 0.10 mm. SEMs by J.F. Putterill.

Larva (Fig. 219)

Capitulum as long as broad, length × breadth ranging from 0.107 mm × 0.107 mm to 0.115 mm × 0.115 mm. Basis capituli nearly 2.5 times as broad as long, lateral margins almost straight, curving posteriorly to meet the slightly concave posterior margin. Palps constricted proximally, then widening markedly before tapering gently to rounded apices. Scutum much broader than long, length × breadth ranging from 0.276 mm × 0.356 mm to 0.281 mm × 0.372 mm; posterior margin broadly rounded. Eyes just anterior to widest point, about halfway back, slightly concave and delimited dorsally by grooves. Cervical grooves short, almost parallel. Ventrally coxae I each with a large sharp spur; coxae II and III each with more rounded spurs, that on III being quite small.

Holotype
♂, laboratory reared, progeny of ♀ collected from Dorper sheep (D 77), Preezfontein, Free State, South Africa, on 14 October 1993 by L.J. Fourie, deposited in Onderstepoort Tick Collection 3146i.

Allotype
♀, data as above.

Paratypes
♂♂, ♀♀, nymphs, larvae, data as above, deposited in Onderstepoort Tick Collection 3146ii; 3 ♂♂, 3 ♀♀, 10 nymphs, 10 larvae, data as above, deposited in the United States National Tick Collection, RML 122749; 3 ♂♂, 3 ♀♀, 10 nymphs, 10 larvae, data as above, deposited in The Natural History Museum, London.

Notes on identification
This tick is one of three closely-related species included under the name *R. pravus* by Theiler (1962). It also features in the South African literature under the following names: as an atypical strain of *R. appendiculatus* occurring in the Fauresmith region of the Free State (Theiler, 1949); as an *R. pravus*-like tick (Fourie, Horak & Marais, 1988a, b); as an *R. punctatus*-like tick (Fourie & Horak, 1990); and as *R. punctatus* in several publications on the ticks of the Free State by Fourie & Horak and their co-workers.

Hosts

A three-host species (L.J. Fourie, unpublished data, 1995). Although cattle, sheep and goats all serve as hosts of adult *R. warburtoni* (Table 57), its relative abundance on goats exceeds that on the other domestic animals (Fourie & Horak, 1991). The preferred wild host of all stages of development is the scrub hare. On two farms in the south-western Free State 46 out of 50 scrub hares examined were infested with a total of 1185 ticks. Twelve out of 34 Cape hares on the same farms carried 52 ticks, and seven out of 28 Smith's red rock rabbits harboured only 11 ticks (Horak & Fourie, 1991). The rock elephant shrew is the preferred host of the immature stages (Fourie, Horak & Van den Heever, 1992); 282 out of 287 elephant shrews examined in the Free State were infested, and 958 larvae and 22 nymphs were collected from a single animal.

The predilection sites of attachment of adult *R. warburtoni* on very young Angora goat kids are the head and ears (Fourie, Horak & Van Zyl, 1991). During the first few weeks of their lives these kids lie-up while their dams are feeding. This, coupled with the fact that the ticks actively quest for their hosts from the ground (Fourie *et al.*, 1993), could account for the large numbers attaching to their heads and ears. On older goats the ticks are found on the neck and brisket as well as the head and ears (Fourie *et al.*, 1991). On scrub hares the adults attach to the ears.

The larvae of *R. warburtoni* are most abundant on rock elephant shrews from December to July and the nymphs from April to October (Fourie *et al.*, 1992). Adults are most abundant on goats and cattle from September or October to February (Fourie & Horak, 1991; Fourie, Kok & Heyne, 1996).

Zoogeography

Rhipicephalus warburtoni has been found only in the Free State and Northern Cape Province, South Africa (Map 61). Here it has been collected at altitudes varying from 1200 m to 1600 m, with annual rainfall, which occurs mainly in summer, ranging from *c.* 200 mm to 600 mm. It occurs in Highveld grassland, Kalahari *Acacia* wooded grassland and in the transition from Karoo shrubland to Highveld. Within these regions the tick and its preferred hosts are most commonly associated with hilly habitats with vegetation cover.

Disease relationships

Paralysis has been reported in heavily-infested young Angora goat kids in the south-western

Free State during the period of peak adult tick abundance (Fourie *et al.*, 1988a). This paralysis is reversible provided the ticks are removed prior to the symptoms becoming too severe.

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The Argasidae, Ixodidae and Nuttalliellidae (Acari: Ixodida): a world list of valid tick names*

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Abstract. The world's argasid tick fauna comprises 183 species in four genera, namely *Argas*, *Carios*, *Ornithodoros* and *Otobius* in the family Argasidae. The ixodid tick fauna consists of 241 species in the genus *Ixodes* and 442 species in the genera *Amblyomma*, *Anomalohimalaya*, *Bothriocroton*, *Cosmiomma*, *Dermacentor*, *Haemaphysalis*, *Hyalomma*, *Margaropus*, *Nosomma*, *Rhipicentor* and *Rhipicephalus* in the family Ixodidae, with the genus *Boophilus* becoming a subgenus of the genus *Rhipicephalus*. The family Nuttalliellidae is represented by the monospecific genus *Nuttalliella*. The species names of these ticks, based on seven previous complete or partial listings, as well as those of recently described new species, are presented in tabular format.

Key words: ticks, Argasidae, Ixodidae, Nuttalliellidae, world checklist, species names

Preamble

We believe that the animal known as the species exists in the world, and that it can be given a name using binominal nomenclature. Only the species exists in nature, and any organization above the species level is conceptual in the mind of humans, and is pure semantics and does not exist in nature. There are no subgenera, genera, subfamilies, families or orders scuttling around out there on the ground, or questing on the vegetation or attached to hosts. But, and this is where the crux of the matter lies, humans love organization, and what better way to organize than to put objects similar in appearance in a compartment with a particular name. However, when you convene a group of

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people to organize almost anything, there will never be complete agreement on the correct arrangement of the entities being organized, and more especially so if instead of working in a group each person works in isolation. We are well aware of differences in opinion, even amongst ourselves, but with considerable discussion and some concessions we have put together a list of tick names (Table 1) that we trust fastidious organizers will be able to live with until someone arranges a better one.

In assembling this list we have had the advantage of having three previous lists, containing the names of all known tick species at the various times of their compilation, to consult (Neumann, 1911; Keirans, 1992; Camicas *et al.*, 1998), as well as a checklist of species published between 1973 and 1997 (Keirans and Robbins, 1999). We have used the systematic relationships of the soft ticks proposed by Klompen and Oliver (1993) in compiling the list of names for the Argasidae. These authors looked at the entire family and the cladistic analysis of the 83 characters they used indicated that there were only four genera, namely *Argas*, *Carios*, *Ornithodoros* and *Otobius* within this family and the available evidence did not permit recognition of subgenera in the latter three genera. This implies that the genera *Alveonasus*, *Argas*, *Ogadenus*, *Persicargas*, *Proknekalia* and *Secretargas* are now subgenera of *Argas* while the genera *Alectorobius*, *Antricola*, *Carios*, *Chiropterargas*, *Nothoaspis*, *Parantricola*, *Reticulinasus*, and *Subparmatus* become synonyms of *Carios*. One of us (JLC) does not fully agree with this classification of the Argasidae, and in particular with the status accorded to the name *Carios*. However, we all agree that the systematic grouping of this family requires further molecular taxonomic study before it can be settled satisfactorily. The acceptance of the classification currently proposed presents us with the problem of homonymy. The catalogue of Camicas *et al.* (1998) lists *Alveonasus cooleyi* (McIvor, 1941) as well as *Argas cooleyi* Kohls and Hoogstraal, 1960, and consequently when these genera are made subgenera of *Argas* we now have two ticks named *Argas cooleyi*. This anomaly will obviously have to be addressed some time in the future.

In the case of the Ixodidae we have incorporated the recommendations of two recent publications. In one all the ticks within the genus *Rhipicephalus* were examined and, but for two undescribed species, were assigned specific names (Walker *et al.*, 2000). In the other the classification of ticks of the genus *Aponomma* has been rearranged and the more 'primitive' members have been transferred to the subgenus *Bothriocroton* Keirans, King and Sharrad, 1994, which has been raised to generic rank, and the remainder to the genus *Amblyomma* (Klompen *et al.*, 2002). The genus *Aponomma* thus in part becomes a synonym of *Bothriocroton* and in part a synonym of *Amblyomma*.

An even more radical change that we have made is placing the five species in the genus *Boophilus* in the genus *Rhipicephalus*. We do so with trepidation,

but the current evidence in support of this change is overwhelming (Murrell *et al.*, 2000, 2001; Beati and Keirans, 2001), and in effect we are following a proposal already made towards the end of the 19th century by Neumann (1897). The genus *Boophilus* probably contains the globally best-known tick of all, namely *Boophilus microplus* and arguably the best-known African tick, *Boophilus decoloratus*. To avoid confusion, and even disbelief, amongst fieldworkers concerning this name change, we have retained *Boophilus* as a subgeneric epithet, and these ticks now become *Rhipicephalus* (*Boophilus*) *microplus* and *Rhipicephalus* (*Boophilus*) *decoloratus*. In addition we have not buried them in alphabetical sequence within the list of species belonging to the genus *Rhipicephalus*, but have placed them separately at the head of this list. This way, even if investigators continue to use *Boophilus*, everyone will still know to what ticks they are referring.

We have added the names of four argasid ticks and five ixodid ticks, described since 1996, to the list and that of one ixodid species omitted from the previous list. We have not furnished sub-specific names in our list, except where these are of importance in assisting with the identification of particular ticks. Even a cursory comparison of our list with the earlier lists will reveal that we have again organized things differently. This may infuriate zoologists, parasitologists and veterinarians who are not systematists, but who work within the discipline of acarology and prefer classifications as well as binominal epithets, and their spelling, to be cast in stone. For this we apologize, but hope that you will nevertheless find the list useful.

Table 1. List of valid names for the Argasidae, Ixodidae and the Nuttalliellidae

Argasidae
Argasinae
Argas
A. abdussalami Hoogstraal and McCarthy, 1965
A. acinus (Whittick, 1938)
A. africolumbae Hoogstraal, Kaiser, Walker, Ledger, Converse and Rice, 1975
A. arboreus Kaiser, Hoogstraal and Kohls, 1964
A. assimilis Teng and Song, 1983
A. beijingensis Teng, 1983
A. beklemischevi Pospelova-Shtrom, Vasil'eva and Semashko, 1963
A. brevipes Banks, 1908
A. brumpti Neumann, 1907
A. bureschi Dryenski, 1957
A. canestrinii (Birula, 1895)
A. cooleyi (McIvor, 1941)

Table 1. (*continued*)

A. cooleyi Kohls and Hoogstraal, 1960
A. cucumerinus Neumann, 1901
A. dalei Clifford, Keirans, Hoogstraal and Corwin, 1976
A. delanoei (Roubaud and Colas-Belcour, 1931)
A. dulus Keirans, Clifford and Capriles, 1971
A. eboris (Theiler, 1959)
A. echinops Hoogstraal, Uilenberg and Blanc, 1967
A. falco Kaiser and Hoogstraal, 1974
A. foleyi (Parrot, 1928)
A. giganteus Kohls and Clifford, 1968
A. gilcolladoi Estrada-Peña, Lucientes and Sánchez, 1987
A. hermanni Audouin, 1827
A. himalayensis Hoogstraal and Kaiser, 1973
A. hoogstraali Morel and Vassiliades, 1965
A. japonicus Yamaguti, Clifford and Tipton, 1968
A. lagenoplastis Froggatt, 1906
A. lahorensis (Neumann, 1908)
A. latus Filippova, 1961
A. lowryae Kaiser and Hoogstraal, 1975
A. macrostigmatus Filippova, 1961
A. magnus Neumann, 1896
A. miniatus Koch, 1844
A. monachus Keirans, Radovsky and Clifford, 1973
A. monolakensis Schwan, Corwin and Brown, 1992
A. moreli Keirans, Hoogstraal and Clifford, 1979
A. neghmei Kohls and Hoogstraal, 1961
A. nullarborensis Hoogstraal and Kaiser, 1973
A. peringueyi (Bedford and Hewitt, 1925)
A. persicus (Oken, 1818)
A. peusi (Schulze, 1943)
A. polonicus Siuda, Hoogstraal, Clifford and Wassef, 1979
A. radiatus Railliet, 1893
A. reflexus (Fabricius, 1794)
A. ricei Hoogstraal, Kaiser, Clifford and Keirans, 1975
A. robertsi Hoogstraal, Kaiser and Kohls, 1968
A. sanchezi Dugès, 1887
A. streptopelia Kaiser, Hoogstraal and Horner, 1970
A. striatus Bedford, 1932
A. theilerae Hoogstraal and Kaiser, 1970

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A. gilcolladoi Estrada-Peña, Lucientes and Sánchez, 1987
A. hermanni Audouin, 1827
A. himalayensis Hoogstraal and Kaiser, 1973
A. hoogstraali Morel and Vassiliades, 1965
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A. lagenoplastis Froggatt, 1906
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A. macrostigmatus Filippova, 1961
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A. miniatus Koch, 1844
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A. monolakensis Schwan, Corwin and Brown, 1992
A. moreli Keirans, Hoogstraal and Clifford, 1979
A. neghmei Kohls and Hoogstraal, 1961
A. nullarborensis Hoogstraal and Kaiser, 1973
A. peringueyi (Bedford and Hewitt, 1925)
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A. peusi (Schulze, 1943)
A. polonicus Siuda, Hoogstraal, Clifford and Wassef, 1979
A. radiatus Railliet, 1893
A. reflexus (Fabricius, 1794)
A. ricei Hoogstraal, Kaiser, Clifford and Keirans, 1975
A. robertsi Hoogstraal, Kaiser and Kohls, 1968
A. sanchezi Dugès, 1887
A. streptopelia Kaiser, Hoogstraal and Horner, 1970
A. striatus Bedford, 1932
A. theilerae Hoogstraal and Kaiser, 1970

Table 1. (*continued*)

A. transgariepinus White, 1846
A. tridentatus Filippova, 1961
A. vansomereni (Keirans, Hoogstraal and Clifford, 1977)
A. vulgaris Filippova, 1961 (?=*A. delicatus Neumann*, 1910)
A. walkerae Kaiser and Hoogstraal, 1969
A. zumpti Hoogstraal, Kaiser and Kohls, 1968

Ornithodorinae
Carios
C. amblus (Chamberlin, 1920)
C. aragaoi (Fonseca, 1960)
C. armasi (de la Cruz and Estrada-Peña, 1995)
C. australiensis (Kohls and Hoogstraal, 1962)
C. azteci (Matheson, 1935)
C. batuensis (Hirst, 1929)
C. boueti (Roubaud and Colas-Belcour, 1933)
C. brodyi (Matheson, 1935)
C. camicasi (Sylla, Cornet and Marchand, 1997)
C. capensis (Neumann, 1901)
C. casebeeri (Jones and Clifford, 1972)
C. centralis (de la Cruz and Estrada-Peña, 1995)
C. cernyi (de la Cruz, 1978)
C. ceylonensis (Hoogstraal and Kaiser, 1968)
C. cheikhi (Vermeil, Marjolet and Vermeil, 1997)
C. chironectes (Jones and Clifford, 1972)
C. chiropterphila (Dhanda and Rajagopalan, 1971)
C. clarki (Jones and Clifford, 1972)
C. collocaliae (Hoogstraal, Kadarsan, Kaiser and Van Peenen, 1974)
C. concanensis (Cooley and Kohls, 1941)
C. confusus (Hoogstraal, 1955)
C. coniceps (Canestrini, 1890)
C. coprophilus (McIntosh, 1935)
C. cordiformis (Hoogstraal and Kohls, 1967)
C. cyclurae (de la Cruz, 1984)
C. darwini (Kohls, Clifford and Hoogstraal, 1969)
C. daviesi (Kaiser and Hoogstraal, 1973)
C. denmarki (Kohls, Sonenshine and Clifford, 1965)
C. dewae (Kaiser and Hoogstraal, 1974)
C. dusbabeki (Černý, 1967)

Table 1. (*continued*) .

C. dyeri (Cooley and Kohls, 1940)
C. echimys (Kohls, Clifford and Jones, 1969)
C. elongatus (Kohls, Sonenshine and Clifford, 1965)
C. eptesicus (Kohls, Clifford and Jones, 1969)
C. faini (Hoogstraal, 1960)
C. galapagensis (Kohls, Clifford and Hoogstraal, 1969)
C. granasi (de la Cruz, 1973)
C. habanensis (de la Cruz, 1976)
C. hadiae Klompen, Keirans and Durden, 1995
C. hasei (Schulze, 1935)
C. hummelincki (de la Cruz and Estrada-Peña, 1995)
C. jerseyi Klompen and Grimaldi, 2001
C. jul (Schulze, 1940)
C. kelleyi (Cooley and Kohls, 1941)
C. kohlsi (Guglielmone and Keirans, 2002)
C. macrodermae (Hoogstraal, Moorhouse, Wolf and Wassef, 1977)
C. madagascariensis (Hoogstraal, 1962)
C. marginatus (Banks, 1910)
C. marinkellei (Kohls, Clifford and Jones, 1969)
C. maritimus (Vermeil and Marguet, 1967)
C. marmosae (Jones and Clifford, 1972)
C. martelorum (de la Cruz, 1978)
C. mexicanus (Hoffmann, 1959)
C. mimon (Kohls, Clifford and Jones, 1969)
C. mormoops (Kohls, Clifford and Jones, 1969)
C. muesebecki (Hoogstraal, 1969)
C. multisetosus Klompen, Keirans and Durden, 1995
C. naomiae (de la Cruz, 1978)
C. natalinus (Černý and Dusbábek, 1967)
C. occidentalis (de la Cruz, 1978)
C. papuensis Klompen, Keirans and Durden, 1995
C. peropteryx (Kohls, Clifford and Jones, 1969)
C. peruvianus (Kohls, Clifford and Jones, 1969)
C. piriformis (Warburton, 1918)
C. puertoricensis (Fox, 1947)
C. pusillus (Kohls, 1950)
C. reddelli (Keirans and Clifford, 1975)
C. rennellensis (Clifford and Sonenshine, 1962)
C. rossi (Kohls, Sonenshine and Clifford, 1965)

Table 1. (continued)

C. rudis (Karsch, 1880)
C. salahi (Hoogstraal, 1953)
C. sawaii (Kitaoka and Suzuki, 1973)
C. setosus (Kohls, Clifford and Jones, 1969)
C. siboneyi (de la Cruz and Estrada-Peña, 1995)
C. silvai (Černý, 1967)
C. sinensis (Jeu and Zhu, 1982)
C. solomonis (Dumbleton, 1959)
C. spheniscus (Hoogstraal, Wassef, Hays and Keirans, 1985)
C. stageri (Cooley and Kohls, 1941)
C. tadaridae (Černý and Dusbábek, 1967)
C. talaje (Guérin-Méneville, 1849)
C. tiptoni (Jones and Clifford, 1972)
C. tuttlei (Jones and Clifford, 1972)
C. vespertilionis Latreille, 1796
C. viguerasi (Cooley and Kohls, 1941)
C. yumatensis (Cooley and Kohls, 1941)
C. yunkeri (Keirans, Clifford and Hoogstraal, 1984)
Ornithodoros
O. alactagalis Issaakjan, 1936
O. antiquus Poinar, 1995 (a fossil species)
O. apertus Walton, 1962
O. arenicolous Hoogstraal, 1953
O. asperus Warburton, 1918
O. brasiliensis Aragão, 1923
O. cholodkovskyi Pavlovsky, 1930
O. compactus Walton, 1962
O. coriaceus Koch, 1844
O. eremicus Cooley and Kohls, 1941
O. erraticus (Lucas, 1849)
O. furcosus Neumann, 1908
O. graingeri Heisch and Guggisberg, 1953
O. grenieri Klein, 1965
O. gurneyi Warburton, 1926
O. hermsi Wheeler, Herms and Meyer, 1935
O. indica Rau and Rao, 1971
O. knoxjonesi Jones and Clifford, 1972
O. macmillani (Hoogstraal and Kohls, 1966)
O. marocanus Velu, 1919

Table 1. (continued)

O. moubata (Murray, 1877)
O. nattereri Warburton, 1927
O. nicollei Mooser, 1932
O. normandi Larrousse, 1923
O. parkeri Cooley, 1936
O. porcinus avivora Walton, 1979
O. porcinus domesticus Walton, 1962
O. porcinus porcinus Walton,1962
O. procaviae Theodor and Costa, 1960
O. rostratus Aragão, 1911
O. savignyi (Audouin, 1827)
O. sonrai Sautet and Witkowski, 1943
O. steini (Schulze, 1935)
O. tartakovskyi Olenev, 1931
O. tholozani Laboulbène and Mégnin, 1882
O. transversus (Banks, 1902)
O. turicata (Dugès, 1876)
O. zumpti Heisch and Guggisberg, 1953
Otobius
O. lagophilus Cooley and Kohls, 1940
O. megnini (Dugès, 1883)
O. sparnus (Kohls and Clifford, 1963)

Ixodidae
Ixodinae
Ixodes
I. abrocomae Lahille, 1917
I. acuminatus Neumann, 1901
I. acutitarsus (Karsch, 1880)
I. affinis Neumann, 1899
I. albignaci Uilenberg and Hoogsraal, 1969
I. alluaudi Neumann, 1913
I. amarali Fonseca, 1935
I. amersoni Kohls, 1966
I. anatis Chilton, 1904
I. andinus Kohls, 1956
I. angustus Neumann, 1899
I. antechini Roberts, 1960
I. apronophorus Schulze, 1924

Table 1. (*continued*)

I. arabukiensis Arthur, 1959
I. aragaoi Fonseca, 1935
I. arboricola Schulze and Schlottke, 1930
I. arebiensis Arthur, 1956
I. asanumai Kitaoka, 1973
I. aulacodi Arthur, 1956
I. auriculaelongae Arthur, 1958
I. auritulus Neumann, 1904 (=*I. auritulus zealandicus* Dumbleton, 1953)
I. australiensis Neumann, 1904
I. baergi Cooley and Kohls, 1942
I. bakeri Arthur and Clifford, 1961
I. banksi Bishopp, 1911
I. bedfordi Arthur, 1959
I. bequaerti Cooley and Kohls, 1945
I. berlesei Birula, 1895
I. bivari Santos Dias, 1990
I. boliviensis Neumann, 1904
I. brewsterae Keirans, Clifford and Walker, 1982
I. browningi Arthur, 1956
I. brumpti Morel, 1965
I. brunneus Koch, 1844
I. calcarhebes Arthur and Zulu, 1980
I. caledonicus Nuttall, 1910
I. canisuga Johnston, 1849
I. capromydis Černý, 1966
I. catherinei Keirans, Clifford and Walker, 1982
I. cavipalpus Nuttall and Warburton, 1908
I. ceylonensis Kohls, 1950
I. chilensis Kohls, 1956
I. colasbelcouri Arthur, 1957
I. collocaliae Schulze, 1937
I. columnae Takada and Fujita, 1992
I. conepati Cooley and Kohls, 1943
I. confusus Roberts, 1960
I. cookei Packard, 1869
I. cooleyi Aragão and Fonseca, 1951
I. copei Wilson, 1980
I. cordifer Neumann, 1908

Table 1. (*continued*)

I. cornuae Arthur, 1960
I. cornuatus Roberts, 1960
I. corwini Keirans, Clifford and Walker, 1982
I. crenulatus Koch, 1844
I. cuernavacensis Kohls and Clifford, 1966
I. cumulatimpunctatus Schulze, 1943
I. dampfi Cooley, 1943
I. daveyi Nuttall, 1913
I. dawesi Arthur, 1956
I. dendrolagi Wilson, 1967
I. dentatus Marx, 1899
I. diomedeae Arthur, 1958
I. diversifossus Neumann, 1899
I. djaronensis Neumann, 1907
I. domerguei Uilenberg and Hoogstraal, 1965
I. downsi Kohls, 1957
I. drakensbergensis Clifford, Theiler and Baker, 1975
I. eadsi Kohls and Clifford, 1964
I. eastoni Keirans and Clifford, 1983
I. eichhorni Nuttall, 1916
I. eldaricus Dzhaparidze, 1950
I. elongatus Bedford, 1929
I. eudyptidis Maskell, 1885
I. euplecti Arthur, 1958
I. evansi Arthur, 1956
I. fecialis Warburton and Nuttall, 1909
I. festai Rondelli, 1926
I. filippovae Černý, 1961
I. fossulatus Neumann, 1899
I. frontalis Panzer, 1798
I. fuscipes Koch, 1844
I. galapagoensis Clifford and Hoogstraal, 1980
I. ghilarovi Filippova and Panova, 1988
I. gibbosus Nuttall, 1916
I. granulatus Supino, 1897
I. gregsoni Lindquist, Wu and Redner, 1999
I. guatemalensis Kohls, 1956
I. hearlei Gregson, 1941

Table 1. (*continued*)

I. heinrichi Arthur, 1962
I. hexagonus Leach, 1815
I. himalayensis Dhanda and Kulkarni, 1969
I. hirsti Hassall, 1931
I. holocyclus Neumann, 1899
I. hoogstraali Arthur, 1955
I. howelli Cooley and Kohls, 1938
I. hyatti Clifford, Hoogstraal and Kohls, 1971
I. hydromyidis Swan, 1931
I. jacksoni Hoogstraal, 1967
I. jellisoni Cooley and Kohls, 1938
I. jonesae Kohls, Sonenshine and Clifford, 1969
I. kaiseri Arthur, 1957
I. kashimiricus Pomerantsev, 1948
I. kazakstani Olenev and Sorokoumov, 1934
I. kerguelenensis André and Colas-Belcour, 1942
I. kingi Bishopp, 1911
I. kohlsi Arthur, 1955
I. kopsteini Oudemans, 1926
I. kuntzi Hoogstraal and Kohls, 1965
I. laguri Olenev, 1929 *sensu* Olenev, 1931
I. lasallei Méndez Arocha and Ortiz, 1958
I. latus Arthur, 1958
I. laysanensis Wilson, 1964
I. lemuris Arthur, 1958
I. lewisi Arthur, 1965
I. lividus Koch, 1844
I. longiscutatus Boero, 1944
I. loricatus Neumann, 1899
I. loveridgei Arthur, 1958
I. luciae Sénevet, 1940
I. lunatus Neumann, 1907
I. luxuriosus Schulze, 1932
I. macfarlanei Keirans, Clifford and Walker, 1982
I. malayensis Kohls, 1962
I. marmotae Cooley and Kohls, 1938
I. marxi Banks, 1908
I. maslovi Emel'yanova and Kozlovskaya, 1967
I. matopi Spickett, Keirans, Norval and Clifford, 1981

Table 1. (continued)

I. mexicanus Cooley and Kohls, 1942
I. minor Neumann, 1902
I. minutae Arthur, 1959
I. mitchelli Kohls, Clifford and Hoogstraal, 1970
I. monospinosus Saito, 1968
I. montoyanus Cooley, 1944
I. moreli Arthur, 1957
I. moscharius Teng, 1982
I. moschiferi Nemenz, 1968
I. muniensis Arthur and Burrow, 1957
I. muris Bishopp and Smith, 1937
I. murreleti Cooley and Kohls, 1945
I. myospalacis Teng, 1986
I. myotomys Clifford and Hoogstraal, 1970
I. myrmecobii Roberts, 1962
I. nairobiensis Nuttall, 1916
I. nchisiensis Arthur, 1958
I. nectomys Kohls, 1956
I. neitzi Clifford, Walker and Keirans, 1977
I. nesomys Uilenberg and Hoogstraal, 1969
I. neuquenensis Ringuelet, 1947
I. nicolasi Santos Dias, 1982
I. nipponensis Kitaoka and Saito, 1967
I. nitens Neumann, 1904
I. nuttalli Lahille, 1913
I. nuttallianus Schulze, 1930
I. occultus Pomerantsev, 1946
I. ochotonae Gregson, 1941
I. okapiae Arthur, 1956
I. oldi Nuttall, 1913
I. ornithorhynchi Lucas, 1846
I. ovatus Neumann, 1899
I. pacificus Cooley and Kohls, 1943
I. pararicinus Keirans and Clifford, 1985
I. pavlovskyi Pomerantsev, 1946
I. percavatus Neumann, 1906
I. peromysci Augustson, 1940
I. persulcatus Schulze, 1930

Table 1. (*continued*)

I. petauristae Warburton, 1933
I. philipi Keirans and Kohls, 1970
I. pilosus Koch, 1844
I. pomerantzi Kohls, 1956
I. pomeranzevi Serdyukova, 1941
I. priscicollaris Schulze, 1932
I. procaviae Arthur and Burrow, 1957
I. prokopjevi (Emel'yanova, 1979)
I. radfordi Kohls, 1948
I. rageaui Arthur, 1958
I. randrianasoloi Uilenberg and Hoogstraal, 1969
I. rangtangensis Teng, 1973
I. rasus Neumann, 1899
I. redikorzevi Olenev, 1927
I. rhabdomysae Arthur, 1959
I. ricinus (Linnaeus, 1758)
I. rothschildi Nuttall and Warburton, 1911
I. rotundatus Arthur, 1958
I. rubicundus Neumann, 1904
I. rubidus Neumann, 1901
I. rugicollis Schulze and Schlottke, 1930
I. rugosus Bishopp, 1911
I. sachalinensis Filippova, 1971
I. scapularis Say, 1821
I. schillingsi Neumann, 1901
I. schulzei Aragão and Fonseca, 1951
I. sculptus Neumann, 1904
I. semenovi Olenev, 1929
I. shahi Clifford, Hoogstraal and Kohls, 1971
I. siamensis Kitaoka and Suzuki, 1983
I. sigelos Keirans, Clifford and Corwin, 1976
I. signatus Birula, 1895
I. simplex Neumann, 1906
I. sinaloa Kohls and Clifford, 1966
I. sinensis Teng, 1977
I. soricis Gregson, 1942
I. spinae Arthur, 1958
I. spinicoxalis Neumann, 1899
I. spinipalpis Hadwen and Nuttall, 1916

Table 1. (continued)

I. steini Schulze, 1932
I. stilesi Neumann, 1911
I. stromi Filippova, 1957
I. subterranus Filippova, 1961
I. taglei Kohls, 1969
I. tamaulipas Kohls and Clifford, 1966
I. tancitarius Cooley and Kohls, 1942
I. tanuki Saito, 1964
I. tapirus Kohls, 1956
I. tasmani Neumann, 1899
I. tecpanensis Kohls, 1956
I. texanus Banks, 1909
I. theilerae Arthur, 1953
I. thomasae Arthur and Burrow, 1957
I. tiptoni Kohls and Clifford, 1962
I. tovari Cooley, 1945
I. transvaalensis Clifford and Hoogstraal, 1966
I. trianguliceps Birula, 1895
I. trichosuri Roberts, 1960
I. tropicalis Kohls, 1956
I. turdus Nakatsuji, 1942
I. ugandanus Neumann, 1906
I. unicavatus Neumann, 1908
I. uriae White, 1852
I. vanidicus Schulze, 1943
I. venezuelensis Kohls, 1953
I. ventalloi Gil Collado, 1936
I. vespertilionis Koch, 1844
I. vestitus Neumann, 1908
I. victoriensis Nuttall, 1916
I. walkerae Clifford, Kohls and Hoogstraal, 1968
I. werneri Kohls, 1950
I. woodi Bishopp, 1911
I. zaglossi Kohls, 1960
I. zairensis Keirans, Clifford and Walker, 1982
I. zumpti Arthur, 1960

Amblyomminae
Amblyomma
A. albolimbatum Neumann, 1907
A. albopictum Neumann, 1899

Table 1. (*continued*)

A. americanum (Linnaeus, 1758)
A. antillorum Kohls, 1969
A. argentinae Neumann, 1905
A. astrion Dönitz, 1909
A. aureolatum (Pallas, 1772)
A. auricularium (Conil, 1878)
A. australiense Neumann, 1905
A. babirussae Schulze, 1933
A. boulengeri Hirst and Hirst, 1910
A. brasiliense Aragão, 1908
A. breviscutatum Neumann, 1899
A. cajennense (Fabricius, 1787)
A. calabyi Roberts, 1963
A. calcaratum Neumann, 1899
A. chabaudi Rageau, 1964
A. clypeolatum Neumann, 1899
A. coelebs Neumann, 1899
A. cohaerens Dönitz, 1909
A. compressum (Macalister, 1872)
A. cordiferum Neumann, 1899
A. crassum Robinson, 1926
A. crenatum Neumann, 1899
A. cruciferum Neumann, 1901
A. darwini Hirst and Hirst, 1910
A. dissimile Koch, 1844
A. dubitatum Neumann, 1899
A. eburneum Gerstäcker, 1873
A. echidnae Roberts, 1953
A. extraoculatum Neumann, 1899
A. falsomarmoreum Tonelli-Rondelli, 1935
A. fulvum Neumann, 1899
A. geayi Neumann, 1899
A. gemma Dönitz, 1909
A. geochelone Durden, Keirans and Smith, 2002
A. geoemydae (Cantor, 1847)
A. glauerti Keirans, King and Sharrad, 1994
A. goeldii Neumann, 1899
A. hainanense Teng, 1981
A. hebraeum Koch, 1844
A. helvolum Koch, 1844
A. hirtum Neumann, 1906

Table 1. (*continued*)

A. humerale Koch, 1844
A. imitator Kohls, 1958
A. incisum Neumann, 1906
A. inornatum (Banks, 1909)
A. integrum Karsch, 1879
A. javanense (Supino, 1897)
A. laticaudae Warburton, 1933
A. lepidum Dönitz, 1909
A. limbatum Neumann, 1899
A. loculosum Neumann, 1907
A. longirostre (Koch, 1844)
A. macfarlandi Keirans, Hoogstraal and Clifford, 1973
A. macropi Roberts, 1953
A. maculatum Koch, 1844
A. marmoreum Koch, 1844
A. moreliae (Koch, 1867)
A. moyi Roberts, 1953
A. multipunctum Neumann, 1899
A. naponense (Packard, 1869)
A. neumanni Ribaga, 1902
A. nitidum Hirst and Hirst, 1910
A. nodosum Neumann, 1899
A. nuttalli Dönitz, 1909
A. oblongoguttatum Koch, 1844
A. ovale Koch, 1844
A. pacae Aragão, 1911
A. papuanum Hirst, 1914
A. parvitarsum Neumann, 1901
A. parvum Aragão, 1908
A. paulopunctatum Neumann, 1899
A. pecarium Dunn, 1933
A. personatum Neumann, 1901
A. pictum Neumann, 1906
A. pilosum Neumann, 1899
A. pomposum Dönitz, 1909
A. postoculatum Neumann, 1899
A. pseudoconcolor Aragão, 1908
A. pseudoparvum Guglielmone, Mangold and Keirans, 1990
A. quadricavum (Schulze, 1941)

Table 1. (*continued*)

A. rhinocerotis (de Geer, 1778)
A. robinsoni Warburton, 1927
A. rotundatum Koch, 1844
A. sabanerae Stoll, 1890
A. scalpturatum Neumann, 1906
A. scutatum Neumann, 1899
A. sparsum Neumann, 1899
A. splendidum Giebel, 1877
A. squamosum Kohls, 1953
A. supinoi Neumann, 1905
A. sylvaticum (de Geer, 1778)
A. tapirellum Dunn, 1933
A. testudinarium Koch, 1844
A. tholloni Neumann, 1899
A. tigrinum Koch, 1844
A. torrei Pérez Vigueras, 1934
A. triguttatum ornatissimum Roberts, 1962
A. triguttatum queenslandense Roberts, 1962
A. triguttatum rosei Roberts, 1962
A. triguttatum triguttatum Koch, 1844
A. triste Koch, 1844
A. tuberculatum Marx, 1894
A. usingeri Keirans, Hoogstraal and Clifford, 1973
A. variegatum (Fabricius, 1794)
A. varium Koch, 1844
A. vikirri Keirans, Bull and Duffield, 1996
A. williamsi Banks, 1924
Amblyomma (Former *Aponomma*, now synonyms of *Amblyomma*)
A. arcanum (Karsch, 1879)
A. crassipes (Neumann, 1901)
A. elaphense (Price, 1959)
A. exornatum Koch, 1844
A. fimbriatum Koch, 1844
A. flavomaculatum (Lucas, 1846)
A. fuscolineatum (Lucas, 1847)
A. gervaisi (Lucas, 1847)
A. inopinatum (Santos Dias, 1989)
A. komodoense (Oudemans, 1928)
A. kraneveldi (Anastos, 1956)

Table 1. (continued)

A. latum Koch, 1844
A. orlovi (Kolonin, 1992)
A. oudemansi (Neumann, 1910)
A. pattoni (Neumann, 1910)
A. soembawense (Anastos, 1956)
A. sphenodonti (Dumbleton, 1943)
A. transversale (Lucas, 1844)
A. trimaculatum (Lucas, 1878)
A. varanense (Supino, 1897)

Bothriocrotoninae
Bothriocroton
B. auruginans (Schulze, 1936)
B. concolor (Neumann, 1899)
B. glebopalma (Keirans, King and Sharrad, 1994)
B. hydrosauri (Denny, 1843)
B. undatum (Fabricius, 1775)

Haemaphysalinae
Haemaphysalis
H. aborensis Warburton, 1913
H. aciculifer Warburton, 1913
H. aculeata Lavarra, 1904
H. adleri Feldman-Muhsam, 1951
H. anomala Warburton, 1913
H. anomaloceraea Teng and Cui, 1984
H. anoplos Hoogstraal, Uilenberg and Klein, 1967
H. aponommoides Warburton, 1913
H. asiatica (Supino, 1897)
H. atheruri Hoogstraal, Trapido and Kohls, 1965
H. bancrofti Nuttall and Warburton, 1915
H. bandicota Hoogstraal and Kohls, 1965
H. bartelsi Schulze, 1938
H. bequaerti Hoogstraal, 1956
H. birmaniae Supino, 1897
H. bispinosa Neumann, 1897
H. borneata Hoogstraal, 1971
H. bremneri Roberts, 1963

Table 1. (*continued*)

H. calcarata Neumann, 1902
H. calva Nuttall and Warburton, 1915
H. campanulata Warburton, 1908
H. canestrinii (Supino, 1897)
H. capricornis Hoogstraal, 1966
H. caucasica Olenev, 1928
H. celebensis Hoogstraal, Trapido and Kohls, 1965
H. chordeilis (Packard, 1869)
H. colasbelcouri (Santos Dias, 1958)
H. concinna Koch, 1844
H. cooleyi Bedford, 1929
H. cornigera Neumann, 1897
H. cornupunctata Hoogstraal and Varma, 1962
H. cuspidata Warburton, 1910
H. dangi Phan Trong, 1977
H. danieli Černý and Hoogstraal, 1977
H. darjeeling Hoogstraal and Dhanda, 1970
H. davisi Hoogstraal, Dhanda and Bhat, 1970
H. demidovae Emel'yanova, 1978
H. doenitzi Warburton and Nuttall, 1909
H. elliptica (Koch, 1844)
H. elongata Neumann, 1897
H. erinacei erinacei Pavesi, 1884
H. erinacei ornata Feldman-Muhsam, 1956
H. erinacei taurica Pospelova-Shtrom, 1940
H. erinacei turanica Pospelova-Shtrom, 1940
H. eupleres Hoogstraal, Kohls and Trapido, 1965
H. filippovae Bolotin, 1979
H. flava Neumann, 1897
H. formosensis Neumann, 1913
H. fossae Hoogstraal, 1953
H. fujisana Kitaoka, 1970
H. garhwalensis Dhanda and Bhat, 1968
H. goral Hoogstraal, 1970
H. grochovskajae Kolonin, 1992
H. heinrichi Schulze, 1939
H. hirsuta Hoogstraal, Trapido and Kohls, 1966
H. hispanica Gil Collado, 1938

Table 1. (*continued*)

H. hoodi Warburton and Nuttall, 1909
H. hoogstraali Kohls, 1950
H. houyi Nuttall and Warburton, 1915
H. howletti Warburton, 1913
H. humerosa Warburton and Nuttall, 1909
H. hylobatis Schulze, 1933
H. hyracophila Hoogstraal, Walker and Neitz, 1971
H. hystricis Supino, 1897
H. ias Nakamura and Yajima, 1937
H. indica Warburton, 1910
H. indoflava Dhanda and Bhat, 1968
H. inermis Birula, 1895
H. intermedia Warburton and Nuttall, 1909
H. japonica douglasi Nuttall and Warburton, 1915
H. japonica japonica Warburton, 1908
H. juxtakochi Cooley, 1946
H. kadarsani Hoogstraal and Wassef, 1977
H. kashmirensis Hoogstraal and Varma, 1962
H. kinneari Warburton, 1913
H. kitaokai Hoogstraal, 1969
H. koningsbergeri Warburton and Nuttall, 1909
H. kopetdaghica Kerbabaev, 1962
H. kutchensis Hoogstraal and Trapido, 1963
H. kyasanurensis Trapido, Hoogstraal and Rajagopalan, 1964
H. lagostrophi Roberts, 1963
H. lagrangei Larrousse, 1925
H. laocayensis Phan Trong, 1977
H. leachi (Audouin, 1826)
H. lemuris Hoogstraal, 1953
H. leporispalustris (Packard, 1869)
H. lobachovi Kolonin, 1995
H. longicornis Neumann, 1901
H. luzonensis Hoogstraal and Parrish, 1968
H. madagascariensis Colas-Belcour and Millot, 1948
H. mageshimaensis Saito and Hoogstraal, 1973
H. megalaimae Rajagopalan, 1963
H. megaspinosa Saito, 1969
H. menglaensis Pang, Chen and Xiang, 1982
H. minuta Kohls, 1950

Table 1. (continued)

H. mjoebergi Warburton, 1926
H. montgomeryi Nuttall, 1912
H. moreli Camicas, Hoogstraal and El Kammah, 1972
H. moschisuga Teng, 1980
H. muhsamae Santos Dias, 1954
H. nadchatrami Hoogstraal, Trapido and Kohls, 1965
H. nepalensis Hoogstraal, 1962
H. nesomys Hoogstraal, Uilenberg and Klein, 1966
H. norvali Hoogstraal and Wassef, 1983
H. novaeguineae Hirst, 1914
H. obesa Larrousse, 1925
H. obtusa Dönitz, 1910
H. orientalis Nuttall and Warburton, 1915
H. ornithophila Hoogstraal and Kohls, 1959
H. palawanensis Kohls, 1950
H. papuana Thorell, 1883
H. paraleachi Camicas, Hoogstraal and El Kammah, 1983
H. paraturturis Hoogstraal, Trapido and Rebello, 1963
H. parmata Neumann, 1905
H. parva Neumann, 1897
H. pavlovskyi Pospelova-Shtrom, 1935
H. pedetes Hoogstraal, 1972
H. pentalagi Pospelova-Shtrom, 1935
H. petrogalis Roberts, 1970
H. phasiana Saito, Hoogstraal and Wassef, 1974
H. pospelovashtromae Hoogstraal, 1966
H. primitiva Teng, 1982
H. psalistos Hoogstraal, Kohls and Parrish, 1967
H. punctaleachi Camicas, Hoogstraal and El Kammah, 1973
H. punctata Canestrini and Fanzago, 1878
H. qinghaiensis Teng, 1980
H. quadriaculeata Kolonin, 1992
H. ramachandrai Dhanda, Hoogstraal and Bhat, 1970
H. ratti Kohls, 1948
H. renschi Schulze, 1933
H. roubaudi Toumanoff, 1940
H. rugosa Santos Dias, 1956
H. rusae Kohls, 1950
H. sambar Hoogstraal, 1971

Table 1. (*continued*)

H. sciuri Kohls, 1950
H. semermis Neumann, 1901
H. shimoga Trapido and Hoogstraal, 1964
H. silacea Robinson, 1912
H. silvafelis Hoogstraal and Trapido, 1963
H. simplex Neumann, 1897
H. simplicima Hoogstraal and Wassef, 1979
H. sinensis Zhang, 1981
H. spinigera Neumann, 1897
H. spinulosa Neumann, 1906
H. subelongata Hoogstraal, 1953
H. subterra Hoogstraal, El Kammah and Camicas, 1992
H. sulcata Canestrini and Fanzago, 1878
H. sumatraensis Hoogstraal, El Kammah, Kadarsan and Anastos, 1971
H. sundrai Sharif, 1928
H. suntzovi Kolonin, 1993
H. susphilippensis Hoogstraal, Kohls and Parrish, 1968
H. taiwana Sugimoto, 1936
H. taufflebi Morel, 1965
H. theilerae Hoogstraal, 1953
H. tibetensis Hoogstraal, 1965
H. tiptoni Hoogstraal, 1953
H. toxopei Warburton, 1927
H. traguli Oudemans, 1928
H. traubi Kohls, 1955
H. turturis Nuttall and Warburton, 1915
H. verticalis Itagaki, Noda and Yamaguchi, 1944
H. vidua Warburton and Nuttall, 1909
H. vietnamensis Hoogstraal and Wilson, 1966
H. warburtoni Nuttall, 1912
H. wellingtoni Nuttall and Warburton, 1908
H. xinjiangensis Teng, 1980
H. yeni Toumanoff, 1944
H. zumpti Hoogstraal and El Kammah, 1974

Hyalomminae
Hyalomma
H. aegyptium (Linnaeus, 1758)
H. albiparmatum Schulze, 1919
H. anatolicum anatolicum Koch, 1844

Table 1. (*continued*)

H. anatolicum excavatum Koch, 1844
H. arabica Pegram, Hoogstraal and Wassef, 1982
H. asiaticum asiaticum Schulze and Schlottke, 1930
H. asiaticum caucasicum Pomerantsev, Matikashvili and Lototsky, 1940
H. asiaticum kozlovi Olenev, 1931
H. brevipunctata Sharif, 1928
H. detritum detritum Schulze, 1919
H. detritum scupense Schulze, 1918
H. dromedarii Koch, 1844
H. erythraeum Tonelli-Rondelli, 1932
H. franchinii Tonelli-Rondelli, 1932
H. hussaini Sharif, 1928
H. hystricis Dhanda and Raja, 1974
H. impeltatum Schulze and Schlottke, 1930
H. impressum Koch, 1844
H. kumari Sharif, 1928
H. lusitanicum Koch, 1844
H. marginatum isaaci Sharif, 1928
H. marginatum marginatum Koch, 1844
H. marginatum rufipes Koch, 1844
H. nitidum Schulze, 1919
H. punt Hoogstraal, Kaiser and Pedersen, 1969
H. rhipicephaloides Neumann, 1901
H. schulzei Olenev, 1931
H. sinaii Feldman-Muhsam, 1960
H. truncatum Koch, 1844
H. turanicum Pomerantsev, 1946
Nosomma
N. monstrosum (Nuttall and Warburton, 1908)

Rhipicephalinae
Anomalohimalaya
A. cricetuli Teng and Huang, 1981
A. lamai Hoogstraal, Kaiser and Mitchell, 1970
A. lotozkyi Filippova and Panova, 1978
Cosmiomma
C. hippopotamensis (Denny, 1843)
Dermacentor
D. abaensis Teng, 1963
D. albipictus (Packard, 1869)

Table 1. (*continued*)

D. andersoni Stiles, 1908
D. asper Arthur, 1960
D. atrosignatus Neumann, 1906
D. auratus Supino, 1897
D. circumguttatus Neumann, 1897
D. compactus Neumann, 1901
D. dispar Cooley, 1937
D. dissimilis Cooley, 1947
D. everestianus Hirst, 1926
D. halli McIntosh, 1931
D. hunteri Bishopp, 1912
D. imitans Warburton, 1933
D. latus Cooley, 1937
D. marginatus (Sulzer, 1776)
D. montanus Filippova and Panova, 1974
D. nitens Neumann, 1897
D. niveus Neumann, 1897
D. nuttalli Olenev, 1928
D. occidentalis Marx, 1892
D. parumapertus Neumann, 1901
D. pavlovskyi Olenev, 1927
D. pomerantzevi Serdyukova, 1951
D. raskemensis Pomerantsev, 1946
D. reticulatus (Fabricius, 1794)
D. rhinocerinus (Denny, 1843)
D. silvarum Olenev, 1931
D. sinicus Schulze, 1932
D. steini Schulze, 1933
D. taiwanensis Sugimoto, 1935
D. ushakovae Filippova and Panova, 1987
D. variabilis (Say, 1821)
Margaropus
M. reidi Hoogstraal, 1956
M. wileyi Walker and Laurence, 1973
M. winthemi Karsch, 1879
Rhipicentor
R. bicornis Nuttall and Warburton, 1908
R. nuttalli Cooper and Robinson, 1908

Table 1. (*continued*)

Rhipicephalus
R. (*Boophilus*) *annulatus* (Say, 1821)
R. (*Boophilus*) *decoloratus* (Koch, 1844)
R. (*Boophilus*) *geigyi* (Aeschlimann and Morel, 1965)
R. (*Boophilus*) *kohlsi* (Hoogstraal and Kaiser, 1960)
R. (*Boophilus*) *microplus* (Canestrini, 1888)

R. appendiculatus Neumann, 1901
R. aquatilis Walker, Keirans and Pegram, 1993
R. armatus Pocock, 1900
R. arnoldi Theiler and Zumpt, 1949
R. bequaerti Zumpt, 1949
R. bergeoni Morel and Balis, 1976
R. boueti Morel, 1957
R. bursa Canestrini and Fanzago, 1878
R. camicasi Morel, Mouchet and Rodhain, 1976
R. capensis Koch, 1844
R. carnivoralis Walker, 1966
R. complanatus Neumann, 1911
R. compositus Neumann, 1897
R. cuspidatus Neumann, 1906
R. deltoideus Neumann, 1910
R. distinctus Bedford, 1932
R. duttoni Neumann, 1907
R. dux Dönitz, 1910
R. evertsi evertsi Neumann, 1897
R. evertsi mimeticus Dönitz, 1910
R. exophthalmos Keirans and Walker, 1993
R. follis Dönitz, 1910
R. fulvus Neumann, 1913
R. gertrudae Feldman-Muhsam, 1960
R. glabroscutatum Du Toit, 1941
R. guilhoni Morel and Vassiliades, 1963
R. haemaphysaloides (Supino, 1897)
R. humeralis Rondelli, 1926
R. hurti Wilson, 1954
R. interventus Walker, Pegram and Keirans, 1995
R. jeanneli Neumann, 1913
R. kochi Dönitz, 1905

Table 1. (*continued*)

R. leporis Pomerantsev, 1946
R. longiceps Warburton, 1912
R. longicoxatus Neumann, 1905
R. longus Neumann, 1907
R. lounsburyi Walker, 1990
R. lunulatus Neumann, 1907
R. maculatus Neumann, 1901
R. masseyi Nuttall and Warburton, 1908
R. moucheti Morel, 1965
R. muehlensi Zumpt, 1943
R. muhsamae Morel and Vassiliades, 1965
R. neumanni Walker, 1990
R. nitens Neumann, 1904
R. oculatus Neumann, 1901
R. oreotragi Walker and Horak, 2000
R. pilans Schulze, 1935
R. planus Neumann, 1907
R. praetextatus Gerstäcker, 1873
R. pravus Dönitz, 1910
R. pseudolongus Santos Dias, 1953
R. pulchellus (Gerstäcker, 1873)
R. pumilio Schulze, 1935
R. punctatus Warburton, 1912
R. pusillus Gil Collado, 1936
R. ramachandrai Dhanda, 1966
R. rossicus Yakimov and Kol-Yakimova, 1911
R. sanguineus (Latreille, 1806)
R. scalpturatus Santos Dias, 1959
R. schulzei Olenev, 1929
R. sculptus Warburton, 1912
R. senegalensis Koch, 1844
R. serranoi Santos Dias, 1950
R. simpsoni Nuttall, 1910
R. simus Koch, 1844
R. sulcatus Neumann, 1908
R. supertritus Neumann, 1907
R. theileri Bedford and Hewitt, 1925
R. tricuspis Dönitz, 1906
R. turanicus Pomerantsev, 1936

Table 1. (*continued*)

R. warburtoni Walker and Horak, 2000
R. zambeziensis Walker, Norval and Corwin, 1981
R. ziemanni Neumann, 1904
R. zumpti Santos Dias, 1950
Nuttalliellidae
Nuttalliellinae
Nuttalliella
N. namaqua Bedford, 1931

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The genus *Hyalomma* Koch, 1844. I. Reinstatement of *Hyalomma (Euhyalomma) glabrum* Delpy, 1949 (Acari, Ixodidae) as a valid species with a redescription of the adults, the first description of its immature stages and notes on its biology

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ABSTRACT

APANASKEVICH, D.A. & HORAK, I.G. 2006. The genus *Hyalomma* Koch, 1844. I. Reinstatement of *Hyalomma (Euhyalomma) glabrum* Delpy, 1949 (Acari, Ixodidae) as a valid species with a redescription of the adults, the first description of its immature stages and notes on its biology. *Onderstepoort Journal of Veterinary Research*, 73:1–12

For nearly 50 years the ixodid tick *Hyalomma marginatum turanicum*, reputedly introduced into South Africa on imported Persian sheep, has been considered identical to the Asian *Hyalomma (Euhyalomma) marginatum turanicum* Pomerantzev, 1946. Comparisons of this tick with the Asian *H. (E.) m. turanicum* and other subspecies of *Hyalomma (Euhyalomma) marginatum*, however, reveal that it is an old taxon, namely *Hyalomma rufipes glabrum* Delpy, 1949. It is hereby reinstated as *Hyalomma (Euhyalomma) glabrum*, and its adults are redescribed and its immature stages described for the first time. The preferred hosts of its adults are large herbivores such as zebras, gemsbok and eland, on which it occurs during summer. The preferred hosts of its immature stages are scrub hares and ground-frequenting birds, on which it is present during autumn and winter. Data on its distribution and possible disease relationships are also provided.

Keywords: Description, distribution, hosts, *Hyalomma (Euhyalomma) glabrum*, immature stages, seasonality

INTRODUCTION

It was originally assumed that only two species of the genus *Hyalomma* Koch, 1844, namely *Hyalomma* (*Euhyalomma*) *truncatum* Koch 1844 and *Hyalomma* (*Euhyalomma*) *rufipes* Koch 1844, occurred in South Africa. In 1949 Delpy described a new subspecies of *H.* (*E.*) *rufipes*, naming it *Hyalomma rufipes glabrum* Delpy, 1949. This name persisted until Theiler (1956) raised it to species level as *Hyalomma glabrum*, but in the same year Hoogstraal (1956) synonymized it with *Hyalomma marginatum turanicum* Pomerantzev, 1946. He based this decision on a study of reared specimens of adult *H. r. glabrum* that were sent to him by Gertrud Theiler, and on some adults of *H.* (*E.*) *m. turanicum* originating from Iran. No immature stages were studied. Furthermore, Hoogstraal (1956) assumed that *H.* (*E.*) *m. turanicum* had been introduced into South Africa on Persian sheep apparently imported from the Mediterranean region. Since then the name *H.* (*E.*) *m. turanicum* has been used for this tick in all publications devoted to the *Hyalomma* ticks of South Africa. Four years later, the subspecific status of *H.* (*E.*) *rufipes* was demonstrated by Hoogstraal & Kaiser (1960), and it

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became *H.* (*E.*) *marginatum rufipes*. There are thus currently two species and two subspecies of *Hyalomma* recognized in South Africa, namely *H.* (*E.*) *truncatum*, *H.* (*E.*) *m. rufipes* and *H.* (*E.*) *m. turanicum*.

The systematics of species within the *H.* (*E.*) *marginatum* group is one of the most complex in the subgenus *Euhyalomma* Filippova, 1984, and within the genus *Hyalomma* as a whole. This group of ticks consists of one extremely polymorphic species, namely *Hyalomma* (*Euhyalomma*) *marginatum*, which contains the four subspecies, *Hyalomma* (*Euhyalomma*) *marginatum marginatum* Koch, 1844, *H.* (*E.*) *m. rufipes*, *Hyalomma* (*Euhyalomma*) *marginatum isaaci* Sharif, 1928 and *H.* (*E.*) *m. turanicum*. Apanaskevich (2003, 2004) has published a preliminary differentiation of these subspecies based on all their life stages. However, after large numbers of South African *H.* (*E.*) *m. turanicum* had been examined and compared with Asian *H.* (*E.*) *m. turanicum* it was obvious that these taxa are entirely different. As a consequence we have now compared the morphological characters of males, females, nymphs and larvae of South African *H.* (*E.*) *m. turanicum* with those of *H.* (*E.*) *m. marginatum*, *H.* (*E.*) *m. rufipes* and *H.* (*E.*) *m. isaaci*, and those of *H.* (*E.*) *m. turanicum* from Asia.

The presence of a number of distinctive diagnostic characters on all developmental stages of South African *H.* (*E.*) *m. turanicum* has persuaded us to designate this taxon as a separate species within the *H.* (*E.*) *marginatum* group, namely *Hyalomma* (*Euhyalomma*) *glabrum*.

Hyalomma (*Euhyalomma*) *glabrum* Delpy, 1949

Type specimens: the original, extremely brief description in the form of an identification key was based on adult specimens from the Karoo, South Africa ("Karro", Delpy 1949). The deposition of the type specimens is unknown. Gertrud Theiler's laboratory-reared specimens, from amongst which Delpy described *H. r. glabrum*, are deposited in the Tick Museum at the Onderstepoort Veterinary Institute (OVI), South Africa, and could be considered as paratypes or syntypes. The male and female are illustrated under the name *Hyalomma turanicum* in Hoogstraal (1956).

Synonym: *Hyalomma rufipes glabrum* Delpy, 1949.

Material examined: 876 males, 111 females, 100 nymphs and 100 larvae from four localities in South Africa (Mountain Zebra National Park (32°15' S, 25°27' E), Eastern Cape Province; Karoo National Park (32°16' S, 22°32' E), Western Cape Province; and the farms "Outuin" (30°10' S, 18°02' E), Northern Cape Province; and "Klipfontein" (33°20' S, 23°19' E), south-western Eastern Cape Province). In addition to the abovementioned field collected specimens, we have also examined the laboratory-reared specimens in the Gertrud Theiler collection (De Aar, 23.XI.1942; No.: 2850, 2851, 2852, 2853, 2854, 2855; 46 males, 88 females, nymphs and exuviae of nymphs, larvae and exuviae of larvae) deposited in the Tick Museum at the OVI.

Description

The measurements are given as follows: minimum – maximum (average ± standard error, *n* = number of specimens examined). All measurements of adults are given in millimetres and those of immature stages in micrometres.

Male (Fig. 1, 2A–I)

Conscutum (Fig. 1): length 4.03–5.48 (4.72 ± 0.02, *n* = 100), width 2.77–3.63 (3.27 ± 0.02, *n* = 100),

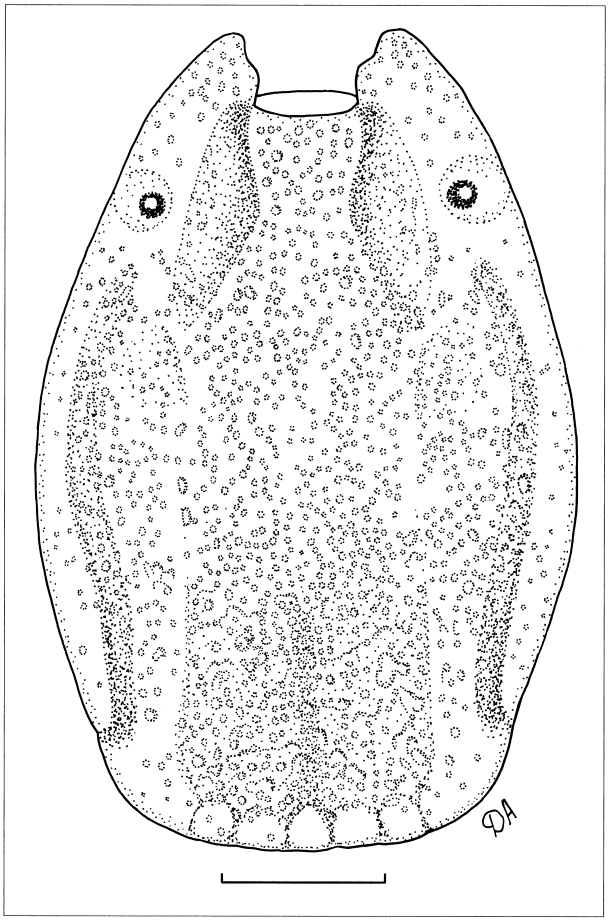

FIG. 1 *Hyalomma glabrum*, male, conscutum. Bar = 1 mm

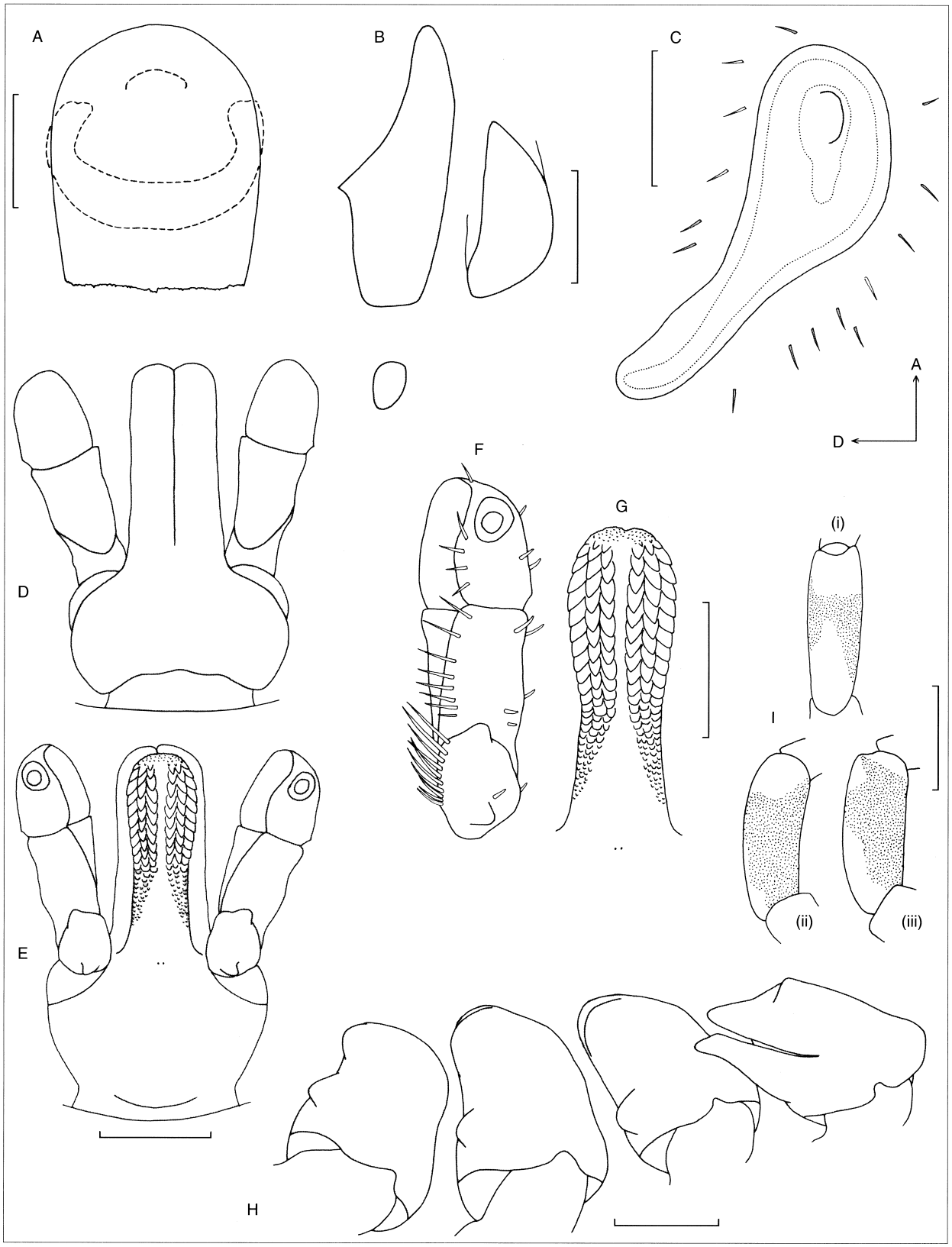

FIG. 2 *Hyalomma glabrum*, male, A, genital structures: apron, postgenital sclerite, pregenital arch. Bar = 200 µm; B, anal plates. Bar = 500 µm; C, spiracular plate and circumspiracular setae (A—anterior; D—dorsal). Bar = 400 µm; D, gnathosoma dorsally. Bar = 500 µm; E, gnathosoma ventrally. Bar = 500 µm; F, palp ventrally. Bar = 400 µm; G, hypostome. Bar = 400 µm; H, coxae. Bar = 500 µm; I, genu IV: (i), dorsal view, (ii), medial view, (iii), lateral view. Bar = 1 mm

ratio length: width 1.35–1.55 (1.44 ± 0.004, *n* = 100); very dark brown to nearly black in colour; broad oval in shape; widest near mid-length; slight narrowing in region of the spiracular plates; cervical and lateral grooves shallow, one third the length of conscutum; marginal grooves long, almost reaching eyes; five well-defined festoons along the posterior margin of conscutum; parma not obvious; posteromedian and paramedian grooves indistinct; caudal field conspicuous; dense medium-sized punctations cover almost entire conscutum, especially so in caudal field, sparser (often rare) and sometimes smaller in size in central and lateral fields at mid-length of conscutum.

Genital structures (Fig. 2A) as illustrated. *Anal plates* (Fig. 2B): 3 pairs; adanal plates long, broad, narrowing slightly to posterior margin, lateral margin slightly convex, anteromedian margin concave, posteromedian margin straight, median projection moderately distinct; subanal plates usually small, narrow and longitudinally aligned with adanal plates. Ventral sclerotized plaques on median and paramedian festoons absent. *Spiracular plate* (Fig. 2C): dorsal projection long and clearly separable from body of plate; perforated portion of dorsal projection straight and very narrow curving at its apex. Setae in circumspiracular area sparse.

Basis capituli (Fig. 2D, E): without lateral projections; dorsal posterior margin slightly concave; cornua modest. *Palps* (Fig. 2F): segment I bears more than five ventromedian setae. *Hypostome* (Fig. 2G): club-shaped; denticulate portion slightly longer than denticle-free portion (small scale-like projections posterior to last large denticle are not considered denticles). *Coxae* (Fig. 2H): Posteromedian and posterolateral spurs on coxa I long, close together, tapering to apices; posterolateral spurs on coxae II–IV distinct, triangular, with rounded apex; posteromedian spurs on coxae II and III indistinct, broadly arcuate; posteromedian spur on coxa IV distinct, broadly triangular. Ivory coloured bands encircle posterior margin of each segment of legs; dorsal, longitudinal, ivory-coloured enamelling on each segment (particularly distinct on hind legs) (Fig. 2I).

FEMALE (Fig. 3, 4A–H)

Scutum (Fig. 3): length 2.28–3.04 (2.65 ± 0.01, *n* = 100), width 2.28–3.00 (2.69 ± 0.01, *n* = 100), ratio length: width 0.87–1.08 (0.98 ± 0.004, *n* = 100); dark red-brown to nearly black in colour; length and breadth approximately equal; posterolateral angles of scutal margin prominent; cervical and lateral grooves deep, reaching posterior margin of the scutum; moderate to very dense medium-sized to large punctations cover almost entire scutum, less dense on scapulae and in lateral and cervical fields.

Genital structures (Fig. 4A): genital aperture wide, shallow, rounded; vestibular portion of vagina slightly bulging. *Spiracular plates* (Fig. 4B): perforated portion of dorsal projection very narrow. Circumspiracular setae sparse. *Basis capituli* (Fig. 4C, D): dorsally lateral projections short, absent ventrally; posterodorsal margin straight; dorsal cornua inconspicuous. *Palps* (Fig. 4E): segment I bears more than five ventromedian setae. *Hypostome* (Fig. 4F): club-shaped; denticulate portion slightly longer than denticle-free portion. *Coxae* (Fig. 4G): posteromedian and posterolateral spurs of coxa I long, close together, tapering to apices; posterolateral spurs of coxae II–IV well developed, broadly triangular; posteromedian spurs of coxae II and III indistinct, broadly, arcuate; posteromedian spur of coxa IV distinct, broadly triangular. Colouration of legs similar to male (Fig. 4H).

The scheme of measurements for nymphs and larvae is illustrated in Fig. 5.

NYMPH (Fig. 6A–F)

Scutum (Fig. 6A): length 574–752 (684 ± 6.25, *n* = 36), width 678–921 (811 ± 8.56, *n* = 38), ratio length: width 0.77–0.89 (0.85 ± 0.005, *n* = 36), distance between posterior margin of eyes and posterior margin of scutum 247–337 (300 ± 3.93, *n* = 34), width: length of posterior portion of scutum 2.45–3.08 (2.68 ± 0.03, *n* = 34); posterior margin broadly rounded;

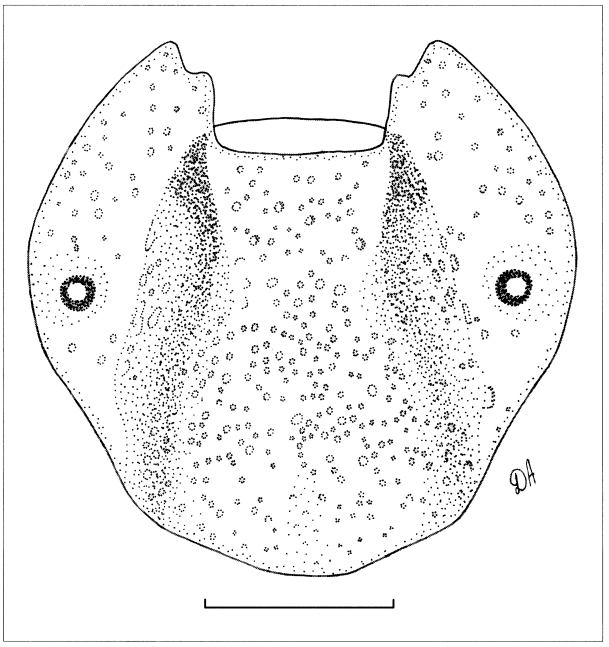

FIG. 3 *Hyalomma glabrum*, female, scutum. Bar = 1 mm

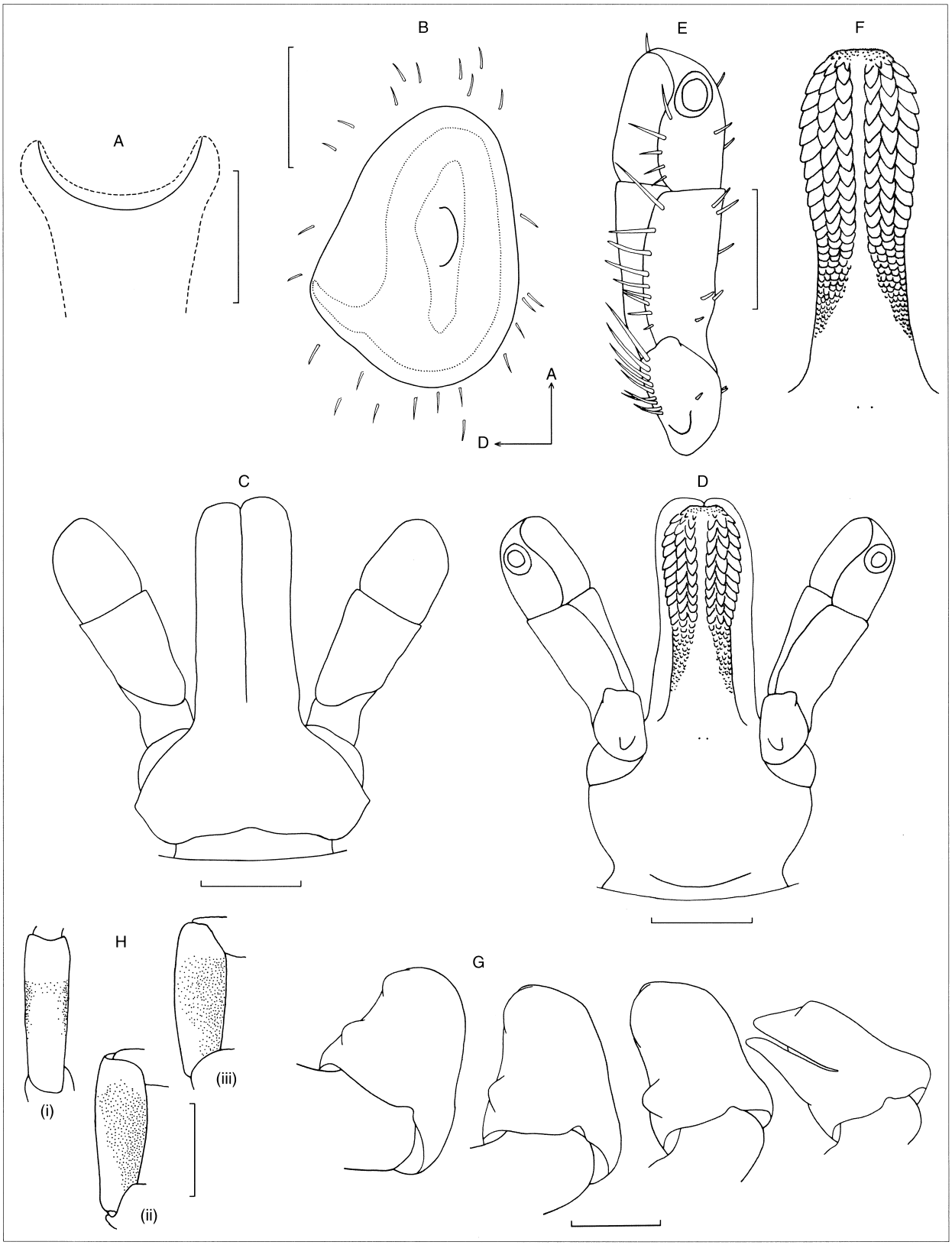

FIG. 4 *Hyalomma glabrum*, female, A, genital structures: genital operculum, vestibular part of vagina. Bar = 200 µm; B, spiracular plate and circumspiracular setae (A—anterior; D—dorsal). Bar = 400 µm; C, gnathosoma dorsally. Bar = 500 µm; D, gnathosoma ventrally. Bar = 500 µm; E, palp ventrally. Bar = 400 µm; F, hypostome. Bar = 400 µm; G, coxae. Bar = 500 µm; H—genu IV: (i), dorsal view, (ii), medial view, (iii), lateral view. Bar = 1 mm

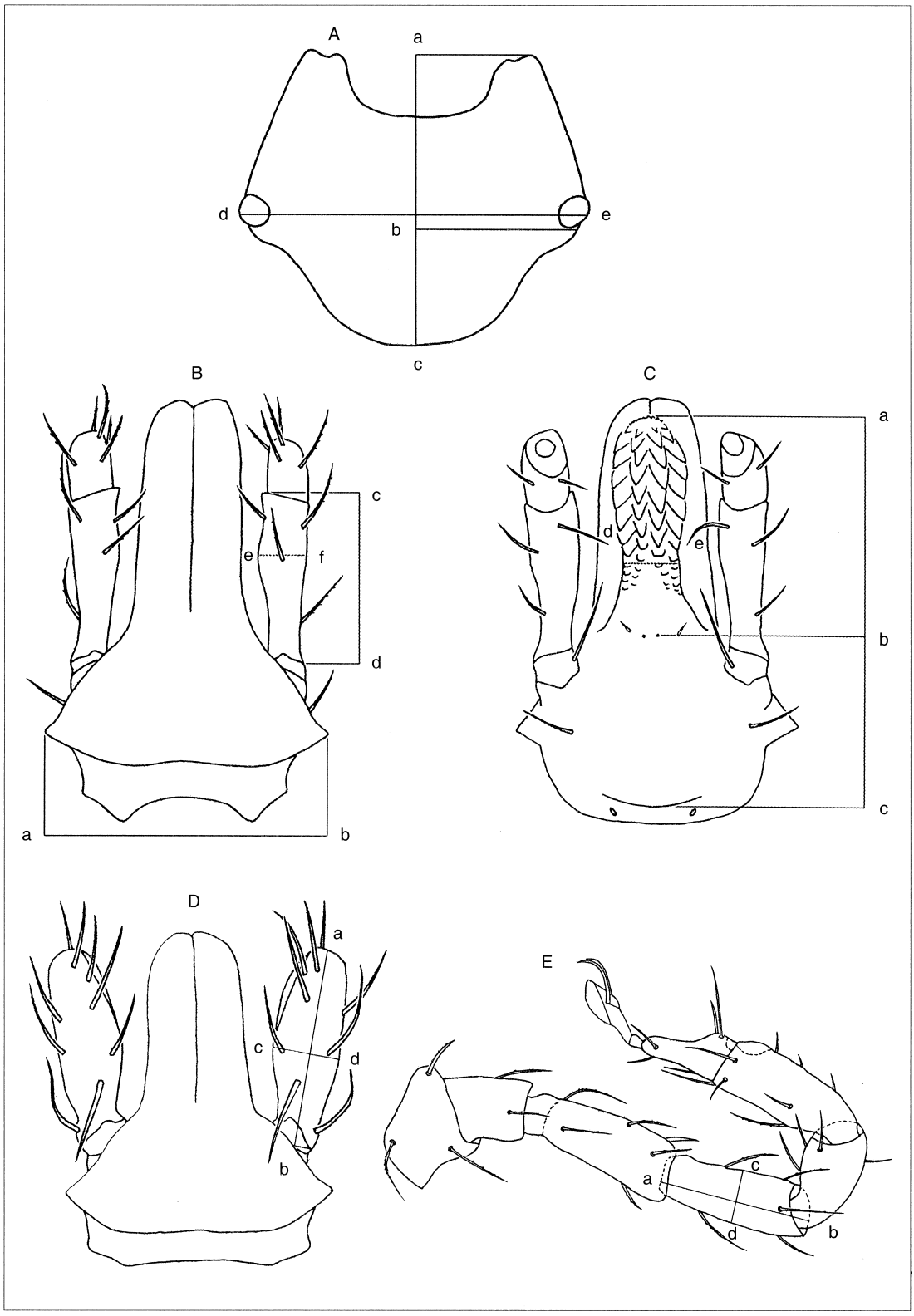

FIG. 5 Detail of measurements for nymphs and larvae, A, nymph, scutum: a–c—length, b–c—distance from posterior margin of eyes to posterior margin of scutum, d–e—width; B, nymph, gnathosoma dorsally: a–b—width of gnathosoma, c–d—length of palp (segment II), e–f—width of palp (segment II); C, nymph, gnathosoma ventrally: a–c—length of gnathosoma, a–b—length of hypostome, d–e—width of hypostome; D, larva, gnathosoma dorsally: a–b—length of palp (segments II–III), c–d—width of palp (segments II–III); E, larva, leg I: a–b—length of genu, c–d—width of genu

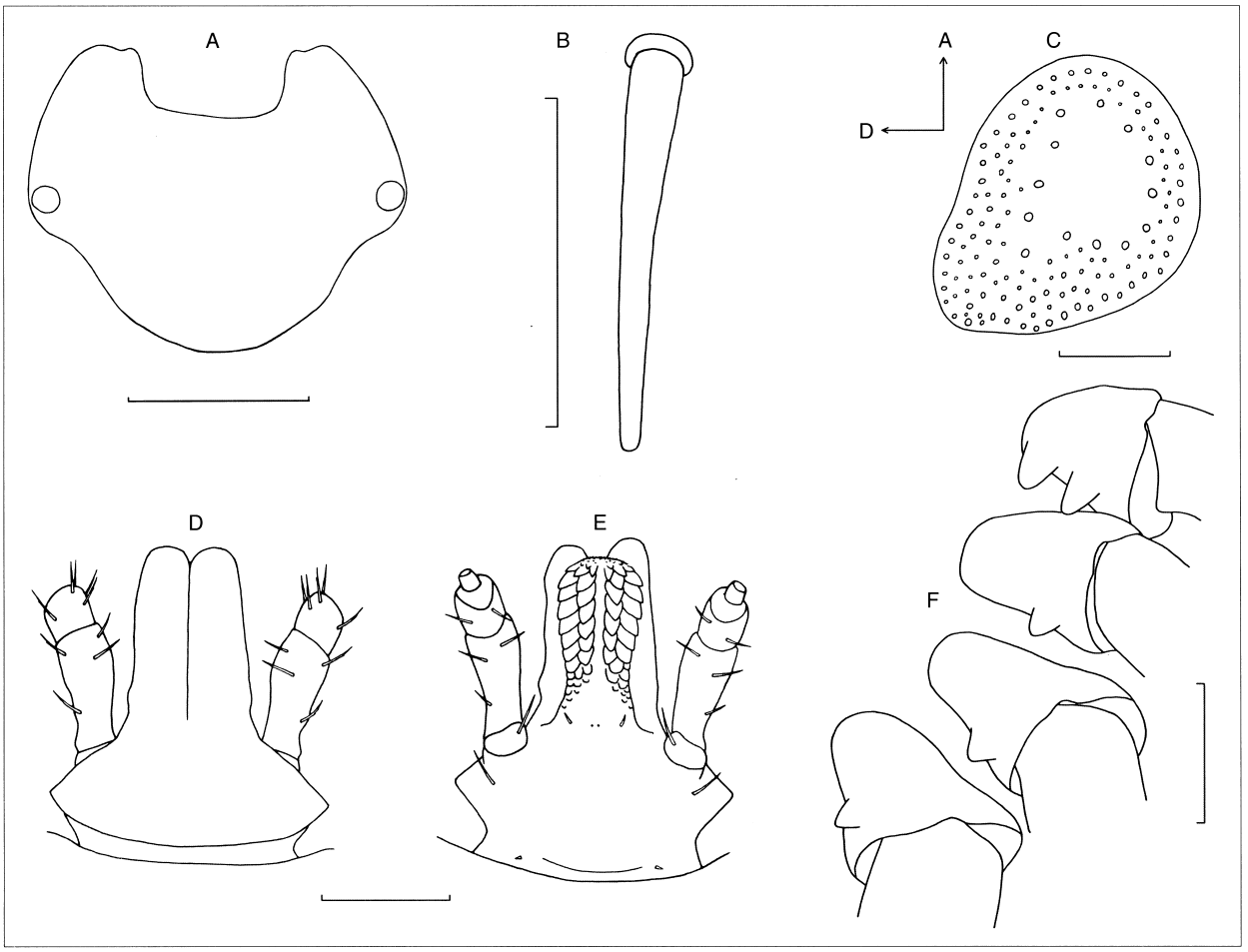

FIG. 6 *Hyalomma glabrum*, nymph, A, scutum. Bar = 400 µm; B, seta of alloscutum. Bar = 50 µm; C, spiracular plate (A—anterior; D—dorsal). Bar = 50 µm; D, gnathosoma dorsally. Bar = 200 µm; E, gnathosoma ventrally. Bar = 200 µm; F, coxae. Bar = 200 µm

posterolateral indentations deep. *Setae of alloscutum* (Fig. 6B): narrowing slightly to rounded apex. *Spiracular plates* (Fig. 6C): oval; dorsal tail well developed, broad, gradually tapering to rounded tip; submarginal row of perforations complete. *Basis capituli* (Fig. 6D, E): width 354–469 (412 ± 3.75, *n* = 39); anterolateral margin of basis capituli shorter than or equal to half its width. *Palps* (segment II) (Fig. 6D, E): length 144–186 (171 ± 1.54, *n* = 39), width 62–78 (69 ± 0.61, *n* = 39), ratio length: width 2.23–2.75 (2.48 ± 0.02, *n* = 39); palpal segment II proximally narrow, gradually expanding distally. *Hypostome* (Fig. 6E): length 216–276 (251 ± 2.32, *n* = 34), width 85–106 (95 ± 0.96, *n* = 37), ratio length: width 2.33–3.16 (2.66 ± 0.03, *n* = 33); transition of denticulate portion of the hypostome to denticle-free portion smooth; denticulate portion of hypostome more than twice as long as denticle-free portion. *Coxae* (Fig. 6F): spurs of coxa I long, approximately equal in length, broad, subtriangular in shape; spurs of coxae II–IV very large, subequal, decreasing slightly in size from coxa II to coxa IV; coxal pore absent.

LARVA (Fig. 7A–D)

Scutum (Fig. 7A): length 288–337 (312 ± 0.92, *n* = 97), width 377–455 (428 ± 1.36, *n* = 98), ratio length: width 0.67–0.79 (0.73 ± 0.002, *n* = 97), distance from posterior margin of eyes to posterior margin of scutum 117–158 (139 ± 0.81, *n* = 98), width: length ratio of posterior portion 2.69–3.63 (3.09 ± 0.02, *n* = 98). Length of scutum extended posterior to eyes, nearly half the length of scutum; scutal margin shallowly rounded or flattened posteriorly; posterolateral margins almost straight without indentations. *Basis capituli* (Fig. 7B, C): width 136–175 (157 ± 0.77, *n* = 97); dorsally hexagonal, ventrally rectangular; apex of lateral projections directed slightly forward or laterally. *Palps* (segments II and III) (Fig. 7B, C): length 97–115 (105 ± 0.37, *n* = 97), width 39–48 (45 ± 0.15, *n* = 97), ratio length: width 2.05–2.60 (2.36 ±

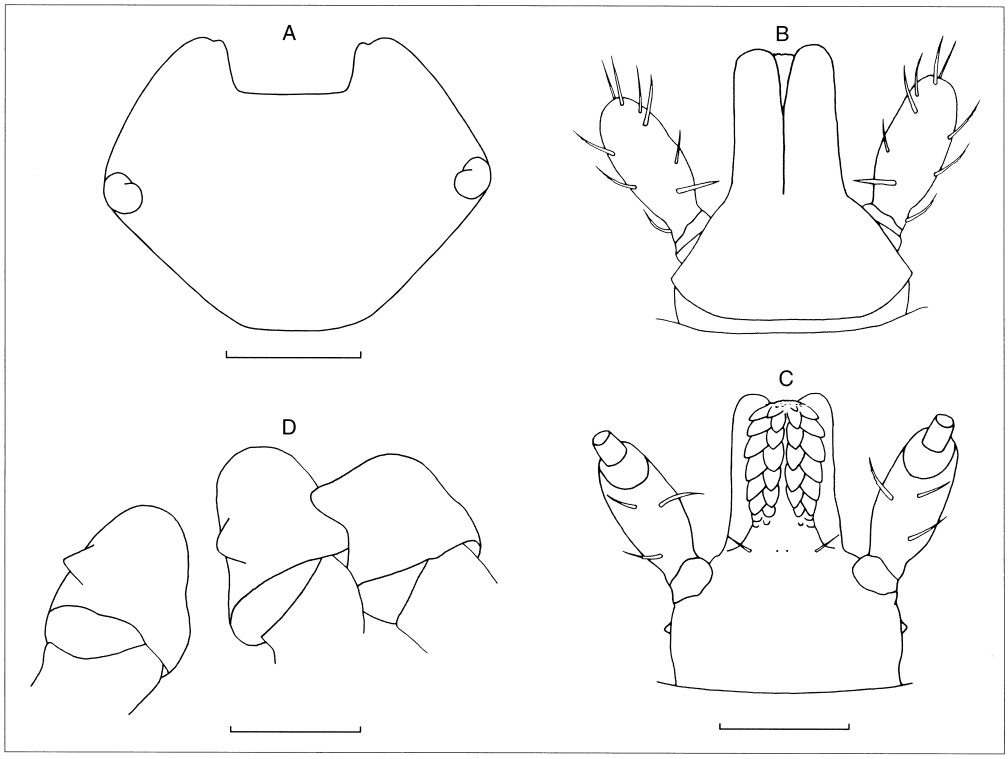

FIG. 7 *Hyalomma glabrum*, larva, A, scutum. Bar = 150 µm; B, gnathosoma dorsally. Bar = 100 µm; C, gnathosoma ventrally. Bar = 100 µm; D, coxae. Bar = 100 µm

0.01, $n = 97$). *Hypostome* (Fig. 7C): length 101–126 (117 ± 0.34, $n = 185$), width 36–45 (40 ± 0.14, $n = 259$), ratio length: width 2.57–3.31 (2.88 ± 0.01, $n = 184$); large denticles in median files of 6 or 7; denticulate portion constitutes approximately 2/3 of hypostome length, transition to denticle-free portion smooth. *Coxae* (Fig. 7D): spurs of coxa I very large, subtriangular, tapering; spurs of coxae II and III very large and broad; spur of coxa II arcuate; spur of coxa III triangular. *Genu* I: length 110–136 (122 ± 0.58, $n = 95$), width 49–57 (53 ± 0.23, $n = 53$), ratio length: width 2.12–2.49 (2.28 ± 0.01, $n = 52$).

IDENTIFYING FEATURES

ADULTS

The adults of *H.* (*E.*) *glabrum* are distinguishable from those of subspecies of *H.* (*E.*) *marginatum* by the following characters:

MALES

Males are distinguished from *H.* (*E.*) *m. marginatum*, which has few large punctations as well as numerous small and medium-sized ones, but sparser punctations on its conscutum, sclerotized plaques on ventral aspect of median and paramedian festoons and broad tail of the perforated portion of the spiracular plate; from *H.* (*E.*) *m. rufipes*, which has medium-sized, very dense punctations that uniformly cover the conscutum, sclerotized plaques on ventral aspect of median and paramedian festoons, setae in circumspiracular area very dense, and no enamelled strip on dorsal aspect of legs; from *H.* (*E.*) *m. isaaci*, which has few large punctations on its conscutum, sclerotized plaques on ventral aspect of median and paramedian festoons, dorsal tail of perforated portion of spiracular plate broader and no enamelled strip on dorsal aspect of legs and from *H.* (*E.*) *m. turanicum*, which is smaller in size, lighter in colour, punctations on conscutum fewer and smaller, sclerotized plaques on ventral aspect of median and paramedian festoons present, setae in circumspiracular area denser, dorsal tail of perforated portion of the spiracular plate broader and ivory colouring on dorsal aspect of legs may be present or absent.

FEMALES

The females are differentiated from *H.* (*E.*) *m. marginatum*, which has a few large punctations as well as numerous fine, but sparser punctations on the entire scutum, and the broad tail of the perforated portion of the spiracular plate; from *H.* (*E.*) *m. rufipes*, which has large and medium-sized punctations cov-

TABLE 1 Host records of *Hyalomma* (*Euhyalomma*) *glabrum* in South Africa

Host species	No. examined	No. infested	Number of ticks collected		
			Immatures	Adults	Total
Domestic animals					
Sheep (*Ovis aries*)	259	12	0	16	16
Horses (*Equus caballus*)	2	2	0	18	18
Humans					
Humans (*Homo sapiens*)	Tick bites	2	0	2	2
Wild animals					
Eland (*Taurotragus oryx*)	11	11	0	1 146	1 146
Gemsbok (*Oryx gazella*)	2	2	0	49	49
Black wildebeest (*Connochaetes gnou*)	12	4	0	28	28
Cape mountain zebras (*Equus zebra zebra*)	14	14	0	245	245
Springbok (*Antidorcas marsupialis*)	18	1	0	2	2
Scrub hares (*Lepus saxatilis*)	29	19	2 710	0	2 710
Smith's red rock rabbits (*Pronolagus rupestris*)	28	6	325	0	325
Springhares (*Pedetes capensis*)	17	4	14	0	14
Rock dassies (*Procavia capensis*)	25	1	1	0	1
Birds					
Helmeted guineafowls (*Numida meleagris*)	16	5	22	0	22
Thick-billed larks (*Galerida magnirostris*)	4	3	26	0	26
Long-billed larks (*Certhilauda curvirostris*)	10	7	84	0	84
Familiar chats (*Cercomela familiaris*)	5	3	17	0	17
Nicholson's pipits (*Anthus similis*)	5	3	10	0	10

ering the entire scutum, setae in circumspiracular area very dense and enamelled strips on the dorsal aspect of the legs are lacking; from *H.* (*E.*) *m. isaaci*, which has few large punctations on the scutum, dorsal tail of the perforated portion of the spiracular plate broader and no enamelled strips on the dorsal aspect of the legs and from *H.* (*E.*) *m. turanicum*, which is smaller in size, yellow-brown in colour, punctuations of the scutum are less dense and smaller, the dorsal tail of the perforated portion of the spiracular plate is broader, setae in circumspiracular area fairly dense and ivory colouring may or may not be present on the dorsal aspect of the legs.

NYMPHS

Nymphs of *H.* (*E.*) *glabrum* are distinguishable from the subspecies of *H.* (*E.*) *marginatum* by the following characters: from *H.* (*E.*) *m. isaaci*, which has moderate posteriolateral indentations on the scutum, larger spiracular plates and narrow spurs on coxa I; from *H.* (*E.*) *m. marginatum*, *H.* (*E.*) *m. rufipes* and *H.* (*E.*) *m. turanicum*, which have slender palps and narrow hypostomes, and additionally, from *H. (E.) m. marginatum*, which has a larger spiracular plate.

LARVAE

The larvae of *H.* (*E.*) *glabrum* are distinguishable from the various subspecies of *H.* (*E.*) *marginatum* by the following characters: the latter do not have large spurs on coxae I–III, their palps are longer and more slender (ratio length: width), their hypostomes are narrower (ratio length: width) and articles of legs are narrower (ratio of genua I length: width).

HOSTS (TABLE 1)

Hyalomma (*E.*) *glabrum* and the various subspecies of the *H.* (*E.*) *marginatum* group are two-host ticks (Knight, Norval & Rechav 1978; Horak, Swanepoel & Gummow 2001). Adults of *H.* (*E.*) *glabrum* infest large ungulates, namely eland, *Taurotragus oryx* (Pallas, 1766), gemsbok, *Oryx gazella* (Linnaeus, 1758), black wildebeest, *Connochaetes gnou* (Zimmermann, 1780), Cape mountain zebra, *Equus zebra zebra* Linnaeus, 1758, horses, *Equus caballus* Linnaeus, 1758, and occasionally smaller animals such as sheep, *Ovis aries* Linnaeus, 1758 and springbok, *Antidorcas marsupialis* (Zimmermann, 1780). Adults have occasionally been collected from humans. The

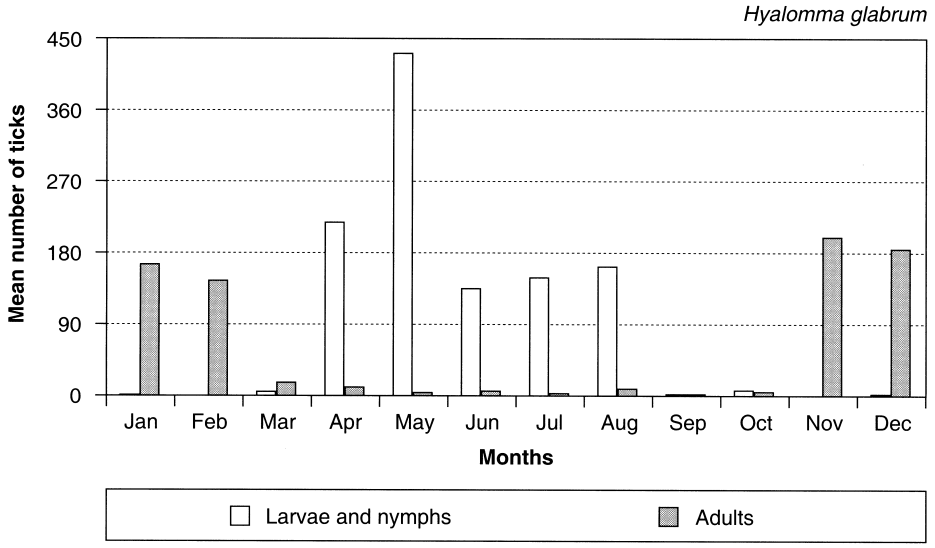

FIG. 8 Seasonal occurrence of adult *Hyalomma glabrum* on Cape mountain zebras and eland and immature ticks on scrub hares in the Mountain Zebra National Park, Eastern Cape Province, South Africa (3-month running means were used to estimate the values for January, April and July during which no collections were made)

immature stages have been collected from scrub hares, *Lepus saxatilis* Cuvier, 1823, Smith's red rock rabbits, *Pronolagus rupestris* (Smith, 1834), and various species of birds, namely helmeted guineafowls, *Numida meleagris* Linnaeus, 1758, thick-billed larks, *Galerida magnirostris* (Stephens, 1826), long-billed larks, *Certhilauda curvirostris* (Hermann, 1783), familiar chats, *Cercomela familiaris* (Stephens, 1826), and Nicholson's pipits, *Anthus similis* Jerdon, 1840. Immature stages have occasionally been found on springhares, *Pedetes capensis* (Forster, 1778), and a single larva on a rock dassie, *Procavia capensis* (Pallas, 1766) (Theiler 1962; Horak, Knight & De Vos 1986; Horak & Williams 1986; Horak Fourie, Novellie & Williams 1991; Horak & Fourie 1992). The host-parasite relationships of *H.* (*E.*) *glabrum* are thus typical for those of the *H.* (*E.*) *marginatum* group of ticks. Less than 1 % of adult ticks were collected from the head and ears, lower legs and feet and tails of the mountain zebras and eland, but no accurate indication of the preferred attachment sites of the remaining 99 % of ticks on the remainder of these animals' bodies can be given because these were not subdivided into smaller anatomical regions.

SEASONALITY (Fig. 8)

The greatest numbers of adult *H.* (*E.*) *glabrum* were present on large mammals from November to February (summer), and most immature ticks on scrub hares from April to August (autumn and winter). This pattern of seasonal occurrence implies that only one life cycle is completed annually.

ZOOGEOGRAPHY (Fig. 9)

Hyalomma (*E.*) *glabrum* is known only from South Africa (Theiler 1956) and a single record from the Kaokoveld, Namibia (Zumpt 1956). Populations of this tick occur in the Karoo regions of the Eastern, Western and Northern Cape provinces, and in the Brokenveld of the southern Free State Province (Theiler 1956; Howell, Walker & Nevill 1978). There are isolated records from other localities in South Africa, namely near Estcourt in KwaZulu-Natal Province and in the Kruger National Park in Limpopo Province (Zumpt 1956; Spickett, Horak, Braack & Van Ark 1991). With the exception of the latter isolated records the localities at which ticks were collected in the present studies complement those plotted previously (Fig. 9).

Hyalomma (*E.*) *glabrum* is the only taxon of *Hyalomma* ticks that occurs exclusively in the Southern hemisphere, furthermore it has an extremely limited distribution as it occurs only in South Africa and perhaps Namibia. This unique distribution pattern could have resulted from the ancient dissemination of the immature stages by migrating birds from Europe or Asia. These could have transported the ancestors of *H.* (*E.*) *glabrum* to the region now known as South Africa. After the engorged nymphs detached from their avian hosts and moulted to adults they may

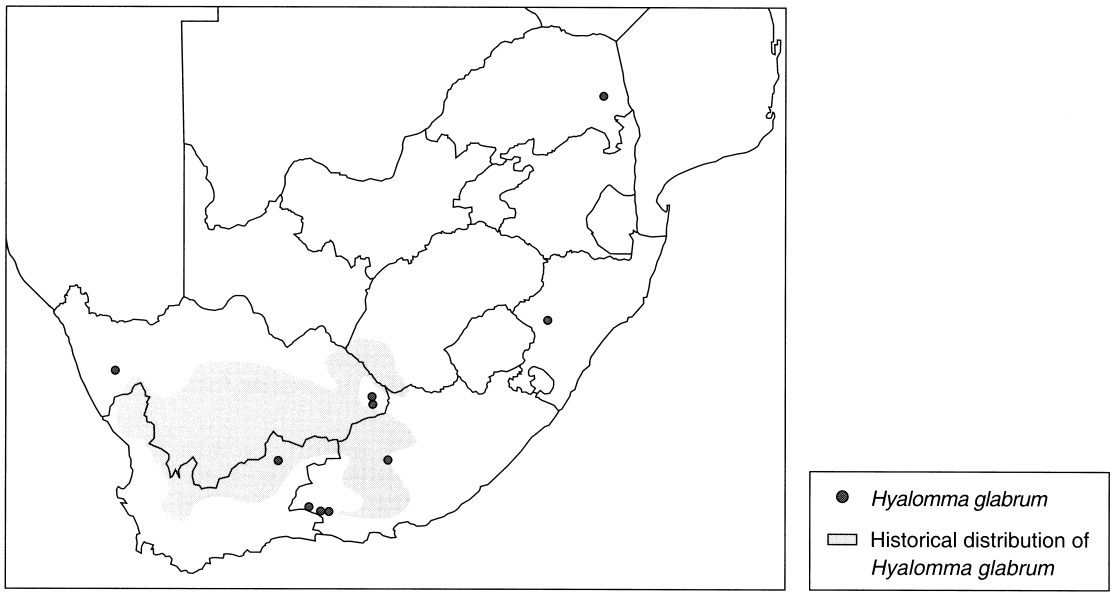

FIG. 9 Geographic distribution of *Hyalomma glabrum* in South Africa. Adapted from Howell *et al.* (1978), with recent data indicated by dark circles

have found the climate and available hosts suitable for their continued survival, and the newly established populations of *H.* (*E.*) *glabrum* developed the unique features characteristic of the species. If at that time the Karoo region was free of *H.* (*E.*) *marginatum rufipes* this would have precluded the likelihood of crossbreeding between the two taxa and hence the genetic elimination of the ancestors of *H.* (*E.*) *glabrum*. Crossbreeding between subspecies of *H.* (*E.*) *marginatum* has to date not been studied.

The reinstatement of this member of the *H.* (*E.*) *marginatum* group as a valid species has led us to re-evaluate the taxonomic status of the other representatives of this group. This re-evaluation will be reported separately.

Disease relationships

There are no records concerning the vector capacity of this species. Only eight of the 158 cases of Crimean-Congo haemorrhagic fever confirmed in South Africa between 1981 and 2000 originated within the distribution range of *H.* (*E.*) *glabrum* (Horak *et al.* 2001). However, this does not exclude the possibility of it being a vector of the virus causing this disease, as are *H.* (*E.*) *m. marginatum*, *H.* (*E.*) *m. rufipes* and *H.* (*E.*) *m. turanicum* (Hoogstraal 1979; Horak *et al.* 2001; Swanepoel & Burt 2004). Because *H.* (*E.*) *glabrum* may yet prove to be a vector of various agents causing disease in humans and in domestic and wild animals, it deserves the attention of virologists, microbiologists and parasitologists.

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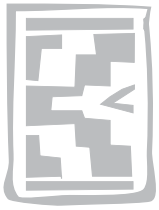

Redescription of *Haemaphysalis* (*Rhipistoma*) *elliptica* (Koch, 1844), an old taxon of the *Haemaphysalis* (*Rhipistoma*) *leachi* group from East and southern Africa, and of *Haemaphysalis* (*Rhipistoma*) *leachi* (Audouin, 1826) (Ixodida, Ixodidae)

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ABSTRACT

APANASKEVICH, D.A., HORAK, I.G. & CAMICAS, J-L. 2007. Redescription of *Haemaphysalis* (*Rhipistoma*) *elliptica* (Koch, 1844), an old taxon of the *Haemaphysalis* (*Rhipistoma*) *leachi* group from East and southern Africa, and of *Haemaphysalis* (*Rhipistoma*) *leachi* (Audouin, 1826) (Ixodida, Ixodidae). *Onderstepoort Journal of Veterinary Research*, 74:181–208

Koch (1844) originally described only the male of *Haemaphysalis* (*Rhipistoma*) *elliptica* (Koch, 1844), which he named *Rhipistoma ellipticum*. For the past century, however, this name has been considered a junior synonym of *Haemaphysalis* (*Rhipistoma*) *leachi* (Audouin, 1826), or a *nomen nudum*. We redescribe here the male and larva of *H.* (*R.*) *elliptica* and describe the female and nymph for the first time. Our redescription is based on the male holotype, plus numerous specimens from southern and East Africa. The adults of this tick parasitize domestic and wild carnivores, and the immature stages infest rodents in these regions. For comparative purposes redescriptions of all parasitic stages of *H.* (*R.*) *leachi* are provided. It parasitizes the same hosts as *H.* (*R.*) *elliptica* in Egypt, and in northeastern, Central, West and East Africa.

Keywords: Descriptions, geographic distribution, *Haemaphysalis (Rhipistoma) elliptica, Haemaphysalis (Rhipistoma) leachi*, hosts

INTRODUCTION

For those involved in their identification, the systematics of the African *Haemaphysalis* (*Rhipistoma*) *leachi* group of ticks has been fraught with problems. Before the studies of Hoogstraal and Camicas practically all ticks in the group were considered to belong to a single species, namely *Haemaphysalis* (*Rhipistoma*) *leachi* (Audouin, 1826). However, a redescription of an Egyptian population of *H.* (*R.*) *leachi* by Hoogstraal (1958), and his designation of a neotype, stimulated taxonomic studies of ticks belonging to this cluster of species. During the 1970s and 1980s Camicas and Hoogstraal and their co-workers elucidated taxonomic problems associated with this group and described or re-established a number

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of species. Hoogstraal & Kim (1985) consolidated the accumulated data on *Haemaphysalis* Koch, 1844 and on the subgenus *Rhipistoma* Koch, 1844 as well as on the *H.* (*R.*) *leachi* group. They placed these ticks in three subgroups, namely *H.* (*R.*) *leachi*, *Haemaphysalis* (*Rhipistoma*) *pedetes* and *Haemaphysalis* (*Rhipistoma*) *spinulosa*. Camicas, Hervy, Adam & Morel (1998) concurred with this decision and updated the species composition of the three subgroups. The *H.* (*R.*) *leachi* subgroup now consisted of five species, namely *H.* (*R.*) *elliptica* (Koch, 1844), *H.* (*R.*) *leachi* (Audouin, 1826), *Haemaphysalis* (*Rhipistoma*) *moreli* Camicas, Hoogstraal & El Kammah, 1972, *Haemaphysalis* (*Rhipistoma*) *paraleachi* Camicas, Hoogstraal & El Kammah, 1983, and *Haemaphysalis* (*Rhipistoma*) *punctaleachi* Camicas, Hoogstraal & El Kammah, 1973. The *H.* (*R.*) *pedetes* subgroup contained two species, viz. *H.* (*R.*) *pedetes* Hoogstraal, 1972 and *Haemaphysalis* (*Rhipistoma*) *zumpti* Hoogstraal & El Kammah, 1974, while the *H.* (*R.*) *spinulosa* subgroup incorporated four species, namely *Haemaphysalis* (*Rhipistoma*) *muhsamae* Santos Dias, 1954, *Haemaphysalis* (*Rhipistoma*) *norvali* Hoogstraal & Wassef, 1983, *H.* (*R.*) *spinulosa* Neumann, 1906 and *Haemaphysalis* (*Rhipistoma*) *subterra* Hoogstraal, El Kammah & Camicas, 1992.

There are only two synonyms for species within the *H.* (*R.*) *leachi* group, and these are *Haemaphysalis leachi* var. *humerosoides* Theiler, 1943, that has been synonymized with *H.* (*R.*) *leachi*, and *Haemaphysalis ethiopica* Santos Dias, 1958, that has been synonymized with *H.* (*R.*) *spinulosa*. Camicas *et al*. (1998), in their review of the ticks of the world, created two problems within the taxonomy of the *H.* (*R.*) *leachi* group by re-establishing two names, namely *H.* (*R.*) *elliptica* and *H.* (*R.*) *muhsamae*. The present paper addresses the taxonomic status of *H.* (*R.*) *elliptica*, while that of *H.* (*R.*) *muhsamae*, which for several decades has been considered a junior synonym of *H.* (*R.*) *spinulosa*, will be tackled in a future communication.

Koch (1844) originally described *Haemaphysalis* (*Rhipistoma*) *elliptica* (Koch, 1844) as *Rhipistoma ellipticum*. Neumann (1897) placed this species in the genus *Haemaphysalis* Koch, 1844 and synonymized it with *H.* (*R.*) *leachi* (Audouin, 1826). Thereafter the majority of tick taxonomists considered *H.* (*R.*) *elliptica* to be a junior synonym of *H.* (*R.*) *leachi*, or a *nomen nudum* (Nuttall & Warburton 1915; Camicas *et al*. 1972). Little more than a century later Camicas *et al*. (1998) re-established this taxon, but gave no reasons for their decision, thus begging the question, is *H.* (*R.*) *elliptica* a valid taxon or not?

After an exhaustive study of many collections of *Haemaphysalis* that had been identified as *H.* (*R.*) *leachi*, and a comparison of these ticks with true *H.* (*R.*) *leachi* from North Africa and with the holotype specimen of *H.* (*R.*) *elliptica*, we concluded that many of the southern and East African ticks previously identified as *H.* (*R.*) *leachi* are actually *H.* (*R.*) *elliptica*. Furthermore, these studies enabled us to delimit the geographic distributions of both ticks. We here redescribe the male [the first description is given by Koch (1844), under the name *Rhipistoma ellipticum*], and the larva [the first description is given by Bedford (1934), under the name *Haemaphysalis leachi*], and describe the female and nymph of *H.* (*R.*) *elliptica* for the first time. For comparative purposes we have also redescribed all stages of development of *H.* (*R.*) *leachi*.

MATERIAL EXAMINED

The material examined is summarized in Tables 1, 2 and 3. Specimens from South Africa and Mozambique were studied by IGH, or by IGH and DAA, and the remainder were examined by DAA. Because of difficulties experienced in the identification of specimens we used the following material for the present study:

(i) All primary identifications have been based on males.

(ii) With the exception of collections from Egypt and South Africa, collections containing only females have been excluded.

(iii) Females in collections containing males of two or more species have been excluded.

(iv) The immature stages that we have studied come only from laboratory-reared specimens from allopatric localities within the distribution ranges of the two ticks, namely South Africa for *H.* (*R.*) *elliptica*, and Egypt and the Central African Republic for *H.* (*R.*) *leachi*.

The records of JLC have not been included because they need to be rechecked in relation to the new characters that we have found.

The descriptions of the adults of various *Haemaphysalis* species by Hoogstraal and his co-authors are characterized by the use of proportions between measurements of particular structures, mainly those of the gnathosoma. However, we could not find any exact description of the scheme of measurements taken by Hoogstraal and his co-workers, who gave only brief explanations in the texts. The exact features or structures between which some of the meas-

urements were made are for the most part quite easily recognizable, but for several they are not. Consequently, we have taken those measurements that we consider are the most suitable for describing the species. Except for the measurements for which an explanation is given in the text, a scheme of the measurements that we have taken is illustrated in Fig. 1.

Because the larva and nymph have sometimes been inadequately described or not described at all, our set of measurements for them does not differ substantially from that used for these stages of development of previously described species. For the adults we tried to follow Hoogstraal's format so that our measurements would at least approximate those that had been used before.

Measurements for the male conscutum and female scutum and their total lengths are given in millimetres (mm), and those for the immature stages in micrometres (μm). The measurements are arranged as follows: minimum – maximum (average ± standard deviation, *n* = number of specimens measured).

When measuring the dorsal and ventral spurs on palpal segments II and III, it must be noted that they are not in the same plane as the gnathosoma as they are directed either dorsally or ventrally. Con-

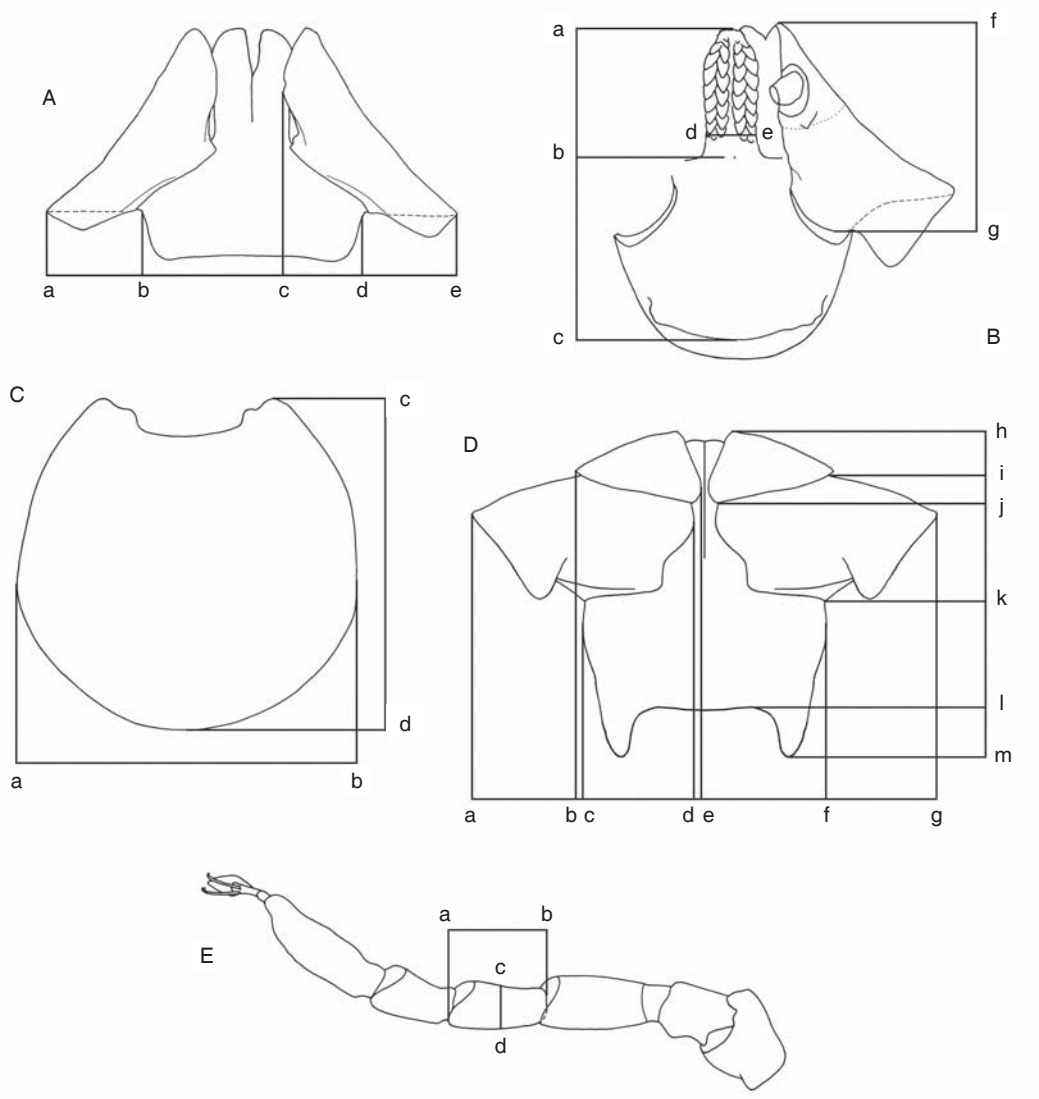

FIG. 1 Scheme of measurements for *Haemaphysalis*. A, nymph, gnathosoma dorsally: a-e—combined palpal width, b-d – width of basis capituli, c-e – width of palp; B, nymph, gnathosoma ventrally: a-b – length of hypostome, a-c – length of gnathosoma, d-e – width of hypostome, f-g – length of palp; C, nymph, scutum: a-b – width, c-d – length; D, male, gnathosoma dorsally: a-d – width of palpal segment II, a-g – combined palpal width, b-e – width of palpal segment III, c-f – width of basis capituli, h-j – length of palpal segment III, i-k – length of palpal segment II, k-m – length of basis capituli, l-m – length of dorsal cornua; E, nymph, leg I: a-b – length of genu, c-d – width of genu

sequently, the shape and the length of these spurs vary according to the plane along which they are observed. DAA's illustrations of the gnathosoma of the larvae and nymphs are based on slide-mounted specimens, but because of the differences in planes even in these preparations, the spurs on the palpal segments are in reality longer than illustrated. This observation has been verified by scanning electron microscopy. Furthermore, in order to simplify identification for persons who may in future examine these species we have attempted to use a minimum of poorly defined diagnostic characters.

Haemaphysalis (*Rhipistoma*) *elliptica* (Koch, 1844)

THE SOUTH AFRICAN CARNIVORE HAEMAPHYSALID
(Fig. 2–7)

Synonym

Haemaphysalis leachi humerosoides Theiler, 1943 *sensu* Theiler, 1943.

The collection lot (no. 2754), identified as *Haemaphysalis leachi* var. *humerosoides* by G. Theiler, contains nine vials. In the catalogue listing the specimens in the Onderstepoort Veterinary Institute tick collection the first vial (i) is marked as "Type": i (13 ♂, 17 ♀) – Bilene, Macia [Mozambique], 25.V.1940, PEAf Collection, XIII, Banino. According to its label, the second vial may also contain specimens of the original type series: ii (10 ♂, 15 ♀) – Angonia, Massoane [Mozambique], 12.VII.1940, PEAf Collection, XXV, Banino. DAA and IGH have identified all the specimens in these vials as *H.* (*R.*) *elliptica*. The other vials contain various ticks of the *H. leachi* group as well as *Rhipicephalus* Koch, 1844 collected from localities in Africa at a later stage.

Holotype

Male, Cape of Good Hope (Western Cape Province, South Africa), deposited in the Natural History Museum of Berlin, Berlin, Germany; collection no. ZMB 1099. This specimen has been examined by all of us and studied by DAA and JLC.

DESCRIPTION AND REDESCRIPTION

Male (Fig. 2A–C, 3A–F)

Length from palpal apices to posterior margin of conscutum 2.41–3.54 (3.00 ± 0.19, *n* = 323); *breadth* of conscutum (at widest point) 1.19–1.75 (1.47 ± 0.10, *n* = 322); ratio 1.78–2.32 (2.05 ± 0.10, *n* = 319). *Colour* reddish brown.

Conscutum (Fig. 2A–C): *ca* 1.9 times as long as broad; margins slightly convex, broadest at level of

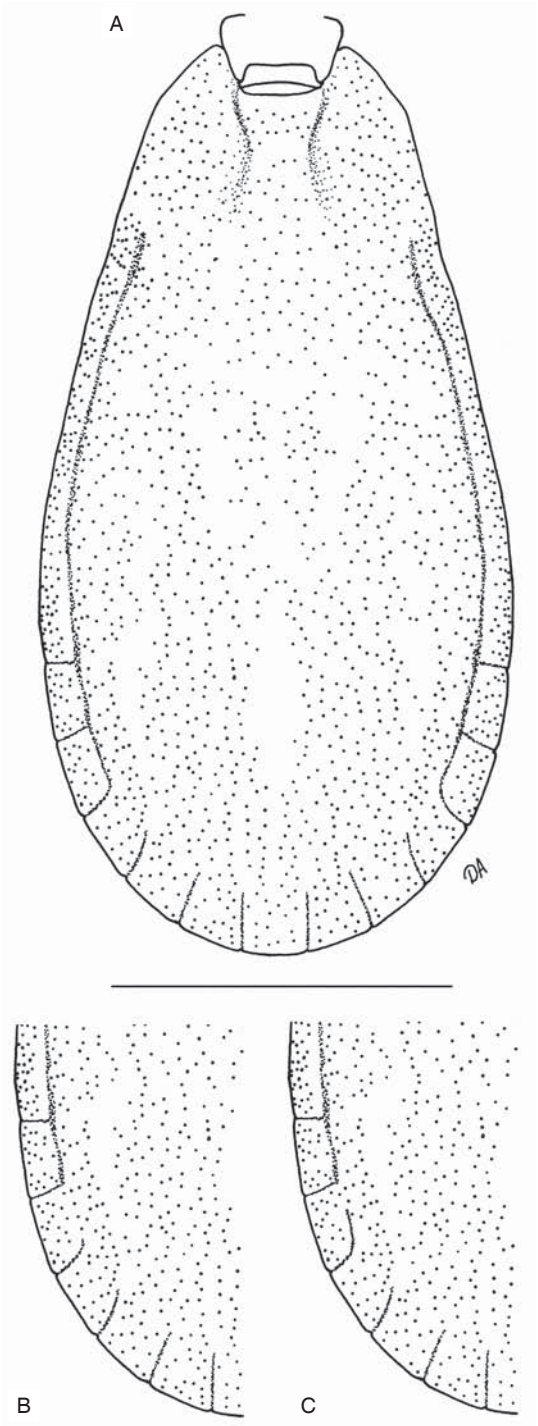

FIG. 2 *Haemaphysalis elliptica*, male, A, conscutum. Bar = 1 mm; B, C, left posterior half of conscutum . Bar = 1 mm. All setation is omitted

spiracular plates, smoothly rounded posteriorly. *Cervical pits* narrow, deep, converging. *Cervical grooves* indistinct, short, shallow, diverging. *Lateral grooves* deep, distinct, extend to anterior 1/4 of scutal length; enclose first or first and second festoons. *Punctations* dense, medium-sized, discrete, relatively deep. *Festoons* number 11. *Genital structures* (Fig. 3A): as illustrated. *Spiracular plates* (Fig. 3B): variable in

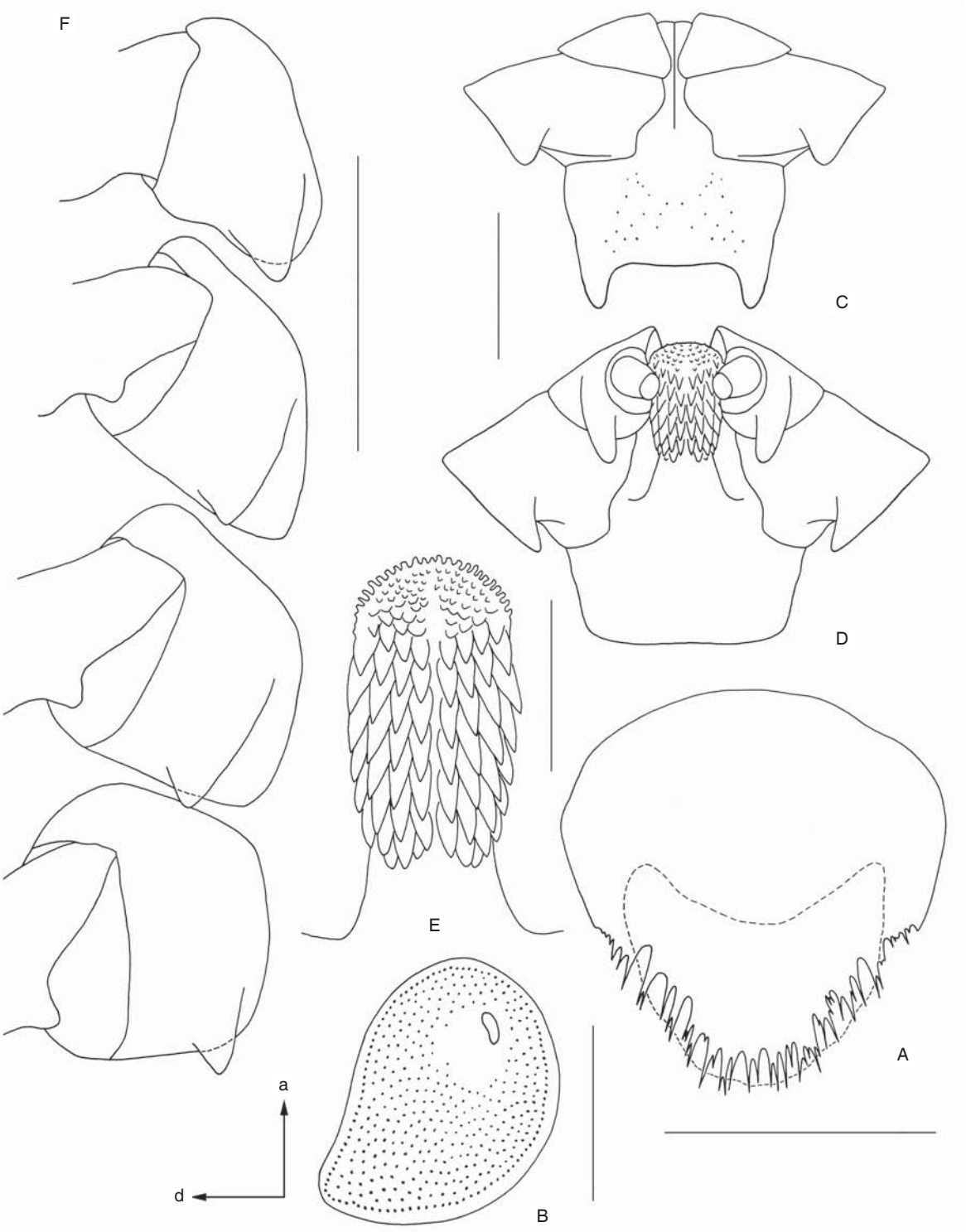

FIG. 3 *Haemaphysalis elliptica*, male, A, genital structures: apron and postgenital sclerite. Bar = 200 µm; B, spiracular plate (a – anterior; d – dorsal). Bar = 200 µm; C, gnathosoma dorsally. Bar = 200 µm; D, gnathosoma ventrally. Bar = 200 µm; E, hypostome. Bar = 100 µm; F, coxae. Bar = 500 µm. All setation is omitted

size, usually slightly broader than long; suboval; dorsal projection triangular.

Capitulum (Fig. 3C, D): *Basis capituli* dorsally *ca.* 1.7 times as broad as long; lateral margins diverging anteriorly; cornua elongately triangular, apices rounded, *ca.* 1/3 as long as length of basis capituli; ventrally as illustrated. *Palps* broadly salient (*leachi* type); combined breadth *ca.* 1.9 times breadth of basis capituli. Segment II *ca.* 1.7 times as broad as long; dorsomedian margin of segment II gradually widening anteriorly at level of its mid-length; posterodorsal spur large, triangular; posteroventral spur large, triangular, with straight lateral margin. Segment III *ca*. 1.6 times as broad as long; *ca*. 1/2 the length of segment II; ventral spur of segment III narrowly elongate, U-shaped apex at level of anterior 1/4 of length of segment II. *Hypostome* (Fig. 3E): slightly shorter than palps; dental formula 4/4; denticles in subequal-length files of 6 or 7.

Coxae (Fig. 3F): I to IV each with a short, subtriangular, more or less bluntly pointed spur, extending somewhat beyond coxal margin; spur of coxae IV usually subequal to that of coxae III.

Female (Fig. 4, 5A–F)

Length from palpal apices to posterior margin of scutum 1.42–1.92 (1.73 ± 0.10, *n* = 131); *breadth* of scutum (at widest point) 0.82–1.14 (1.02 ± 0.06, *n* = 133); *ratio* 1.50–1.86 (1.70 ± 0.07, *n* = 131).

Scutum (Fig. 4): *ca*. 1.3 times as long as broad; anterior margins diverging for anterior 1/5 of total length, subparallel 1/5 of the length, thence gradually converging, bluntly rounded posteriorly; slight postero-lateral angles. *Cervical grooves* narrow arcs extending 2/3 of total scutal length. *Punctations* moderately dense, denser on lateral fields, absent in cervical grooves; medium-sized, discrete, relatively deep. *Posterior lip of genital aperture* (Fig. 5A): broadly U-shaped. *Spiracular plates* (Fig. 5B): varying in size; irregularly suboval or subcircular; dorsal projection short, broadly triangular.

Capitulum (Fig. 5C, D): *Basis capituli* dorsally *ca*. 2.4 times as broad as long; external margins diverging anteriorly; cornua short, broadly triangular, bluntly pointed, *ca*. 1/6 as long as the length of the of basis capituli; porose areas elongate-oval, tilted inwards, moderate size, widely spaced. Basis capituli ventrally as illustrated. *Palps* broadly salient (*leachi* type); combined breadth *ca*. 1.6 times breadth of basis capituli. Segment II *ca*. 1.4 times as broad as long; dorsomedian margin of segment II gradually widening anteriorly at level of its midlength; posterodorsal spur large, triangular; posterolateral margin straight; posteroventral spur reduced to short rounded projection or curve. Segment III *ca*. 1.2 times as broad as long; *ca*. 0.7 times as long as segment II; ventral spur of segment III narrowly U-shaped, elongate, apex at level of anterior 1/3 of length of segment II. *Hypostome* (Fig. 5E): nearly as long as palps; dental formula 4/4; denticles usually in files of 9 or 10.

Coxae (Fig. 5F): I to IV each with a short, subtriangular, more or less bluntly pointed spur, extending somewhat beyond coxal margin; spur on coxae IV subequal to that of coxae III.

Nymph (Fig. 6A–E)

Length (unengorged) from palpal apices to posterior body margin 1 366–1 683 (1 543 ± 77.93, *n* = 32); *breadth* of idiosoma (at widest point) 756–988 (896 ± 62.33, *n* = 32); *ratio* 1.60–1.85 (1.73 ± 0.06, *n* = 32).

Scutum (Fig. 6A): length 431–510 (472 ± 20.95, *n* = 32), breadth 421–549 (427 ± 27.71, *n* = 32), ratio 0.92–1.08 (1.00 ± 0.04, *n* = 32); irregularly circular. *Spiracular plates* (Fig. 6B): suboval.

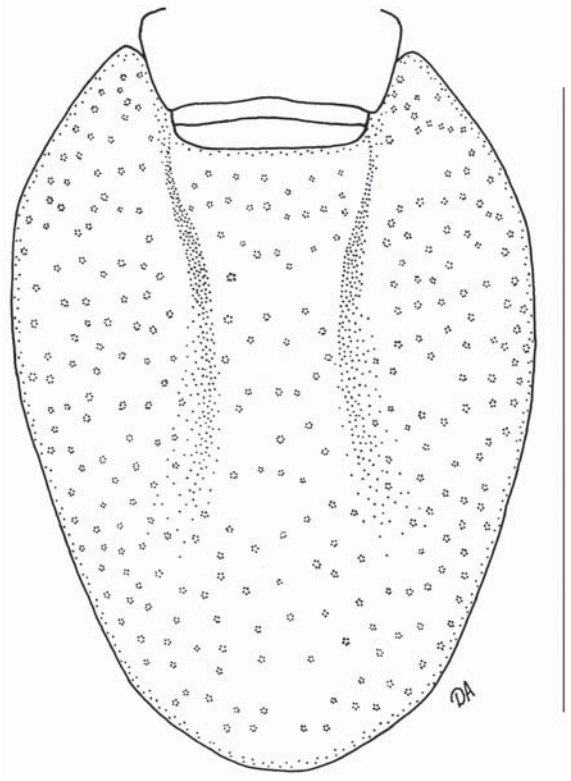

FIG. 4 *Haemaphysalis elliptica*, female, scutum. Bar = 1 mm. All setation is omitted

Capitulum (Fig. 6C, D): length 240–284 (265 ± 11.91, *n* = 32), breadth (palps combined) 336–402 (371 ± 16.97, *n* = 32), ratio 0.69–0.79 (0.71 ± 0.004, *n* = 32). *Basis capituli* dorsally subrectangular; cornua slight bulges; ventrally as illustrated. *Palps*: length 167–198 (182 ± 8.69, *n* = 32), breadth 147–181

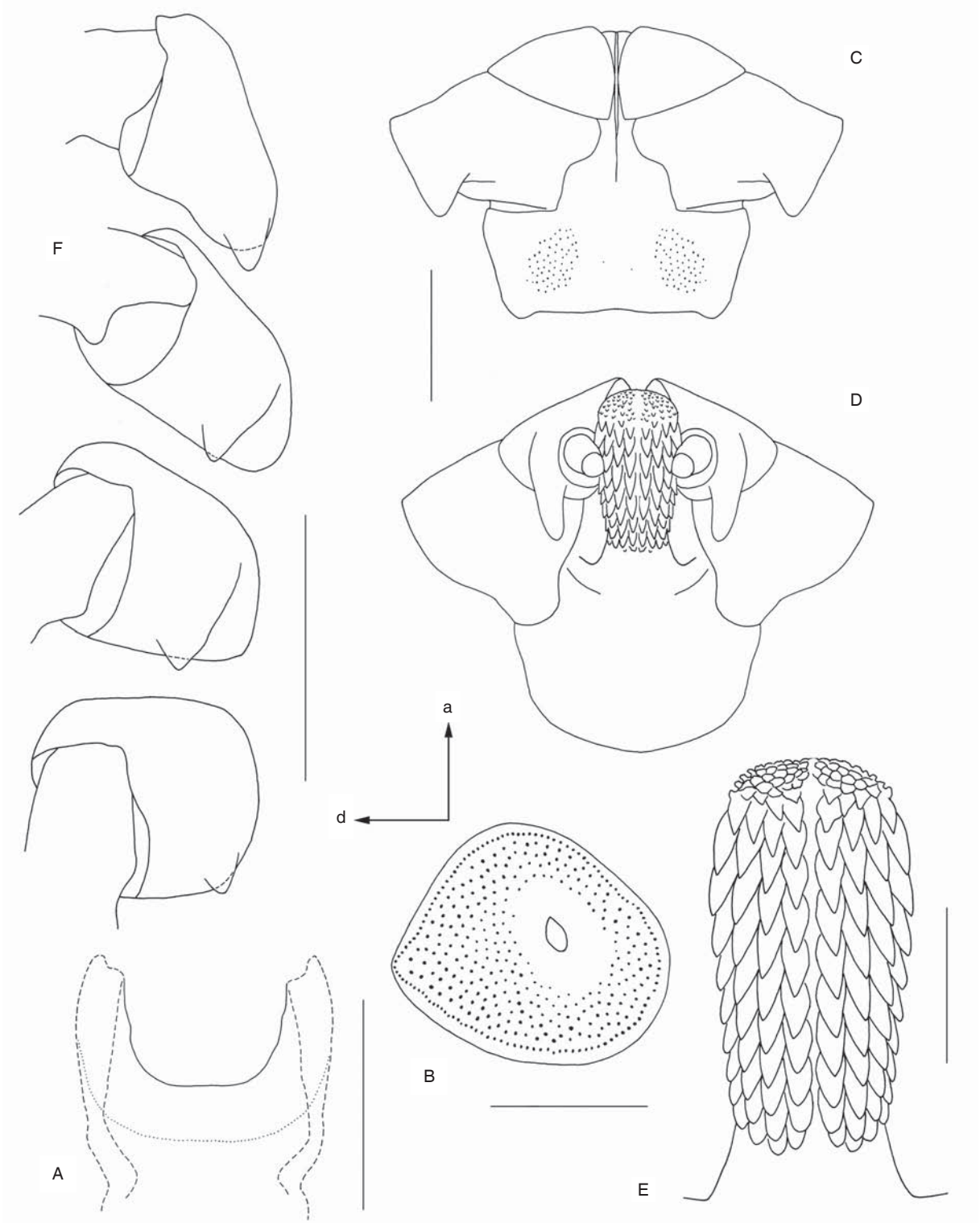

FIG. 5 *Haemaphysalis elliptica*, female, A, genital structures: posterior lip of the genital aperture and vestibular part of vagina. Bar = 200 µm; B, spiracular plate (a – anterior; d – dorsal). Bar = 200 µm; C, gnathosoma dorsally. Bar = 200 µm; D, gnathosoma ventrally. Bar = 200 µm; E, hypostome. Bar = 100 µm; F, coxae. Bar = 500 µm. All setation is omitted

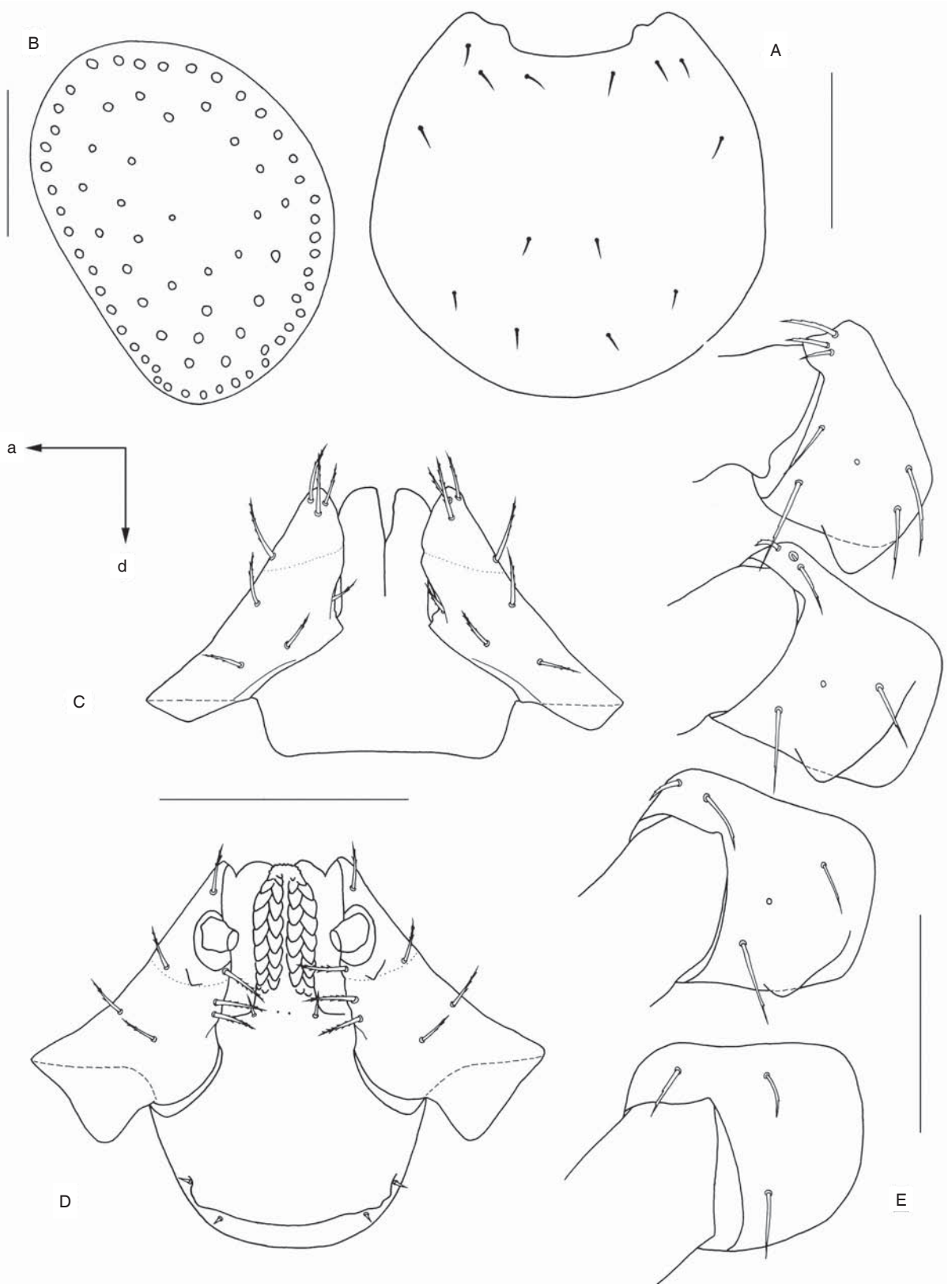

FIG. 6 *Haemaphysalis elliptica*, nymph, A, scutum. Bar = 200 µm; B, spiracular plate (a – anterior; d – dorsal). Bar = 50 µm; C, gnathosoma dorsally. Bar = 200 µm; D, gnathosoma ventrally. Bar = 200 µm; E, coxae. Bar = 200 µm. Setation of palpal segment IV is omitted

(160 ± 7.77, *n* = 32), ratio 1.08–1.21 (1.14 ± 0.03, *n* = 32); broadly salient; anterolateral margin slightly concave. Dorsomedian margin of segment II gradually widening anteriorly at level of its midlength; dorsal spur moderate; ventral spur large, broad; lateral margin of spur slightly concave. Ventral spur of segment III distinct, broadly triangular, with sharp apex. *Hypostome* (Fig. 6D): length 97–116 (107 ± 5.47, *n* = 32), breadth 40–48 (45 ± 2.05, *n* = 32), ratio 2.20–2.67 (2.39 ± 0.10, *n* = 32); nearly as long as palps; dental formula 2/2; denticles in files of 7 to 9 (usually 8).

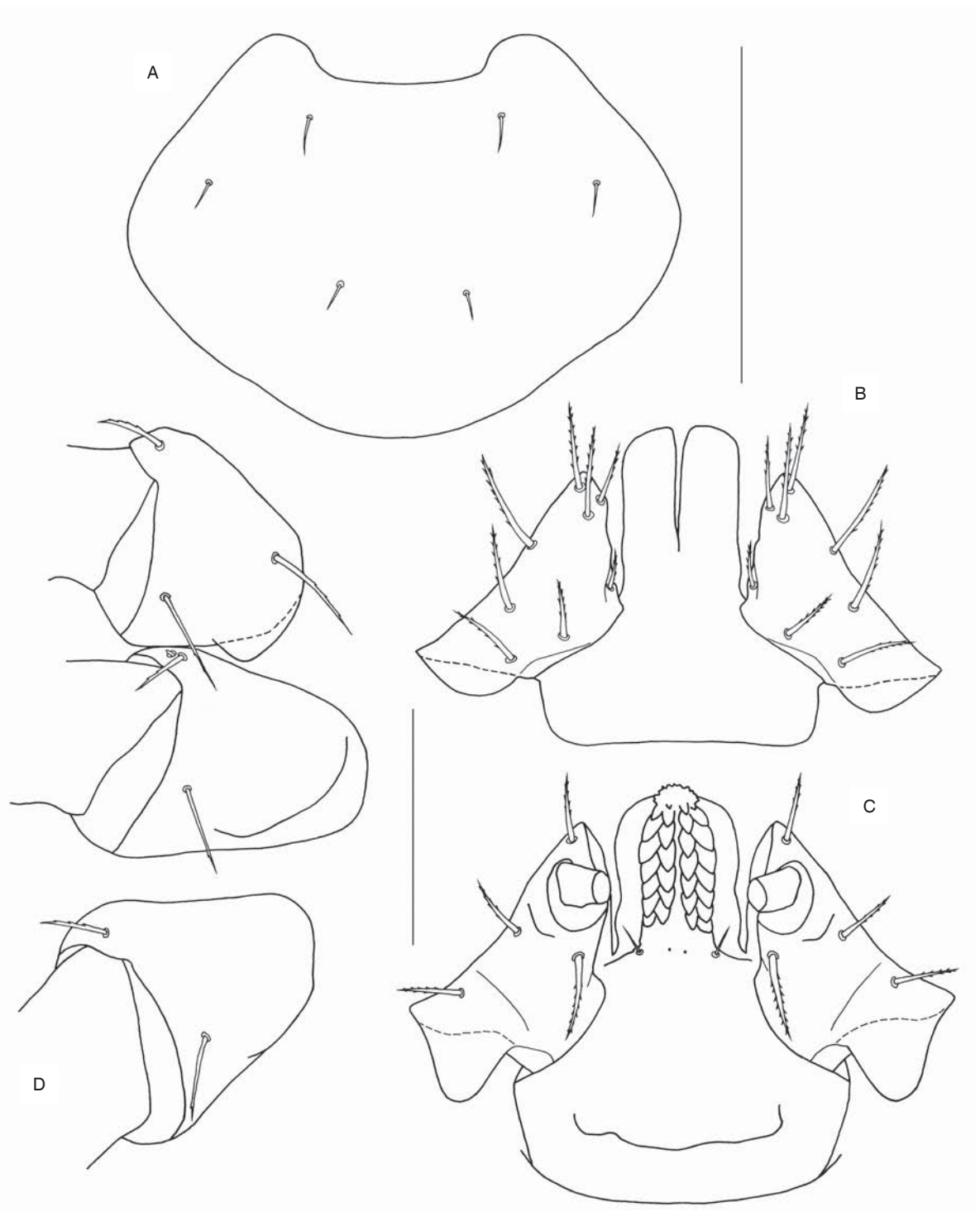

FIG. 7 *Haemaphysalis elliptica*, larva, A, scutum. Bar = 200 µm; B, gnathosoma dorsally. Bar = 100 µm; C, gnathosoma ventrally. Bar = 100 µm; D, coxae. Bar = 100 µm. Setation of palpal segment IV is omitted

Coxae (Fig. 6E): coxae I spur prominent, triangular; coxae II and III spur small, triangular; no spur on coxae IV. *Genu*: length 168–212 (193 ± 8.92, *n* = 32), breadth 78–93 (86 ± 4.06, *n* = 32), ratio 2.08–2.43 (2.26 ± 0.09, *n* = 32).

Larva (Fig. 7A–D)

Length (unengorged) from palpal apices to posterior body margin 657–755 (704 ± 22.01, *n* = 90); *breadth* of idiosoma (at widest point) 461–529 (498 ± 16.80, *n* = 90); *ratio* 1.31–1.53 (1.41 ± 0.04, *n* = 90).

Scutum (Fig. 7A): length 220–269 (237 ± 10.24, *n* = 90), breadth 294–372 (324 ± 14.60, *n* = 90), ratio 0.66–0.80 (0.73 ± 0.02, *n* = 90); margins markedly diverging to level of *ca*. anterior 1/3 of scutal length, subparallel along mid-third; thence abruptly converging, bluntly rounded posteriorly.

Capitulum (Fig. 7B, C): length 126–159 (143 ± 6.21, *n* = 90), breadth (palps combined) 189–221 (206 ± 6.25, *n* = 90), ratio 0.65–0.76 (0.70 ± 0.02, *n* = 90). *Basis capituli* dorsally subrectangular; cornua as slight marginal bulges; ventrally as illustrated. *Palps*: length 90–111 (99 ± 4.47, *n* = 90), breadth 74–87 (82 ± 2.92, *n* = 90), ratio 1.12–1.37 (1.21 ± 0.04, *n* = 90); broadly salient; lateral margin slightly concave. Dorsal spur of segment II prominent, broadly rounded; ventral spur of segment II long, broad; lateral margin of spur slightly concave. Ventral spur of segment III distinct, fold-like. *Hypostome* (Fig. 7C): length 57–74 (66 ± 3.43, *n* = 90), breadth 25–30 (28 ± 1.17, *n* = 90), ratio 2.08–2.70 (2.38 ± 0.13, *n* = 90); longer than palps; dental formula 2/2; denticles in files of 7 or 8.

Coxae (Fig. 7D): coxae I spur moderate, triangular; coxae II and III spur short, fold-like. *Genu:* length 99–129 (112 ± 5.69, *n* = 90), breadth 48–61 (54 ± 2.82, *n* = 90), ratio 1.83–2.22 (2.06 ± 0.09, *n* = 90).

Haemaphysalis (*Rhipistoma*) *leachi* (Audouin, 1826)

THE YELLOW DOG HAEMAPHYSALID
(Fig. 8–13)

Synonyms

Haemaphysalis leachi humerosoides Theiler, 1943 *sensu* Hoogstraal 1956.

Haemaphysalis leachi humerosoides Theiler, 1943 *sensu* Santos Dias, 1958.

Haemaphysalis leachi humerosoides Theiler, 1943 *sensu* Theiler, 1962.

Haemaphysalis leachi humerosoides Theiler, 1943 *sensu* Camicas *et al*. 1998.

Neotype

Male, collected as an engorged nymph in a nest of *Arvicanthis niloticus niloticus* (Desmarest, 1822) at Kirdasa, Imbaba, Giza, Egypt, 14 June 1953 by H. Hoogstraal (moulted to adult in laboratory, 28 June 1953). The neotype was selected by Hoogstraal and

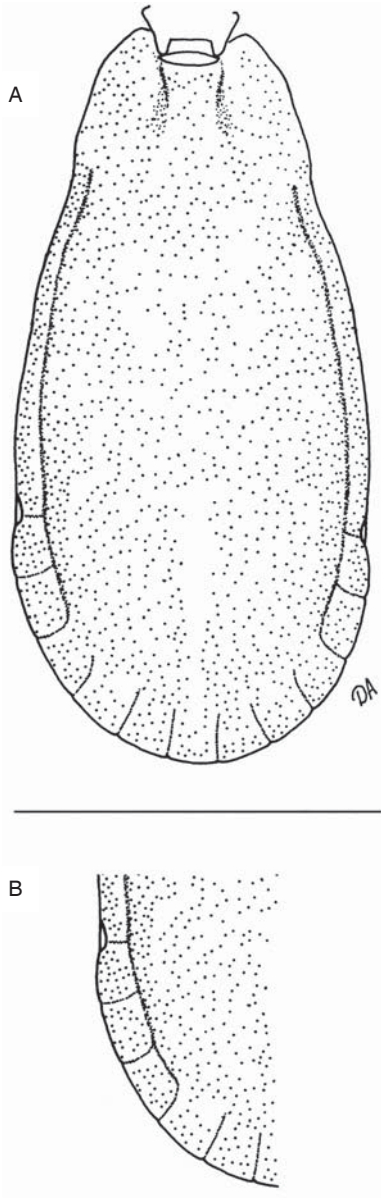

FIG. 8 *Haemaphysalis leachi*, male, A, conscutum. Bar = 1 mm; B, left posterior half of conscutum. Bar = 1 mm. All setation is omitted

deposited in the United States National Tick Collection, Georgia Southern University, Statesboro, USA; collection number: 56757. This specimen has been examined by DAA.

REDESCRIPTION

Male (Fig. 8A, B, 9A–F)

Length from palpal apices to posterior body margin 1.88–2.97 (2.45 ± 0.15, *n* = 714); *breadth* of conscutum (at widest point) 0.82–1.29 (1.06 ± 0.07, *n* = 718); *ratio* 1.94–2.78 (2.30 ± 0.12, *n* = 698). *Colour* yellowish brown.

Conscutum (Fig. 8A, B): *ca*. 2.1 times as long as broad; margins slightly convex, broadest at level of spiracular plates, smoothly rounded posteriorly. *Cervical pits* narrow, deep, converging. *Cervical grooves* indistinct, short, shallow, diverging. *Lateral grooves* deep, distinct, extend to anterior 1/4 of scutal length; enclose first two or three festoons. *Punctations* dense, medium-sized, discrete, walls vertical, relatively deep. *Festoons* number 11. *Genital apron* (Fig. 9A): as illustrated. *Spiracular plates* (Fig. 9B): variable in size, usually slightly longer than broad; suboval or subrectangular; dorsal projection bluntly triangular.

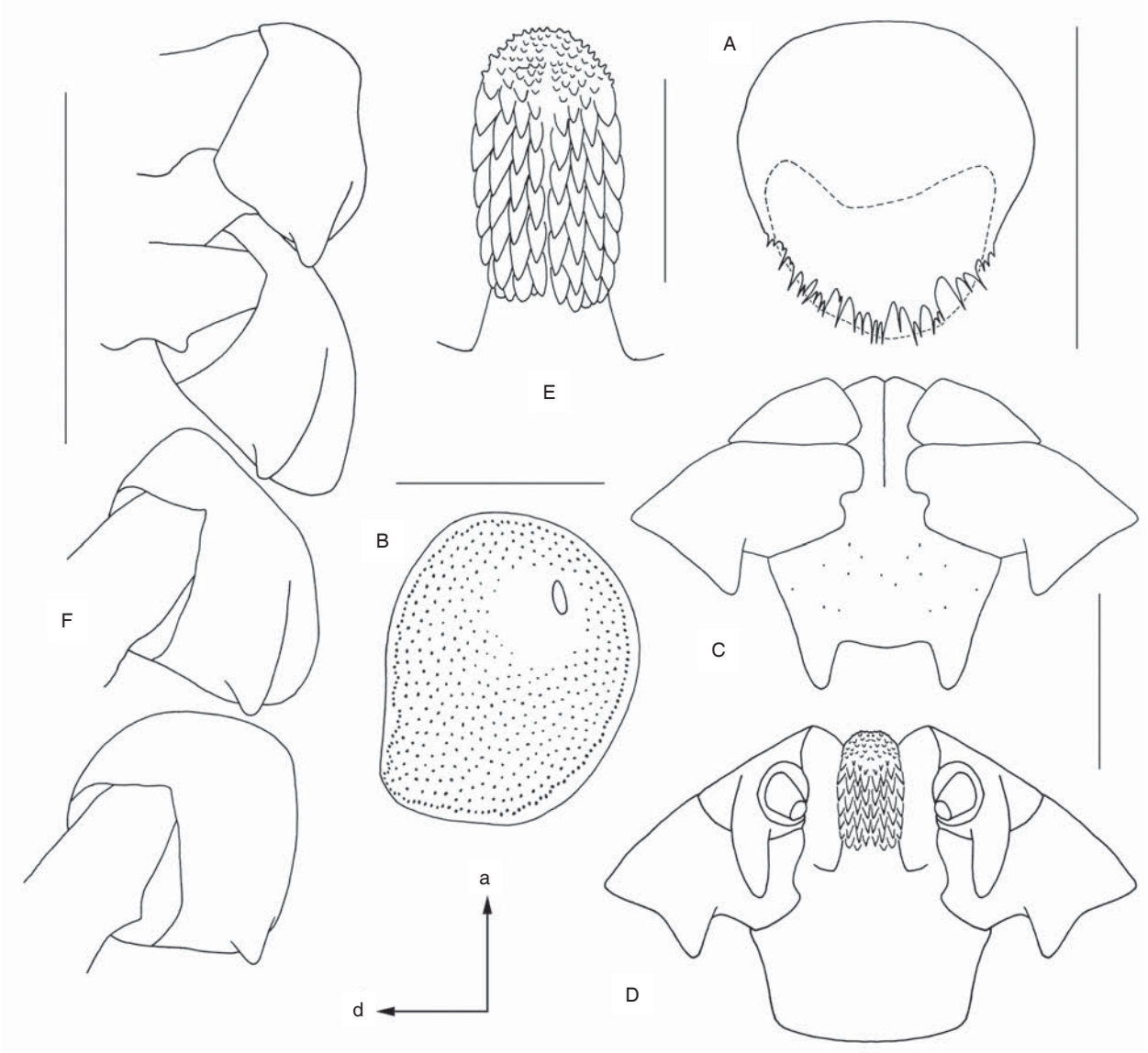

FIG. 9 *Haemaphysalis leachi*, male, A, genital structures: apron and postgenital sclerite. Bar = 200 µm; B, spiracular plate (a – anterior; d – dorsal). Bar = 200 µm; C, gnathosoma dorsally. Bar = 200 µm; D, gnathosoma ventrally. Bar = 200 µm; E, hypostome. Bar = 100 µm; F, coxae. Bar = 500 µm. All setation is omitted

Capitulum (Fig. 9C, D): *Basis capituli* dorsally *ca.* 1.7 times as broad as long; lateral margins diverging slightly anteriorly; cornua elongately triangular, apices rounded, *ca*. 1/3 as long as length of basis capituli; ventrally as illustrated. *Palps* broadly salient (*leachi* type); combined breadth *ca*. 2.1 times breadth of basis capituli. Segment II *ca.* 1.8 times as broad as long; dorsomedian margin of segment II sharply bulging anteriorly at mid-length; posterodorsal spur large, triangular; posteroventral spur large, triangular; lateral margin of spur markedly concave. Segment III *ca*. 1.7 times as broad as long; *ca*. 1/2 as long as segment II; ventral spur of segment III narrowly elongate, apex at level of mid-length of segment II. *Hypostome* (Fig. 9E): slightly shorter than palps; dental formula 4/4; denticles in subequal-length files of 6 or 7.

Coxae (Fig. 9F): I to IV each with a short, subtriangular, more or less bluntly pointed spur, extending somewhat beyond coxal margin; spur of coxae IV usually shorter than that of coxae III.

Female (Fig. 10, 11A–F)

Length from palpal apices to posterior scutal margin 1.17–1.70 (1.53 ± 0.08, *n* = 267); *breadth* of scutum (at widest point) 0.66–0.96 (0.84 ± 0.04, *n* = 267); *ratio* 1.58–2.14 (1.81 ± 0.08, *n* = 267). *Colour* yellowish brown.

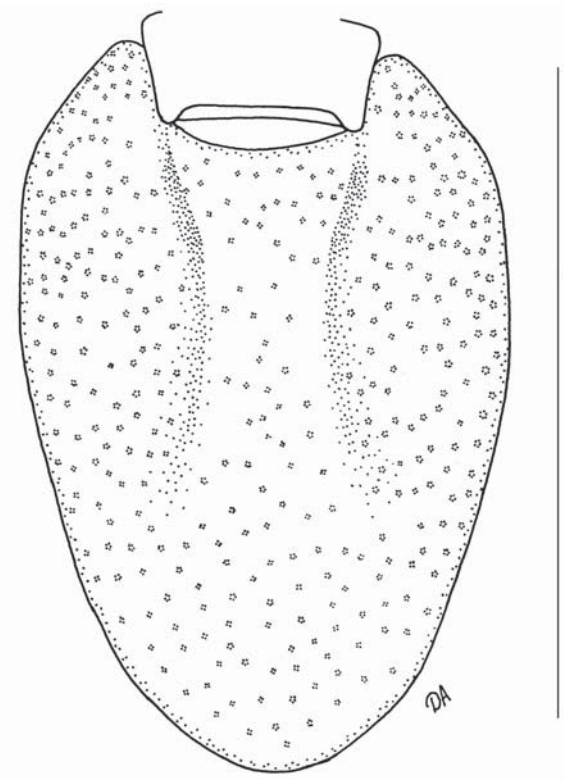

FIG. 10 *Haemaphysalis leachi*, female, scutum. Bar = 1 mm. All setation is omitted

Scutum (Fig. 10): *ca*. 1.4 times as long as broad; margins diverging for anterior 1/5 of total length, subparallel 1/5 of length, thence gradually converging, bluntly rounded posteriorly; slight postero-lateral angles. *Cervical grooves* narrow arcs extending 2/3 of total scutal length. *Punctations* moderately dense, denser on lateral fields, absent in cervical grooves; medium-sized, discrete, walls vertical, relatively deep. *Genital aperture* (Fig. 11A): posterior lip broadly U-shaped. *Spiracular plates* (Fig. 11B): variable in size; irregularly subcircular; dorsal projection short, broadly triangular.

Capitulum (Fig. 11C, D): *Basis capituli* dorsally *ca*. 2.2 times as broad as long; external margins slightly diverging anteriorly; cornua relatively long, broadly triangular, bluntly pointed, *ca*. 1/4 as long as length of basis capituli; porose areas elongately-oval, tilted inwards, moderate size, widely spaced. Basis capituli ventrally as illustrated. *Palps* broadly salient (*leachi* type); combined breadth *ca.* 1.8 times breadth of basis capituli. Segment II *ca*. 1.5 times as broad as long; dorsomedian margin of segment II sharply bulging anteriorly at mid-length; posterodorsal spur large, triangular; posterolateral margin slightly concave; posteroventral spur reduced to short, rounded projection or curve. Segment III *ca*. 1.4 times as broad as long; *ca*. 0.6 times as long as segment II; ventral spur of segment III narrowly elongate, apex at level of mid-length of segment II. *Hypostome* (Fig. 11E): nearly as long as palps; dental formula 4/4; denticles in files usually of 8 or 9.

Coxae (Fig. 11F): I to IV each with a short, subtriangular, more or less bluntly pointed spur, extending somewhat beyond coxal margin; spur on coxae IV subequal or shorter than that on coxae III.

Nymph (Fig. 12A–E)

Length (unengorged) from palpal apices to posterior body margin 1 293–1 427 (1 344 ± 45.04, *n* = 8); *breadth* of idiosoma (at widest point) 707–817 (755 ± 36.55, *n* = 8); *ratio* 1.66–1.84 (1.78 ± 0.06, *n* = 8).

Scutum (Fig. 12A): length 392–431 (412 ± 13.86, *n* = 10), breadth 402–446 (416 ± 12.53, *n* = 10), ratio 0.95–1.02 (0.99 ± 0.02, *n* = 10); irregularly sub-circular. *Spiracular plates* (Fig. 12B): suboval.

Capitulum (Fig. 12C, D): length 208–252 (236 ± 11.62, *n* = 10), breadth (palps combined) 326–363 (339 ± 13.53, *n* = 10), ratio 0.64–0.72 (0.70 ± 0.02,

n = 10). *Basis capituli* dorsally subrectangular; cornua slight bulges; ventrally as illustrated. *Palps*: length 152–167 (158 ± 4.48, *n* = 10), breadth 142–162 (150 ± 6.68, *n* = 10), ratio 1.00–1.12 (1.06 ± 0.04, *n* = 10); broadly salient; anterolateral margin markedly concave. Dorsomedian margin of segment II widening sharply anteriorly at level of its midlength; dorsal spur moderate; ventral spur large, narrow; posterolateral margin distinctly concave. Ventral spur of segment III distinct, triangular, with sharp apex. *Hypostome* (Fig. 12D): length 76–94 (87 ± 5.68, *n* = 10), breadth 36–41 (38 ± 1.63, *n* = 10), ratio 1.94–2.50 (2.28 ± 0.16, *n* = 10); nearly as long as palps; dental formula 2/2; denticles in files of 5 or 6.

Coxae (Fig. 12E): coxae I spur moderate, triangular; coxae II and III spur small, triangular; no spur on coxae IV. *Genu*: length 160–184 (167 ± 7.24, *n* = 10), breadth 71–80 (76 ± 2.92, *n* = 9), ratio 2.03–2.42 (2.19 ± 0.11, *n* = 9).

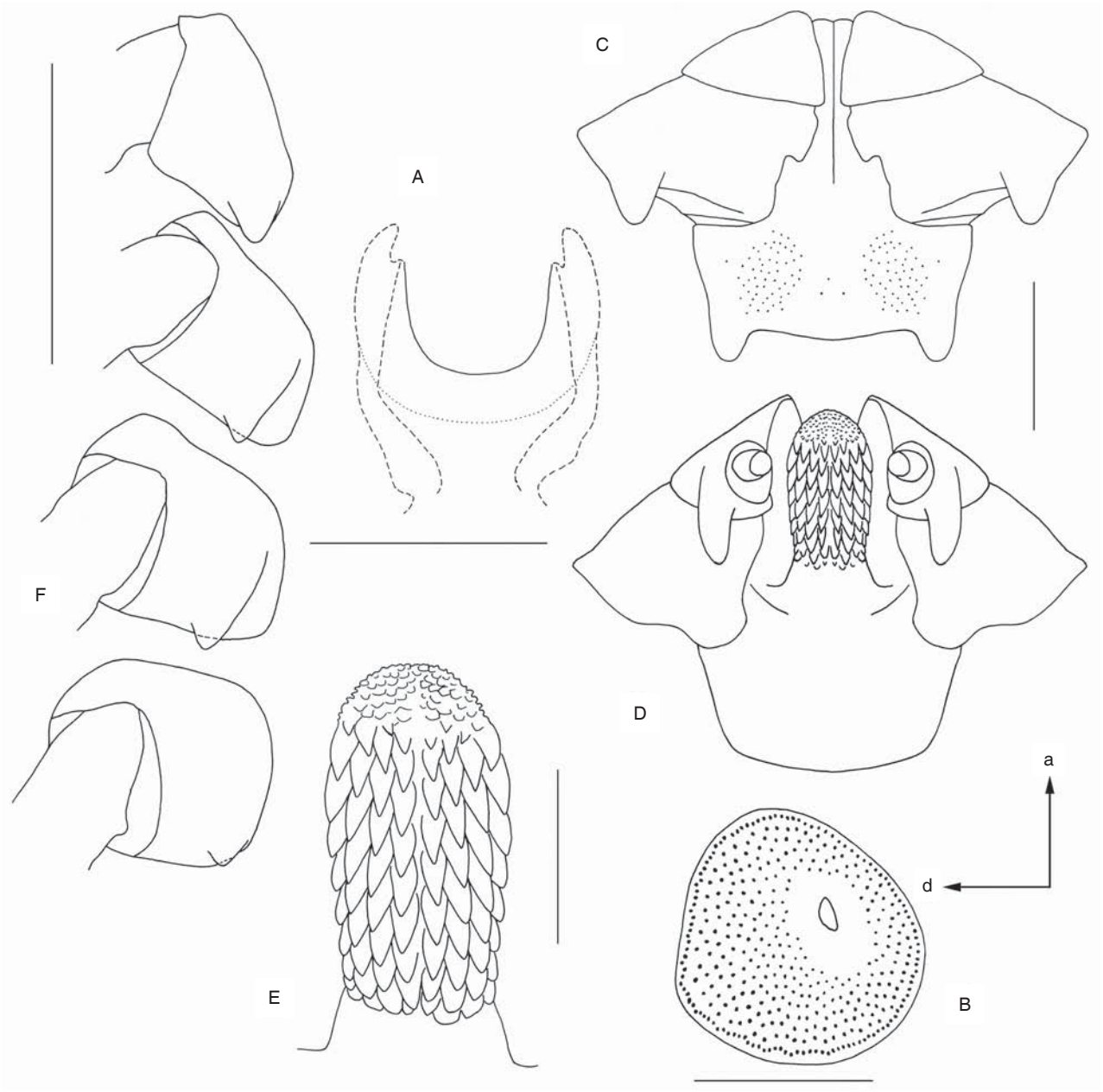

FIG. 11 *Haemaphysalis leachi*, female, A, genital structures: posterior lip of the genital aperture and vestibular part of vagina. Bar = 200 µm; B, spiracular plate (a – anterior; d – dorsal). Bar = 200 µm; C, gnathosoma dorsally. Bar = 200 µm; D, gnathosoma ventrally. Bar = 200 µm; E, hypostome. Bar = 100 µm; F, coxae. Bar = 500 µm. All setation is omitted

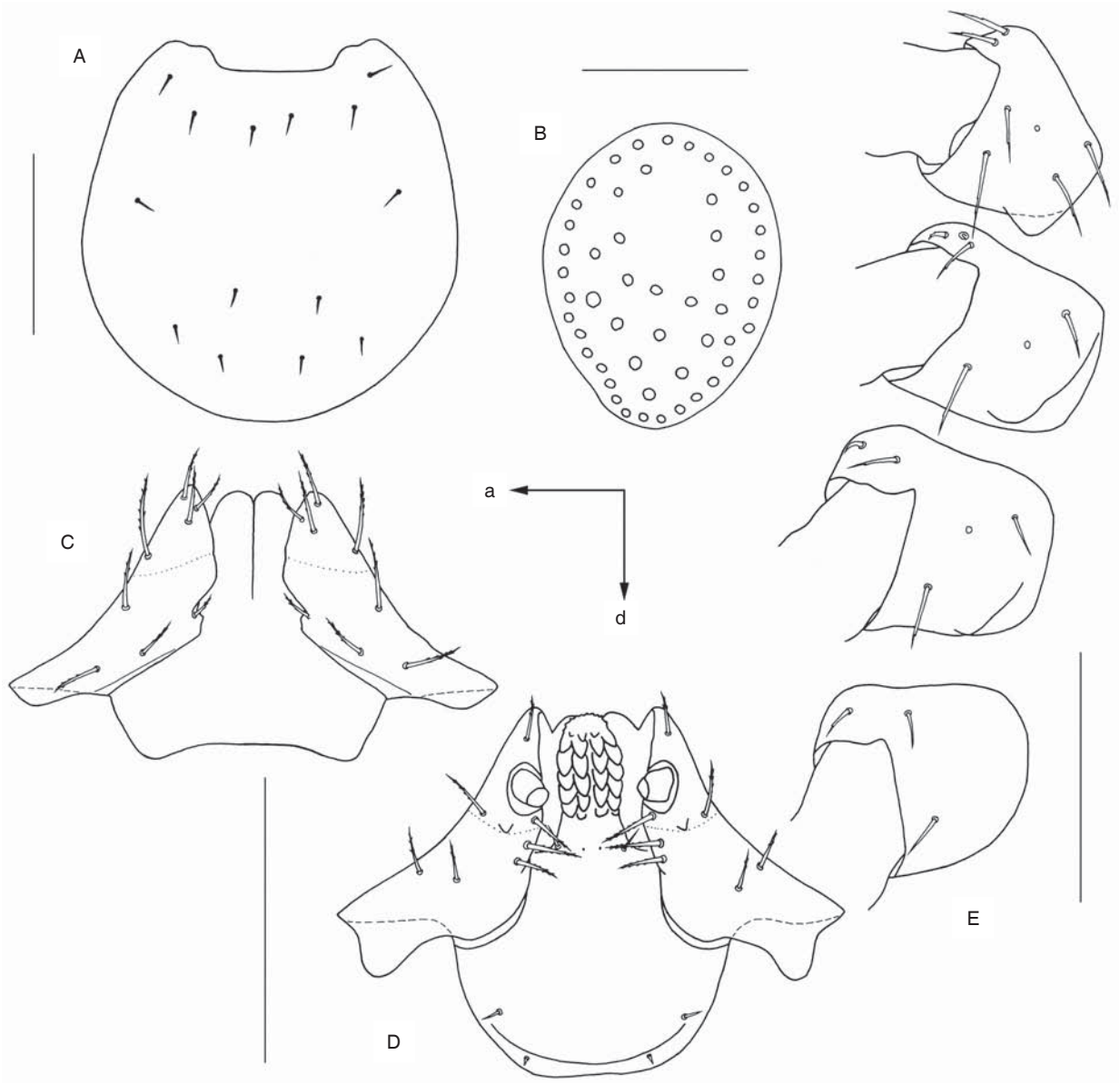

FIG. 12 *Haemaphysalis leachi*, nymph, A, scutum. Bar = 200 µm; B, spiracular plate (a – anterior; d – dorsal). Bar = 50 µm; C, gnathosoma dorsally. Bar = 200 µm; D, gnathosoma ventrally. Bar = 200 µm; E, coxae. Bar = 200 µm. Setation of palpal segment IV is omitted

Larva (Fig. 13A–D)

Length (unengorged) from palpal apices to posterior body margin 608–681 (652 ± 17.56, *n* = 116); *breadth* of idiosoma (at widest point) 431–559 (457 ± 16.05, *n* = 112); *ratio* 1.14–1.50 (1.43 ± 0.05, *n* = 112).

Scutum (Fig. 13A): length 196–225 (208 ± 6.64, *n* = 117), breadth 279–323 (302 ± 9.30, *n* = 120), ratio 0.62–0.74 (0.69 ± 0.02, *n* = 117); margins sharply diverging to level of *ca*. anterior 1/3 of scutal length, subparallel along mid-third; thence abruptly converging, bluntly rounded posteriorly.

Capitulum (Fig. 13B, C): length 117–140 (128 ± 4.74, *n* = 119), breadth (palps combined) 177–205 (192 ± 4.78, *n* = 118), ratio 0.61–0.73 (0.67 ± 0.02, *n* = 117). *Basis capituli* dorsally subrectangular; cornua as slight marginal bulges; ventrally as illustrated. *Palps*: length 87–108 (97 ± 4.25, *n* = 120), breadth 67–80 (73 ± 2.61, *n* = 120), ratio 1.18–1.44 (1.32 ± 0.06, *n* = 120); broadly salient; lateral margin slightly concave. Dorsal spur of segment II prominent, slightly tapering to apex; ventral spur of segment II long, relatively narrow; lateral margin of spur distinctly concave. Ventral spur of segment III dis-

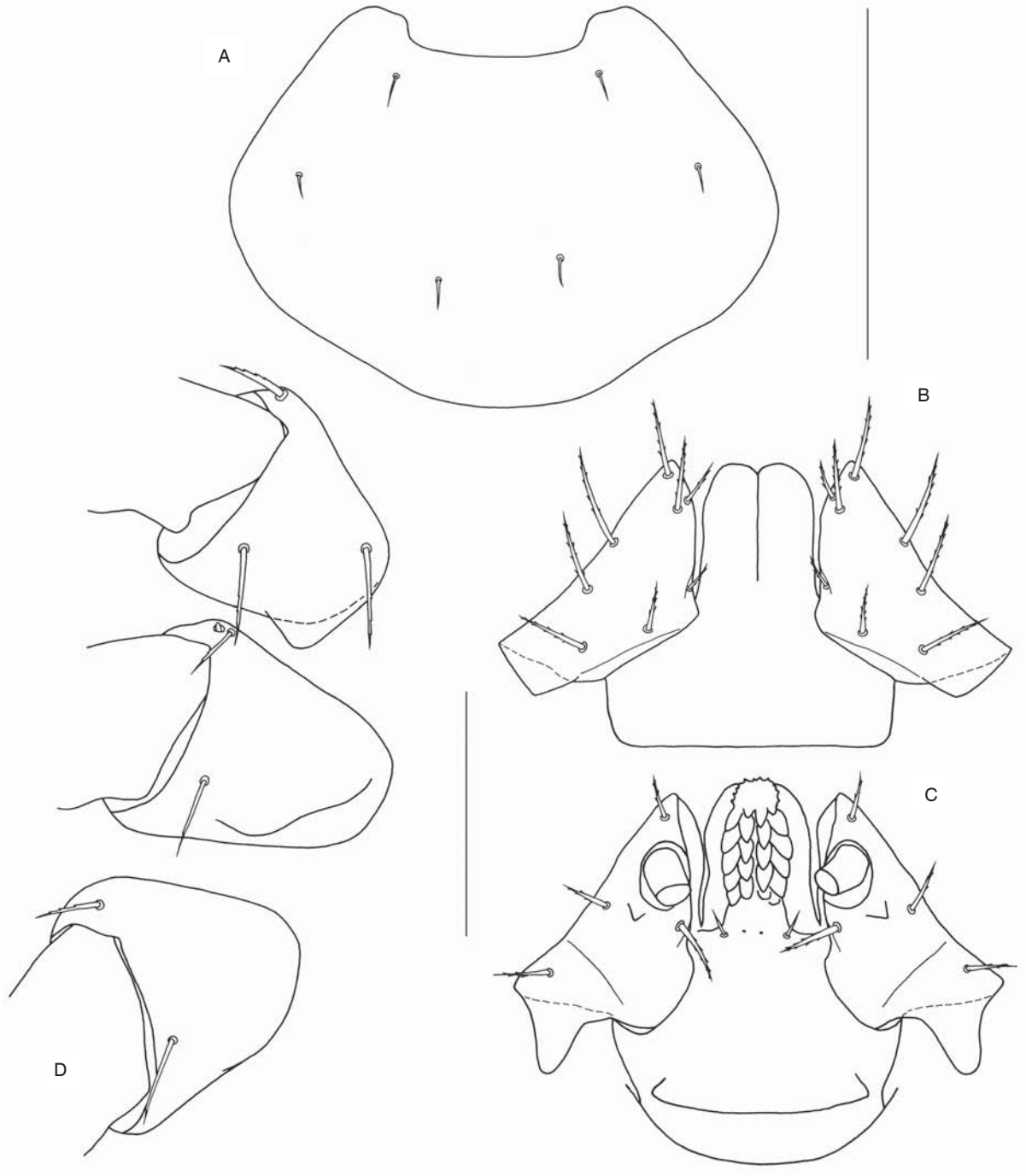

FIG. 13 *Haemaphysalis leachi*, larva, A, scutum. Bar = 200 µm; B, gnathosoma dorsally. Bar = 100 µm; C, gnathosoma ventrally. Bar = 100 µm; D, coxae. Bar = 100 µm. Setation of palpal segment IV is omitted

tinct, triangular, pointed apex. *Hypostome* (Fig. 13C): length 52–62 (57 ± 2.36), breadth 22–28 (25 ± 1.53, *n* = 120), ratio 1.92–2.74 (2.28 ± 0.19, *n* = 119); longer than palps; dental formula 2/2; denticles in files of 4 to 6 (usually 5).

Coxae (Fig. 13D): coxae I spur moderate, triangular; coxae II and III spur short, fold-like. *Genu*: length 103–120 (114 ± 3.51, *n* = 119), breadth 48–60 (54 ± 2.27, *n* = 110), ratio 1.88–2.38 (2.11 ± 0.11, *n* = 110).

The differential diagnosis of the two species is summarized in Table 4.

TABLE 1 *Haemaphysalis* (*Rhipistoma*) *elliptica* (Koch, 1844), material examined

No. of ticks		Host	Locality	Date of collection	Collector	Collection no.*
♂	♀					
Democratic Republic of Congo						
13	10	Domestic dog	Monigi	05 Aug 1949	F. Schoenaers	027837
Kenya						
1		*Lepus capensis*	Nairobi	09 Jan 1968	J.E.C. Flux	095065
	2	Domestic dog	Nairobi airport	22 Sep 1954	C.B. Philip	032318
1	2	Domestic dog	Nairobi-Kilimani area	22 Sep 1953	C.B. Philip	032319
1	1	Domestic dog	Rift Valley, Nakuru dist., Subukiya	26 Jun 1948	H. Hoogstraal	123754
28	12	*Civettictis civetta*	Rift Valley, Narok, Langata	Mar 1964	R. Harmsen	095064
3		*Civettictis civetta*	Sultan Hamud	26 Sep 1953	C.B. Philip, Barnett	032320
1				1976	A.E. Bianco	123755
1	2			1976	A.E. Bianco	123756
South Africa						
10	12	Domestic cat	Grahamstown	23 Jul 1936	F. Zumpt	123748
4+	2+	*Otomys irroratus* (nest of)	Johannesburg	Aug 1957		123759
2		*Canis mesomelas*	Johannesburg (imported into USA: Missouri, Jackson County, Kansas City, Kansas City Zoo)	1995	E.C. Greiner	121742
	1		Kruger National Park, Krugertabletkop	03 Mar 1989	J.E. Keirans	119549
2		*Canis mesomelas*	Kruger National Park, Skukuza	20 Feb 1969		123749
	7	Domestic dog	North Transvaal, Naboomspruit			123750
	1		Transvaal, Bon Accord			120362
1			Transvaal, Bon Accord, Onderstepoort	Nov 1951	R.A. Cooley	120364
	1		Transvaal, Bon Accord, Onderstepoort	Nov 1951	R.A. Cooley	120368
2	1	*Canis mesomelas*	Transvaal, Potchefstroom	14 Apr 1952		123751
	4	*Tatera* nest	Transvaal, Randfontein	06 Oct 1965		123752
2	1					123747
Tanzania						
4		Civettictis civetta	Coast, Dar es Salaam, University campus	15 Sep 1974	K.M. Howell	106728
3	4	*Panthera leo*	Mara, Serengeti National Park	16 Oct 1966	G.R. Schaller	094949
1		*Canis mesomelas*	Mara, Serengeti Plains, Seronera	25 Sep 1974	D. Schmidt	095204
1	1	*Canis mesomelas*	Mara, Serengeti Plains, Seronera	22 Nov 1974	D. Schmidt	094955
	1	*Panthera leo*	Serengeti National Park	21 Aug 1985	L. Herbst	118227
	1	*Panthera leo*	Serengeti National Park	21 Aug 1985	L. Herbst	118254

TABLE 1 (*cont.*)

No. of ticks		Host	Locality	Date of collection	Collector	Collection no.*
♂	♀					
Tanzania (*cont.*)						
	2	*Panthera leo*	Serengeti National Park	21 Aug 1985	L. Herbst	118206
1		*Panthera leo*	Serengeti National Park	02 Oct 1985	L. Herbst	118219
1	4	*Panthera leo*	Serengeti National Park	21 Aug 1985	L. Herbst	118251
	1	*Panthera leo*	Serengeti National Park	11 Sep 1985	L. Herbst	118235
2	3	*Panthera leo*	Serengeti National Park	26 Sep 1985	L. Herbst	118237
	1	*Panthera leo*	Serengeti National Park	25 Aug 1985	L. Herbst	118226
4	2	*Panthera leo*	Serengeti National Park, along Seronera River	03 Oct 1985	L. Herbst	118215
	2	*Panthera leo*	Serengeti National Park, at Downey's Dam	26 Sep 1985	L. Herbst	118257
1	1	*Panthera leo*	Serengeti National Park, base of Nyamanga River	02 Aug 1985	L. Herbst	118248
	1	*Panthera leo*	Serengeti National Park, base of Nyamanga River	02 Aug 1985	L. Herbst	118246
	1	*Panthera leo*	Serengeti National Park, base of Nyamanga River	05 Sep 1985	L. Herbst	118225
3	6	*Panthera leo*	Serengeti National Park, base of Nyamanga River	05 Sep 1985	L. Herbst	118212
	3	*Panthera leo*	Serengeti National Park, Loliondo South Kopjes	02 Sep 1985	L. Herbst	118218
4	1	*Panthera leo*	Serengeti National Park, near Masai Marsh	31 Aug 1985	L. Herbst	118220
	1	*Panthera leo*	Serengeti National Park, near Masai Marsh	31 Aug 1985	L. Herbst	118229
3	1	*Panthera leo*	Serengeti National Park, Simba Kopjes	21 Sep 1985	L. Herbst	118240
	1	*Panthera leo*	Serengeti National Park, Simba Kopjes	21 Sep 1985	L. Herbst	118209
Uganda						
22	3	*Canis aureus*	Ruwenzori National Park		M.H. Woodford	088635
Zambia						
Many	Many	*Canis adustus*	Chipata, Susa Camp	08 Aug 1980	S.G.A. Weak	123753
1		*Civettictis civetta*	Lochinvar	Jul 1959		123757
4		*Civettictis civetta*	Lochinvar	Jul 1959	F. Zumpt	091302
1		*Panthera leo*	Southern, Namwala	19 Aug 1951	J.G. Matthysse	091294
Zimbabwe						
2	2	Domestic cat	Manicaland, Umtali, Maranke T.T.L.	1976	R.A.I. Norval	103030
5	4	Domestic dog	Mashonaland North, Mukwichi T.T.L., Kadunga Dip	19 Aug 1976	R.A.I. Norval	103028
2+	2+	*Canis familiaris*	Mashonaland South, Salisbury	1980	R.A.I. Norval	121602
21		*Civettictis civetta*	Mashonaland South, Salisbury, Atlantica Foundation Research Station	07 Jul 1977	R.A.I. Norval	107272
5		*Civettictis civetta*	Mashonaland South, Salisbury, Calgary Farm	16 May 1977	R.A.I. Norval	107096
1		*Civettictis civetta*	Mashonaland South, Salisbury, Calgary Farm	14 Feb 1977	R.A.I. Norval	121599

TABLE 1 (*cont.*)

No. of ticks		Host	Locality	Date of collection	Collector	Collection no.*
♂	♀					
Zimbabwe (*cont.*)						
3	2	*Felis silvestris* (= *lybica*)	Mashonaland South, Salisbury, Mazoe Vet. Farm	06 Sep 1976	R.A.I. Norval	103029
10	10	*Canis mesomelas*	Mashonaland South, Salisbury, Mt. Pleasant	10 Sep 1976	R.A.I. Norval	103026
30	14	*Canis adustus*	Mashonaland South, Salisbury, Wingate Club	23 Dec 1976	R.A.I. Norval	107097
1		*Atelerix albiventris*	Matabeleland, Bulawayo	04 Feb 1981	R.A.I. Norval	121600
5	3	*Felis silvestris* (= *lybica*)	Matabeleland, Bulawayo, Khami prison	05 May 1976	R.A.I. Norval	103032
3	6	Domestic dog	Matabeleland, Shashani, Tribal Trust Land (T.T.L.), Sinti Dip	14 Oct 1976	R.A.I. Norval	103027
16	2	*Civettictis civetta*	N Rhodesia, Chizarira Nat. Park, Manzituba Camp	03 Jun 1976	R.A.I. Norval	103033
2	1	*Panthera pardus*	NW Rhodesia, Matetsi, Safari Area, Dibangombe Siding	18 Jun 1976	R.A.I. Norval	103031
I.G. Horak collection (South Africa & Mozambique)						
23	18	Vegetation	Kruger National Park (KNP) 2510 S, 3144 E (Horak *et al.* 2006)	Jan to Dec 1999	I.G. Horak	Burnplots
31	28	Vegetation	KNP 2508 S, 3138 E (Horak *et al.* 2006)	Jan to Dec 1999	I.G. Horak	Burnplots
358	327	Vegetation	KNP 2510 S, 3144 E (Horak *et al.* 2006)	Jan to Dec 2000	I.G. Horak	Burnplots
287	316	Vegetation	KNP 2508 S, 3138 E (Horak *et al.* 2006)	Jan to Dec 2000	I.G. Horak	Burnplots
65	77	Vegetation	KNP 2510 S, 3144 E (Horak *et al.* 2006)	Jan to Dec 2001	I.G. Horak	Burnplots
116	95	Vegetation	KNP 2508 S, 3138 E (Horak *et al.* 2006)	Jan to Dec 2001	I.G. Horak	Burnplots
24	29	Vegetation	KNP 2510 S, 3144 E (Horak *et al.* 2006)	Jan to Mar 2002	I.G. Horak	Burnplots
43	45	Vegetation	KNP 2508 S, 3138 E (Horak *et al.* 2006)	Jan to Mar 2002	I.G. Horak	Burnplots
167	194	Vegetation	KNP 2516 S, 3204 E (Spickett *et al.*1992)	Aug 1988 to Mar 2002	I.G. Horak	Zone 17N
98	100	Vegetation	KNP 2458 S, 3136 E (Spickett *et al.* 1992)	Aug 1988 to Mar 2002	I.G. Horak	Zone 4
77	573	*Canis familiaris*	Maputaland, KwaZulu-Natal (Horak *et al.* 2001)	Feb 1999 to Apr 2000	I.G. Horak	
107	100	*Canis familiaris*	Maputo 2557 S, 3235 E and vicinity, Mozambique (Neves *et al.* 2004)		Various	
410	826	*Canis familiaris*	Individual owners, Stellenbosch 3355 S, 1850 E (Horak & Matthee 2003)	Sep 2000 to Dec 2001	Owners	WP Dogs
1 560	4 566	*Canis familiaris*	Vet. clinics and animal shelter, Stellenbosch 3355 S, 1850 E (Horak & Matthee 2003)	Oct 2000 to Dec 2002	Vet. assistants	WP Dogs
506	449	*Canis familiaris*	Animal shelter, Franschhoek 3350 S, 1907 E (Horak & Matthee 2003)	Dec 2001 to Dec 2002	Assistants	WP dogs
25	168	*Canis familiaris*	Eastern Eastern Cape Province (Nyangiwe *et al.* 2006)	Jan 2004 to May 2005	N. Nyangiwe	
1 184	843	*Canis familiaris*	Vet. Faculty Clinic, Onderstepoort (Horak 1995)	Jun 1991 to May 1994	Vet. students	OP dogs

TABLE 1 (*cont.*)

No. of ticks ♂	No. of ticks ♀	Host	Locality	Date of collection	Collector	Collection no.*
I.G. Horak collection (South Africa & Mozambique) (*cont.*)						
2 426	3 720	*Canis familiaris*	Grahamstown 3319 S, 2632 E (Horak *et al.* 1987)	Aug 1983 to Jul 1986	Owners	
87	269	*Canis familiaris*	Boschkop, North West Province	Oct 1999 to May 2000	Z. v.d. Merwe	
6	9	*Canis familiaris*	Luala, 1744 S, 3615 E, Zambezia Prov. Mozambique (Neves *et al.* 2004)		G. Bester	
2	2	*Canis familiaris*	Xai-Xai, 2506 S, 3334 E Gaza Prov. Mozambique (Neves *et al.* 2004)		G. Bester	
70	65	Domestic cats	Vet. clinic Stellenbosch 3355 S, 1850 E (Horak & Matthee 2003)	Oct 2000 to Dec 2002	Assistant	Cats
604	663	Domestic cat	Pretoria	Sep 2003 to May 2006	N. Donkin	Cats
3	1	*Canis mesomelas* (1)	KNP (Horak *et al.* 2000)		I.G. Horak	
4	5	*Canis mesomelas* (1)	Vekeerdevlei, Free State (Horak *et al.* 2000)			
159	34	*Acinonyx jubatus* (3)	KNP (Horak *et al.* 2000)		I.G. Horak	
2 198	831	*Panthera leo* (19)	KNP (Horak *et al.* 2000)		I.G. Horak	
63	26	*Panthera pardus* (3)	KNP (Horak *et al.* 2000)		I.G. Horak	
1	6	*Panthera pardus* (1)	Roodeplaat Dam, Gauteng (Horak *et al.* 2000)			
85	23	*Civettictis civetta* (4)	KNP (Horak *et al.* 2000)		I.G. Horak	
8	7	*Parahyaena brunnea* (1)	Bon Accord, Gauteng (Horak *et al.* 2000)		I.G. Horak	

* All the collection numbers are those of specimens in the United States National Tick Collection
\+ Reared specimens

TABLE 2 *Haemaphysalis* (*Rhipistoma*) *leachi* (Audouin, 1826), material examined

No. of ticks		Host	Locality	Date of collection	Collector	Collection no.*
♂	♀					
Cameroon						
1		Domestic dog		26 Dec 1949		094716
Central African Republic						
4	4	*Panthera leo*	Bamingui Bangoran, Bamingui, Gazao		J. Thal	096988
2	3	Domestic dog	La Topia	12 Aug 1969	G. Uilenberg	096991
3	18	Domestic dog	Nana Nambere, Bouar	23 Jul 1969	M. Giret	096982
6	16	Domestic dog	Nana Nambere, Bouar	24 Jul 1969	M. Giret	096977
22	31	Domestic dog	Nana Nambere, Bouar	Late Aug 1969	M. Giret	096990
12	46	Domestic dog	Nana Nambere, Bouar	Aug 1969	M. Giret	096996
16	51	Domestic dog	Nana Nambere, Bouar	Aug 1969	M. Giret	096987
1	2	Domestic cat	Nana Nambere, Bouar	27 Jul 1969	M. Giret	096995
3	2	Domestic cat	Nana Nambere, Bouar	Aug 1969	M. Giret	096985
2	4	Domestic cat	Nana Nambere, Bouar	07 Jan 1970	R. Lacotte	096984
8	4	Domestic cat	Nana Nambere, Bouar	11 Jan 1970	R. Lacotte	096986
1	5	Domestic cat	Nana Nambere, Bouar	18 Jan 1970	G. Uilenberg	096993
13	5	*Civettictis civetta*		14 Apr 1971	J. Thal	097149
28	7	*Panthera leo*		26 Feb 1971	J. Thal	097150
Democratic Republic of Congo						
1	1	*Panthera leo*	Bodio	15 Dec 1950		086264
6	1	*Genetta maculata*	Garamba Park	16 Sep 1951	H. de Saeger	036711
2		*Panthera pardus*	Kasai, Luluaburg	1925	C. Waert	046717
1			Katanga (N), Muhilo	1966	J. Bafort	123771
1	3	*Crocuta crocuta*		12 Apr 1951	P. Schoemaker	037461
19	2	*Leptailurus serval*		17 Aug 1951	J.V.	037454
8	3	*Leptailurus serval*		29 Sep 1951	H. de Saeger	037452
Egypt						
1		*Felis chaus*	Alexandria, Amiriya road	29 Jan 1965	I. Helmy, D. Osborn	078789
5		*Felis chaus*	Alexandria, 14 km SW of Alexandria	09 Nov 1965	I. Helmy, D. Osborn	078791
35	6	*Vulpes vulpes*	Beni Suef, Beni Suef, Al Hakamnah	20 Jan 1982	Local hunter	123769
2	3	*Arvicanthis niloticus* nest	Daqahliya, Aga, Minshat El Ikhwa	12 Nov 1953	H. Hoogstraal	078732
4		*Vulpes vulpes*	Daqahliya, Village of Tanboul (5 miles W of Simbillawein)	24 Feb 1947		025480

TABLE 2 (*cont.*)

No. of ticks		Host	Locality	Date of collection	Collector	Collection no.*
♂	♀					
Egypt (*cont.*)						
	1	*Felis silvestris* (= *lybica*)	El Wadi El Gedeed, Dakhla Oasis, Mut	26 Apr 1974	I. Helmy, S. Tawfik	094366
1	9	*Canis aureus*	Faiyum, Faiyum	15 Aug 1956	H. Hoogstraal	078760
1		*Canis aureus*	Faiyum, Faiyum (near)	02 Feb 1955	H. Hoogstraal	078756
4		*Vulpes vulpes*	Faiyum, Ibshawai, Abu Dinqash	09 Feb 1983	Local hunter	123768
12	3	*Vulpes vulpes*	Faiyum, Ibshawai, El Nazla	09 Feb 1983	Local hunter	123773
24		*Canis aureus*	Faiyum, Ibshawai, Qasr El Gibali	09 Feb 1983	Local hunter	121756
1		*Vulpes vulpes*	Faiyum, Kom Oshim	06 Feb 1948	H. Hoogstraal	078759
1		*Felis chaus*	Faiyum, Kom Oshim (1 mile North of)	28 Dec 1953	H. Hoogstraal	078761
1	1	*Felis chaus*	Faiyum, Tamiya, Fanus	12 Apr 1954	H. Hoogstraal	078763
5		*Felis chaus*	Faiyum, Tamiya, Fanus	12 Apr 1954	H. Hoogstraal	078764
5	4	*Felis chaus*	Faiyum, Tamiya, Fanus	12 Apr 1954	H. Hoogstraal	034583
1			Giza, Aiyat, Kafr Ammar		H. Hoogstraal	078755
2	2	*Arvicanthis niloticus* nest	Giza, Imbaba, Beni Magdul	14 Jun 1953	H. Hoogstraal	078737
6		Felis chaus	Giza, Imbaba, El Baragil	04 Nov 1958	H. Hoogstraal	078784
1	2	*Vulpes vulpes*	Giza, Imbaba, Gizzaya	30 Apr 1954	H. Hoogstraal	078785
5	5	*Arvicanthis niloticus* nest	Giza, Imbaba, Kirdasa	14 Feb 1957	H. Hoogstraal	078730
3	3	*Arvicanthis niloticus* nest	Giza, Imbaba, Kirdasa	14 Jun 1953	H. Hoogstraal	078738
9+	11+	*Arvicanthis niloticus* nest	Giza, Imbaba, Kirdasa	28–29 Jun 1953	H. Hoogstraal	078736
1		*Arvicanthis niloticus* nest	Giza, Imbaba, Kirdasa	15 Jul 1953	H. Hoogstraal	078741
1+	2+	*Arvicanthis niloticus* nest	Giza, Imbaba, Kirdasa	14 Jun 1953	H. Hoogstraal	056757
1		*Arvicanthis niloticus* nest	Giza, Imbaba, Kirdasa	03 Jan 1955	H. Hoogstraal	078731
1		*Vulpes vulpes*	Giza, Imbaba, Tanash	14 Jan 1960	H. Hoogstraal	078765
	2	*Arvicanthis niloticus* burrow	Miniya, Maghagha, Maghagha	12 Mar 1952	H. Hoogstraal	078744
1		*Vulpes vulpes*	Miniya, Maghagha, Saft	01 Jan 1979	Local hunter	123772
1		*Canis aureus*	Miniya, Minya	11 Jan 1981	Local hunter	123767
13	7	*Felis chaus*	Qalyubiya, El Amar El Kubra	15 Jan 1954	H. Hoogstraal	078757
4	2	*Canis aureus*	Qalyubiya, Qalyubiya, Sanatir, Ezbet Ihsan	03 Feb 1966	I. Helmy, D. Osborn	078790
4		*Felis chaus*	Qena, Isna, Wadi Nassim	07 Apr 1953	H. Hoogstraal	078762
Ethiopia						
1		Vegetation	Gamo-Gofa, Arba Mineh	14 Jan 1966	H. Hoogstraal	092735
5	1	*Colobus polykomos*	Harer, Hirna valley, Dire Dawa College (80 km W of)	21 Sep 1962	B. Glass	092730
1		*Canis mesomelas*	Harer, Rd. between Dacata and Erer Rivers		B. Glass	092732

TABLE 2 (*cont.*)

No. of ticks		Host	Locality	Date of collection	Collector	Collection no.*
♂	♀					
Ethiopia (*cont.*)						
9	1	*Ichneumia albicauda*	Harer, Rd. between Dacata and Erer Rivers	04 Jul 1962	B. Glass	092731
1	2	Domestic cat	Ilubabor, Gambella		J.S. Ash	092741
1		Human	Ilubabor, Gambella	30 Jul 1972	J.S. Ash	092742
17	10	*Civettictis civetta*	Kefa, Mezan Tefari	10 Mar 1980	H.K. Lall	123760
7	3	*Vulpes* sp.	Kefa, Sokoru/Deke	Aug 1979	H.K. Lall	123770
19		*Hyaena hyaena*	Rock Valley		B. Glass	092733
1	3	Domestic dog	Shashamani	25 Jun 1961	L.W. Teller	092726
	1	Human	Shoa, Addis Ababa	11 Mar 1970	J.S. Ash	092743
1		"Black-tailed mongoose"	Shoa, Koka	25 Feb 1973	R. Traub, J.S. Ash	092747
22	11	*Leptailurus serval*	Shoa, Lake Langono Rd (10 miles N of)	28 Dec 1974	L. Sholdt	092746
Kenya						
16	2	*Civettictis civetta*	Central, Muranga, Mitubiri	08 Feb 1953	D.G. MacInnes	095066
Liberia						
1	1	Domestic dog	Bolahim	1930	T. Kolbe	046716
8	5	Domestic cat	Harbel		R. Fox	087923
Mali						
64	5	*Civettictis civetta*	Kayes, Nioro du Sahel, Lorak Banc	12 Feb 1956		084578
14	2	*Leptailurus serval*	Kayes, Nioro du Sahel, Lorak Banc	06 Feb 1956		089579
3		*Panthera pardus*	Sikasso, Sikasso	20 Aug 1954		089576
Senegal						
1		*Leptailurus serval*	Casamance, Bignona	21 Oct 1945	From P.C. Morel	088278
1		Vegetation	Sangalkam	05 Apr 1945	L. Kartman	021793
3		*Felis silvestris* (= *lybica*)	Senegal Oriental, Niokolo Koba, Badi	Mar 1957	From P.C. Morel	088277
7		*Civettictis civetta*	Senegal Oriental, Niokolo Koba	Feb 1956	From P.C. Morel	088276
9	39	*Leptailurus serval*	Thies, Mbour, Sandiara	18 May 1956	From P.C. Morel	088279
Sudan						
1		*Hyaena hyaena*	Bahr El Ghazal, Tirol	21 Jan 1955	E.T.M. Reid	093012
1	3	Domestic cat	Bahr El Ghazal, Wau	Oct 1953	S.V.S.	093025
2	1	*Arvicanthis* sp. burrow	Equatoria, Juba, Juba	10 Dec 1952		093013
8		*Civettictis civetta*	Equatoria, Torit, Obbo	09 Apr 1950	H. Hoogstraal	093031

TABLE 2 (*cont.*)

No. of ticks ♂	No. of ticks ♀	Host	Locality	Date of collection	Collector	Collection no.*
Sudan (*cont.*)						
13	5	*Canis aureus*	Equatoria, Torit, Torit	25 Nov 1949	H. Hoogstraal	094959
14		*Canis aureus*	Equatoria, Torit, Torit	06 Dec 1949		093014
22	2	*Canis aureus*	Equatoria, Torit, Torit	02 Dec 1949		093016
1		*Canis aureus*	Equatoria, Torit, Torit	06 Dec 1949	H. Hoogstraal	093015
1	1	*Civettictis civetta*	Equatoria, Torit, Torit	08 Feb 1951	H. Hoogstraal	093023
1	4	Domestic dog	Equatoria, Torit, Torit	04 Jan 1952		093024
1		*Mungos mungo*	Equatoria, Torit, Torit	13 Apr 1950		093011
6		*Panthera leo*	Equatoria, Torit, Torit	15 Mar 1952	J. Owen	093028
14	3	*Canis mesomelas*	Equatoria, Ubo	08 May 1948		093018
1		*Canis adustus*	Upper Nile, Malakal (near)	14 Mar 1964	H. Hoogstraal, S. Gaber	094960
2		*Canis adustus*	Upper Nile, Malakal, Malakal (7 miles N of)	01 Feb 1962	H. Hoogstraal, S. Gaber	094961
	8	*Panthera leo*	Upper Nile, 40 mi S of Malakal, Abwong	27 Feb 1961	H. Hoogstraal	092978
1		*Canis adustus*	Upper Nile, Paloich, Gelhak Forest	23 May 1962	H. Hoogstraal, S. Gaber	092881
1		*Felis silvestris* (=*lybica*)	Upper Nile, Paloich, Paloich (5 miles N of)	27 Feb 1962	H. Hoogstraal, S. Gaber	094962
2		*Felis silvestris*	Upper Nile, Paloich, Tir (near)	23 Feb 1961	H. Hoogstraal, S. Gaber	092973
2	1	*Leptailurus serval*	Upper Nile, Paloich, Tir (near)	07 Feb 1961	H. Hoogstraal, S. Gaber	094958
Tanzania						
1		*Canis mesomelas*	Mara, Serengeti Plains, Seronera	25 Sep 1974	D. Schmidt	095204
1		*Connochaetes taurinus*	Yeida, Swamps	04 Oct 1938	L.R. Paddock	115774
Uganda						
11	1	*Panthera leo*	Ankole, Nyabushozi	22 Oct 1965	J. Matthysse	123763
1	2	*Panthera leo*	Ankole, Nyabushozi	09 Oct 1965	J. Matthysse	120367
7	6	*Panthera pardus*	Ankole, Mbarara	09 Aug 1965	J. Matthysse	123762
2		*Panthera leo*	Ankole, Mbarara (35 miles SW of)	14 Apr 1962	Major Price	089542
	2	Domestic dog	Baganda, Entebbe	27 Apr 1966	J. Matthysse	053826
7	1	Domestic dog	Karamoja, Kampala	05 Feb 1940	G.H.E. Hopkins	120365
3		*Panthera pardus*	Karamoja, Moroto, Labwor	16 Aug 1965	J. Matthysse	123764

TABLE 2 (*cont.*)

No. of ticks		Host	Locality	Date of collection	Collector	Collection no.*
♂	♀					
Uganda (*cont.*)						
2			Kigezi, Nakabande	25 Oct 1940		120366
1	1	Domestic dog	Pacota, Aswa, Acholi	21 Jun 1966	J. Matthysse	053835
10	2	*Panthera leo*	Ruwenzori National Park	31 Jul 1969	M.H. Woodford	088634
3		*Panthera leo*	Ruwenzori National Park, Mweya	19 Jun 1974	M.H. Woodford	120363
21		*Civettictis civetta*	W. Mengo, Entebbe	Apr 1979	M.N. Kaiser	123761
Zambia						
10	17	*Panthera leo*	Southern, Namwala	19 Aug 1951	J.G. Matthysse	091294
1	10	Domestic dog	Barotseland, Kalabo (E of)	Apr 1965	R.G. Japp	091297
1	1	*Felis silvestris* (= *lybicus*)	Barotseland, Kalabo (E of)	30 Dec 1964	R.G. Japp	091296
1		*Mastomys natalensis*	Mt. Makulu	16 Jun 1970	M.H. Colbo	091300
6		*Civettictis civetta*	Eastern, Lundazi, Chibembe Pontoon (10 mi N of)	07 Aug 1962	G. Corbet, J. Ingles	091304
15	1	*Civettictis civetta*	Lochinvar	Jul 1959		123765
1		*Potamochoerus porcus*	Susa Camp, Chipata, Eastern	24 Jul 1980	S.G.A. Weak	123766
Zimbabwe						
16		*Civettictis civetta*	Mashonaland South, Salisbury, Atlantica Foundation Research Station	07 Jul 1977	R.A.I. Norval	107272
13		*Civettictis civetta*	Mashonaland South, Salisbury, Calgary Farm	16 May 1977	R.A.I. Norval	107096
3		*Civettictis civetta*	Mashonaland South, Salisbury, Calgary Farm	14 Feb 1977	R.A.I. Norval	121599
6		*Leptailurus serval*	Mashonaland South, Salisbury, Calgary Farm	09 Feb 1977	R.A.I. Norval	121603
7		*Felis silvestris* (= *libyca*)	Mashonaland South, Salisbury, Mazoe Veterinary Farm	06 Sep 1976	R.A.I. Norval	103047
8	9	*Leptailurus serval*	Mashonaland South, Sinoia	25 May 1977	R.A.I. Norval	121595

* All the collection numbers are those of specimens in the United States National Tick Collection
\+ Reared specimens from engorged nymphs found in *Arvicanthis niloticus* nests

TABLE 3 *Haemaphysalis* (*Rhipistoma*) *elliptica* and *Haemaphysalis* (*Rhipistoma*) *leachi*, immature stages examined

No. of ticks		Host	Locality	Date of collection	Collector	Collection no.*
N	L					
Haemaphysalis* (*Rhipistoma*) *elliptica						
16+	30+		South Africa			IGH
16+	30+	Domestic dog	South Africa, Pretoria	13 Jul 2005	K. Junker	IGH
	30+	*Acinonyx jubatus*	South Africa, Hoedspruit	21 Feb 2006	I. Hubmer	IGH
Haemaphysalis* (*Rhipistoma*) *leachi						
8+		Domestic dog	Central African Republic, Nana Nambere, Bouar	10 Oct 1969 to 14 Jan 1970	R. Lacotte	096992
	30+	Domestic dog	Central African Republic, Nana Nambere, Bouar	16 Oct to 10 Dec 1969	R. Lacotte	096979
	30+	Domestic dog	Central African Republic, Nana Nambere, Bouar	02 Aug to 03 Sep 1969	M. Giret	096980
	30+	Domestic dog	Egypt, El Wadi El Gedeed, Dakhla Oasis, El Hindaw	20 Nov 1972	I. Helmy	078801
2+		*Arvicanthis niloticus* nest	Egypt, Giza, Imbaba, Ausim	Sep 1953	H. Hoogstraal	078734
	30+	*Vulpes vulpes*	Egypt, Giza, Imbaba, Saft El Laban	06 Mar 1958	H. Hoogstraal	078749

* All the collection numbers are those of specimens in the United States National Tick Collection

\+ Reared specimens

TABLE 4 Differential diagnosis between *Haemaphysalis* (*Rhipistoma*) *elliptica* and *Haemaphysalis* (*Rhipistoma*) *leachi*

Haemaphysalis* (*R.*) *elliptica	***Haemaphysalis* (*R.*) *leachi***
Male (Fig. 2, 3, 8 and 9)	
1. Longer and broader tick: – Length (from palpal apices to posterior margin of conscutum) avg. 3.00 mm – Width (of conscutum) avg. 1.47 mm – Ratio length to width avg. 2.05	1. Shorter and more slender tick: – Length (from palpal apices to posterior margin of conscutum) avg. 2.45 mm – Width (of conscutum) avg. 1.06 mm – Ratio length to width avg. 2.30
2. One or two of first festoons enclosed by marginal groove	2. Two or three of first festoons enclosed by marginal groove
3. Dorsally median margin of palpal segment II gradually widening anteriorly from the segment's mid-length	3. Dorsally median margin of palpal segment II abruptly widening anteriorly from the segment's mid-length
4. Lateral margin of ventral spur on palpal segment II straight	4. Lateral margin of ventral spur on palpal segment II concave
Female (Fig. 4, 5, 10 and 11)	
1. Longer and broader tick: – Length (from palpal apices to posterior margin of scutum) avg. 1.73 mm – Width (of scutum) avg. 1.02 mm – Ratio length to width avg. 1.70	1. Shorter and more slender tick: – Length (from palpal apices to posterior margin of scutum) avg. 1.53 mm – Width (of scutum) avg. 0.84 mm – Ratio length to width avg. 1.81
2. Dorsal cornua shorter, approximately 1/6 length of basis capituli	2. Dorsal cornua longer, approximately 1/4 length of basis capituli
3. Dorsally median margin of palpal segment II gradually widening anteriorly at segment's mid-length	3. Dorsally median margin of palpal segment II abruptly widening anteriorly at segment's mid-length
Nymph (Fig. 6 and 12)	
1. Larger (see description)	1. Smaller (see description)
2. Dorsally median margin of palpal segment II widening gradually anteriorly	2. Dorsally median margin of palpal segment II widening sharply anteriorly
3. Ventral spur of palpal segment II broad	3. Ventral spur of palpal segment II narrow
4. Denticles of hypostome in files of 7 to 9 (usually 8)	4. Denticles of hypostome in files of 5 or 6
Larva (Fig. 7 and 13)	
1. Larger (see description)	1. Smaller (see description)
2. Ventral spur of palpal segment II broad	2. Ventral spur of palpal segment II narrow
3. Ventral spur of palpal segment III indistinct, fold-like	3. Ventral spur of palpal segment III distinct, triangular
4. Denticles in files of 7 or 8	4. Denticles in files of 4 to 6 (usually 5)

REMARKS ON IDENTIFICATION

Our study has shown that *H.* (*R.*) *elliptica* is an independent species belonging to the *H.* (*R.*) *leachi* subgroup and that it is clearly distinguishable from *H.* (*R.*) *leachi*. However, the value of diagnostic characters varies from stage to stage.

The easiest stage to distinguish is the larval. All the larval characters that we have chosen clearly differentiate the larvae of *H.* (*R.*) *elliptica* from those of *H.* (*R.*) *leachi*. Males of *H.* (*R.*) *elliptica* are also quite easily distinguishable from those of *H.* (*R.*) *leachi*. The main differentiating characters are the shape of the lateral margin of the ventral spur on palpal segment II and total size of the ticks. The most obvious character for nymphs is the number of denticles per file on the hypostome, and total size. Females are the most difficult to distinguish. The main characters are total size and the size of the dorsal cornua, and because both characters have a metric value, difficult specimens do not have to be excluded during routine examinations. The females of most closely related species within the *H.* (*R.*) *leachi* group are difficult to distinguish interspecifically. However, because of the morphological stability of *Haemaphysalis* species, the size of various structures is of consid-

erable value for discriminating between all the parasitic stages of closely related species.

Finally, unpublished molecular data confirm our opinion on the species independency of *H.* (*R.*) *elliptica*.

DISTRIBUTION AND HOSTS

Haemaphysalis (*R.*) *elliptica* is present in East and southern Africa, and DAA and IGH have recorded it in the *Democratic Republic of Congo*, *Kenya*, *Mozambique*, *South Africa*, *Tanzania*, *Uganda*, *Zambia* and *Zimbabwe* (Table 1). JLC adds *Ethiopia*, *Malawi* and *Rwanda* to this list.

Haemaphysalis (*R.*) *leachi* has chiefly been recorded from North (Egypt) and East Africa south to the north of Zimbabwe. Judging by collection data this species is probably quite common in Central Africa. A few collections have been made in West Africa. DAA and IGH record this species from *Cameroon*, *Central African Republic*, *Democratic Republic of Congo*, *Egypt*, *Ethiopia*, *Kenya*, *Liberia*, *Mali*, *Senegal*, *Sudan*, *Tanzania*, *Uganda*, *Zambia* and *Zimbabwe* (Table 2). JLC adds *Burundi*, *Chad* and *Guinea* to this list. Both species share a large area of sympatry in East Africa.

The hosts of adult *H.* (*R.*) *elliptica* are various carnivore species, amongst which are the domestic dog, domestic cat, lion, *Panthera leo*, and leopard, *Panthera pardus* (Table 1). The hosts of the immature stages are diverse rodent species, and they may very occasionally be present on the same hosts as the adults. The hosts of adult *H.* (*R.*) *leachi* are similar to those of *H.* (*R.*) *elliptica*, namely domestic and wild carnivores (Table 2). The immature stages use various rodents and other small mammals as hosts. It will, however, only be possible to determine the actual host range of the immature stages of *H.* (*R.*) *elliptica* and *H.* (*R.*) *leachi* once a taxonomic revision of the whole *H.* (*R.*) *leachi* group has been completed.

The adults of both species have been found in a number of collections taken from a single host. Both geographic and host sympatry indirectly confirm the specific independency of *H.* (*R.*) *elliptica* and *H.* (*R.*) *leachi*.

DISEASE RELATIONSHIPS

Haemaphysalis (*R.*) *elliptica* (then referred to as *H. leachi*) is the vector of *Babesia canis rossi*, the cause of virulent babesiosis in domestic dogs in South Africa (Lewis, Penzhorn, Lopez-Rebollar & De Waal 1996). We are, however, unable to find any records of *H.* (*R.*) *leachi* transmitting *Babesia canis* in Egypt. In South Africa, *H.* (*R.*) *elliptica* (as *H. leachi*) has been recorded as transmitting *Rickettsia conori*, resulting in tick bite fever in humans (Gear 1954). Possibly because of its preference for carnivores, adult *H.* (*R.*) *elliptica* (then recorded as *H. leachi*) is one of the tick species most frequently collected from humans working in the field (Horak, Fourie, Heyne, Walker & Needham 2002).

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CHAPTER 2

MORPHOMETRICS (Hosts)

It might appear rather incongruous to include a chapter on the morphometrics of host animals in a document such as this, but host size and habitat are important contributing factors to both the composition and magnitude of their tick burdens. During surveys in the Kruger National Park, in which five helmeted guineafowls, *Numida meleagris*, were examined for ticks at monthly intervals for a period of two years, and six scrub hares, *Lepus saxatilis*, were examined at monthly intervals for a period of four years, I took various measurements and recorded several weights for these two host species. B.L. Penzhorn processed these data, and this led to publications on the morphometrics of helmeted guineafowls and scrub hares (Penzhorn, Horak, Spickett & Braack 1991, 1993), both of which are important hosts of the immature stages of various ixodid tick species. The role that size and habitat of host animals play in determining the magnitude of tick burdens is emphasized by Gallivan & Horak (1997). In the latter publication we demonstrate that larger animal species are more important hosts for adult ticks than smaller species, while the intensity of infestation with nymphs and larvae is proportional to the surface area of the host.

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Morphometrics of helmeted guineafowls from the Kruger National Park

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Linear measurements and masses of various body parts were recorded for veld-collected and refuse dump-frequenting helmeted guineafowls *Numida meleagris*. Body length, foot length, toe span and casque height were significantly greater in males than in females. Dressed carcass mass and mass of perirectal fat of dump-frequenting males and females, respectively, significantly exceeded those of veld-collected birds, whereas the mass of the gastrointestinal tract plus ingesta of veld-collected birds was significantly greater than that of dump-frequenting birds and varied seasonally; this seemed to be inversely related to rainfall.

Lengteafmetings en massa van verskeie liggaamsdele van gewone tarentale *Numida meleagris* wat òf veldlewend was òf by 'n vullishoop geboer het, is aangeteken. Liggaamslengte, voetlengte, toonspanning en helmlengte van mannetjies was groter as dié van wyfies. Die massa van die geslagte karkas en die perirektale vet van onderskeidelik mannetjies en wyfies wat by die vullishoop geboer het, was betekenisvol hoër as dié van veldversamelde voëls, terwyl die massa van veldversamelde voëls se maagdermkanaal plus ingesta betekenisvol hoër was as dié van die voëls by die vullishoop en ook seisoenaal gevarieer het. Dit het voorgekom of daar 'n omgekeerde verwantskap met reënval was.

Keywords: Morphometrics, helmeted guineafowl, *Numida meleagris*, wildlife use, gamebird

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Introduction

Helmted guineafowls *Numida meleagris* are important gamebirds in southern Africa. The literature concerning morphological characteristics of non-domesticated southern African guineafowls *N. m. coronata* Gurney includes: a major study of growth, plumage development and moult with data on body mass, as well as length of culmen, tarsus and casque (Siegfried 1966); a study of taxonomy, phylogeny, speciation and biogeography in which 18 qualitative and 44 quantitative external characters of museum specimens were taken into account (Crowe 1978a); and body mass of birds shot in the eastern and northern Cape Province (Crowe 1978b; Skead 1962).

Data presented here were collected during an investigation into the seasonal occurrence of parasites of helmeted guineafowls in the Kruger National Park (KNP). The study was partially occasioned to attempt to define what role, if any, helmeted guineafowls play in the epidemiology of heartwater, an important disease of domestic ruminants in Africa, caused by *Cowdria ruminantium*. Not only are helmeted guineafowls naturally infested with immature stages of three *Amblyomma* species which are known vectors of heartwater (Petney, Horak & Rechav 1987; Walker & Olwage 1987), but the guineafowls themselves can become infected with the causative organism (Oberem & Bezuidenhout 1987).

This survey was carried out in the southern portion of the KNP. Small flocks of helmeted guineafowls are scattered throughout the region, with several hundred birds concentrated around the Skukuza rest camp, where they frequent the refuse dump. This enabled us to compare carcass mass of veld-collected birds living on a natural diet, with that of birds scavenging on the refuse dump.

Crowe (1979) demonstrated that size of exposed structures on the head of guineafowls, such as the casque, tended to have lower values in hotter and/or drier localities. This may be a possible adaptation to limit uptake of heat via radiation, or limit the loss of body water through cutaneous evaporation. Our collection localities were towards the limit of distribution of *N. m. coronata*, which is replaced eastward and northward by *N. m. mitrata* Pallas. Comparisons of casque height would indicate whether birds from the southern KNP fell within ranges given for *N. m. coronata* (Crowe 1978a), or were intergrading with *N. m. mitrata*.

Materials and Methods

Each month, from August 1988 to August 1990, two helmeted guineafowls were shot on or near the refuse dump at Skukuza (24°59'S / 31°35'E) in the KNP, and three were shot at other sites, away from the dump, in the southern part of the Park. It was not always possible to obtain guineafowls at the latter sites and none were shot during January and February 1990 and only two during May 1990. We attempted to shoot only adult birds; the seven subadult birds *ca.* 7–10 months old which were shot are not included in the sample, which comprised 111 adult birds.

The body mass of each newly shot bird was determined and the following measurements were taken:

Body length (from tip of beak to tip of pygostyle).
Girth (immediately caudal to the wings).
Wing span (distance between tips of second phalanges with wings extended — length of feathers excluded).
Foot (from proximal end of ossified tibial cartilage to distal end of tarsometatarsus).
Toe span (from distal end of first phalanx to distal end of third phalanx, excluding claws).
Beak (exposed part of culmen from cere to tip along the dorsal curvature).
Casque frontal length (from dorsal surface of cranium to apex, along rostral curvature).

The carcass was then dressed as follows:

The head and neck were removed (the incision was made immediately caudal to the junction of the bare and feathered parts of the neck).
The pygostyle was removed.
The carcass was skinned, with the feet and tips of the wings left attached to the skin; the incisions were made immediately proximal to the distal condyles of the tibiotarsus and humerus respectively.
The carcass was eviscerated; the lungs were removed, but the kidneys were left *in situ;* the perirectal fat was removed.

The following mass determinations were made:

Dressed carcass
Gastrointestinal tract (including ingesta)
Perirectal fat
Heart, liver, spleen and pancreas
Reproductive organs

Unless stated otherwise, a t test (two-tailed) was used to compare the samples. Where excessive kurtosis occurred, a Mann-Whitney U test was performed. If a high incidence of zero values occurred, the data set was transformed to $\log_{10}(x + 1)$.

Table 1 Linear measurements (in mm) of various body parts of helmeted guineafowls from the Kruger National Park ($\bar{x}$ = mean; SD = standard deviation; SE = standard error of the mean)

		Males	Females	Test statistic
Body length	$\bar{x}$	444,8	435,2	$t = 2{,}6074$*
	SD	17,3	19,5	$p < 0{,}05$
	SE	2,1	3,2	
Girth	$\bar{x}$	313,3	310,0	$t = 0{,}8225$
	SD	21,5	16,6	$p > 0{,}05$
	SE	2,6	2,7	
Wing span	$\bar{x}$	467,8	468,0	$t = 0{,}045$
	SD	23,6	23,0	$p > 0{,}05$
	SE	2,9	3,7	
Foot	$\bar{x}$	93,5	87,4	$t = 8{,}368$*
	SD	7,9	4,0	$p < 0{,}01$
	SE	1,0	0,7	
Toe span	$\bar{x}$	85,8	83,0	$t = 3{,}39$*
	SD	4,2	3,8	$p < 0{,}01$
	SE	0,5	0,6	
Beak	$\bar{x}$	26,3	25,9	$t = 0{,}998$
	SD	1,5	2,1	$p > 0{,}05$
	SE	0,2	0,3	
Casque frontal length	$\bar{x}$	57,7	52,3	$t = 3{,}0023$*
	SD	9,8	6,9	$p < 0{,}01$
	SE	1,2	1,1	

* Significant

Results

The linear measurements of various body parts of helmeted guineafowls are shown in Table 1. As there were no significant differences between the means of veld-collected and dump-frequenting males and females, respectively, the data of each gender were lumped and compared. Body length, foot length, toe span and casque frontal length were significantly greater in males than in females.

The masses of various body parts of male and female helmeted guineafowls, respectively, are shown in Table 2. The monthly mean mass of the gastrointestinal tract plus ingesta

Table 2 Mass (in grams) of various body parts of veld-collected and refuse dump-frequenting male and female helmeted guineafowls, respectively, from the Kruger National Park ($\bar{x}$ = mean; SD = standard deviation; SE = standard error of the mean)

		Veld	Dump	Test statistic
Males				
Body	$\bar{x}$	1508,2	1539,7	$t = 1{,}1229$
	SD	96,6	108,8	$p > 0{,}05$
	SE	16,3	19,5	
Dressed carcass	$\bar{x}$	854,3	891,7	$U^a = 360{,}5$*
	SD	65,7	80,0	$p < 0{,}01$
	SE	11,1	14,6	
Gastro-intestinal tract	$\bar{x}$	203,1	152,8	$t = 3{,}812$*
	SD	47,3	53,7	$p < 0{,}01$
	SE	8,0	9,3	
Perirectal fat	$\bar{x}$	1,1	6,4	$t^b = 4{,}792$*
	SD	1,9	5,6	$p < 0{,}05$
	SE	0,3	1,0	
Females				
Body	$\bar{x}$	1449,5	1561,9	$t = 2{,}5067$*
	SD	141,5	131,4	$p < 0{,}05$
	SE	29,5	32,8	
Dressed carcass	$\bar{x}$	811,5	896,4	$t = 3{,}0218$*
	SD	99,8	61,4	$p < 0{,}05$
	SE	20,8	15,4	
Gastro-intestinal tract	$\bar{x}$	212,0	156,1	$t = 3{,}1393$*
	SD	64,1	37,2	$p < 0{,}01$
	SE	13,4	9,3	
Perirectal fat	$\bar{x}$	2,2	13,8	$t^b = 3{,}986$*
	SD	4,1	12,1	$p < 0{,}05$
	SE	0,9	3,0	

[a] Mann-Whitney test

[b] Transformed $\log_{10}(x + 1)$

* Significant.

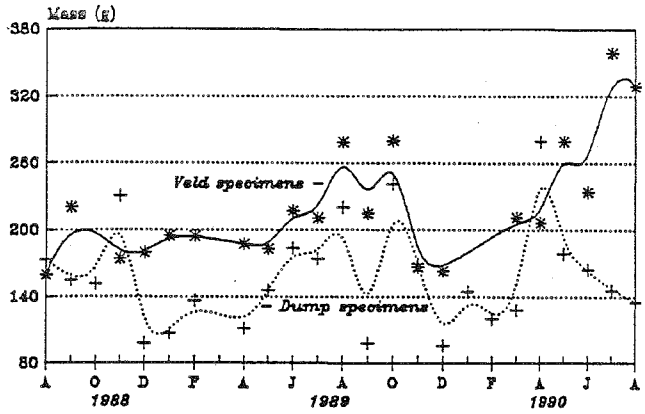

Figure 1 The monthly mean mass of the gastrointestinal tract plus ingesta of veld-collected and refuse dump-frequenting helmeted guineafowls from the Kruger National Park.

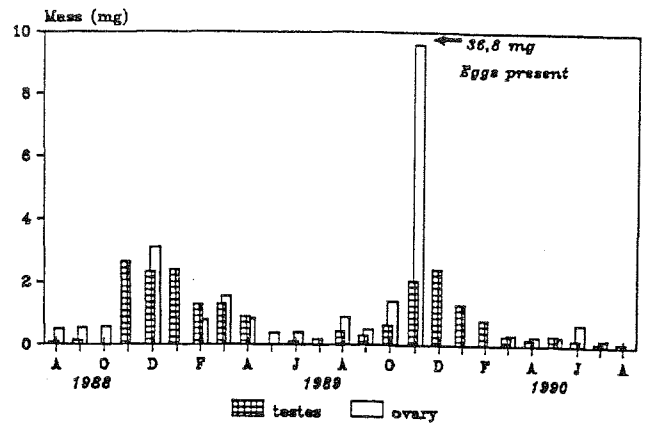

Figure 2 The monthly mean mass of the gonads of helmeted guineafowls from the Kruger National Park.

of veld-collected and dump-frequenting birds is shown in Figure 1. Dressed carcass mass and perirectal fat of dump-frequenting males significantly exceeded those of veld-collected males, whereas the mass of the gastrointestinal tract plus ingesta of veld-collected males was significantly greater than that of dump-frequenting males. The same pattern occurred among females. In addition, body mass of dump-frequenting females was significantly greater than that of veld-collected females. Dump-frequenting males and females showed no statistically significant differences between their respective mean values. Mean carcass mass of veld-collected males was significantly greater than that of females ($t = 2{,}219$; $p < 0{,}05$); means of the other parameters did not differ significantly.

The mass of heart, liver, spleen and pancreas of male and female helmeted guineafowls is shown in Table 3.

The monthly mean masses of helmeted guineafowl testes and ovaries are shown in Figure 2.

Table 3 Mass (in grams) of various organs of male and female helmeted guineafowls from the Kruger National Park ($\bar{x}$ = mean; *SD* = standard deviation; *SE* = standard error of the mean)

		Males	Females
Heart	$\bar{x}$	7,27	5,07
	SD	1,88	1,14
	SE	0,23	0,18
Liver	$\bar{x}$	23,98	23,11
	SD	4,44	6,10
	SE	0,55	1,00
Spleen	$\bar{x}$	3,63	2,85
	SD	1,35	1,13
	SE	0,17	0,18
Pancreas	$\bar{x}$	2,37	2,03
	SD	0,62	0,54
	SE	0,08	0,09

Discussion

Mean beak length of both males and females closely corresponded to the value of 25,1 mm for *N. m. coronata* and 25,7 mm for *N. m. mitrata* (Crowe 1978a). We found sexual dimorphism in casque frontal length. Crowe (1978a) lumped data for both sexes, however, and found a mean casque frontal length of 54,8 mm (*SD* = 9,6) for *N. m. coronata* which falls between the means for the two genders found by us. Mean casque frontal length of *N. m. mitrata* was 38,3 mm (*SD* = 9,5) (Crowe 1978a), substantially less than the means found by us for *N. m. coronata*.

The mean body mass of newly shot veld-collected guineafowl males and females slightly exceeded that of birds from the northern Cape Province (Crowe 1978b), where mean male mass varied between 1419 g and 1504 g over three seasons, while mean female mass varied between 1339 g and 1428 g. Male ($n = 3$) and female ($n = 3$) birds collected in winter on a farm in the Albany District of the eastern Cape Province were much heavier, with a mean mass of 1740 g and 1710 g, respectively (calculated from data in Skead 1962).

Body mass of the KNP birds did not show marked seasonal variation. This contrasts with findings at Stellenbosch, south-western Cape Province, where mean live mass of trapped males exceeded that of females in winter (non-breeding season), while the situation was reversed during the breeding season (Siegfried 1966).

Mean mass of birds ($n = 9$) of the nominate race *N. m. meleagris* Linnaeus of north-eastern Africa was 1300 g (range 1150–1600) (Crowe, Keith & Brown 1986). The so-called grey-breasted helmeted guineafowl *N. m. galeata* Pallas of West Africa, from which domesticated birds are derived (Crowe *et al.* 1986), are substantially smaller; free-ranging birds captured during the dry season in Nigeria had a mean live mass of 1000 g (males) and 930 g (females) (Ayeni, Tewe & Ajayi 1983).

An inverse relationship was found between dressed carcass mass and mass of gastrointestinal tract plus ingesta: veld-collected birds had a low carcass mass, but a high gastrointestinal tract mass, while the opposite was found in dump-frequenting birds. The refuse dump would therefore appear to be a rich food source: guineafowls frequenting the

refuse dump appear to be able to meet their nutritional requirements and even grow plump on a relatively low mass of food intake, compared with veld-collected birds. The monthly mean mass of gastrointestinal tract plus ingesta of dump-frequenting birds fluctuated erratically (Figure 1). Guineafowls are opportunistic feeders, however, and the crop contents vary from bird to bird shot out of the same flock at much the same time of day; the crop is capable of extending up to 118 ml (Skead 1962).

Free-ranging helmeted guineafowls are omnivorous, taking seeds, berries, tubers and invertebrates (mainly insects) (Saayman 1966). The last-mentioned prey, especially grasshoppers and termites, are preferred when abundant, such as during periods of high rainfall. During the dry season helmeted guineafowls eat mainly bulbs, roots, and especially tubers of *Cyperus* species (Crowe *et al.* 1986). The mass of the gastrointestinal tract of veld-collected birds appeared to fluctuate seasonally (Figure 1): in 1989 and 1990 the highest figures were recorded during late winter and early summer, which is the driest time of the year. The low monthly mean mass recorded during the corresponding months of 1988 seems anomalous. However, the winter of 1988 had been preceded by a summer with above-average rainfall (Figure 3). The total rainfall for July 1987 to June 1988 at Skukuza was 682,8 mm, the annual mean being 546,3 mm (Gertenbach 1980). The rainfall during December to March was 473,5 mm, or 69,3% of the total for the period; these good rains were followed by some rain during every winter month. This probably resulted in an ample supply of insects and other arthropods during the winter of 1988. A high-quality diet would therefore have been available to the veld-collected guineafowls and they would have been able to meet their nutritional requirements from a fairly low mass of ingesta.

The following two years were drier. Although the total rainfall of 659,7 mm for July 1988 to June 1989 exceeded the average, 286,3 mm or 43,4% of the total was recorded during February. This was followed by a seven-month period during which only 123 mm were recorded; in fact, the rainfall during July — September was only 3,3 mm. The 498,5 mm recorded during July 1989 — June 1990 was below average; the winter was especially dry, only 13,3 mm being recorded from May to August 1990. The guineafowls would have had to rely more on dry fare of lower quality and would have had to ingest a greater volume and mass in order to meet their nutritional requirements.

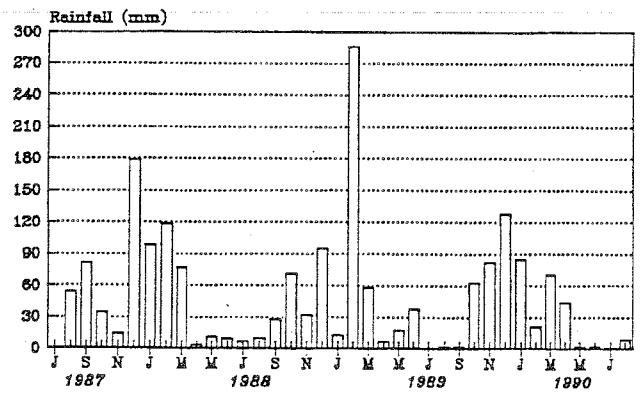

Figure 3 Monthly rainfall recorded at Skukuza (Station 0596179) in the Kruger National Park. (Data supplied by the Weather Bureau, Department of Environment Affairs, Pretoria.)

No statistical comparisons were made of the masses of the various organs, as any deductions based on these data would probably be spurious. Death was not necessarily instantaneous and time lapsed until processing also varied considerably. This could have a major influence on blood content of the spleen and the heart, for example. The mean mass of livers of KNP birds was more than double that of the birds from Nigeria (Ayeni *et al.* 1983), while heart mass of KNP birds exceeded that of Nigerian birds by at least 50%; it should be borne in mind that the Nigerian birds were substantially smaller overall.

The marked seasonal differences in gonad mass (Figure 2) reflect the well-known fact that helmeted guineafowls breed during summer (Crowe *et al.* 1986); hens are said to start laying eggs about 2–3 weeks after the first spring rains have fallen (Joubert 1987).

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Observations on reproduction and morphometrics of scrub hares in the Kruger National Park

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Linear measurements and body masses of various body parts of scrub hares *Lepus saxatilis* were recorded during an intensive investigation into the role of these hares as hosts of ixodid ticks in the Kruger National Park. There was a preponderance of males in the sample. Body length (excluding tail), body mass and eviscerated carcass mass of females were significantly greater than those of males. Perinephric fat mass showed distinct seasonality, reaching a peak in July and August in males, and peaking in August and September in females. Reproduction was aseasonal; 85,1% of adult females were gravid, lactating, or both gravid and lactating. Mean litter size was 1,87 and mean birth mass 115 g.

Lengte-afmetings en massas van verskeie liggaamsdele van kolhase *Lepus saxatilis* is versamel tydens 'n intensiewe ondersoek na die rol van hierdie hase as gashere van skildbosluise in die Nasionale Krugerwildtuin. Die monster het oorwegend uit mannetjies bestaan. Liggaamslengte (stert uitgesluit), liggaamsmassa en ontweide karkasmassa van wyfies was betekenisvol groter as dié van mannetjies. Niervetmassa het seisoenaal gewissel; by die mannetjies was die piek in Julie en Augustus en by die wyfies in Augustus en September. Voortplanting was nie-seisoenaal; 85,1% van die volwasse wyfies was dragtig, lakterend, of dragtig en lakterend. Gemiddelde werpselgrootte was 1,87 en gemiddelde geboortemassa 115 g.

Keywords: *Lepus saxatilis*, morphometrics, reproduction, scrub hare

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Introduction

Scrub hares *Lepus saxatilis* are common and widespread in southern Africa (Smithers 1971; Smithers & Wilson 1979; Rautenbach 1982; Lynch 1983; Skinner & Smithers 1990). Various authors have reported on the morphometrics of the species, the major paper being that of Robinson & Dippenaar (1987), based on museum specimens. An analysis of geographic variation in ear and skull length indicates that scrub hares vary clinally from the larger form found in the south-western Cape Province in a north-easterly direction to at least Zimbabwe (Skinner & Smithers 1990). In the present study, which was occasioned by an intensive investigation into the role of scrub hares as hosts of ixodid ticks, we examined specimens collected over a four-year period in the vicinity of Skukuza, Kruger National Park (KNP), an area not extensively sampled previously. The large number of specimens collected enabled us to take various linear measurements for comparison with published results from other populations, as well as record masses of certain organs and make observations on the reproductive status of females.

Materials and Methods

Sets of five scrub hares were collected at approximately monthly intervals from August 1988 to July 1992 within a 25-km radius of Skukuza (24°58'S; 31°36'E). They were shot at night before 21:30 using a spotlight and a single-shot, small-bore rifle or .410 shotgun. An attempt was made to shoot only adult animals but this was not always possible. A total of 240 hares was collected.

Ear length (inner commissure to tip), body length (tip of nose to base of tail along dorsal curve), tail length, and length of hind foot (from heel to the end of the longest claw) were measured. In addition, the masses of the body, carcass (eviscerated, but with skin, head and legs attached), gastro-intestinal tract plus ingesta, heart, liver, spleen, kidneys (both), perinephric fat, uterus (plus contents) plus ovaries, foetus(es) (individually) and both testes were recorded. The reproductive condition of the females was noted.

Unless otherwise stated, a *t*-test (two-tailed) was used to compare the samples.

Results

There was a preponderance of males in the sample (151 ♂♂ vs. 89 ♀♀; $\chi^2 = 16{,}017$; $p < 0{,}005$).

None of the females with a body mass < 1700 g was gravid and we have therefore assumed females with body masses > 1700 g to be adult. Smithers & Wilson (1979) and Rautenbach (1982) found the body mass of males to be *c.* 85% of that of females and we have therefore arbitrarily taken males with a mass > 1500 g to be adult.

The linear measurements of various body parts of adult scrub hares are summarized in Table 1. The only significant difference between the sexes was in the body length (excluding tail) which was significantly greater in females than in males.

Table 1 Linear measurements (in mm) of various body parts of adult male and female scrub hares in the Kruger National Park ($\bar{x}$ = mean; *SD* = standard deviation; *SE* = standard error of the mean; NS = not significant)

		Males	Females	Test statistic
Body length	$\bar{x}$	465,2	528,9	$t = -11,765$
	Range	404–530	438–612	$p < 0,05$
	SD	28,52	40,15	
	SE	2,85	4,67	
	n	142	74	
Tail length	$\bar{x}$	81,7	84,0	$t = 1,372$
	Range	43–112	50–110	NS
	SD	12,48	12,73	
	SE	1,25	1,52	
	n	143	73	
Ear length	$\bar{x}$	100,7	100,8	$t = 0,809$
	Range	90–128	87–122	NS
	SD	6,68	6,85	
	SE	0,67	0,80	
	n	144	74	
Hind foot	$\bar{x}$	118,3	119,9	$t = 0,663$
	Range	105–133	110–130	NS
	SD	6,04	5,39	
	SE	0,80	0,86	
	n	57	39	

The body mass of non-gravid females was significantly greater than that of males, while the eviscerated carcass mass of all adult females was also significantly greater than that of adult males (Table 2).

The mean masses of all organs of females exceeded those of males (Table 3), the differences being significant except for spleen mass. The mass of perinephric fat showed distinct seasonality, in males reaching a peak in July and August and in females peaking in August and September (Figure 1). Testes mass showed no distinct seasonality.

The monthly reproductive status of female scrub hares is summarized in Table 4. Of 74 adult females collected during the study, 85,1% were gravid, lactating or both

Table 2 Total body mass and eviscerated carcass mass (in grams) of adult male and female scrub hares in the Kruger National Park ($\bar{x}$ = mean; *SD* = standard deviation; *SE* = standard error of the mean)

		Males	All females	Non-gravid females	Test statistic
Body	$\bar{x}$	1920,0		2231,7	$t = 5,955$
	Range	1516–2389		1745–2696	$p < 0,05$
	SD	227,41		292,73	
	SE	22,74		56,34	
	n	144		27	
Eviscerated carcass	$\bar{x}$	1522,0	1728,6		$t = 6,973$
	Range	1202–1943	1332–2139		$p < 0,05$
	SD	183,57	205,76		
	SE	18,36	23,92		
	n	144	74		

Table 3 Mass (in grams) of various organs of adult male (n = 144) and female (n = 74) scrub hares in the Kruger National Park ($\bar{x}$ = mean; *SD* = standard deviation; *SE* = standard error of the mean)

		Males	Females	Test statistic
Heart	$\bar{x}$	12,0	13,3	$t = -4,168$
	Range	8,5–18,6	9,2–18,1	$p < 0,05$
	SD	2,03	1,76	
	SE	0,20	0,21	
Liver	$\bar{x}$	38,5 (n = 143)	47,09	$t = -6,342$
	Range	26,4–63,3	23,6–74,5	$p < 0,05$
	SD	7,04	9,94	
	SE	0,71	1,16	
Spleen	$\bar{x}$	2,2	2,4	$t = -1,608$
	Range	0,4–6,2	1,0–6,7	NS
	SD	0,97	1,11	
	SE	0,10	0,13	
Kidneys (paired)	$\bar{x}$	10,6	12,8	$t = -6,622$
	Range	7,5–17,5	7,3–19,1	$p < 0,05$
	SD	1,86	2,39	
	SE	0,19	0,28	
Perinephric fat	$\bar{x}$	1,8	2,6	$t = -1,989$
	Range	0,0–12,1	0,0–14,0	$p < 0,05$
	SD	2,19	3,23	
	SE	0,22	0,38	
Uterus + ovaries	$\bar{x}$	–	71,0	
	Range		2,1–452,0	
	SD		96,85	
	SE		11,26	
Testes (paired)	$\bar{x}$	6,5 (n = 143)	–	
	Range	1,3–14,8		
	SD	2,87		
	SE	0,29		
Gastro-intestinal tract	$\bar{x}$	273,8	339,5	$t = -7,129$
	Range	161,0–372,0	219,0–506,0	$p < 0,05$
	SD	47,02	67,70	
	SE	4,70	7,92	

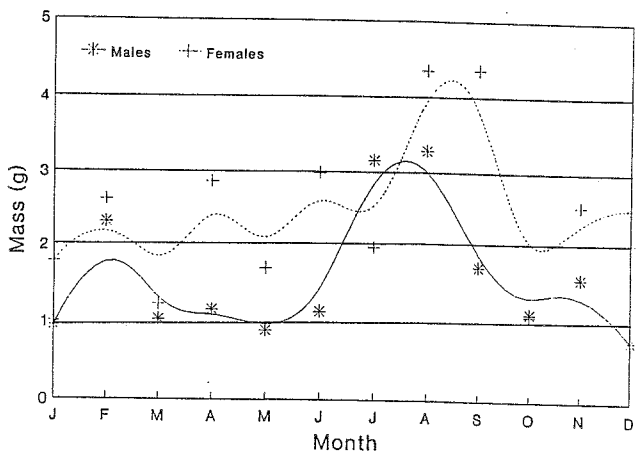

Figure 1 The monthly mean perinephric fat mass (g) of male and female scrub hares collected in the Kruger National Park.

Table 4 Monthly reproductive status and distribution of single, twin and triplet conceptuses in scrub hares in the Kruger National Park

	Number of female hares		Number of conceptuses		
Month	Examined	Pregnant and/or lactating	Single	Twin	Triplet
January	9	7	1	3	3
February	4	4	1	–	2
March	5	5	1	2	1
April	5	5	1	2	–
May	12	10	3	4	–
June	4	4	1	1	–
July	6	4	1	3	–
August	6	5	2	1	1
September	6	6	–	3	1
October	5	4	–	2	–
November	5	4	1	2	–
December	7	5	1	1	2
Total	74	63	13	24	10

gravid and lactating (63,5% were gravid, 45,9% were lactating and 24,3% were gravid and lactating).

The smallest gravid female had a body mass of 1721 g, the smallest lactating female had a body mass of 1787 g and the smallest lactating, gravid female (i.e. at least her second pregnancy) had a body mass of 1882 g. Thirteen of the 47 gravid females carried single, 24 carried twin and 10 triplet conceptuses; three of the last-mentioned showed evidence of resorption of one conceptus. The monthly distribution of single, twin and triplet conceptuses is also presented in Table 4. The mean was 1,87 conceptuses per female. In four females the location of the conceptuses was not recorded; in the others, 41 conceptuses were carried in the left and 43 in the right uterine horn, which did not differ significantly from parity ($\chi^2 = 0{,}0476$; $0{,}75 < p < 0{,}90$). Ten of the 22 twin and four of the triplet conceptuses were carried in the same uterine horn. The largest foetuses found in females still lactating after the previous parturition were a singleton of 75,5 g, twins of 75,1 g and 73,6 g and triplets of 69,5 g, 68,4 g and 62,5 g. Four females with advanced foetuses had milk in the udder. The two singletons had masses of 116,5 and 117 g, respectively, the set of twins 116,6 and 114,0 g and the triplets 108, 110 and 126 g, with an overall mean of 115 g, which we estimate as the mean birth mass of scrub hares. These leverets were fully haired and their eyes were open.

Discussion

The preponderance of males in the sample may be an artifact of the sampling technique which for some reason favours males, or males predominate in the population. We suspect the latter since the sampling technique actually favoured females because we tried to collect only adult and therefore large hares. Unfortunately the gender of the foetuses was not recorded.

Age determination criteria have been described for European hares *Lepus europaeus* which are closely related to scrub hares (Skinner & Smithers 1990). Broekhuizen & Maaskamp (1979) and Simoens, De Rycke & Verschooten (1992) showed that determining the age of European hares is difficult because they reach adult mass by the age of four months; tooth eruption and replacement is completed by Day 25 and tooth wear cannot be used as a criterion. Postnatal ossification of the limbs and pelvis enables age determination of hares younger than 12 months, but this was beyond the scope of our study. Even though body mass can vary depending on food availability, season and presence of conceptuses, our use of total body mass as an indication of maturity was practical under the circumstances. Our criteria should, however, not be extrapolated to other populations since, for example, the smallest gravid female found in Botswana had a body mass of *c.* 1,6 kg (Smithers 1971).

The mean ear length recorded in the present study fits in well with the cline extending in a north-easterly direction from the south-western Cape Province (Robinson & Dippenaar 1987; Skinner & Smithers 1990). The mean body mass of males in this study (1,92 kg; range 1,52 – 2,39 kg) was substantially less than the 3,19 kg (range 2,70 – 3,75 kg; $n = 8$) of those in mountainous areas of the south-western Cape Province (Robinson 1981), but corresponded fairly closely with the mean body mass of 2,04 kg (range 1,50 – 2,50 kg; $n = 20$) reported from Zimbabwe (Smithers & Wilson 1979).

Skinner & Smithers (1990) stated that scrub hare females are larger than males, but not significantly so. In our long series we found non-gravid females to be significantly heavier than males, and eviscerated carcasses of all adult females to be significantly heavier than those of males.

Both male and female scrub hares reached peak condition during the dry season, as indicated by the amount of perinephric fat found. The reason could be physiological or could indicate an abundance of food resources at that time of the year, which is unexpected, as scrub hares are said to live on the leaves, stems and rhizomes of dry and green grass, but have a preference for green grass (Skinner & Smithers 1990). They may in fact ingest other foodstuffs with high nutritive values, such as dropped seeds and pods, which are usually available at the start of the dry season. Hares masticate their food very finely and the stomach contents gave no indication of the nature of the foodstuff. In seasonally-breeding mountain hares *Lepus timidus scoticus* in north-east Scotland, the highest body fat composition was found in late winter, coinciding with the onset of reproduction (Van der Merwe & Racey 1991).

The non-seasonal breeding of scrub hares was confirmed by our study. The mean number of conceptuses per gravid female (1,87; $n = 47$) agreed closely with the figure of 1,9 for both the Transvaal ($n = 13$; Rautenbach 1982) and the Orange Free State ($n = 14$; Lynch 1983), but exceeded the mean of 1,6 conceptuses per gravid female found in both Botswana ($n = 62$; Smithers 1971) and Zimbabwe ($n = 24$; Smithers & Wilson 1979). With the exception of one set of triplets in August and another in September, eight of the ten sets of triplets were present in summer between December and March. Similarly, in the series from Botswana, there were six sets of triplets: two in January, three in February and one in April (Smithers 1971), and it is suggested that triplets are more common in summer than during the other seasons.

The gestation period of scrub hares is *c.* 42 days (Kingdon 1974). If it is assumed that all adult females in the population sampled by us are fertile and that reproduction is strictly non-seasonal, the 63,5% pregnancy rate would be equivalent to 42 days of the conception interval and hence conception could occur every 66 days. Each female would therefore be capable of bearing 5,5 litters, each comprising a mean of 1,87 leverets, or 10,3 offspring per annum.

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Body size and habitat as determinants of tick infestations of wild ungulates in South Africa

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The purpose of the present work was to test the hypothesis that the intensity of tick infestation on South African wild ungulates is proportional to surface area of the host (body weight$^{0.67}$) and to assess the role of habitat preference on the intensity of infestations. The results support previous suggestions that larger ungulates are more important hosts for adult ticks, however, the intensity of infestation of nymphs and larvae is proportional to the surface area of the host. Grazers had a lower intensity of infestation than browsers and intermediate feeders. The difference was most pronounced in the 30 to 150 kg weight range within which the grazers were predominantly short-grass grazers which utilize habitat less suitable for ticks. These patterns appeared to be consistent within the three major collection areas, Kruger National Park, KwaZulu-Natal and Mountain Zebra National Park.

Keywords: allometric relationships, habitat, tick infestation, wild ungulates

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Introduction

Southern Africa contains a mosaic of ticks and native ungulate hosts whose interactions are complex and often poorly understood. Climatic constraints which determine the distribution of both host and tick species are important in determining the host-parasite associations within the region. Locally, the density of both host and tick populations determines the intensity of infestation. However, some host species accumulate more tick species and are more heavily infested than others, suggesting that factors other than the tick density also determine the mosaic of infestations. Some tick species seem to prefer a specific host species, but most have been collected from a range of hosts. This suggests that host susceptibility rather than tick specificity is the primary determinant of infestation patterns.

Factors which could account for the differential susceptibility to tick infestation of ungulates are body size, tick resistance, and host behaviour and habitat use. Larger ungulates appear to be more heavily infested with ticks than smaller ungulates, and it has been suggested that larger species are more important hosts of adult ticks while smaller species are more important hosts for the immature stages (Horak 1982; MacLeod 1970). Tick resistance is well documented in cattle (Tatchell 1987) and has been invoked to explain the low tick burdens on blue wildebeest *Connochaetes taurinus* (Horak, MacIvor, Petney & De Vos 1987). Host behaviours, such as grooming, have been invoked to explain differences in tick burdens of sympatric antelope species (Olubayo, Jono, Orinda, Grootenhuis & Hart 1993), and differences in tick burdens related to differences in habitat use have been suggested both within and between host species (Barnard 1989; Fourie & Kok 1992; Gallivan & Surgeoner 1995; Hart, Hart & Mooring 1990).

The objective of the present study was to test the hypothesis that the intensity of tick infestation is primarily a function of body size and to assess the role of habitat preference on the intensity of infestation. If tick infestation is simply a function of body size, the intensity of infestation should be proportional to the surface area and scale to the 0.67 power of body weight. If habitat preference is not a factor influencing intensity of infestation the relationship between body weight and intensity of infestation should not differ between antelope utilizing different habitats.

Methods

The data used in this study are from a series of papers on the parasites of domestic and wild animals in South Africa by Horak and colleagues who made quantitative collections of ticks from wild ungulates in various nature reserves throughout South Africa (Figure 1). These papers provide an extensive dataset of quantitative tick collections from a large variety of wild ungulates. The procedures for the tick collections were described by Horak, Brown, Boomker, DeVos & Van Zyl (1982), Horak, De Vos & Brown (1983a), Horak, Potgieter, Walker, De Vos & Boomker (1983b) and Horak, Boomker, Spickett & De Vos (1992).

The present study used data from the Northern, Mpumalanga, KwaZulu-Natal, Eastern Cape, Western Cape, Free State and Gauteng provinces of South Africa (Figure 1). Collections from Namibia and areas within South Africa receiving less than 400 mm rainfall annually (Tainton 1981) were excluded as the intensity of infestation was low in these drier areas. Collections from the Golden Gate Highlands National Park, Free State were excluded as the intensity of infestation

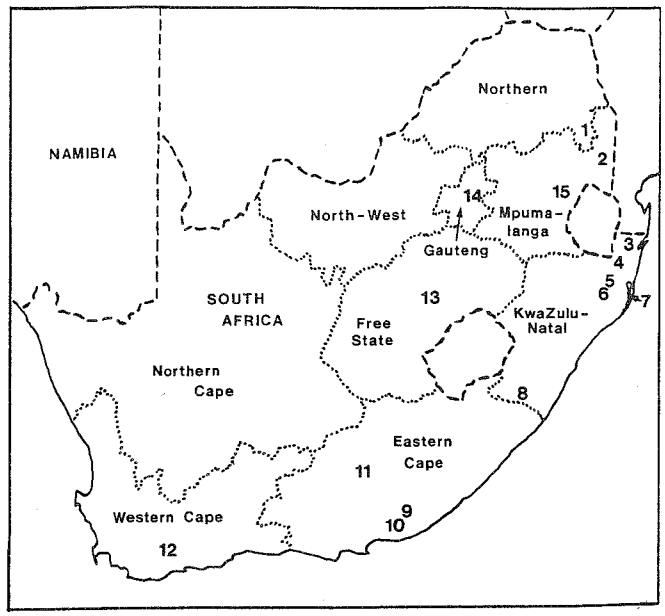

Figure 1 Map of South Africa with the locations of the reserves from which ungulates and their ticks were collected. (1) Hoedspruit Nature Reserve, (2) Kruger National Park, (3) Ndumu Game Reserve (4) Mkuzi Game Reserve, (5) Hluhluwe Game Reserve, (6) Umfolozi Game Reserve, (7) St. Lucia Nature Reserve, (8) Weza State Forest, (9) Andries Vosloo Kudu Reserve, (10) Thomas Baines Nature Reserve, (11) Mountain Zebra National Park, (12) Bontebok National Park, (13) Willem Pretorius Nature Reserve, (14) Rietvlei Nature Reserve, (15) Rob Ferreira Nature Reserve. The latitude and longitude of the reserves are given in the original works.

is lower at high altitudes (Baker, Ducasse, Sutherst & Maywald 1989). Collections from areas with cattle which were treated with acaricide were also excluded as intensity of infestation is reduced on the wild ungulates in these areas (Horak & Knight 1986; Petney & Horak 1987).

The mean intensity of infestation of the adults, nymphs and larvae of all of the tick species infesting each host species was recorded (Table 1). The mean intensity of infestation of the three stages of the most common tick species was also recorded. As many tick species occur seasonally, and there may be age and sex differences in intensity of infestation (Gallivan, Culverwell, Girdwood & Surgeoner 1995; Horak *et al.* 1992), the mean intensity of infestation was based on samples collected over an entire year and from the broadest cross-section of the population. When this was not possible, the weighted average of separate collections was used. However, for some host species, ticks were only collected from a few individuals during a limited time period.

Weights for the ungulates were taken from the literature (Table 1). When the ages and sexes were provided, average weights for the age and sex classes were used. When there was a broad range of ages, or the age distribution of the sample was not given, the estimated average weight for the species was used.

It was difficult to develop a consistent habitat classification scheme as the habitats available often differed between nature reserves. Many ungulates also occur in a wide range of habitat types (Coetzee 1980), some of which may be heterogeneous. To circumvent this problem, feeding preferences were used as a surrogate measure of habitat. Feeding occupies 25–55% of the daily activity budget (Ben-Shahar & Fairall 1987; Jarman & Jarman 1973; Owen-Smith 1994) and is an important factor in the spatial separation which occurs within restricted areas in heterogeneous habitat types (Ferrar & Walker 1974; Hirst 1975). The ungulates were classified as browsers, intermediate feeders, selective grazers, short-grass grazers and coarse grazers (Hofmann 1989; Skinner & Smithers 1990).

All of the analyses were carried out using allometric regressions of the form: $I = aW^b$, where I = intensity of infestation, and W = host body weight (kg). The regressions were linearized using the form: $\log(I) = \log(a) + b.\log(W)$. Standard procedures were used for significance testing and comparison between regressions (Zar 1974).

Results

Body weight and feeding preference (browser/intermediate feeder or grazer) accounted for 69%, 39% and 33% of the variability in the mean intensity of infestation of adults, nymphs and larvae respectively. The mean intensity of infestation of all stages increased with increasing body weight of the ungulate hosts (Figure 2). The exponent for adult ticks (Table 2) was higher than the surface area exponent of 0.67 ($p_{\alpha(1)} = 0.05$), but the exponent for nymphs and larvae did not differ from the surface area exponent ($p > 0.5$).

The browser/intermediate feeder group was more heavily infested with ticks than the grazers, but the exponents did not differ between the two groups (Table 2). The exponent for adult ticks on grazers was significantly higher than the surface area exponent of 0.67 ($p_{\alpha(1)} = 0.02$). When giraffe *Giraffa camelopardalis* were excluded, the exponent for the browser/intermediate feeder group (1.29) was also significantly higher than 0.67 ($p_{\alpha(1)} = 0.03$). Excluding giraffe also increased the exponents for nymphs and larvae on the browser/intermediate feeder group to 0.76 and 0.71 respectively.

There were two obvious groupings in the data for adult ticks (Figure 2). The upper group consisted of larger browsers frequenting savanna woodland, intermediate feeders and large coarse grazers, while the lower group included the small solitary browsers, small selective grazers and short-grass grazers. The difference between the browsers/intermediate feeders and grazers was most apparent in the 30 to 150 kg weight range where all of the browsers and intermediate feeders were above the regression for all species, and, with the exception of gemsbok *Oryx gazella*, all of the short-grass grazers were below the regression line. Similar patterns were apparent for the nymphs and larvae, where most of the browsers, intermediate feeders, coarse grazers and small selective grazers were above the regression line, and the larger short-grass grazers were below. Three exceptions in the general patterns were blesbok *Damaliscus pygargus phillipsi* which harboured few adult ticks but were heavily infested with nymphs and larvae, and bushpigs *Potamochoerus larvatus* and gemsbok which had relatively heavy infestations of adults but had lighter infestations of nymphs and larvae.

The slopes and intercepts of the allometric relationships did not differ significantly between the three main collection areas, Kruger National Park, KwaZulu-Natal and Mountain Zebra National Park (Table 3). In Kruger National Park the

Table 1 Body weight, feeding classification and intensity of infestation of adult, nymphal and larval ticks on South African ungulates

Species	Weight	Feeding* strategy	Number of hosts	Intensity of infestation			Source** (Horak *et al.*)
				Adult	Nymph	Larva	
Cape mountain zebra *(Equus zebra zebra)*	200[1,2]	CG[a]	14	1374	2343	4631	1991b
Burchell's zebra *(Equus burchelli)*	216[1]	CG[a]	33	456	874	2095	1984
Bushpig *(Potamochoerus larvatus)*	541	I[a]	8	411	55	42	1991a
Warthog *(Phacochoerus africanus)*	45[3,4]	SGG[a]	79	32	81	64	1988a
Giraffe *(Giraffa camelopardalis)*	1100[2]	B[a,b]	5	1523	827	1102	1983b; unpubl. obs.
Black wildebeest *(Connochaetes gnou)*	110[1]	SGG[a]	9	8	5	144	1991b
Blue wildebeest *(Connochaetes taurinus)*	137[5]	SGG[a]	47	50	173	593	1983a
Bontebok *(Damaliscus pygargus dorcas)*	55[1]	SGG[a]	16	31	223	600	1986
Blesbok *(Damaliscus pygargus phillipsi)*	55[1]	SGG[a]	9	13	682	2796	1982
Red duiker *(Cephalophus natalensis)*	14[2]	B[a,b]	20	30	206	833	1991a
Common duiker *(Sylvicapra grimmia)*	19.5[2]	B[a,b]	13	18	168	422	1989
Springbok *(Antidorcas marsupialis)*	28[1]	SGG/I[a]	18	9	1	24	1991b
Impala *(Aepyceros melampus)*	44[6]	I[a,b]	65	466	1004	2678	1995b
Grey rhebok *(Pelea capreolus)*	20[2]	B[c]	30	27	59	360	1986
Gemsbok *(Oryx gazella)*	134[7]	SGG[a]	24	447	197	263	Fourie *et al.* 1991
Buffalo *(Syncerus caffer)*	450[3]	CG[a,b]	15	827	3844	16108	1983b; unpubl. obs.
Kudu *(Tragelaphus strepsiceros)*	136[1]	B[a,b]	95	648	1302	2787	1992
Nyala *(Tragelaphus angasii)*	73[1,2]	I[a]	73	580	1086	5662	1995a
Bushbuck *(Tragelaphus scriptus)*	35.5[2]	B[a,b]	13	177	361	3337	1989
Eland *(Taurotragus oryx)*	385[1,2]	I[a,b]	17	1007	1029	5199	1983b; 1991b; unpubl. obs.
Common reedbuck *(Redunca arundinum)*	46[8]	SG[a,b]	27	10	77	337	1988b
Mountain reedbuck *(Redunca fulvorufula)*	28[1]	SG[a,b]	18	49	237	1094	1991b

*the feeding strategies were: browser (B), intermediate feeder (I), coarse grazer (CG), selective grazer (SG) and short-grass grazer (SGG).

** all of the sources of the intensity of infestation are Horak *et al.*, except for one additional reference (Boomker, Horak, Booyse & Meyer 1991) for warthog, and the reference for gemsbok (Fourie, Vrahimis, Horak, Terblanche & Kok 1991).

References for weight

[1]Mentis & Duke 1976; [2]Smithers 1983; [3]Coe, Cumming & Phillipson 1976; [4]Mason 1985; [5]Young, Wagener & Bronkhorst 1969; [6]Fairall & Braack 1976; [7]Fourie, Vrahimis, Horak, Terblanche & Kok 1991; [8]De Vos 1977

References for feeding strategy

[a]Skinner & Smithers 1990; [b]Hofmann 1989; [c]Ferreira & Bigalke 1987

relationships between body weight and the intensity of infestation with the three life stages of ticks were not significant. However, there were no small ungulates (< 20 kg) in this sample. The short-grass grazers, warthog *Phacochoerus africanus* and blue wildebeest, had lower intensities of infestation than the coarse grazers, browsers and intermediate feeders. This pattern was apparent for *Boophilus decoloratus*, and for the larvae and nymphs of *Rhipicephalus appendiculatus* and *Rhipicephalus zambeziensis*. The pattern was also apparent for *R. appendiculatus* and *R. zambeziensis* adults on blue wildebeest, warthog, kudu *Tragelaphus strepsiceros*, impala *Aepyceros melampus* and Burchell's zebra *Equus burchelli* which were collected over an entire year, but there were few *R. appendiculatus* or *R. zambeziensis* adults on giraffe, bushbuck *Tragelaphus scriptus*, nyala *Tragelaphus angasii* and eland *Taurotragus oryx* which were collected from May to November (Horak *et al.* 1983b; unpubl. obs.).

With the exception of reedbuck *Redunca arundinum* and buffalo *Syncerus caffer*, the ungulates collected in KwaZulu-Natal were browsers or intermediate feeders. There were marginally significant relationships between body weight and the intensity of infestation of adult ticks and nymphs, but the exponents were not significantly higher than 0.67. The relationship between weight and the intensity of infestation of larvae was significant (exponent = 1.01; $p = 0.03$) when bushpigs were excluded.

There was a significant relationship between body weight and the intensity of infestation of adult ticks in Mountain Zebra National Park, but the exponent did not differ significantly from 0.67. The relationships between weight and the intensity of infestation of nymphs and larvae were not significant. Habitat was an important factor in the patterns of

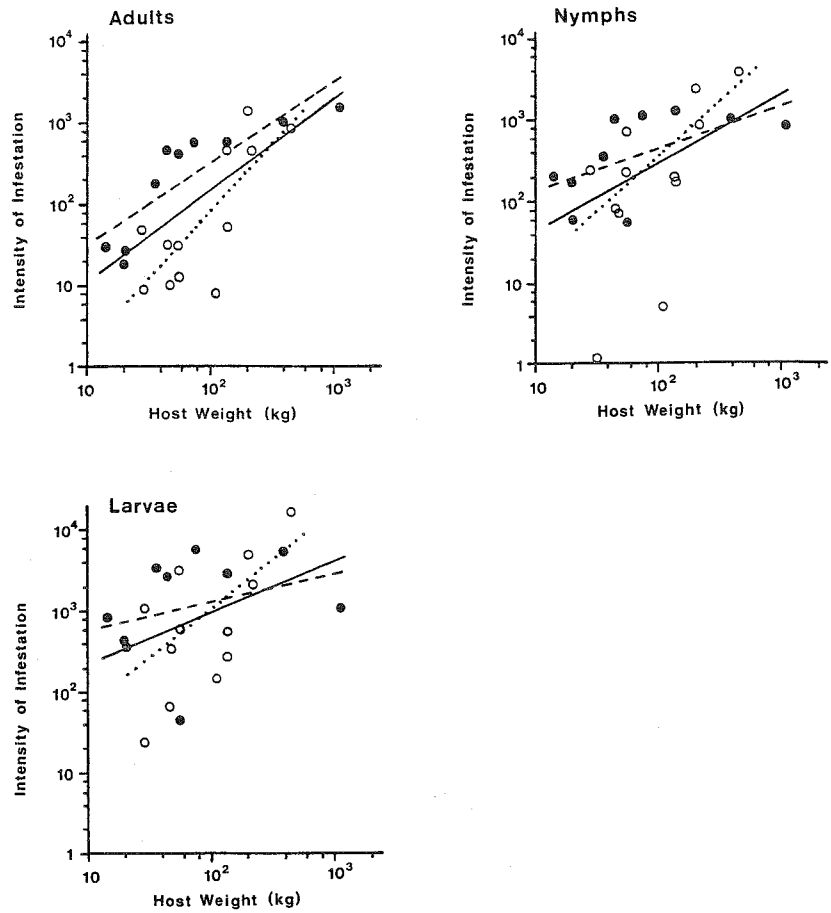

Figure 2 Relationships between intensity of infestation of adult, nymphal and larval ticks and host body weight of South African ungulates. (▬▬) all host species; (●-------●) browsers/intermediate feeders; (O·····O) grazers. The equations for the regressions are in Table 2.

Table 2 Regression coefficients for intensity of infestation of adult, nymphal and larval ticks versus host body weight. The regressions are of the form: $I = aW^b$, where I = intensity of infestation, and W = host body weight (kg). The regression lines are in Figure 2

Stage	Group[1]	n	a	b	r	$p_{(b=0)}$
Adults	All	22	0.84	1.13	0.69	<0.001
	B/I	10	3.37	0.99	0.85	0.002
	G	12	0.04	1.65	0.77	0.003
		$p_{(a_{B/I}=a_G)} = 0.05$		$p_{(b_{B/I}=b_G)} = 0.18$		
Nymphs	All	22	6.52	0.82	0.52	0.02
	B/I	10	40.89	0.52	0.60	0.07
	G	12	0.12	1.61	0.60	0.05
		$p_{(a_{B/I}=a_G)} = 0.07$		$p_{(b_{B/I}=b_G)} = 0.13$		
Larvae	All	22	50.52	0.64	0.42	0.01
	B/I	10	265.05	0.35	0.32	0.26
	G	12	1.36	1.37	0.65	0.02
		$p_{(a_{B/I}=a_G)} = 0.08$		$p_{(b_{B/I}=b_G)} = 0.12$		

[1] The group represents the host species used in the calculations. All = all host species, B/I = browsers and intermediate feeders, and G = grazers.

Table 3 Regression coefficients for intensity of infestation of adult, nymphal and larval ticks *versus* host body weight in the three main collection areas. The regressions are of the form: $I = aW^b$, where I = intensity of infestation, and W = host body weight (kg)

Stage	Area[1]	n[2]	a	b	r	$p_{(b=0)}$
Adults	KNP3	9	12.68	0.64	0.57	0.11
	KZN	8	1.55	1.10	0.69	0.06
	MZNP	7	0.07	1.56	0.76	0.05
	$p_{(a_{KNP}=a_{KZN}=a_{MZNP})} > 0.5$			$p_{(b_{KNP}=b_{KZN}=b_{MZNP})} > 0.5$		
Nymphs	KNP	9	165.88	0.26	0.32	0.40
	KZN	8	6.48	0.95	0.68	0.06
	MZNP	7	0.03	1.63	0.57	0.18
	$p_{(a_{KNP}=a_{KZN}=a_{MZNP})} > 0.3$			$p_{(b_{KNP}=b_{KZN}=b_{MZNP})} > 0.5$		
Larvae	KNP	9	357.49	0.22	0.21	0.58
	KZN	8	26.89	0.96	0.53	0.17
	MZNP	7	1.03	1.04	0.35	0.45
	$p_{(a_{KNP}=a_{KZN}=a_{MZNP})} > 0.5$			$p_{(b_{KNP}=b_{KZN}=b_{MZNP})} > 0.5$		

[1] Kruger National Park (KNP), KwaZulu-Natal (KZN) and Mountain Zebra National Park (MZNP).

[2] Number of host species in the area. Some species occurred in two areas.

[3] The sources for the tick burdens of the host species in the three areas were: KNP: Horak *et al.* 1983a; 1983b; 1984; 1988a; 1992; 1995b; unpubl., KZN: Horak *et al.* 1983b; 1988b; 1989; 1991a; 1995a; unpubl., MZNP: 1982; 1983b; 1991b.

infestation. Eland, an intermediate feeder, and Cape mountain zebra *Equus zebra zebra*, a coarse grazer, were heavily

infested, and were the most important hosts of *Hyalomma* spp., *Margaropus winthemi, Rhipicephalus evertsi evertsi, Rhipicephalus follis* and adult *Rhipicephalus glabroscutatum* (Horak, Fourie, Novellie & Williams 1991b). Mountain reedbuck *Redunca fulvorufula*, a small selective grazer, was heavily infested with *R. glabroscutatum.* The short-grass grazers, black wildebeest *Connochaetes gnou*, springbok *Antidorcas marsupialis*, blesbok and gemsbok harboured few ticks (Horak *et al.* 1982; 1983b; 1991b).

Discussion

The exponents in this study support previous suggestions (Horak 1982; MacLeod 1970) that larger ungulates are more important hosts for adult ticks, but suggest that the intensity of infestation of nymphs and larvae is proportional to the surface area of the host. However, the exponents for the intensity of infestation of the immature stages may have been overestimated and the exponent for adults may have been underestimated as the two largest hosts, giraffe and buffalo, were collected from May to September when adult *R. appendiculatus, R. zambeziensis* and *Rhipicephalus maculatus* are inactive but the larvae and nymphs of these species are common (Gallivan & Surgeoner 1995; Horak *et al.* 1983a; 1992; Horak, Boomker & Flamand 1995a; Horak, De Vos & De Klerk 1984). Buffalo and giraffe are also heavily attended by oxpeckers *Buphagus* spp. (Hart *et al.* 1990) which will reduce the numbers of adult ticks.

The reasons for the differential utilization of hosts by different life stages of ticks are unknown. Larger ungulates have relatively larger home ranges (Du Toit 1990) and may encounter ticks more frequently, but this should affect all stages equally. Rechav, Magano & Fielden (1994) have suggested that the antigenic stimulus injected by feeding ticks is proportionately greater in small animals and induces a higher resistance to infestations. However, this should influence all stages of the ticks equally, and the exponents for nymphs and larvae should also be greater than the surface area exponent.

Two factors which may account for the relationships between intensity of infestation and host body size are grooming and the questing height of the ticks. Grooming may be effective in reducing the numbers of adult ticks, and smaller antelope groom more frequently than larger antelope (Hart, Hart, Mooring & Olubayo 1992). Engorging adult female ticks reduce live weight gain in cattle (Norval, Sutherst, Jorgensen, Gibson & Kerr 1989; Norval, Sutherst, Kurki, Gibson & Kerr 1988), and larger ungulates may be able to tolerate the metabolic cost better than smaller ungulates. Larvae and nymphs do not appear to influence weight gain in cattle (Norval *et al.* 1988; 1989), and the metabolic cost of grooming may be greater than the metabolic cost of the infestations. Short, Floyd, Norval & Sutherst (1989a) reported that the preferred questing height for *R. appendiculatus* larvae, nymphs and adults was approximately 26 cm, 31 cm and 70 cm respectively. As ungulate height increases with body size, larvae would encounter the body of small ungulates, but only the legs of large ungulates. In contrast, smaller ungulates such as duiker, which are 40–50 cm at the shoulder (Skinner & Smithers 1990), would pass underneath the majority of questing *R. appendiculatus* adults. Observations of the distribution of ticks on larger ungulates support the height based stratification. On cattle, which are coarse grazers, *R. appendiculatus* and *A. hebraeum* larvae and nymphs were most common on the head and on the feet and lower legs, while *R. appendiculatus* adults were most common on the ears and *A. hebraeum* adults were found on the belly and perineum (Baker & Ducasse 1967). On kudu, the majority of larvae and nymphs of most tick species were on the lower legs and feet, and the adults were on the upper legs, body and head (Horak *et al.* 1983b).

Grazers supported fewer adult ticks than the browsers and intermediate feeders. The difference between the two groups was most pronounced in the intermediate-sized antelope where the grazers were predominantly short-grass grazers. Short, open grasslands are unsuitable habitat for the free-living stages of most ticks (Londt & Whitehead 1972; Short *et al.* 1989a; Short, Floyd, Norval & Sutherst 1989b), and the short grasses will limit the questing heights of the ticks. The intensity of infestation did not differ between the large coarse grazers and the large browsers and intermediate feeders, nor between the small selective grazers and small browsers. The large coarse grazers and small selective grazers frequent longer grasslands which provide more favourable microclimates for the free-living stages of ticks. These habitats also support larger populations of small mammals and ground birds which are important hosts for the immature stages of many ticks (Horak & Williams 1986; Horak, *et al.* 1991b; Horak, Spickett, Braack & Williams 1991c; Walker 1991).

The infestation patterns for nymphs and larvae were similar to those for adult ticks, but there was a much greater variability in the intensity of infestation. Most ungulates were more heavily infested with nymphs and larvae than adults. However, bushpig and gemsbok were heavily infested with adults, but had lighter infestations of nymphs and larvae. The thick skin of bushpigs and warthogs, which also harboured few immature ticks, may make them unsuitable hosts for the immature stages. The predominance of adults on gemsbok is more difficult to explain. *Margaropus winthemi*, a one-host tick (Walker 1991), accounted for 74% of the total tick burden (Fourie, Vrahimis, Horak, Terblanche & Kok 1991). In Mountain Zebra National Park the larvae:nymph:adult ratio of *M. winthemi* was 3.2:1.6:1.0 and 4.6:2.4:1.0 on Cape mountain zebra and eland respectively (Horak *et al.* 1991b). On gemsbok in the Willem Pretorius Nature Reserve, Free State, the ratio was 0.2:0.4:1.0. The low intensity of infestation of the immature stages may have been caused by an under-collection using the scrub technique (van Dyk & McKenzie 1992), however, this should also have occurred in the collections in Mountain Zebra National Park. The low intensity of infestation of the immature stages may also have been caused by the age and sex distribution of the hosts. All of the gemsbok with relatively heavy infestations were adult males collected from July to September (Horak unpubl. obs.), a period in which the abundance of *M. winthemi* declines (Horak *et al.* 1991b). The adult males may not have been exposed to significant numbers of larvae as no larvae and few nymphs were collected from gemsbok calves in September and October in the Willem Pretorius Nature Reserve (Horak unpubl. obs.). Blesbok harboured few adult ticks, but four individuals were heavily infested with *R. appendiculatus* nymphs and larvae in May and June in the Rob Ferreira

Nature Reserve, Mpumalanga. This reserve had a high stocking density (Horak *et al.* 1982), a factor associated with higher tick burdens (Gallivan *et al.* 1995).

Despite differences in tick species and ungulate hosts, the basic patterns were similar in the three main collection areas. This consistency suggests that there is an upper limit to the potential tick burden on most ungulates. Repeated feeding of ticks on hosts induces an immune response which limits the feeding success and survival of ticks (Tatchell 1987). Thus, tick infestation may be self-limiting. However, factors which alter the host-parasite balance can cause an increase in the intensity of infestation. Many ungulates are more heavily infested when they are in poor condition (Gallivan *et al.* 1995) or under nutritional stress (Horak *et al.* 1983b; Horak, Boomker, De Vos & Potgieter 1988a) which reduces the resistance to tick infestations (O'Kelly & Seifert 1969; Sutherst, Kerr, Maywald & Stegeman 1983). The reduction in resistance may occur because of inhibition of the immune response and/or a reduction in the energy available for behaviours such as grooming.

Several ungulate species could not be included in these analyses because of lack of data. Among them were sable antelope (*Hippotragus niger*) and waterbuck (*Kobus ellipsiprymnus*), two species for which heavy tick infestation has been suggested as a primary cause of mortality (Grobler 1981; Lightfoot & Norval 1981; Melton & Melton 1982). Both species have restricted habitat requirements and prefer long, moist grasslands (Skinner & Smithers 1990) which are excellent tick habitat. Other species considered susceptible to tick infestation are eland, kudu, reedbuck and zebra (Lewis 1981; Lightfoot & Norval 1981). With the exception of the reedbuck, these are large ungulates frequenting bush and long grasslands which are good tick habitat. Reedbuck were lightly infested with ticks in KwaZulu-Natal, and their preference for long grass areas not utilized by other species (Skinner & Smithers 1990) may be protective as the mortality reported by Lightfoot & Norval (1981) occurred in an overpopulated area where the population was under nutritional stress.

The potential for tick-related problems in susceptible host species will be greatly increased when large numbers of medium-sized browsers or intermediate feeders, such as impala and nyala, are present. These species appear to be efficient hosts for immature ticks, and may contribute to a rapid increase in tick populations. Impala and nyala are also wide-niche species which may compete with other habitat-sensitive ungulates for resources and alter the structure and species composition of the grassland. Thus, habitat-sensitive species may be under nutritional stress while being exposed to increased tick populations.

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CHAPTER 3

GEOGRAPHIC DISTRIBUTION

I supplied much of the data on the distribution of the subgenus *Boophilus* in South Africa that is included in the publication by Estrada-Peña, Bouattour, Camicas, Guglielmone, Horak, Jongejan, Latif, Pegram & Walker 2006). In the latter paper we note that the Asiatic blue tick, *Boophilus microplus*, which was introduced into southern Africa more than a century ago, has adapted to temperatures 4°C lower and to drier winters than those that the same species in South America can tolerate. I supplied much of the data on the current distribution of various *Rhipicephalus* spp. for the publication on the effect of climate change on ticks of this genus in Africa (Olwoch, Van Jaarsveld, Scholtz & Horak 2006). In the two papers on the ticks of reptiles in Chapter 7 of this treatise the geographic distributions of five of the ixodid tick species infesting these animals have been mapped (Horak, McKay, Heyne & Spickett 2006a; Horak, McKay, Henen, Hofmeyr, Heyne & De Villiers 2006d). I also supplied the information and wrote the subsection on ticks in the publication on invasive arthropod species in the Kruger National Park (Braack, Maggs, Zeller & Horak 1995), in which we note that *Rhipicephalus maculatus* was introduced into the park, probably on translocated nyalas, *Tragelaphus angasii*, that *Dermacentor rhinocerinus* was reintroduced with the reintroduction of rhinoceroses into the park, and that the single specimen of *Hyalomma maginatum turanicum* (now known as *Hyalomma glabrum*) that we collected, had probably arrived on a migratory bird.

Furthermore, with the exception of *Rhipicephalus deltoideus*, which was originally collected in Lesotho and for which very few records exist, distribution maps or collection localities for all the *Rhipicephalus* species that occur in southern Africa have been supplied by Walker, Keirans & Horak (2000) in their monograph on this genus.

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Exotic arthropods in the Kruger National Park, South Africa: modes of entry and population status

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At least 21 species of exotic arthropods have successfully established breeding populations in the Kruger National Park, South Africa. Of these, seven species were intentionally introduced as biological control agents of alien weeds, four species inadvertently accompanied vertebrate hosts during game translocation, and the remainder are presumed to have gained entry through packing crates, human activities, or natural dispersal in some instances. The modes of entry of exotic species are discussed and, where known, the time of first appearance in the Kruger National Park recorded. The rapidly escalating practice of wildlife translocation within and between countries is discussed in relation to passive transfer of diseases and parasites, and reasons are listed why routine precautionary steps should be instituted to avoid transfer of non-target organisms during translocation operations.

Key words: alien species, wildlife translocation, pests, quarantine, species transfer, biological control.

INTRODUCTION

The considerable cost (U.S.$ 81.7 million; FAO 1992) and sophisticated effort required to eradicate New World screwworm, *Cochliomyia hominivorax* (Coquerel) (Diptera: Calliphoridae), accidentally accompanying sheep into Libya in 1988 (Beesley 1991; Anon. 1992), should amply illustrate the risk and potential consequences of international traffic and exchange of goods between countries. The literature abounds with examples of exotic pathogens or pests entering new countries, often as a result of inadequate screening, pre-treatment or quarantine. This has resulted in the spread of vectors (Mertins & Schlater 1991; Goh *et al.* 1985; Norval *et al.* 1991), disease agents (Verster *et al.* 1991; Whitfield *et al.* 1984; Lawrence 1991) and pests (Braack 1991). Natural dispersal and epidemics unrelated to human cultural practice also occur, examples being the translocation of potential disease vectors on migrating birds (Kaiser & Hoogstraal 1958; Hoogstraal *et al.* 1964) and the devastating late-nineteenth century spread of rinderpest through Africa (Scott 1981; Plowright 1982). Deliberate introductions have also occurred, dating back to at least the previous century, usually as specifically-targeted biocontrol programmes where selected narrow host-range predators or parasites are introduced to achieve reduction in numbers of alien pests (Pettey 1947). The effects of such deliberate introductions have, in most cases, been positive (Samways 1988), although in some instances have had disastrous consequences, the introduction into Australia of rabbits (for hunting) and frogs (to control beetle larvae in cane fields) being well known examples.

Aside from any direct impact of the introduction of new species, such as losses through disease, parasitism or consumption of agricultural products, there is the potentially greater long-term risk of genetic interaction with indigenous species. The so-called 'Africanized bees' in South and Central America, which are more aggressive than the original indigenous species, is a case in point (Crawford 1990; Smith 1991).

This paper discusses exotic species that have become established in the Kruger National Park (KNP), South Africa, as a consequence of human activities, and also examines the issue of transfer of wildlife and their associated parasites within and between countries. The data are summarized in Table 1.

EXOTIC ARTHROPODS IN THE KRUGER NATIONAL PARK

Acarina

The establishment of black and white rhinoceros in KNP is a particularly good example of the range of non-target passengers that can accompany such hosts. Through hunting, white rhinoceros, *Ceratotherium simum* (Burchell), became extinct in the Transvaal in 1896 (Pienaar *et al.* 1992) and black rhinoceros, *Diceros bicornis* (Linnaeus), by 1940 (Hall-Martin 1988). White rhinoceros were reintroduced into KNP from the Umfolozi Game Reserve in Natal over a 12-year period commencing in 1961, the total number of animals imported being 345 (Pienaar *et al.* 1992). Twenty black rhinoceros were reintroduced into KNP from Natal in 1971, followed by 12 more from Zimbabwe in 1972 and additional specimens from Natal in ensuing years, totalling 76 successfully reintroduced animals (Hall-Martin 1988; Pienaar, pers. comm.). All rhinoceros were released in the southern half of the Park, mostly south of the Sabie River. Populations of both black and white rhinoceros are increasing (about 8 % p.a.), the black rhinoceros total in KNP for August 1993 being 230 animals and white rhinoceros totalling about 1876 individuals (Pienaar, pers. comm.).

Questing adults of the so-called rhino tick, *Dermacentor rhinocerinus* (Denny) (Ixodidae), are commonly encountered on grass stems throughout the southwestern part of KNP where a high density of rhinoceros occurs. Although little is known of the general biology of *D. rhinocerinus*, it has not been recorded from 542 other mammal hosts of all sizes intensively examined for parasites and occurring sympatrically with both black and white rhinoceros (Horak *et al.* 1983a,b, 1984, 1987, 1988, 1992, 1993). In the literature it is recorded as being host-specific to black and white rhinoceros, with infrequent records from other hosts (Matthysse & Colbo 1987). Since rhinoceros were extinct in KNP and the entire Transvaal for several decades, *D. rhinocerinus* probably became re-established in KNP through passive transfer with rhinoceros when these animals were reintroduced during the 1960s.

Rhipicephalus maculatus Neumann (Ixodidae) is another tick apparently introduced into KNP through host translocation. During a routine monthly monitoring programme of off-host tick populations in the southern KNP, a single nymph of *R. maculatus* was found in the area between Lower Sabie and Crocodile Bridge. In February 1992 inspectors of the State Veterinary Department at Skukuza collected an engorged female and a male *R. maculatus* from an elephant culled near Sekurakwane (24.58S 31.16E). This species is endemic to Zululand where it is common on nyala, bushpig, buffalo and a range of other animals (Horak *et al.* 1983a, 1991b). It is likely that a small founding population of *R. maculatus* was introduced from Zululand either with translocated rhinoceros or with 20 nyala released along the Sabie River in 1980. Despite their apparent low numbers, *R. maculatus* must be well established, as suggested by the presence of an adult male and a female on the elephant at Sekurakwane.

The tick *Hyalomma marginatum turanicum* Pomerantsev (Ixodidae) is not indigenous to KNP, being essentially confined to more arid zones in South Africa, such as the Karoo (Howell *et al.* 1978; Horak *et al.* 1991a; Walker 1991). During March 1988 a single questing adult was collected in the northern KNP during a tick survey covering the entire Park (Spickett *et al.* 1991).

During surveys in 1989 on water hyacinth, *Eichhornia crassipes* (Martius) Solms-Laubach, in the Crocodile River, the exotic mite *Orthogalumna terebrantis* Wallwork (Galumnidae) was found in large numbers on hyacinths in the Van Graan Dam (31.38S 25.36E) (Cilliers, pers. comm.). This phytophagous mite had previously been released in Egypt and Zambia in unsuccessful attempts at biological control of *E. crassipes*, and its presence in South Africa was unexpected (Cilliers 1991a). A subpopulation of these mites from the Crocodile River was released on 30 March 1993 on water hyacinth on the Letaba River below the Engelhardt Dam (23.50S 31.37E).

Lepidoptera

Sour prickly pear, *Opuntia stricta* Haworth, was introduced into KNP during the first half of this century for use as an ornamental and food plant at Skukuza (24.59S 31.35E). From here it was dispersed by animals and is currently established over a large area exceeding 10 000 ha in the vicinity of this camp. Almost four million plants were treated during herbicidal or mechanical eradication campaigns during the 1980s without achieving effective control. Approximately 2000 newly emerged *Cactoblastis cactorum* (Bergroth) (Pyralidae) caterpillars from the Graaff-

Reinet/Uitenhage area were released on *O. stricta* near Skukuza in March 1988 to complement these eradication programmes. A second release of 200 egg-sticks, with an average of 80 eggs per stick, took place in March 1990. The original parental stock of these moths was from Australia, which in turn originated from Argentina (Moran & Zimmerman 1991; Pettey 1947). A successfully breeding population has established but with a disappointingly low detrimental effect on fecundity and spread of *O. stricta*. Young plants appear to be most vulnerable to insect damage.

During a survey of phytophagous insects that attack the exotic weed *Lantana camara* Linnaeus in the southern KNP in January 1990, Cilliers (1990) found evidence of the blotch leafminer, *Pseudopyrausta acutangulalis* (Sneller) (Pyralidae). This insect is endemic to Mexico and although it is widespread in South Africa, no records exist of its release in this country. It occurs only on *L. camara* but does not effect sufficient damage to be an effective biocontrol agent.

Diptera

Gyrostigma rhinocerontis (Hope) is a large fly (up to 35 mm in length) of the family Gasterophilidae. The larval stages are endoparasitic in the stomachs of both black and white rhinoceros in southern Africa and have not been recorded from any other host (Zumpt 1965). During the past ten years one of us (L.B.) has examined the stomach contents of nine white rhinoceros and two black rhinoceros in KNP; each animal had large numbers of *G. rhinocerontis* larvae in the stomach. Since this species is host-specific to rhinoceros, it must have been introduced into KNP along with its host, probably during the 1960s. Adult *G. rhinocerontis* are rare; they have rudimentary, non-functional mouthparts and survive only a few days, sufficient to find a mate, copulate and lay eggs. The cream-coloured eggs are laid around the base of the horns of the rhinoceros or in clumps laterally or elsewhere on the head. It is therefore likely that *G. rhinocerontis* entered KNP in the egg-stage on rhinoceros and also as larvae in animals introduced from Natal or Zimbabwe.

Rhinomusca dutoiti Zumpt is a large biting fly of the family Muscidae (Stomoxyinae). They are commonly found on white rhinoceros especially, but also black rhinoceros in KNP and Natal, often in large numbers (> 100) laterally and dorsally on the body (Braack, unpubl.). These flies are particularly attracted to and feed avidly at small lesions with serous exudations on the body.

Zumpt (1973) suggests a host preference for white rhinoceros by *R. dutoiti*, although he also says that he 'found that they never attacked humans, but were occasionally caught on bait-cattle used in tsetse research.' In KNP we have collected flies off several hundred animals (tent-trap dropped over drug-immobilized hosts or sweep-net sampling off drug-darted animals), including significant numbers (> 100) of rhinoceros, elephant, buffalo and most of the other species of large mammals. *Rhinomusca dutoiti* has never been recorded on any animal other than black or white rhinoceros. Furthermore, during monthly sampling of dung of white rhinoceros, elephant, buffalo and blue wildebeest over a 12-month period and rearing of flies breeding in the dung, *R. dutoiti* was found to breed exclusively in rhinoceros dung (Braack, Kappmeier & Meiswinkel, unpubl.). Evidence therefore suggests that this fly can exist only in the presence of rhinoceros and, after becoming locally extinct in the Transvaal along with its host earlier this century, was reintroduced into KNP probably with rhinoceros introduced from Natal in the 1960s. Since the adults have preferred periods for feeding and resting on the rhinoceros and do not remain on the hosts the entire day (Braack, unpubl.), they were probably not transferred from Natal as adults, but as eggs in dung deposited in the transfer crates in Natal.

Chrysomya megacephala (Fabricius) (Calliphoridae) is a synanthropic blow fly also known as the Oriental latrine fly which is endemic to southeast Asia (Kurahashi 1978, 1982). During the 1970s and 1980s it rapidly invaded and established itself in various parts of South and North America and Africa (Laurence 1986; Greenberg 1988; Wells 1991). It is a pest by aggregating and laying eggs on fresh fish at marketplaces (Esser 1990), can be a nuisance through abundance on dog faeces and garbage in proximity to humans (Wells 1991), is potentially important in mechanical transmission of helminthic and other disease agents (Greenberg 1973; Monzon *et al.* 1991), and has been known to cause human myiasis (Lee & Yong 1991). It was first recorded in South Africa along the south-western Cape coast in 1978 (Prins 1979) and by 1984 it was established in Skukuza (Braack 1991). Although entry of this exotic species into KNP was almost certainly through natural dispersal, it must have reached the proximity of KNP through human

activity, most likely from ships at Maputo harbour, 140 km from Skukuza (Braack 1991). This distance is well within the dispersal range of even a single generation of many calliphorid species (Braack & Retief 1986).

During a survey of phytophagous insects utilizing the exotic weed *L. camara* in the southern KNP in January 1990, Cilliers (1990) found that *Ophiomyia lantanae* (Froggatt) (Agromyzidae) had established. This fly was not deliberately released in KNP, but dispersed either from East Africa or later stock introduced from Hawaii (provenance Mexico) into South Africa in 1961 (Cilliers & Neser 1991).

A small founding population of *Calcomyza lantanae* Frick (Agromyzidae) originating from Trinidad via Australia, was released as a potential biocontrol agent of *L. camara* along the Sabie River immediately west of Skukuza in 1985. No adults were found subsequently, but leafmining typical of the immature stages was observed on *L. camara* in January 1990 about 8 km downstream from the original release site (Cilliers 1990).

Coleoptera

The exotic species of beetles established in KNP were all deliberately introduced and released as part of biological control programmes against invasive, alien plants.

On 17 December 1985, 1454 *Neochetina eichhorniae* Warner (Curculionidae), imported from Australia, were placed on water hyacinth, *E. crassipes*, in the Van Graan Dam, Crocodile River, downstream of Malelane Gate. This population is flourishing and has spread at least 50 km from the original release site (Cilliers 1991a). Another 230 adult *N. eichhorniae* were released on *E. crassipes* in the Letaba River, below the Engelhardt Dam, on 29 August 1992.

Five hundred adult *Neohydronomus affinis* Hustache (Curculionidae), also imported from Australia, were released on 18 December 1985 at Nhlangaluwe (22.22S 31.12E) (Pafuri Section) in a pan heavily infested with the aquatic plant *Pistia stratiotes* Linnaeus, a floating weed probably originating from South America but now an invader in many parts of the world, including South Africa and KNP (Cilliers 1987). A subpopulation of *N. affinis* was transferred in June 1986 from Nhlangaluwe to the nearby Dakamila Pan (22.22S 31.15E), which was also heavily infested with *P. stratiotes* (Cilliers 1991c). Following successful results at these isolated pans, further releases of *N. affinis* on *P. stratiotes* at various sites in the Sabie River between Skukuza and Lower Sabie were carried out as follows: 1987 (100), 1988 (405), 1989 (400), 1990 (1000), 1992 (3368). Releases of this beetle on *P. stratiotes* were also effected at Orpen Dam (24.47S 31.53E) in 1990 (635) and the Crocodile River (unrecorded site) (1991, unknown number). Localized but generally successful control of *P. stratiotes* has been achieved at these release sites.

Small populations of *Trichapion lativentre* (Béquin-Billecocq) (Apionidae) and *Neodiplogrammus quadrivittatus* (Olivier) (Curculionidae) were released in May 1988 along the Noord-Sand River, a tributary of the Sabie River, 800 metres west of the KNP boundary by Moran and Hoffmann (pers. comm.) in an attempt to initiate biocontrol of the aggressive exotic weed *Sesbania punicea* (Cavanilles) Bentham. Progeny of these released beetles have entered KNP along parts of the Sabie River harbouring *Sesbania*. A small colony of *N. quadrivittatus* was also released on the KNP boundary along the Tshutshe Spruit (23.57S 31.10E) near Phalaborwa in 1992.

Approximately 150 adult *Cyrtobagous salviniae* Calder & Sands (Curculionidae), descendants of stock originally from Brazil (Cilliers 1991b), were released on South American water fern, *Salvinia molesta* Mitchell, infesting the Lower Sabie Dam (25.07S 31.54E) during June 1992, with an additional release of another 150 adult weevils on 17 November 1992. These beetles have established and provide good biological control of *S. molesta*.

Small populations (< 200 each) of the leaf beetles *Octotoma scabripennis* Guérin-Méneville and *Uroplata girardi* Pic (Chrysomelidae), originally endemic to Mexico and Brazil respectively, were released on *L. camara* in 1985 along the Sabie River on the western boundary of Skukuza, and in 1989 about 170 adults of each of these species were again released along the Nsikasi River in the southwestern KNP. The current status of these two species is uncertain as it is suspected that the initial populations may not have established themselves.

Hemiptera

A small population of *Teleonemia scrupulosa* Stål (Tingidae), from parental stock from Mexico via Hawaii, was released near Skukuza 'after 1985' as one of several potential biocontrol agents of the cosmopolitan weed *L. camara* (Cilliers 1990). It feeds on the flowers, young growth tips and

leaves, eventually causing defoliation, dieback of twigs and poor seed set. Its current status in KNP is uncertain.

Orthezia insignis Browne (Ortheziidae) occurs widely throughout South Africa and has been recorded on *L. camara* in the southern KNP (Cilliers 1990.) and on exotic plants in gardens in Skukuza (Braack, unpubl.). *Orthezia insignis* is thought to have been introduced into South Africa (origin unknown) and currently has an almost country-wide distribution (Scholtz & Holm 1985).

Orthoptera

There are at least three species of non-indigenous crickets (Gryllidae) that are established in KNP, and which are likely to have been inadvertently introduced into this area through human activity (Toms, pers. comm.). The first species is the widespread and common garden cricket, *Gryllus bimaculatus* De Geer. It is present in gardens amongst leaf litter and under rocks or logs in many of the tourist camps.

Gryllodes supplicans (Walker) is also widespread in KNP and common in tourist camps, usually in cracks and crevices in rocks and even bituminized roads. It is a cosmopolitan species frequently encountered on ships.

Acanthogryllus fortipes (Walker) appears to be strictly associated with large expanses of lawn and is fairly common in many of the camps in KNP. It has an extensive distribution throughout southern Africa.

The status of *Gymnogryllus compactus* (Walker) is uncertain: it may have been introduced into KNP from more tropical areas of Africa, but may also be a low-density indigenous inhabitant. Despite extensive surveys elsewhere in KNP, Otte *et al.* (1988) recorded this species only from lawns at Skukuza.

Blattodea

Four species of cockroaches, collected in residential units in KNP since 1989, are household pests in many parts of the world.

The Australian cockroach, *Periplaneta australasiae* (Fabricius), is thought to have originated in tropical Africa but has been widely dispersed and established in virtually all the tropical and subtropical countries of the world. It is very common in houses in Skukuza where it maintains year-round activity, being present in low numbers in winter but abundant in the warmer months. Specimens are infrequently encountered in flowerbeds adjoining houses, but we have never recorded this species, or any of the other species mentioned below, in areas away from human dwellings.

The German cockroach, *Blatella germanica* (Linnaeus), was first reported in Skukuza in the spring of 1991. This species became abundant in houses during the following summer and has maintained a constant presence although with decreased activity during winter. *Blatella germanica* is thought to have originated from northeast Africa (Cornwell 1968) or Asia (Atkinson *et al.* 1991) but has become a virtually ubiquitous household pest (Rehn 1945).

Pycnoscelus indicus (Fabricius) has a cosmotropical distribution and is present in low numbers in houses in Skukuza and tourist huts in Letaba.

The cinereous cockroach, *Nauphoeta cinerea* (Olivier), also has a cosmotropical distribution but with its probable provenance being Africa. It is a 'semi-pest' usually transported with fruit into new countries (Marshall, pers. comm.) and is normally present in low numbers. One of us (L.B.) collected a single specimen of this species in KNP, from a hut at Shingwedzi during 1989.

Cockroach populations within houses in KNP were to a large extent controlled by the twice-yearly domiciliary spraying campaign sponsored by the South African Department of National Health & Population Development, but this routine spraying programme with residual insecticides (*e.g.* Cyfluthrin) was discontinued in 1991. Within the same year there was an apparent marked increase of cockroaches in residential units, which resulted in requests from staff for control measures. It is likely that *B. germanica* was present in KNP long before 1991, but had been kept at very low population numbers by the anti-malarial spraying campaign.

Thysanura

The fishmoth, *Ctenolepisma longicaudata* Escherich, is occasionally encountered in residential units in Skukuza, and there is at least one record from Satara. This species, introduced into South Africa from Europe before 1900 (Scholtz & Holm 1985; Irish 1987), is associated with human dwellings in many parts of the world and is usually transferred with books or other items in packing crates (Irish, pers. comm.). It was common in houses during the early 1980s but is currently rarely encountered, presumably a consequence of

Table 1. Exotic arthropod species recorded from the Kruger National Park.

Organism	Mode of introduction	Origin/Source	Ecological niche	Population status[1]
ACARINA				
Ixodidae				
Dermacentor rhinocerinus (Denny)	Attached to black and/or white rhinoceros	Natal, South Africa	Ectoparasite on black and white rhinoceros	Established; common
Hyalomma marginatum turanicum Pomerantsev	Unknown	Unknown	Ectoparasite on wildlife	Unknown (single record)
Rhipicephalus maculatus Neumann	Attached to nyala or black/white rhinoceros	Probably Natal, South Africa	Ectoparasite on wildlife	Established; uncommon
Galumnidae				
Orthogalumna terebrantis Wallwork	Natural dispersal	Unknown	Phytophagous on *Eichhornia crassipes*	Established; common
INSECTA				
THYSANURA				
Lepismatidae				
Ctenolepisma longicaudata Escherich	Natural dispersal	Unknown	Domestic synanthrope	Established; uncommon
BLATTODEA				
Blaberidae				
Nauphoeta cinerea (Olivier)	Natural dispersal	Unknown	Cosmotropical synanthrope	Established; uncommon
Pycnoscelus indicus (Fabricius)	Natural dispersal	Unknown	Cosmotropical synanthrope	Established; uncommon
Blattidae				
Periplaneta australasiae (Fabricius)	Natural dispersal	Unknown	Tropical/subtropical synanthrope	Established; common
Blattellidae				
Blatella germanica (Linnaeus)	Natural dispersal	Unknown	Near-cosmopolitan synanthrope	Established; common
ORTHOPTERA				
Gryllidae				
Acanthogryllus fortipes (Walker)	Natural dispersal	Unknown	Inhabits lawns	Established; common
Gryllodes supplicans (Walker)	Natural dispersal	Unknown	In cracks in rocks and road surfaces	Established; common
Gryllus bimaculatus De Geer	Natural dispersal	Unknown	Tunnels within and feeds on lawn-grass	Established; common
HEMIPTERA				
Tingidae				
Teleonemia scrupulosa (Stål)	Deliberate release on *Lantana camara*	Mexico via Hawaii	Phytophagous on *Lantana camara*	Uncertain

Table 1 – continued

Ortheziidae				
Orthezia insignis Browne	Unintentionally on ornamental garden plants?	Unknown	Sap-feeder on exotic garden plants	Established; common
COLEOPTERA				
Chrysomelidae				
Octotoma scabripennis Guérin-Méneville	Deliberate release on *Lantana camara*	Mexico	Phytophagous on *Lantana camara*	Uncertain
Uroplata girardi Pic	Deliberate release on *Lantana camara*	Brazil	Phytophagous on *Lantana camara*	Uncertain
Curculionidae				
Cyrtobagous salviniae Calder & Sands	Deliberate release on *Salvinia molesta*	Brazil	Phytophagous on *Salvinia molesta*	Established; common
Neochetina eichhorniae Warner	Deliberate release on *Eichhornia crassipes*	Australia	Phytophagous on *Eichhornia crassipes*	Established; common
Neodiplogrammus quadrivittatus (Olivier)	Deliberate release on *Sesbania punicea*	Unknown	Phytophagous on *Sesbania punicea*	Uncertain
Neohydronomus affinis Hustache	Deliberate release on *Pistia stratiotes*	Australia	Phytophagous on *Pistia stratiotes*	Established; common
Apionidae				
Trichapion lativentre (Béquin-Billecocq)	Deliberate release on *Sesbania punicea*	Unknown	Phytophagous on *Sesbania punicea*	Uncertain
DIPTERA				
Agromyzidae				
Calcomyza lantanae Frick	Deliberate release on *Lantana camara*	Trinidad via Australia	Leafminer on *Lantana camara*	Uncertain
Ophiomyia lantanae (Froggatt)	Natural dispersal	East Africa or Mexico via Hawaii	Phytophagous on *Lantana camara*	Established; common
Muscidae				
Rhinomusca dutoiti Zumpt	Eggs in rhinoceros dung	Natal, South Africa	Haematophagous on rhinoceros	Established; common
Calliphoridae				
Chrysomya megacephala (Fabricius)	Natural dispersal	Unknown	Breeds in organic waste	Established; common
Gasterophilidae				
Gyrostigma rhinocerontis (Hope)	Eggs and/or larvae with translocated rhinoceros	Natal, South Africa	Endoparasitic in rhinoceros	Established; common
LEPIDOPTERA				
Pyralidae				
Cactoblastis cactorum (Bergroth)	Deliberate release on *Opuntia stricta*	Graaff-Reinet/Uitenhage ex Australia	Caterpillars feed in cladodes of plant	Established; common
Pseudopyrausta acutangulalis (Sneller)	Natural dispersal	Unknown	Leafminer in *Lantana camara*	Established; uncommon

1. Established = a successfully breeding, viable population; Common = in the area of distribution of the species in KNP, individuals are readily encountered upon searching; Uncommon = concerted effort must be made to find even low numbers of individuals.

anti-mosquito indoor insecticidal spraying during the latter half of the 1980s. As this spraying has been discontinued the species will probably regain its previous abundance.

DISCUSSION

The inadvertent introduction and establishment of a fairly wide range of exotic arthropods in KNP has fortunately not had serious consequences.

Although we have not been able to find proof in the scientific literature, some veterinarians hold the opinion that retaining parasites on their hosts is advantageous as it stimulates the host immune system, thereby improving host vigour and ability to withstand further parasite challenge. The ramifications and uncertainty associated with this approach have possibly been the most important factors contributing to the lack of a clear, standard policy regarding deparasitizing wild vertebrates before translocation. Veterinary practice in this regard currently appears to adhere to prevailing inadequate legal requirements rather than a rational, comprehensive strategy that includes conservation considerations. Animals transferred across international boundaries are usually deparasitized, whereas wildlife moved within South African borders, irrespective of distance or locality, are only rarely subjected to such treatment (Henwood 1989; Raath & Hall-Martin 1989). We suggest that the decision should be based on the potential detrimental effects, rather than the possible but unproven advantages. These disadvantages include, amongst others: retention of parasites which may increase and kill an immunocompromised host as a result of stress through capture, captivity and transfer (*e.g. Trypanosoma*); range extension of a parasite passively transferred with a relocated host, with possible serious consequences for other animals or humans (*e.g. C. hominivorax;* Lyme disease, *Borrelia burgdorferi*); transfer to a new geographic region where the arthropod may serve as an efficient additional vector of indigenous pathogens (*e.g. Anopheles gambiae* Giles (Diptera: Culicidae) vectoring malaria following introduction into South America); introduction of a pathogen into a previously disease-free region where suitable vectors exist; translocation of both the arthropod vector and the pathogen it transmits (*e.g. Amblyomma variegatum* (Fabricius) (Ixodidae) and *Cowdria ruminantium* (Cowdry) (Ehrlichieae) from Africa to the Caribbean islands as described by Barré *et al.* (1987)); the transfer of an otherwise benign parasite from a well-adapted host to a fatally susceptible host following introduction of animals infected by *e.g. Trypanosoma, Theileria;* hybridization or loss of genetic 'purity.'

This latter aspect of maintenance of gene pool purity in geographically separated populations of the same species has received some attention when transferring vertebrate animals, such as attempts to ensure that rhinoceros transferred to a particular area retain genetic integrity by having a common geographic origin (Brooks 1989). In a world where conservation areas are relatively few and concern for preservation of biodiversity is rising, this insidious effect of genetic 'dilution' or hybridization should not be overlooked, it being as relevant to invertebrates as vertebrates.

In conclusion, we hope that game farmers, conservation bodies and other organizations involved in the capture and transfer of wildlife will routinely adopt measures to minimize the risk of passive transport of other organisms, not only internal and external parasites, but also the immature stages of beetles, flies and other organisms in faeces often present inside transport crates.

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The known distribution and ecological preferences of the tick subgenus *Boophilus* (Acari: Ixodidae) in Africa and Latin America

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Abstract. A compilation of the known distribution of *Boophilus* ticks in Africa and Latin America is presented, together with details on climate preferences. *B. annulatus* is recorded mainly in the western part of a strip from the equator to parallel 20° N. It associates with woodlands and forests (lowland rain forest and secondary grassland). This species is also present in the Mediterranean region, associated to woodland and open areas. *B. decoloratus* extends southern to parallel 20° N, in woodland with montane vegetation and Zambezian miombo; some records have been collected in the highveld grassland. *B. geigyi* is mainly collected in the western range of a stripe extending between parallels 5° N and 18° N, associated with Sudanian woodland, lowland rain forest with secondary grassland and woodland. Confirmed records of *microplus* in Africa are restricted to Malagasy region and south and eastern Africa, being predominant in the Zambezian miombo, deciduous forest with secondary grassland, and woodland. In Latin America, *microplus* is abundant in the Mesoamerican corridor to Venezuela and Colombia, and southern in Brazil and Argentina. The tick is mainly associated to the biomes of Chaco and Pampas in Argentina, the North-central moist Andes, the Atlantic forest (southern range) and the moist Meso-American vegetation (northern range). Most collections of *B. annulatus* and *B. geigyi* came from areas where winter minimum temperature is above 15 °C, maximum temperatures remain between 33 and 36 °C and maximum rainfall is recorded between June and September. *B. decoloratus* and African *B. microplus* are recorded in sites with low temperatures in May–September. Minimum temperature requirements are similar for both *B. decoloratus* and African *B. microplus*, and both are around 4 °C less than the value recorded for collections of Latin-American *B. microplus*. The rainfall pattern observed for *decoloratus* shows a minimum in May and June. The requirements of total rainfall are highest for *B. microplus* in Latin America, while records of African *B. microplus* are concentrated in areas of low rainfall between May and October, and high rainfall between November and March (low rainfall in the same period for *B. decoloratus*). Statistical analysis revealed the existence of populations (demes) with ecologically different requirements within each tick species. Both *B. annulatus* and *B. decoloratus* showed many different demes clearly associated

to defined areas. The collections of Latin American *B. microplus* are very homogeneous according climate preferences and well separated from the African counterpart.

Introduction

Boophilids are some of the most important tick species in the world from an economical point of view. Each of the five *Boophilus* species has a one-host life cycle that may be completed in 3–4 weeks and results in heavy tick burden (Walker et al. 2003). *B. microplus*, considered the most important parasite of livestock in the world, has been introduced from the bovid- and cervid-inhabited forests of the Indian region to many areas of tropical and subtropical Asia, northeastern Australia, Madagascar, coastal lowlands of southeastern Africa to the equator, and much of South and Central America, Mexico and the Caribbean. *B. annulatus*, original from the former southern USSR, the Near and Middle East, and the Mediterranean area, was introduced with livestock of the early Spanish colonialists into northeastern Mexico but has not spread into Central America. *B. microplus* and *B. annulatus* were eradicated from the USA after a long, costly control program, and constant surveillance is maintained to prevent its reintroduction (George 1987). *B. decoloratus*, which ranges from southern Africa to the Sahara, is being replaced in the eastern and southeastern part of this area by *B. microplus*. This seems to be caused by the shorter life cycle of *microplus*, as well as the tendency to assortative mating and more successful feeding on cattle and is cause of much concern in the area, because the expansion of *microplus*-transmitted pathogens (Tonnesen et al. 2004). In more humid West African zones, *B. annulatus* mixes with or is totally replaced by *B. geigyi*. However, no competition has been reported between these species, as little is known from the life cycle of *B. geigyi*. *B. annulatus* further extends into eastern Africa, as a line southern to the limits of Sahara desert. The only boophilid restricted to sheep and goats (and occasionally horses) is *B. kohlsi* of Syria, Iraq, Israel, Jordan, western Saudi Arabia, and the Yemen. *Boophilus microplus* is an experimental vector of *Theileria equi*, and this tick and *B. annulatus* are major vectors of *Babesia bigemina*, *Babesia bovis*, and *Anaplasma marginale*. *B. decoloratus* is an efficient vector of *B. bigemina* and *A. marginale* but does not transmit *B. bovis*. This tick apparently does not transmit *T. equi*, but it is an experimental vector of *A. marginale* to cattle. Recent studies of the taxonomy of the group, using molecular taxonomy methodologies, have proposed a radical change placing the five species in the genus *Boophilus* in the genus *Rhipicephalus* (Murrell et al. 2000; Beati and Keirans 2001). Horak et al. (2002) proposed to *Boophilus* as a subgeneric epithet. Throughout this paper, however, *Boophilus* will be used as not final decision about the taxonomic status of these five species has been officially approved. It should be noted that this does not imply a position about the systematics of the boophilids, but only a way to refer to the ticks included in this study.

Ecological niches delineate the set of conditions under which species can maintain populations in the long-term. Individuals living outside the niche

conditions do not replace themselves. There is a wide theoretical treatment of the features of the ecological niche (Holt 1996; Holt and Gomulkiewicz 1996) that clarifies the relationships between ecological niche, geographic distributions and evolutionary dynamics. These studies suggest that, in general, long-term natural selection pressures will maintain the ecological niche without substantial modification. This reasoning supports the idea that species ecological niche represents long-term stable constraints on geographic distributional potential. The fundamental niche can be viewed as the set of conditions and resources that allow a given organism to survive and reproduce in the absence of biotic interactions. An understanding of the fundamental niche can provide us with greater insight into the causes of distribution and abundance. This is a solid foundation for exploring the role of biotic interactions and to extrapolate with greater confidence the adaptation to novel circumstances such as climate change and species introductions. We present in this study data about the known distribution of *Boophilus* ticks in Africa and Latin America. Populations of ticks of the same species are detected, as groups of ticks supporting different climate conditions. An overview of the climate preferences as calculated among the statistically detected populations of ticks is also presented, as a mechanistic approach to study the climatic component as driving force of the distributions of ticks in the subgenus.

Material and methods

The basis for the current study has been the huge compilation of data on the distribution of ticks in Africa, Latin America and the Caribbean performed by the authors (ICTTD 2004). In that preliminary study, published records from ticks as well as data from collections in scientific institutions were compiled, edited by local experts, and mapped to latitude and longitude coordinates. Data from a previous compilation by Cumming (1999) have been also edited to remove inaccurate references or misdeterminations, and added to the database. The compilation on which this paper is based is thus the largest database on the recorded distribution of *Boophilus* ticks. Some data have not been used, as follows. *B. kohlsi* was not included in the original compilation because its importance for domestic animals is unknown (Walker et al. 2003). Our current knowledge about the distribution of *Boophilus* ticks in areas of Asia is still fragmentary. This study is intended to provide a complete review in the areas were these ticks are present, so it has been considered better to not incorporate the records from Asia. Data on *B. microplus* in Australia are selective for the area known to be infested and we lack adequate references (geographical data) to collection sites. Therefore, only records from Africa and the Neotropics have been included. Records from *B. annulatus* in the Americas have been also omitted, as the presence of this taxon in the region is scattered. Furthermore, early records from both *B. microplus* and *B. annulatus* in USA have been avoided, as it is difficult to ascribed these records to the climate at the time they

were collected. For the whole study, records lacking an adequate geographical reference were not included.

This database of tick records has been checked against a spatially and temporally extensive gridded climate data set that extends between 1950 and 1999. The data set of world climate was built by New et al. (1999) and was developed by interpolating observations taken at meteorological stations, corrected with the altitude. This is a gridded data set that contains monthly records of temperature (mean, minimum and maximum) and precipitation (monthly total) at a resolution of 10 km. Other than these basic monthly variables, we compiled a further set of 19 variables that are herein called yearly variables. Those explain much of the variability in the year, and contribute to further homogenize observations. The yearly variables are 1: Annual Mean Temperature, 2: Mean Diurnal Range (Mean of monthly (max temp – min temp)), 3: Isothermality (2/7 * 100), 4: Temperature Seasonality (standard deviation * 100), 5: Max Temperature of Warmest Month, 6: Min Temperature of Coldest Month, 7: Temperature Annual Range (5–6), 8: Mean Temperature of Wettest Quarter, 9: Mean Temperature of Driest Quarter, 10: Mean Temperature of Warmest Quarter, 11: Mean Temperature of Coldest Quarter, 12: Annual Precipitation, 13: Precipitation of Wettest Month, 14: Precipitation of Driest Month, 15: Precipitation Seasonality (Coefficient of Variation), 16: Precipitation of Wettest Quarter, 17: Precipitation of Driest Quarter, 18: Precipitation of Warmest Quarter, 19: Precipitation of Coldest Quarter.

We extracted both monthly and yearly variables for each tick record. Care was taken to associate each tick record with the climate at the time the collection was done, using the averaged climate values of the year of capture (as included in the tick database) and the 5 previous years. This procedure provided every tick record with the climate to which it has been associated and avoided the bias derived from the connection of the tick record with uncommon climate values. No attempts were done to obtain also climate features from sites where no data on *Boophilus* ticks was available to compare with climate values for ticks records. The mapping of ticks as absent in sites where only other species were collected may introduce a potentially dangerous bias in the actual distribution of a species. For each tick species, we obtained the range of values (mean ± SD) for every monthly and yearly variable.

The complete set of records for each species was separated in demes, representing populations of ticks within the same species collected in statistically different ecologically zones. This part of the study is intended to know if populations with statistically different climate preferences exist in diverse geographic areas and to understand the ecological niche relationships within demes of each species. This point has major implications in predictive mapping, as projecting algorithms are commonly evaluated over populations covering relatively large areas. It has been already demonstrated that habitat classification (presence/absence) accuracy for *Glossina* spp. became further accurate by subdividing the habitat into ecological zones prior to performing discriminant analysis (Robinson 1998). However, we cannot use only climate to sub-

divide the habitat into significantly different zones, as the climate conditions under which the ticks have been collected would be correlated with these climatically different regions. The subdivision of the area into statistically different zones based solely on climate would provide automatically different tick populations. For this purpose, we selected a set of remotely sensed images with monthly information of Normalized Derived Vegetation Index (NDVI, which is linearly uncorrelated with climate) and performed an unsupervised classification of the habitat in Africa (including the Mediterranean part) and Latin America. The procedure provided with an assemblage of NDVI-based habitat categories, whose NDVI value are statistically homogeneous within each category, and different for zones between separate categories. Records of each species as collected into each vegetation category were initially treated as separate demes. A cluster analysis was performed in using the climate data associated to every tick record to understand the relationships of the species as clusters in the *n*-dimensional space of the climate variables. To avoid bias in the estimation, vegetation categories representing less than 5% of the captures of the species were avoided in further analysis. This procedure allows a direct comparison of the climate requirements by the strict definition of the space of variables as requirements or each species. Special attention was paid to *B. decoloratus* and the African records of *B. microplus*. The spread of *B. microplus* in Africa has been already reported for some parts of the continent, replacing *B. decoloratus* in parts where the climate is suitable for the invader (Tonnesen et al. 2004). This procedure will provide with information about the ecological space occupied by both species, and the degree of ecological plasticity of *B. microplus* in Africa.

Results

Figures 1 to 3 display the zones where boophilid ticks have been collected, with information about the vegetation categories separated according NDVI. *B. annulatus* is present in a relatively wide strip extending from the equator to parallel 20° N, being predominant in the western part of this stripe (Figure 1a). The species is also present north of the Sahara, with most collections in Morocco and Tunisia, and scattered in zones of Egypt, Libya and Algeria. It associates with two main types of vegetation dynamics, namely one which remains at low NDVI values for much of the year (Mediterranean region and first zone south of Sahara desert) and one with clear increase in NDVI after July–August, coinciding with the rainy season. The species has been collected as associated mainly with woodlands (Sudanian and undifferentiated woodland) and forests (lowland rain forest and secondary grassland). *B. decoloratus* extends into much of Africa, southern to parallel 20° N with some isolated records northern to Sahara. These records appear to be accidental importations. It is associated with several vegetation categories, all of them but two being characterized by a prominent decrease of NDVI values between May and

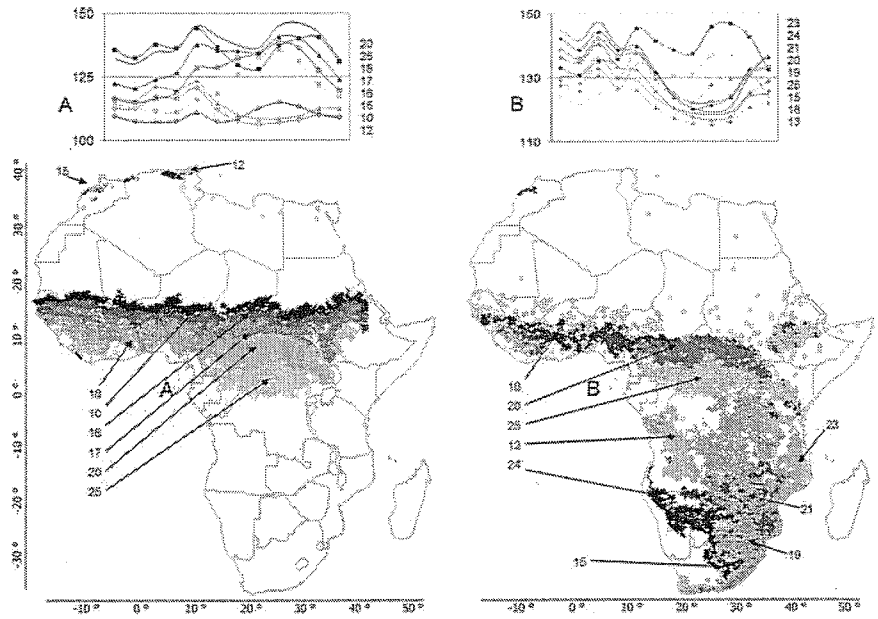

Figure 1. Distribution range of *B. annulatus* (a) and *B. decoloratus* (b) in Africa. Dots show the confirmed records of these ticks. Areas in different shades of grey are the statistically different vegetation areas (according to monthly NDVI values) determined by unsupervised classification, to which records of ticks are associated. Areas where less than 5% of tick records of each species have been collected are not shown. Maps include reference to Latitude and Longitude (bars below and lateral). Upper to each map is a chart with the monthly profile of NDVI values for each vegetation zone, in a range from 0 to 256. Each number as associated with areas in the map and charts are the vegetation classes as recorded by unsupervised classification of NDVI values.

September and then an increase in the last part of the year. The two remaining regions, located at the northern portion of its distribution range (arrows in Figure 1b), are characterized by high values of NDVI, with an increase after September. *B. decoloratus* has been collected associated to a variety of biomes. It is a tick of woodland, mainly undifferentiated woodland with montane vegetation and Zambezian miombo. Some records have been collected in the highveld grassland. *B. geigyi* is mainly collected in the western range of a narrow stripe extending between parallels 5° N and 18° N, although the vegetation zones where the tick has been found extend well into eastern Africa. All these categories of vegetation are characterized by relatively high NDVI values with a small decrease in July–August. The exceptions are the zones in the northern range of distribution (mainly in central Mali) where NDVI values are low in the first months of the year. The species is mainly associated to Sudanian woodland, lowland rain forest with secondary grassland and undifferentiated woodland. A significant proportion of captures has been collected associated to wetter types of lowland forests. Confirmed records of *B. microplus* in Africa are restricted to Malagasy region and south-eastern Africa, in areas mainly

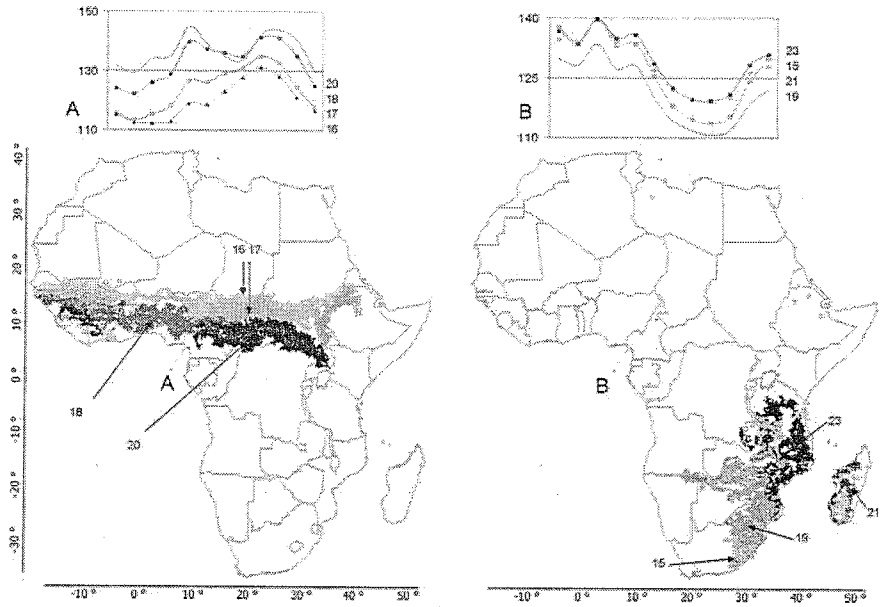

Figure 2. Distribution range of *B. geigyi* (a) and *B. microplus* (b) in Africa. Dots show the confirmed records of these ticks. Areas in different shades of grey are the statistically different vegetation areas (according to monthly NDVI values) determined by unsupervised classification, to which records of ticks are associated. Areas where less than 5% of tick records of each species have been collected are not shown. Maps include reference to Latitude and Longitude (bars below and lateral). Upper to each map is a chart with the monthly profile of NDVI values for each vegetation zone, in a range from 0 to 256. Each number as associated with areas in the map and charts are the vegetation classes as recorded by unsupervised classification of NDVI values.

characterized by very low NDVI values between July and October, coincident with a dry season (see below) while keeping high the rest of the year. While the vegetation zones where *B. microplus* has been found in Africa are easily characterized by NDVI values, they fall within a wide range of biomes, the tick being predominant in the Zambezian miombo, the mosaic of dry deciduous forest with secondary grassland, and the undifferentiated woodland. In Latin America, *B. microplus* has a bipolar distribution, being abundant in the Mesoamerican corridor to Venezuela and Colombia, and southern in Brazil and Argentina. Scatter records occur in the Amazonian region, probably as result of importations. *B. microplus* occupies two types of vegetative areas according to NDVI values: the first is located in the northern portion of its distribution range, and characterized by relatively high, slightly variable NDVI values through the year, while the second is located in its southern distribution range, and characterized by very high NDVI values with a sharp decrease in mid-winter (August–October). The tick is mainly associated to the biomes of Chaco and Pampas regions in Argentina, together with the North-central moist Andes, and the Atlantic forest (southern range) and the moist Meso-American vegetation (northern range).

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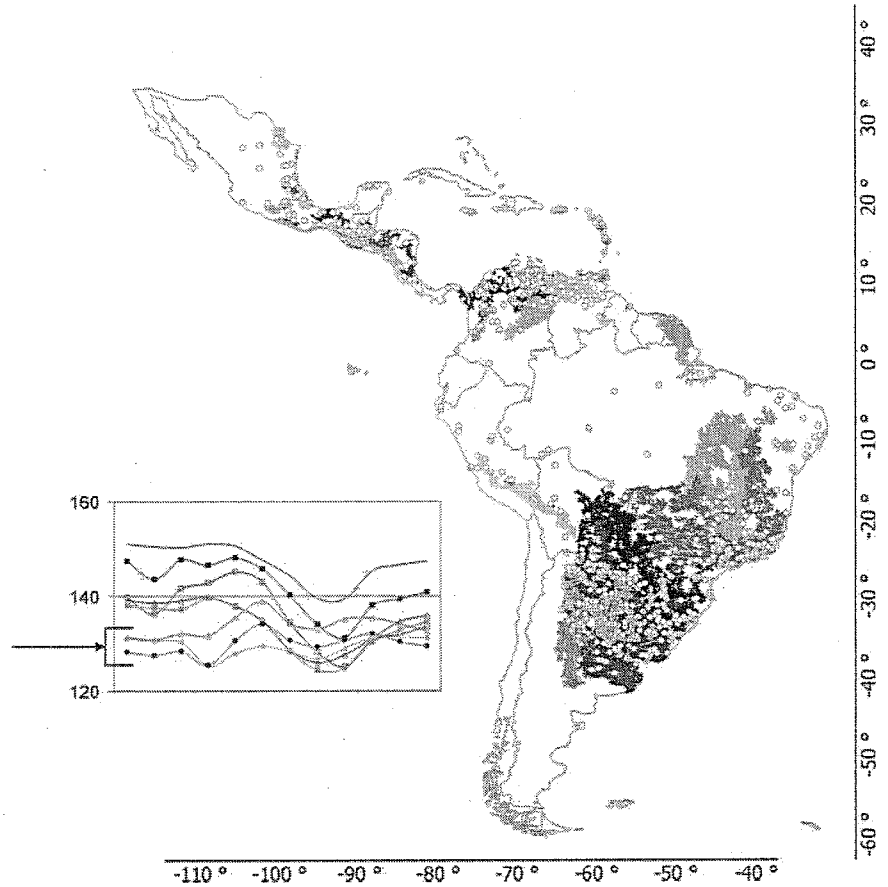

Figure 3. Distribution range of *B. microplus* in Latin America. Dots show the confirmed records of these ticks. The tick is present in many parts of the Caribbean, but adequate coordinates to these records are lacking. Areas in different shades of grey are the statistically different vegetation areas (according to monthly NDVI values) determined by unsupervised classification, to which records of ticks are associated. Areas where less than 5% of tick records of each species have been collected are not shown. Map includes reference to Latitude and Longitude (bars below and lateral). Upper to the map is a chart with the monthly profile of NDVI values for each pictured vegetation zone, in a range from 0 to 256. Arrows in chart point to the monthly NDVI pattern observed for the Meso-American corridor. The other lines correspond to the different areas in the southern distribution range.

Figure 4 shows the averaged monthly and yearly climate variables as recorded in the sites of tick collections. Both *B. annulatus* and *B. geigyi* are the species with preferences towards high temperatures. They have been mainly collected in areas were winter minimum temperature is above 15 °C. They prefer zones where maximum temperatures remain between 33 and 36 °C. The requirements for temperatures are always higher for *B. geigyi* than for *B. annulatus*. Both species have been collected in areas were maximum rainfall

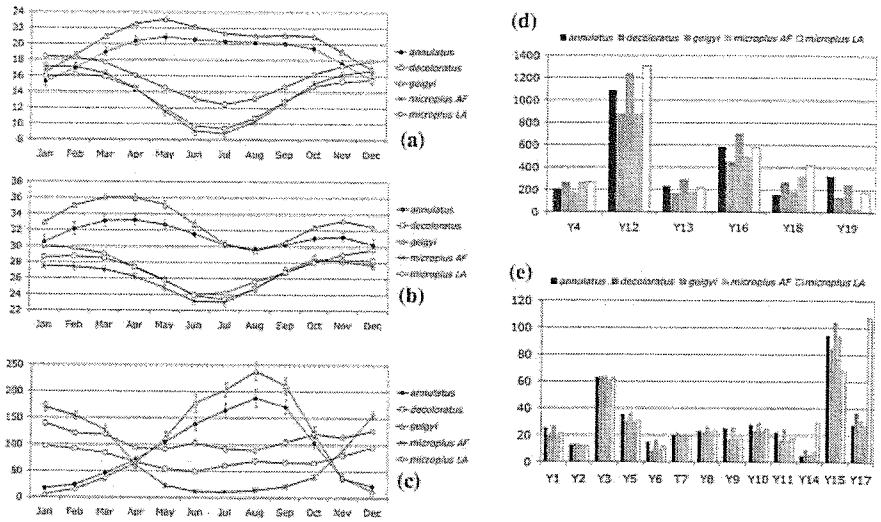

Figure 4. Mean monthly (a, b, c,) and yearly (d, e) values of climate variables recorded for the known collections of *B. annulatus*, *B. decoloratus*, *B. geigyi* and *B. microplus* (in both Latin America, LA, and Africa, AF). Figure 4a shows the mean minimum monthly temperatures recorded for collection points of the species, (b) the mean maximum temperatures, and (c) the mean monthly rainfall. Bars represent SD. Figures 4d and e display the yearly variables (Y) with a number according the list of variables in Material and Methods.

is recorded between June and September (Figure 4c). Populations of these two species support a period of low rainfall when temperatures are maximum. Both species have high requirements of annual precipitation, precipitation of wettest month and precipitation of wettest quarter (Y12, Y13 and Y16, respectively, higher for *geigyi)*, while supporting the smallest values for the precipitation of the warmest quarter (Y18). It is interesting to compare the temperature preferences of both *decoloratus* and African *microplus*. While summer temperature requirements are higher for *microplus*, recorded values for winter are slightly lower than those observed for *decoloratus*. Minimum monthly temperatures are similar for *B. decoloratus* and the African populations of *B. microplus*, and both are around 4 °C less than the mean recorded for sites of collections of *B. microplus* in Latin America. The rainfall outline observed for *decoloratus* shows a pattern of low rainfall regimes, with minimum in May and June. The requirements of rainfall for *microplus* in Latin America are higher, while African *microplus* are concentrated in areas of very low rainfall between May and October, and high rainfall between November and March. The periods of high rainfall in African *microplus* coincides with the periods of maximum temperatures supported by these populations. Although African populations of *microplus* have requirements of high total rainfall, they can support long periods of dryness in winter. Figures 2d and e include the average values observed for the yearly variables. Critical differences can be observed in the precipitation of driest month, precipitation seasonality and precipitation of

driest quarter (Y14, Y15 and Y17) as related with American *microplus* records, for which precipitation seasonality is smaller than for other species and the total rainfall in the driest month and quarter is higher. Interestingly, preferences of American *microplus* for total precipitation show values three times higher than for other taxa analysed.

Figure 5 shows the cluster analysis as performed separately among the demes of each population. In this figure, each symbol corresponds to a record of the species, collected in one of the vegetation areas as separated by signature analysis of the NDVI monthly values. This kind of analysis provides information about the relative position within the space of ecological preferences, and the degree of ecological separation among the demes. The records of *B. annulatus* as well separated demes are easily appreciated, being the bottom-right records those collected around Mediterranean zones. However, sub-Sahelian records appear close to the rest of collections, meaning for similar preferences. Figure 5b displays the relative position of records of both *B. decoloratus* and African *B. microplus*, considered as a whole without separation in demes. It is easily observed that the preferences of *B. microplus* lie almost in the middle of the space of preferences of *B. decoloratus* ticks. Furthermore, it is observed (Figure 5c) that demes within *decoloratus* constitute a very heterogeneous assemblage. Critical demes lying in the border of the statistically homogeneous envelope of the species are those labelled as 25 (portions of Ethiopia, Democratic Republic of Congo and Cameroon, see also Figure 1) and 18 (much of the western distribution range, see Figure 1). Specimens within the deme labelled as 15 have been dispersedly collected in Eastern Africa, in small transitional areas of undifferentiated woodland, Zambezian miombo and zones of mosaic of evergreen bush land and secondary Acacia grassland. It seems that the main factor separating this deme from the main ecological preferences of the species is the relatively high altitude of collections, which causes lower temperatures. Collections for *B. geigyi* specimens show a clear separation among the only 4 demes analysed (Figure 5d). Demes 15 and 16 (collected in the sub-Sahara zones, with lowest NDVI values) are close one to each other in their climate preferences, while deme 20 (recorded in most vegetated parts of western Africa) has obvious differences with the formers. Specimens in deme 18 lie in an intermediate position between the remaining demes. The collections of Latin American *microplus* are very homogeneous according to their climate preferences (Figure 5e) and only deme 47 (present in the North-central moist Andes) appears as separated from the remaining tightly grouped demes.

Discussion

This study presents the distribution and climate preferences of four boophilid tick species in Africa and Latin America, from a database of tick collections including more than 24,000 edited records. Therefore, it is the most extensive

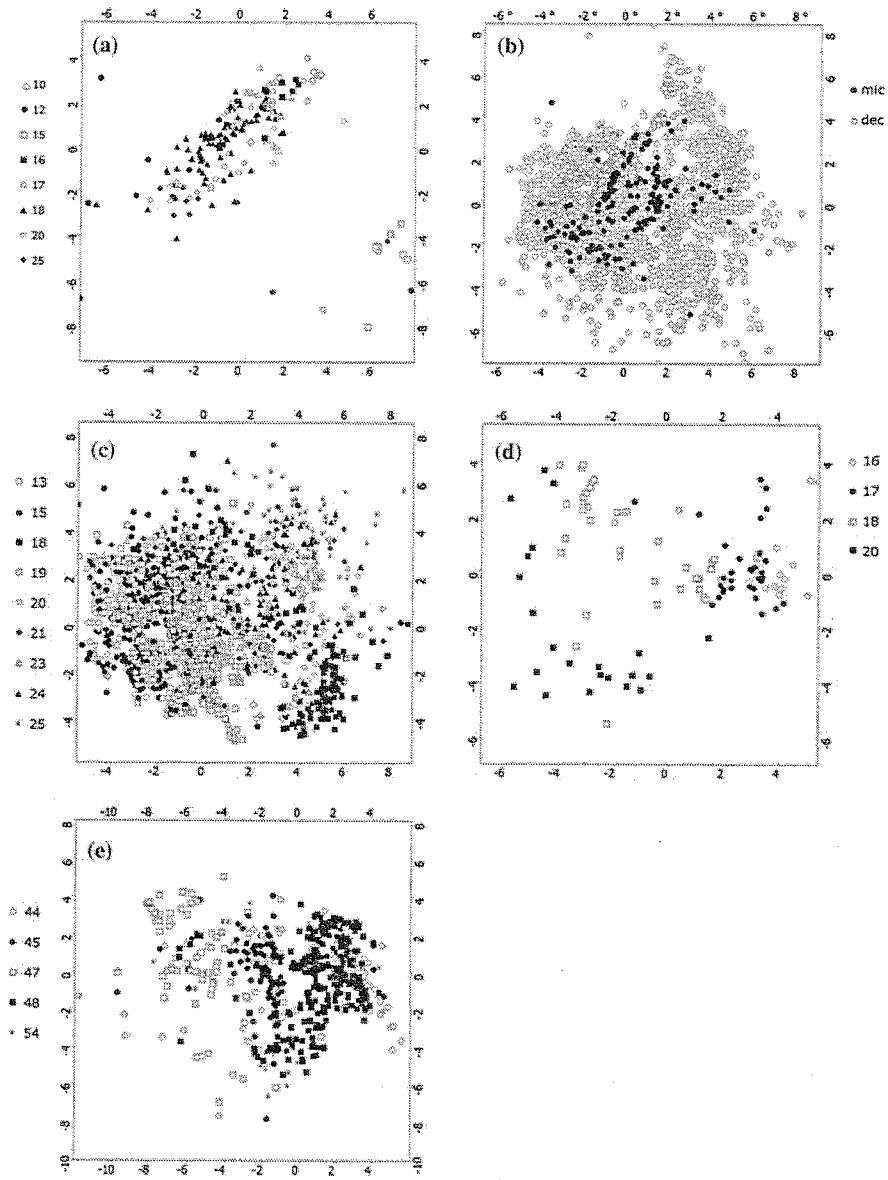

Figure 5. Cluster analysis of demes of *Boophilus* ticks, separated according to the classification of remotely sensed vegetation features (as displayed in Figures 1 to 3). Each symbol represents a deme, identified with a unique number, according to the vegetation category as displayed in previous figures. The charts show the coordinates in the factorial plane of the first two axes of the collections belonging to a given deme. (a) *B. annulatus*; (b) compared distribution of populations of African *B. microplus* (mic) and *B. decoloratus* (dec) without separation in demes; (c) *B. decoloratus*; (d) *B. geigyi*; (e) Latin American *B. microplus*. The analysis was not done separately for African records of *B. microplus* because the high dispersion of records.

and updated registry of the distribution of these ticks within the regions considered. Much work remains to be done with records of *B. microplus* in Asia and the distribution of *B. annulatus* in the former soviet republics. References for these regions lack adequate spatial references (Morel 1965), and accession to the original collections to check the species determination is sometimes difficult.

Cluster analysis has been used in this paper to compare the climate preferences of the involved species, by assessing the *n*-dimensional space of the climate variables as occupied by each species. Hutchinson (1957) defined the fundamental ecological niche as comprising those environmental conditions within which a species can survive and grow: a conceptual space whose axes include all the environmental variables affecting that species. Unsupervised classification of monthly composites of the Normalized Difference Vegetation Index (NDVI) has been explored to further divide each continent into areas with ecological meaning. The classification produces a set of categories based on the seasonal dynamics of NDVI, enclosing regions that are homogeneous within each category and statistically different between them, providing a framework to compare the ecological preferences of the tick populations of each species (called herein demes) collected in the regions. NDVI is an estimation of the vegetation stress and is not linearly correlated with single climate variables (Rasmussen 1998). This procedure together with cluster analysis on demes has been able to show the existence of significant differences in the climate data recorded for the demes within the same species. There is increasing evidence that the concept of undifferentiated species comprising individuals with broad tolerances is not correct (Davis and Shaw 2001). Intra-species variation makes it impossible to define precise limits to the climatic tolerance of a species since there is no guarantee that the limits for one deme at one range margin will be exactly the same as those for another deme at another margin. Predictive modelling of species geographic distributions based on the environmental conditions of sites of known occurrence constitutes an important technique in analytical biology. In this context, a niche-based model represents an approximation of a species ecological niche in the examined environmental dimensions. In a study over a large region, spatial variation exists in the environmental conditions available to the species. It is expected that, for large regions and with the usual spatial variations in environmental conditions, differentiated populations of the target species may exist, occupying different steps within the fundamental niche of the species. These populations are obscured when niche-based models are applied to the whole area of the species distribution. Given that the prediction engines are feed with every available record, geographically projected results can be dangerously biased if populations are not recognized and modelled separately (Osborne and Suárez-Seoane 2002).

Both *B. geigyi* and *B. annulatus* have been collected in areas displaying highest temperatures, and high seasonal rainfall. The known African distribution of the two species lies within a narrow band extending into the

parallels 10° and 20° N. *B. geigyi* is restricted to the warmer and more humid portions of western Africa, while *B. annulatus* extends further east. The later is also common in the Mediterranean basin. Both branches of the African *B. annulatus* distribution (Mediterranean and sub-Saharan) are clearly different according to cluster analysis, but these differences may be produced because the distinct seasonality in the climate recorded in both parts of the distribution range. Anyway, vegetation signatures are clearly different between these demes, those located in the Mediterranean and immediately south of Sahara having a low yearly NDVI, while those collected further south displaying high yearly NDVI values. Analysis of records of *B. geigyi* provides the separation into heterogeneous clusters, demes collected in central and south Mali clustering closely, and those recorded from the most western portions in Africa (around parallel 10° W) into a different group. It is of interest to note that the vegetation areas to which *geigyi* is associated extend further into east Africa. The absence of the species from eastern portions of the Continent may be due to misidentifications or to the absence of adequate prospective work in the zones. Both *annulatus* and *geigyi* may appear together as they share the main signature of NDVI in western Africa. Nothing is known about the compared seasonal activity of both species in the zones where their distribution overlaps.

Boophilus decoloratus is widespread in sub-Saharan Africa. It is absent from deserts and in the most humid parts of central Africa. It is a species with requirements of low temperature and rainfall, being present at most altitude ranges and almost under rainfall zones, being most common in zones obtaining 500–1000 mm per year, surviving in zones with an annual rainfall as low as 380 mm (Walker et al. 1978). *B. decoloratus* can survive in areas where there is a maximum of 90 days of frost spread over a period of 150 days a year (Gothe 1967). At lower temperatures there may be pockets of suitable climatic conditions where it can survive (Theiler 1949). Cluster analysis suggests a relative homogeneity within the demes collected through the continent. Only the specimens collected at the northern part of its distribution range (associated with areas of high and almost seasonally invariable NDVI) show a certain degree of heterogeneity when compared with other demes of the species. The remaining zonesto which it is associated show the same pattern in NDVI: a period of high NDVI values between January and July, then a sudden decrease of this index. In areas of western Africa, *decoloratus*, *annulatus* and *geigyi* may appear associated, but there is a trend for *B. decoloratus* to be located in areas of lower temperature and rainfall.

There is a clear contrast between climate preferences recorded for *B. microplus* in both Africa and America concerning monthly maximum temperatures (higher in American collections), precipitation of driest and coldest quarters (three times higher in American records) and rainfall seasonality (very marked in African collections). However, it must to be realized that high rainfall in the African records has been recorded in the summer period. Therefore, although total rainfall preferences are higher in *B. microplus* than in *B. decoloratus*, the former may stand in areas with relatively long periods of

dryness, probably synchronizing the cycle to avoid coincidence of critical phases with drought. Some references to the rainfall preferences of *B. microplus* in Africa points to high rainfall requirements, like the comments by Theiler (1962, "in all probabilities collected from well irrigated farms") Yeoman and Walker (1967, "must be considered a species of the high rainfall areas...from 400 to 1000 mm") and De Vos) 1979, "absent in areas where rainfall is less than 500 mm"). Seasonal rainfall changes supported by *B. microplus* have been reported as similar to those supported by *B. decoloratus* (Arthur and Londt 1973) as recorded in the current paper.

Cluster analysis between *B. decoloratus* and *B. microplus* shows that the African *B. microplus* are located within the *n*-dimensional ecological niche of demes of *B. decoloratus*. Therefore, the ecological preferences of African *microplus* cannot be extrapolated from those of American populations. In Africa, *B. microplus* had not invaded all areas that were climatically favourable for this species, as obtained by a modelling approach Sutherst and Maywald 1985). This failure was interpreted as being due to attempted interbreeding between *B. microplus* and *B. decoloratus*, resulting in a zone of sterile hybrids, which would present a barrier to further spread (Sutherst 1987). Several authors have discussed the mechanisms of the displacement of one species by the other. We think that previous models should be re-evaluated with the current knowledge of African *B. microplus* preferences. Anyway, there are large geographic areas at risk of colonization by *B. microplus* in Africa, if the tick should continue to spread from its present sites. The tick is common in parts of South Africa, Swaziland, Zimbabwe, where it was probably introduced from Mozambique in the mid-1970s (Norval et al. 1992) or Zambia, and already reported for other parts in Africa (Theiler 1962; McLeod and Mwanaumo 1978; Berkvens et al. 1998). The spread has been recently observed in Tanzania (Lynen, personal communication). Realistic simulations of the impact of climate on the spread of *B. microplus* in Africa will require a better understanding of the complex interactions between the many factors affecting distribution, including dynamic models to simulate the relationships between climate and the potential of the species to disperse through fragmented landscapes, and the relations between *B. microplus* and *B. decoloratus* on host.

The primary purpose of this study should then be regarded as an attempt to provide an accurate ecological basis in the building of predictive models of tick distribution under current and future climate conditions in the considered regions. Modelling strategies for predicting potential distributions of ticks have focused on the characterization of the bioclimate envelope (Cumming 2002; Olwoch et al. 2003; Estrada-Peña 2003). Some recent studies have questioned the validity of this approach by pointing to the many factors other than climate that play an important part in determining species distributions (Davies et al. 1998; Lawton, 2000). Concerning ticks, both dispersal ability by hosts and vegetation may have potential impact in the predictive mapping. However Pearson and Dawson (2003) concluded that the bioclimate envelope approach could provide a useful first approximation, stressing also the importance of the

spatial scale. The limit of the scale in our work and the accuracy of some records imposed a restriction to additional studies on associations with the vegetation. Cumming (2002) proposed that continental-scale distributions of ticks are principally determined by climate, and it is therefore suggested that many species distributions can in fact be considered to be in equilibrium with the current climate at the macro-scale. Genetic adaptation of species is rarely considered, being range shifts frequently seen as the expected response to the climate. It is usually expected that evolutionary change occurs only on long time scales and that the tolerance range of a species remains the same as it shifts its geographical range (Pearson and Dawson 2003). However, studies have shown that climate-induced range shifts can involve not only migration into newly suitable areas, but also selection against phenotypes that are poorly adapted to local conditions (Davis and Shaw 2001). The finding of *Boophilus* populations with statistically different climate preferences should be regarded as an additional problem in understand and map the climate factors responsible for tick distribution. Of particular importance is the divergence of African and American *B. microplus* populations and the apparent difficulty to capture the evolving ecological plasticity of tick populations.

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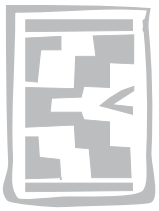

Climate change and the genus *Rhipicephalus* (Acari: Ixodidae) in Africa

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ABSTRACT

OLWOCH, J.M., VAN JAARSVELD, A.S., SCHOLTZ, C.H. & HORAK, I.G. 2007. Climate change and the genus *Rhipicephalus* (Acari: Ixodidae) in Africa. *Onderstepoort Journal of Veterinary Research*, 74:45–72

The suitability of present and future climates for 30 *Rhipicephalus* species in Africa are predicted using a simple climate envelope model as well as a Division of Atmospheric Research Limited-Area Model (DARLAM). DARLAM's predictions are compared with the mean outcome from two global circulation models. East Africa and South Africa are considered the most vulnerable regions on the continent to climate-induced changes in tick distributions and tick-borne diseases. More than 50 % of the species examined show potential range expansion and more than 70 % of this range expansion is found in economically important tick species. More than 20 % of the species experienced range shifts of between 50 and 100 %. There is also an increase in tick species richness in the south-western regions of the sub-continent. Actual range alterations due to climate change may be even greater since factors like land degradation and human population increase have not been included in this modelling process. However, these predictions are also subject to the effect that climate change may have on the hosts of the ticks, particularly those that favour a restricted range of hosts. Where possible, the anticipated biological implications of the predicted changes are explored.

Keywords: Climate change, *Rhipicephalus* species, sub-Saharan Africa, tick-borne disease

INTRODUCTION

The realization that species distributions are significantly influenced by climate has placed considerable emphasis on the need to acquire information concerning the ways in which the present distributions of organisms will be affected by climate change. In response to this challenge, the issue of vector distribution has recently received much attention. Numerous studies (Sutherst & Maywald 1985; Nix 1986; Perry, Lessard, Norval, Kundert & Kruska 1990; Norval, Perry & Young 1992; Rogers & Randolph 1993; Sutherst, Maywald & Skarratt 1995; Randolph & Rogers 1997; Estrada-Peña 1999; Rogers & Randolph 2000; Randolph 2001, 2002; Erasmus, Kshatriya, Mansell, Chown & Van Jaarsveld 2000; Erasmus, Van Jaarsveld, Chown, Kshatriya & Wessels 2002; Olwoch, Rautenbach, Erasmus, Engelbrecht & Van Jaarsveld 2003; Van Staden, Erasmus, Roux, Wingfield & Van Jaarsveld 2004; Thomas, Cameron, Green, Bakkenes, Beaumont, Collingham, Erasmus, Ferrierra, Grainger, Hannah, Hughes, Huntley, Van Jaarsveld, Midgley, Miles, Ortega-Huerta, Peterson,

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Philips & Williams 2004) have attempted to predict the distribution of species based on the major environmental factors that would influence this.

This approach neither disregards the need for further detailed and comprehensive eco-physiological studies nor does it pretend to predict the future. What it does is define the role of climate as a factor in determining the potential for future vector establishment when all other elements are excluded (Sutherst 2003). This paper also accents the necessity of acquiring more detailed information concerning the biology and environmental sensitivities of each species in the light of likely climate change. In the absence of such information, relatively straightforward statistical methods that seek correlations between environmental factors and the presence of animals or plants are likely to remain the best pragmatic approach for exploring the expected future distributions of large numbers of species. This study focuses on climate induced changes likely to occur in the distribution of some species of an economically important African arthropod, namely the tick genus *Rhipicephalus*.

The intimate relationship between climate and the requirements of ticks for survival is well documented (Tukahirwa 1976; Rechav 1981, 1982; Short & Norval 1981; Minshull & Norval 1982; Norval, Walker & Colborne 1982; Dipeolu 1989; Perry *et al.* 1990; Norval *et al.* 1992; Okello-Onen, Tukahirwa, Perry, Rowlands, Nagda, Musisi, Heinonen, Mwayi & Opuda-Asibo 1999). This has led to several studies using climate as a means of predicting the distributions of African ticks (Rogers & Randolph 1993; Randolph 1993, 2001; Randolph & Rogers 1997; Norval, Sutherst, Kurki, Kerr & Gibson 1997; Cumming 2000a, b; Estrada-Peña 2001; Olwoch *et al.* 2003). Collectively the results obtained from these works, some of which used data garnered mainly from interpolated climate databases at 25 km resolution (Perry *et al.* 1990) or 6 x 6 km resolutions (Cumming 2000b), suggest that accurate predictions of tick distributions at different temporal and spatial scales should be feasible. This approach would be especially useful for predicting the distribution of species in poorly sampled species in poorly sampled regions of Africa.

The genus *Rhipicephalus* is the fourth largest in the Family Ixodidae (Walker, Keirans & Horak 2000), and there are 74 species currently recognized. It is essentially an African genus with approximately 63 species recorded only in the Afro-tropical region and ten species outside the region. One species, *Rhipicephalus evertsi evertsi* Dönitz, 1910, whose distribution was originally confined to the Afro-tropical region has now gained a foothold on the Arabian Peninsula and its distribution is expected to spread even further (Walker *et al.* 2000). Only 30 species are included in this paper. They are those whose ecological, life history strategies and climatic requirements are relatively well known and, as two distribution data sets have been used, the current distribution of these ticks are relatively well plotted. The way in which these distributions will be influenced by climate change is poorly documented and forms the essence of this paper.

The use of climate-matching models to predict tick distributions

One of the earliest climate matching approaches was CLIMEX, which calculates the climatic suitability of geographic regions for species using a temperature-dependent growth index moderated by four growth indices: hot, cold, dry and wet (Sutherst & Maywald 1985). The use of CLIMEX in northern Australia was considered a great success for predicting the distribution of the tick *Boophilus microplus* (Canestrini, 1887), and it was anticipated that this initial success could be translated into predicting distributions of African tick species. However, early studies tended to over-estimate the distribution of *B. microplus* across Africa, and the predicted high incidence of *Rhipicephalus appendiculatus* Neumann, 1901 in West Africa was at complete variance with the tick's absence in this region.

Moreover, when the distributions of *Amblyomma* spp. in Africa were modelled using CLIMEX, these were found to be dissimilar to their known distributions. These conflicting results led Norval, Perry, Meltzer, Kruska & Boothroyd (1994) to conclude that the predicted climatic suitability of regions for *Amblyomma hebraeum* Koch and *Amblyomma variegatum* Fabricius, 1794, is almost the opposite of the actual distribution of these ticks, both in Zimbabwe and in the rest of Africa (Norval, Perry, Gebreab & Lessard 1991; Norval *et al.* 1992).

BIOCLIM was the second climate-based approach employed to model tick distributions (Nix 1986; Norval *et al.* 1992). BIOCLIM generates 24 climatic attributes from which annual and seasonal mean conditions, extreme values and intra-year seasonality are derived, for each of a selection of geographic points throughout the distribution range of a tick species. Computer-selected thresholds and limits for each of the indices are matched across a geographical grid to predict potential species distribution. This model generally provided a better fit between the predicted and known distributions of *R.*

appendiculatus, although at a finer scale the match in some areas of the East African highlands was unsatisfactory (Norval *et al.* 1992). The climate database used was interpolated at an increased resolution (8 km), and this factor alone may explain the improved accuracy when compared to the earlier CLIMEX-based attempts. A subsequent logistic regression approach (Cumming 2000c), based on interpolated climate and elevation data for Africa with a resolution of 25 km (Hutchinson, Nix, MacMahon & Ord 1996) achieved even better accuracy. Such an approach, however, normally requires the existence of a training data set that includes presence and absence information (Estrada-Peña 2003). While it is relatively easy to ascertain where ticks have been collected, it is more difficult to confirm the reliability of surveys in which a tick species is cited as not present. Consequently the assumption that non-presence always implies absence may limit the application of this modelling approach (Estrada-Peña 2003).

The use of an Advanced Very High-Resolution Radiometer (AVHRR) mounted on the National Oceanic and Atmospheric Administration's (NOAA's) meteorological satellites was given preference in the 1990s. This instrument allowed the direct detection of environmental factors at an 8 km resolution (Lessard *et al.* 1990). The main predictor in this procedure is the satellite-derived maximum mean monthly Normalized Difference Vegetation Index (NDVI). However, this technique was reportedly very complicated when used to predict the distribution of *R. appendiculatus* (Kruska & Perry 1991). There are, however, initiatives to revive confidence in the NDVI approach as a predictive tool in research (Randolph 2002).

The present study used a single species distribution modelling procedure (Erasmus *et al.* 2000), originally developed by Jeffree & Jeffree (1994, 1996), for predicting species distribution patterns and for evaluating the relative performance of predicted future climate data sets. This model was subsequently modified to accept multivariate inputs to yield probability of presence maps for species (Erasmus *et al.* 2000). When used to predict the contemporary potential distribution of African ticks (Olwoch *et al.* 2003) the model achieved positive predictions of more than 70 % for the four tick species tested.

Climate data used for predicting African tick distributions

The principal sources of climate data for predictive distribution modelling are climate surfaces, generated by interpolating data sampled at varying intensities across a region. Consequently, differences between these climate surfaces can usually be attributed to spatial and temporal evenness of the data used for interpolation. Most modern interpolation techniques are pattern based and statistically incorporate horizontal as well as vertical (altitudinal) adjustments (Hutchinson 1989, 1991; Hutchinson & Gessler 1994). These climate surfaces are, however, relatively smooth because of extensive interpolation between low-resolution point observations.

Another source of climate data is Global Circulation Models (GCMs). These are coupled ocean-atmosphere models that provide three-dimensional simulations of the atmosphere. To date GCMs have produced climate data at a horizontal resolution that is generally too coarse for use in predictive species modelling (> 100 x 100 km grid point resolution), especially for species that are habitat specialists or that are influenced by fine-scale environmental gradients. Computational requirements usually preclude GCMs being run at meso-scale grid resolutions (10–100 km).

The present study used a Division of Atmospheric Research Limited Area Model (DARLAM) as the main climate data set. DARLAM is a potential alternative source of high-resolution climate data that involves the nesting of a high-resolution limited area model within a GCM over the area of interest (for review see McGregor 1997). The GCM supplies the limited area model with initial and boundary conditions. With a grid resolution of 10–100 km, the limited area model is able to simulate some of the meso-scale properties of the circulation model. This technique provides a viable fine scale alternative to the use of observed or interpolated climate surfaces or very coarse scale GCMs climate surfaces. The resolution attained by this dynamic modelling process is essentially limited by the computing power available to the modellers. The implication of using these datasets for predicting current tick distributions has been assessed by Olwoch *et al.* (2003). In this study, DARLAM's future predictions are compared with those obtained by using mean climates from two GCMs (CGCM and Centre for Climate System Research/National Institute for Environmental Studies [CCSR/NIES]).

MATERIALS AND METHODS

Study area

The study area covers sub-Saharan Africa (Fig. 1) and was divided into 3 000 grids cells of 60 x 60 km

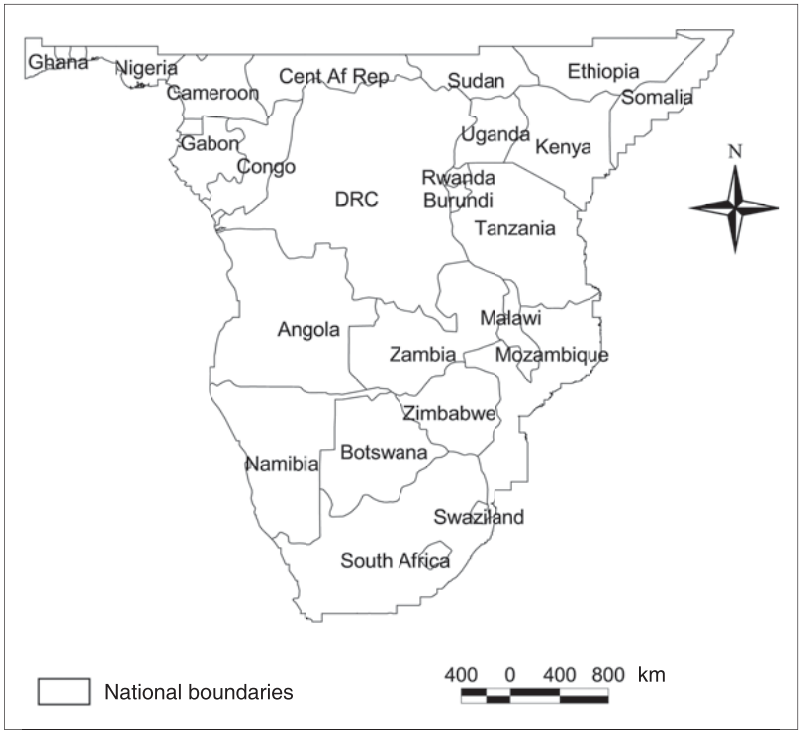

FIG. 1 Study area

resolution. This resolution was determined by the DARLAM climate data.

Tick data

Point localities of tick recoveries were obtained from Cumming (1999), who compiled the data that he used from various collections of ticks, and from recent collections made by one of us (I.G.H.). Combining data sets from different sources frequently compounds identification and distribution errors and for this reason data congruence with Walker *et al.* (2000), who provide well-illustrated distributions of *Rhipicephalus* species, was used to assess data quality in the final compiled dataset. Synonyms provided by the latter authors also solve the common dataset problem of referring to one species, but using different names, or referring to a group of species as a single species. The tick species selected for this study belong to the ixodid genus *Rhipicephalus*. Species point localities were assigned to particular 60 km x 60 km grid cells by means of a spatial intersect in ArcView GIS. A conservative estimate of the accuracy of these point localities is 0.2° (G.S. Cumming, personal communication 2003) and consequently this approximation is considered reasonable. The *Rhipicephalus* species selected are those whose distribution and life history strategies are relatively well known and it is our hope that these results will provide a baseline model for future modelling of other tick species.

Predictive species modelling

A simple climate envelope model was used to predict the future distribution of the focal species (Erasmus *et al.* 2000, 2002). The input data comprised 3 000 grid cells of 60 x 60 km size populated with climate variables covering sub-Saharan Africa. Reliable presence records of the selected tick species and the present climate values at these locations were used to construct a climate envelope, using a principal components-type approach. This climate envelope represents the range of climates within which a particular tick is known to occur, and can be interpreted as the realized niche, as defined solely by climate. To arrive at a predicted distribution in a climate change scenario, the existing climate envelope is applied to a climate surface representing future climates, and a new geographical interpretation of distribution is derived [see Erasmus *et al.* (2000, 2002) and Olwoch *et al.* (2003) for a more detailed explanation]. This approach was used as a standardized base for evaluating the relative performances of the DARLAM and the mean GCM climate data sets, and allows the creation of a probability surface of climate suitability for each species modelled.

DARLAM present and future climate data

The Australian Commonwealth Scientific and Industrial Research Organisation (CSIRO) developed the high-resolution limited-area model DARLAM for use in both short-term meso-scale atmospheric studies and longer-term climate simulation experiments (Walsh & McGregor 1995). In the present study ten separate 30-day simulations were performed for both January and July for separate 10-year periods. The periods selected are the 1990s and 2020. The simulations were performed at a horizontal grid resolution of 60 x 60 km using a domain of 100 x 100 grid points that cover sub-Saharan Africa. The monthly average of the ten simulations constitutes the model climatology for the month. The CSIRO Mark 2 GCM was used to force DARLAM at its lateral boundaries. The GCM was integrated for the period 1960–2100, with greenhouse gas forcing corresponding to the A_2 SRES (Special Report on Emission Scenario, issued by the Intergovernmental Panel on Climate Change) scenario.

Engelbrecht, Rautenbach, MacGregor & Katzfey (2002) illustrated that DARLAM is capable of simulating the regional characteristics of atmospheric variables such as near-surface temperature, low-level wind patterns and rainfall over sub-Saharan Africa with considerable detail. The model does, however, tend to overestimate total rainfall over regions with a steep topography. The DARLAM simulations were performed at the Laboratory for Research in Atmospheric Modelling (LRAM) at the University of Pretoria on a Pentium III workstation with two 550 MHz processors.

GCM future climate data

The GCM climate data used in this study were downloaded from the IPCC/DDC website. Through various stages in ArcView GIS, the original GCM data were processed to fit the 60 x 60 km resolution of DARLAM. The Canadian Global Coupled Model (CGCM2) was the first GCM climate used in this study. It is based on the earlier CGCM1, but with some improvements aimed at addressing shortcomings identified in the first version. In particular, the ocean mixing parameterization has been changed (Gent & McWilliams 1990), and following Flato & Hibler (1992) sea-ice dynamics has been included. The version of GCM2 used for control and doubled CO_2 experiments has ten vertical levels with the lowest prognostic level located at approximately 200 m above the surface. A description of CGCM2 and a comparison, relative to CGCM1, of its response to increasing greenhouse-gas forcing can be found in Flato & Boer (2001). The climate change projections used in this study are those from the newer IPCC SRES A2 scenario.

The second GCM model used was developed by the Center for Climate System Research/National Institute for Environmental Studies, (Japan) (CCSR/NIES) CGCM (Nozawa, Emori, Numaguti, Tsushima, Takemura, Nakajima, Abe-Ouchi & Kimoto 2001). This model is also based on Emission Scenarios (SRES) of the Intergovernmental Panel on Climate Change (IPCC). It is a Transient Coupled Ocean-Atmosphere Model, which was developed to investigate the direct and indirect climate impacts of the anthropogenic sulphate and carbonaceous aerosols in future projections of climate change. The data used here are from the A2 scenarios. Direct radiative forcing of the carbonaceous aerosols nearly nullifies that of the sulphate aerosols for all scenarios. Estimated total indirect radiative forcing is about –1.3 Wm-2 for the A1, B1, and B2 scenarios, and is about –2.0 Wm-2 for the A2 scenario in the latter half of the 21st Century. Global and annual averages of the surface air temperature increase for all scenarios because of the dominance of the radiative forcing of the increased CO_2. Global warming is decelerated with an increase in the anthropogenic sulphate and carbonaceous aerosols, because indirect forcing due to the aerosols has a significant cooling effect. Geographical distribution of the surface warming does not depend much on the scenarios. Cloud feedback becomes dominant in the latter half of the 21st Century, and this introduces further warming at the surface.

Predicting current and future distribution of *Rhipicephalus* species

The predicted current distributions were initially obtained using current climate predicted by DARLAM. This represents a useful comparison between predicted distributions and known records (see Olwoch *et al.* 2003). To obtain predicted future distributions the grid cells are populated with future climate variables. The predicted current distributions were obtained using the predictive species model (Erasmus *et al.* 2000) and six climate variables of current and future mean maximum temperature, mean minimum temperature and mean rainfall of January and July provided by DARLAM. The predicted future distributions were obtained by using both DARLAM and the mean GCM climates. The predictive modelling was executed in S-Plus (S-Plus 2000), while maps of the results were drawn in ArcView GIS. The resultant potential distribution maps represent the probability values of their suitability for ticks based on climate.

Analysis of predicted tick range changes

A number of analyses were performed to compare the predicted current and future distributions of ticks. These included:

(i) Analysis of species range expansion

(ii) An analysis of range contraction

(iii) Change in species richness pattern

(iv) Species range shifts

(v) An assessment of overlap between DARLAM and GCM predicted future distributions.

These range changes were initially analysed for the whole study area and subsequently, in some cases, on a regional basis. In the second analysis, ticks were grouped into the following regions depending on their principal regional distribution, namely East Africa, Central Africa and southern Africa, and a fourth group of ticks that were termed "general" ticks.

The East African tick species include *Rhipicephalus aquatilis* Walker, Keirans & Pegram, 1993, *Rhipicephalus armatus* Pocock, 1900, *Rhipicephalus bequaerti* Zumpt, 1949, *Rhipicephalus carnivoralis* Walker, 1966, *Rhipicephalus humeralis* Rondelli, 1926, *Rhipicephalus kochi* Dönitz, 1905, *Rhipicephalus maculatus* Neumann, 1901, *Rhipicephalus muehlensi* Zumpt, 1943, *Rhipicephalus planus* Neumann, 1907 and *Rhipicephalus pulchellus* Gerstäcker, 1873.

The Central African species include *Rhipicephalus complanatus* Neumann, 1911, *Rhipicephalus compositus* Neumann, 1897, *Rhipicephalus dux* Dönitz, 1910, *Rhipicephalus longus* Neumann, 1907, *Rhipicephalus lunulatus* Neumann, 1907, *Rhipicephalus masseyi* Nuttall & Warburton, 1908, *Rhipicephalus punctatus* Warburton, 1912, *Rhipicephalus senegalensis* Koch, 1844, *Rhipicephalus supertritus* Neumann, 1907 and *Rhipicephalus ziemanni* Neumann, 1904.

The southern African species include ticks of the *Rhipicephalus capensis* group (*Rhipicephalus capensis* Koch, 1844; *Rhipicephalus follis* Dönitz, 1910 and *Rhipicephalus gertrudae* Feldman-Muhsam, 1960), *Rhipicephalus distinctus* Bedford, 1932, *Rhipicephalus exopthalmos* Keirans & Walker, 1993, *Rhipicephalus oculatus* Neumann, 1901, *Rhipicephalus zambeziensis* Walker, Norval & Corwin, 1981 and the subspecies *Rhipicephalus evertsi mimeticus* Dönitz, 1910.

There are also species that have wide ranging distributions that overlap in various regions of Africa. These species, termed "general" ticks include *R. appendiculatus, R. evertsi evertsi* Neumann, 1897, *Rhipicephalus pravus* Dönitz, 1910 and *Rhipicephalus simus* Koch, 1844. The above groupings are presented to facilitate interpretation of the current findings and do not imply that the ticks placed in particular geographical regions are restricted to these areas, but rather localise their distribution with extensions into neighbouring regions.

Range expansion and contraction

In order to obtain range changes in terms of contractions or expansions, predicted current or future distributions were first obtained. The predicted current or future distributions were taken as the number of grid cells in which the probability of occurrence is equal to or greater than 50 %. The difference in the number of grid cells between the predicted *present distribution* (DP) and predicted *future distribution* (DF) constitutes *distribution range change* (DC). These range changes may either represent contractions or expansions. We initially performed this analysis on a sub-Saharan scale and later on a regional scale in order to establish which regions in Africa would experience greater changes in predicted tick distribution ranges (current and future) and therefore appear more vulnerable to climate change. We analysed the differences between the predicted distributions using the Kolmogorov-Smirnoff two-sample test. Furthermore, we divided the ticks into economically important and unimportant species. A comparison of range changes between the current and future predictions was performed on this latter grouping to assess which of the two groups is more vulnerable to climate change.

In all the above analyses we assessed the proportion of species that experienced expanded or contracted range changes and the degree of the predicted expansion/contraction.

Analysis of change in species richness pattern and degree of range shifts

Species richness patterns were calculated as the number of species in the predicted current or future distribution per grid cell following Erasmus *et al.* (2002). This analysis was performed for the whole of sub-Saharan Africa. Range shifts were calculated as the number of additional grid cells in the predicted future distribution as a proportion of the current predicted distribution. We used the current predicted distribution instead of current known records because most regions in Africa are poorly sampled.

Comparing predicted future distributions of ticks based on climates simulated by DARLAM and GCM

The accuracy of any climate model is as good as the initial conditions that are used to configure it. Since there is no climate model that provides an accurate projection of the future, it seemed prudent to use the results from more than one climate model in this study. A comparison was therefore made to assess the differences between the predicted future climate suitability for tick species using a regional climate provided by DARLAM and a mean of two GCMs described above. The analysis was performed on a sub-Saharan scale and also on a regional scale. We assessed the degree of proportional overlap between the predicted current distribution and the predicted future distribution (DARLAM and GCM) by means of the proportional overlap method (Prendergast, Quinn, Lawton, Eversham & Gibbons 1993; Reyers, Van Jaarsveld & Krüger 2000). In this case the proportional overlap was calculated as Nc/Ns where Nc is the number of common grid cells between a pair of areas under comparison and Ns is the number of grid cells containing data for both groups or the maximum number of overlapping grid cells possible.

RESULTS

Model Validation was not performed in this study because the same climate envelope model had previously been subjected to rigorous evaluation using presence-absence data resulting from a coordinated and systematic survey effort. Erasmus *et al.* (2002) used the distribution records of 34 bird species and tested performance of the model using receiver operator characteristic analyses (Fielding & Bell 1997). The model performed significantly better than a random model with no discriminatory ability. It also accurately predicted the complete known distributions for 24 of the 34 bird species, using a 20% sub-sample of the known records (Erasmus *et al.* 2002). This satisfactory documented performance of the model and the relatively good predictions that were obtained when it was used to predict the current distributions of four African ticks (Olwoch *et al.* 2003) are sufficient reasons to consider the model adequate for the present study.

Future climate—DARLAM

The climatological anomalies for the 2020s vs the 1990s as predicted by DARLAM are depicted in Fig. 2. January minimum and maximum temperatures are simulated to increase by more than 2 °C over certain regions of sub-Saharan Africa. Many of the eastern regions are expected to become drier with an associated pattern of higher sea-level pressure, whilst the western subcontinent is expected to be-

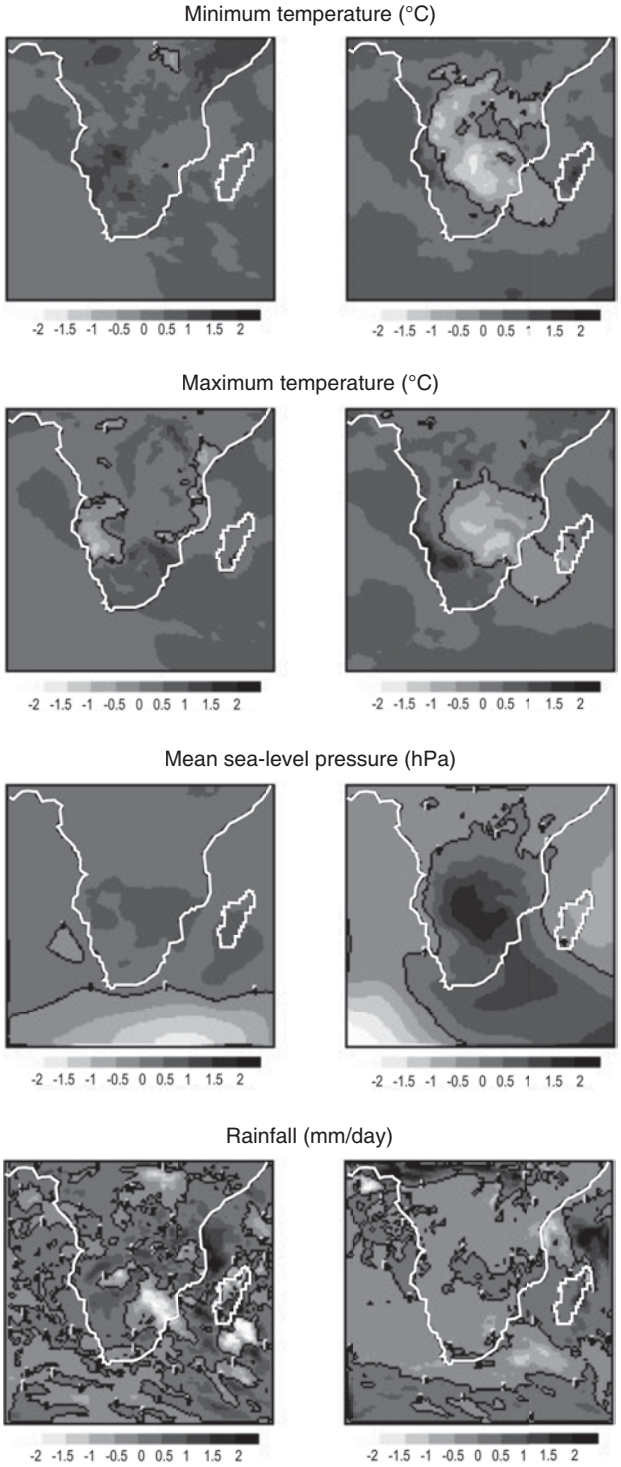

FIG. 2 DARLAM's climatological anomalies for the 2020s v. 1990s

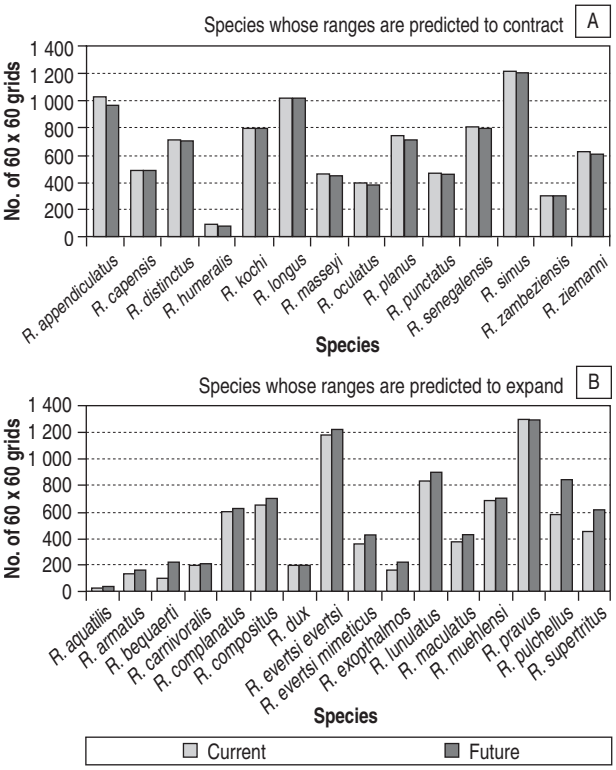

FIG. 3 *Rhipicephalus* species in sub-Saharan Africa that are predicted to show (A) range size contraction and (B) range size expansion

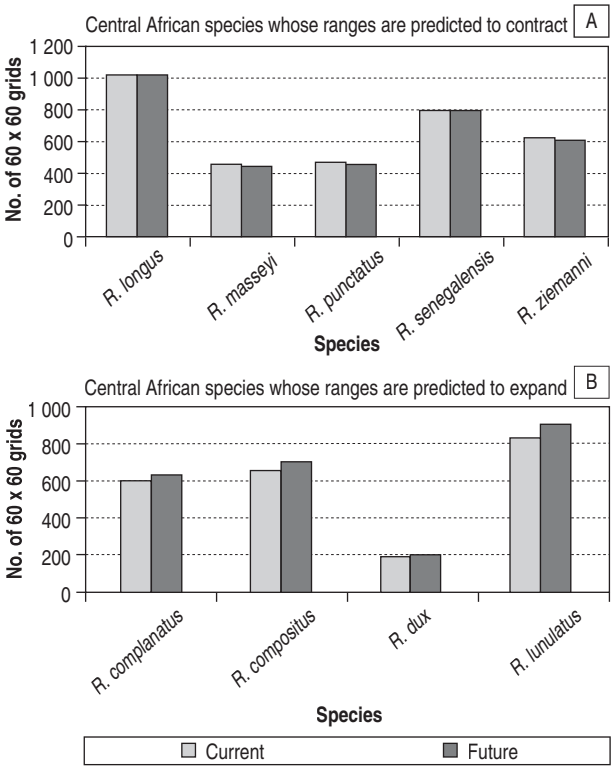

FIG. 4 *Rhipicephalus* species in Central Africa that are predicted to show (A) range size contraction and (B) range size expansion

come wetter. An interesting feature of the July anomaly fields is that parts of the central subcontinent are simulated to become cooler and wetter.

Species distribution changes

Broad scale range changes (Fig. 3A, B)

The predicted current and future distributions of the selected *Rhipicephalus* spp. using DARLAM are provided in figures 10–39. On a sub-Saharan scale, the ranges of 46% of the tick species, namely *R. appendiculatus, R. capensis* group*, R. distinctus, R. humeralis, R. kochi, R. longus, R. masseyi, R. oculatus, R. planus, R. punctatus, R. senegalensis, R. simus, R. zambeziensis and R. ziemanni* are predicted to contract. The ranges of 54% of the species, namely *R. aquatilis, R. armatus, R. bequaerti, R. carnivoralis, R. complanatus, R. compositus, R. dux, R. evertsi evertsi, R. evertsi mimeticus, R. exopthalmos, R. lunulatus, R. maculatus, R. muehlensi, R. pravus, R. pulchellus* and *R. supertritus* are predicted to expand over the same period (Fig. 3A, B). These results translate into an area expansion of 3 502 800 km^2 (12%) in total tick range with a total reduction of 640 800 km^2 (2%).

Central African species (Fig. 4A, B, 16,17, 19, 25, 26, 28, 34, 35 and 39)

Fifty-five percent of species in central Africa are predicted to show range reductions (*R. longus, R. masseyi, R. punctatus, R. senegalensis* and *R. ziemanni*) while 45% (*R. complanatus*, *R. compositus*, *R. dux* and *R. lunulatus*) are predicted to show range expansions. Although the ranges of the majority of tick species are predicted to contract, the total area of contraction is only 19%, while the total area of expansion by the remaining species is 81%. The tick species predicted to expand its range most in this region is *R. lunulatus* with a total expansion of 252 000 km^2.

East African species (Fig. 5A, B, 11, 12, 13, 15, 23, 24, 27, 29, 31 and 33)

In East Africa 30% of the species (*R. humeralis, R. kochi* and *R. planus*) are predicted to show range contractions, while 70% (*R. aquatilis, R. armatus, R. bequaerti, R. carnivoralis R. maculatus, R. muehlensi* and *R. pulchellus*) are predicted to show range expansions. This translates into a total expansion of 1 760 400 km^2 (91%) with a mere 169 200 km^2 (9%) reduction in total area. The predicted greater expansions are mainly attributable to *R. bequaerti* which

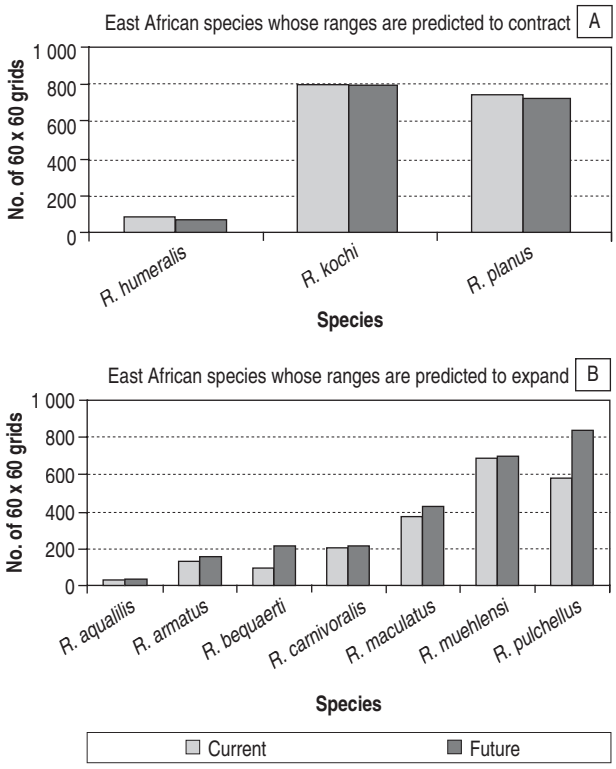

FIG. 5 *Rhipicephalus* species in East Africa that are predicted to show (A) range size contraction and (B) range size expansion

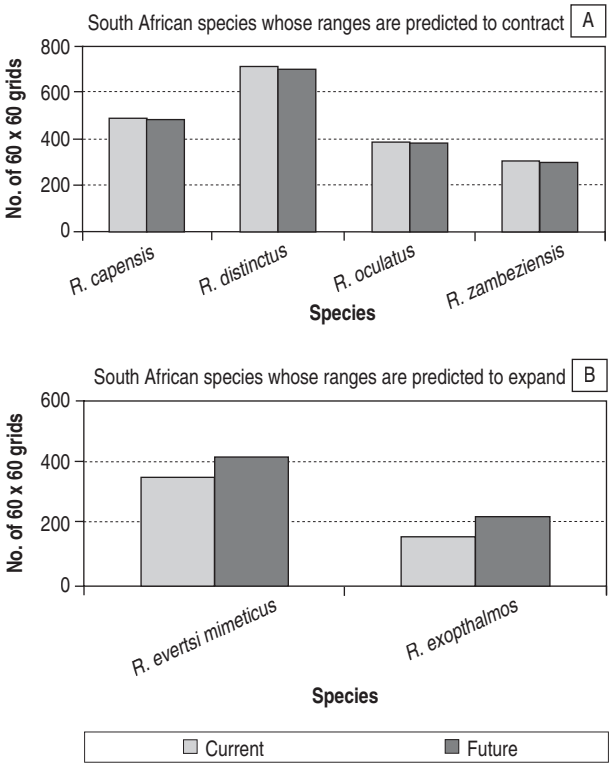

FIG. 6 *Rhipicephalus* species in southern Africa that are predicted to show (A) range size contraction and (B) range size expansion

more than doubles its present range and *R. pulchellus,* which is predicted to expand its range by some 921 600 km^2 (49 %).

Southern African species (Fig. 6A, B, 14, 18, 21, 22, 30 and 38)

In southern Africa some 66 % (*R. capensis* group, *R. distinctus, R. oculatus* and *R. zambeziensis)* of the tick species are predicted to contract their ranges. Although only 33 % (*R. evertsi mimeticus* and *R. exopthalmos*) of the ticks are predicted to expand their current ranges, the total range expansion is 439 200 km^2 (23 %) while the total range reduction is only 64 800 km^2 (1 %). Most of the expansion in this region is attributable to *R. evertsi mimeticus*.

"General" tick species (Fig. 7A, B, 10, 20, 32 and 36)

The "general" ticks are those *Rhipicephalus* species that are widely distributed with current distributions overlapping within various geographical regions of the subcontinent. This does not necessarily mean that these species are not specialists with regard to their ecological requirements, e.g. *R. appendiculatus* is confined to parts of eastern, central and southeastern Africa (Walker *et al.* 2000). It is a species of significant economic importance in Africa because it transmits *Theileria parva,* the cause of East Coast fever (ECF), which is a major cause of cattle mortality and also causes considerable production losses in cattle in most African countries (Okello-Onen *et al.* 1999). The only tick species predicted to contract its range in this group is *R. appendiculatus*, which is predicted to contract its range by 212 400 km^2 (5 %). The ranges of 75 % of the ticks in this category, namely *R. evertsi evertsi, R. pravus* and *R. simus* are predicted to expand. The total range expansion in this region is equivalent to 864 000 km^2 (7 %). This expansion is mainly associated with *R. simus*, which is predicted to expand its range by 601 200 km^2 (70 %).

Changes in species richness patterns and range shifts

The future climate predicted by DARLAM will alter the species richness distribution pattern of African *Rhipicephalus*. Compared to the current pattern (Fig. 8A) the predicted pattern is spatially different and broader (Fig. 8B) with encroachment of ticks into new regions. These regions, which include An-

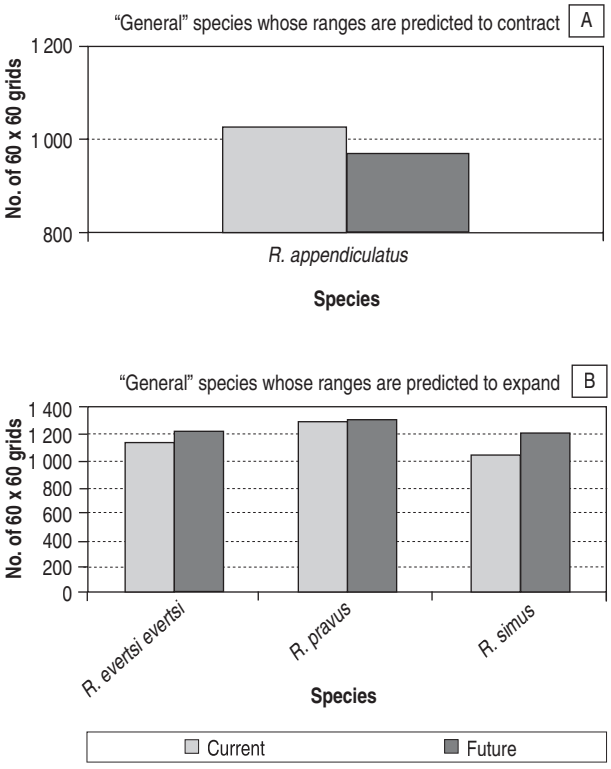

FIG. 7 *Rhipicephalus* species in the "General" ticks that are predicted to show (A) range size contraction and (B) range expansion

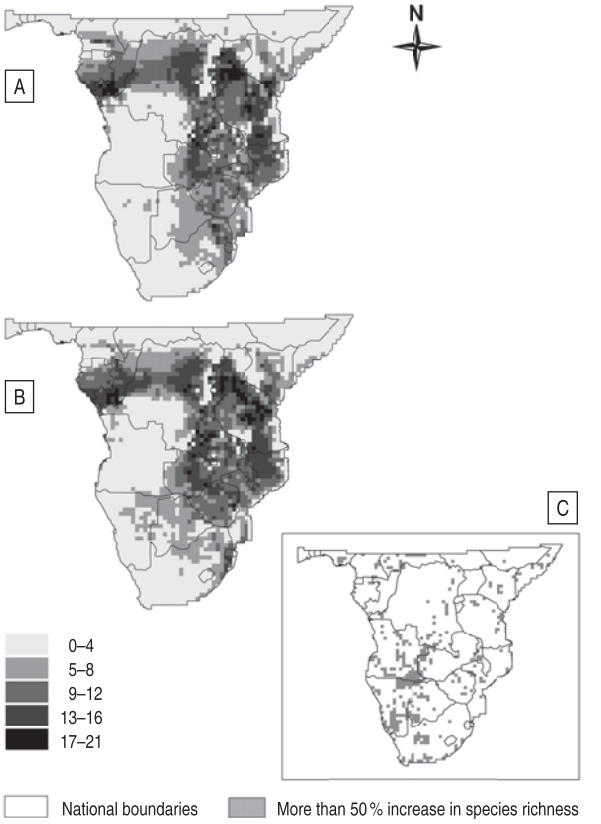

FIG. 8 Species richness pattern of *Rhipicephalus* species in sub-Saharan Africa: (A) current; (B) future; and (C) areas with more than 50 % increase

gola, Namibia, Botswana and the Northern Cape Province of South Africa, are forecast to experience a more than 50 % increase in tick species richness (Fig. 8C). This could be related to increased rainfall in these regions, rendering the south-western regions of sub-Saharan Africa more suitable for ticks. The general west-east shift in species ranges reported by Erasmus *et al.* (2002) is not supported in this study on ticks, in which varying degrees of shift in different directions appears to be the emergent pattern for this taxon. Analysis of range shifts further indicates that 80 % of species show less than a 50 % range shift, while 20 % of species show a range displacement of more than a 100 %. The latter species are mainly those that populate the western arid regions of Africa (Fig. 8).

Species range changes and tick-borne disease implications

Thirty percent of the ticks included in this study are classified as economically important because they are vectors of diseases of domestic livestock or other animals (Table 1). Although *R. appendiculatus*, the principal *Rhipicephalus* vector of disease in Africa shows range contraction, the remaining vectors are responsible for 52 % of the predicted range expansion under future climate conditions. The non-vector species are responsible for 48 % of future tick range expansions.

Predicted future distributions using DARLAM and GCM climate data

The predictions of future climate suitability for ticks when DARLAM is used are generally more extensive than those generated when using the combined GCM climates. With the exception of four species (*R. compositus, R. evertsi mimeticus, R. exopthalmos* and *R. oculatus*), and the *R. capensis* group, DARLAM predicts wider ranges of climatic suitability than the combined GCM climate surfaces. DARLAM's total predictions are 31 % broader than the GCMs. The average difference in the range sizes predicted for DARLAM and GCM is 511 200 km^2. Statistically there is no significant difference between the predictions by DARLAM and GCM using a Kolmogorov-Smirnov test ($P > 0.1$, $n = 30$). However, when the climate data simulated by DARLAM and GCM are analysed for statistical significance, there

TABLE 1 *Rhipicephalus* spp. and the diseases with which they or the toxins they produce are associated

Disease and causal agents	Animal affected	Vectors
East Coast fever (*Theileria parva*)	Cattle	*R. appendiculatus* *R. zambeziensis*
Tick toxicosis	Cattle	*R. appendiculatus*
Corridor disease or Buffalo disease (*Theileria parva*)	Cattle, buffalo	*R. appendiculatus* *R. zambeziensis*
Gall sickness (*Anaplasma marginale*)	Cattle	*R. evertsi evertsi* *R. simus*
Equine biliary fever or equine piloplasmosis (*Babesia caballi*, *Theileria equi*)	Horses, mules, donkeys	*R. evertsi evertsi*
Spring lamb paralysis	Lambs, calves	*R. evertsi evertsi*
Canine biliary fever or canine tick fever (*Babesia canis)*, rickettsiosis (*Ehlichia canis)*	Dogs	*R. sanguineus*
Paralysis	Sheep, lambs, calves	*R. lunulatus*
Nairobi sheep disease (*Bunyaviridae*)	Sheep	*R. pulchellus*

TABLE 2 Proportional overlaps between pairs of grid cells between the predicted ranges from DARLAM and the ranges predicted using mean values for two GCMs

"General" tick species	DARLAM 2030	GCM 2030	Common grids	Proportional overlap value (%)
R. appendiculatus	969	858	476	55
R. evertsi evertsi	1 220	945	611	65
R. pravus	1 300	868	621	29
R. simus	1 209	858	597	60
East Africa				
R. aquatilis	33	17	5	29
R. armatus	153	116	29	25
R. bequaerti	215	40	11	28
R. carnivoralis	205	111	67	60
R. humeralis	79	33	12	55
R. kochi	797	491	326	29
R. maculatus	425	173	98	56
R. muehlensi	699	678*	315	67
R. planus	719	413	278	55
R. pulchellus	841	217	179	25
Central Africa				
R. complanatus	626	595	400	67
R. compositus	**699**	**737***	443	60
R. dux	201	192	77	40
R. longus	1 020	990	642	25
R. lunulatus	897	518	308	28
R. masseyi	450	338	202	60
R. punctatus	458	440	262	28
R. senegalensis	803	622	415	56
R. ziemanni	611	558	352	72
South Africa				
R. capensis group	**485**	**547***	309	56
R. distinctus	707	352	254	72
R. evertsi mimeticus	**423**	**577***	49	49
R. exopthalmos	**212**	**236***	116	15
R. oculatus	**386**	**434***	293	49
R. zambeziensis	299	226	169	60

Bold* = GCM predictions wider than those of DARLAM

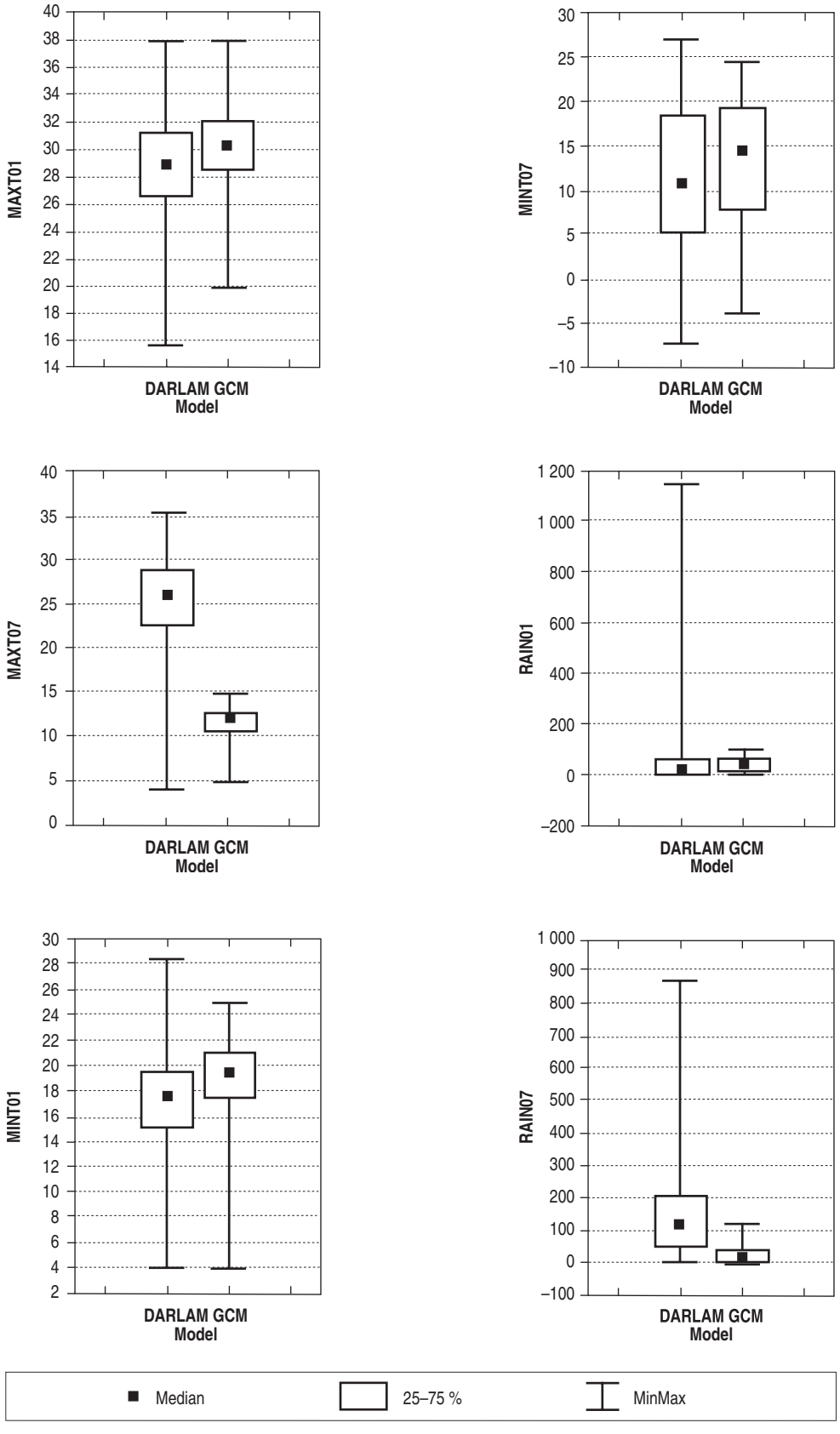

FIG. 9 Box plots based on the Kolmogorov-Smirnov test that compared climate predicted by DARLAM and a combined GCM

FIG. 10–39 Predicted probability distribution of *Rhipicephalus* species using DARLAM and GCM future climates: (A) DARLAM; (B) GCM

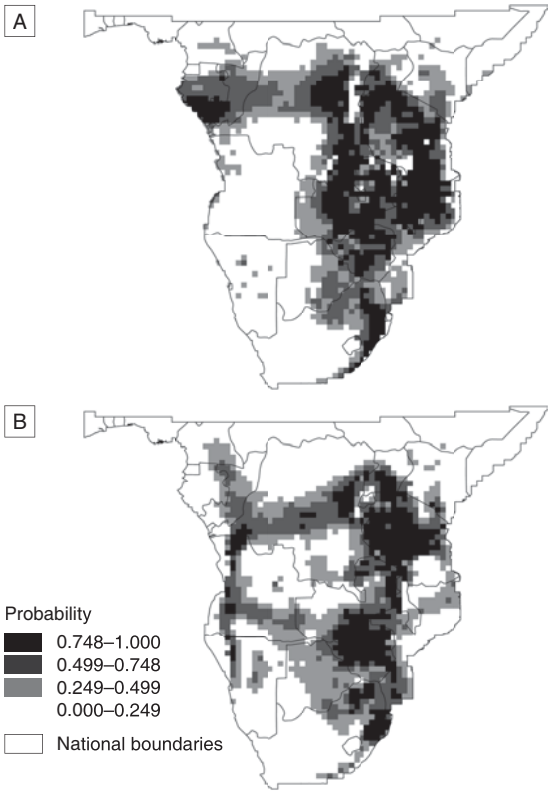

FIG. 10 *R. appendiculatus*

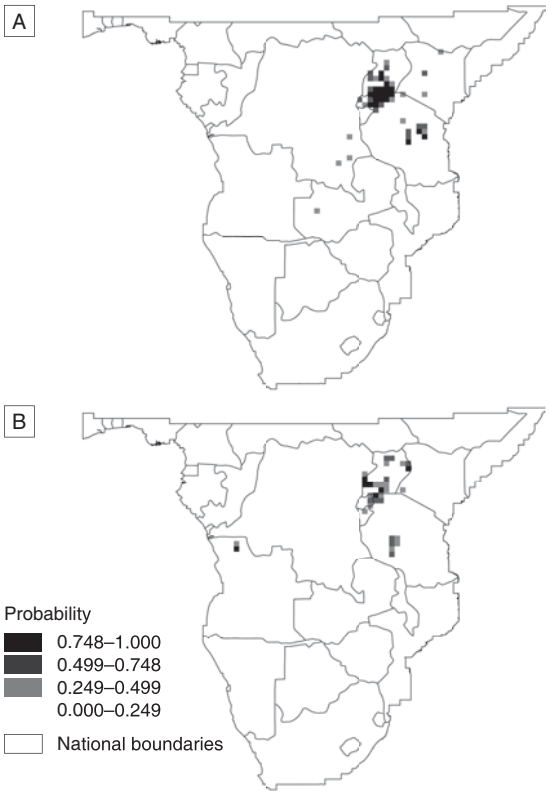

FIG. 11 *R. aquatilis*

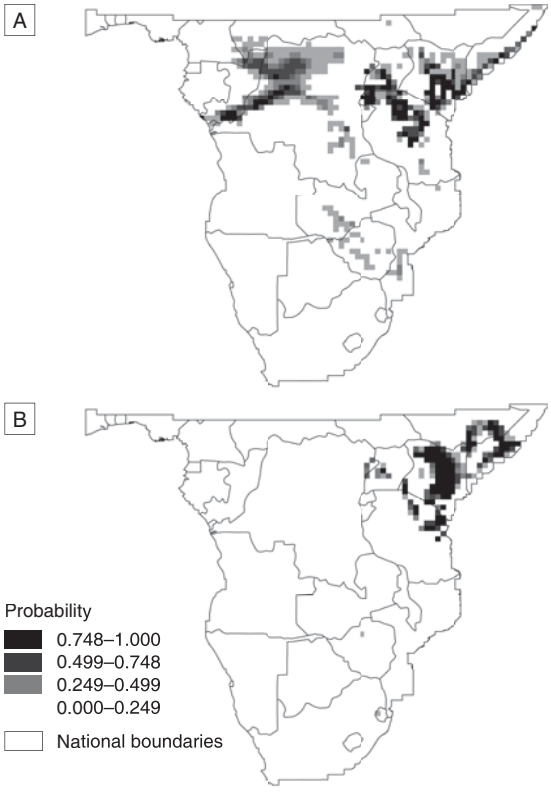

FIG. 12 *R. armatus*

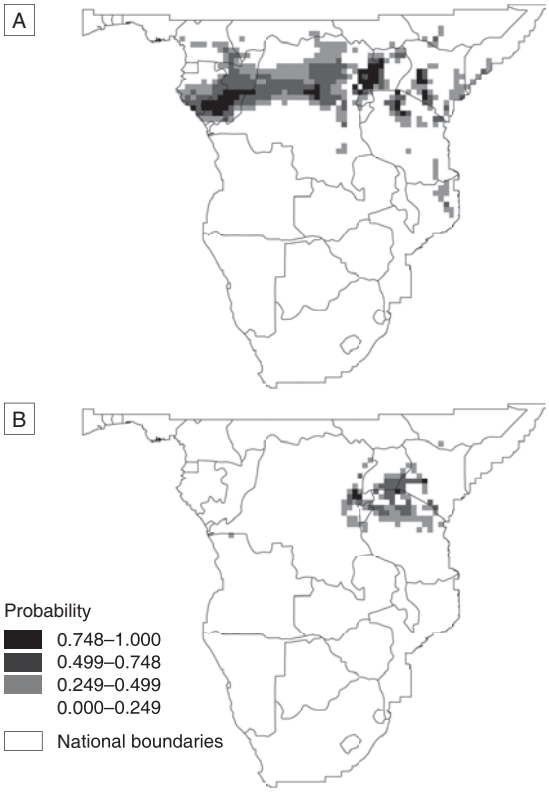

FIG. 13 *R. bequaerti*

FIG. 10–39 *Continued*

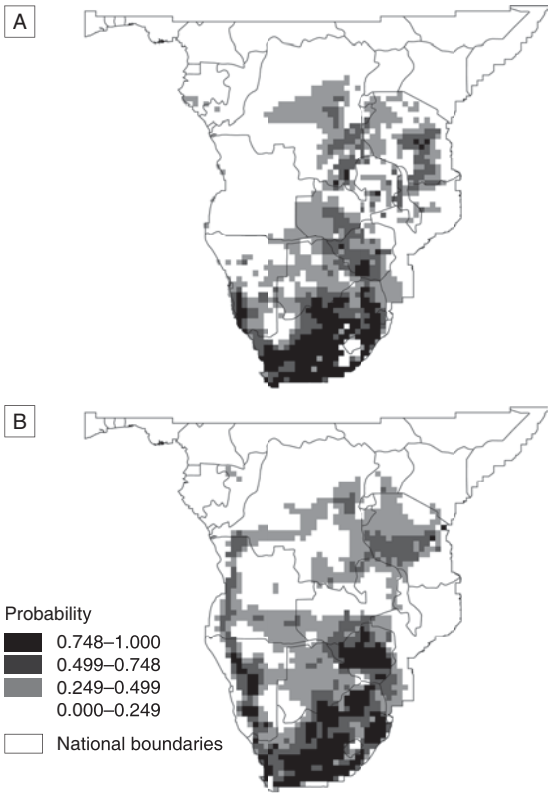

FIG. 14 *R. capensis* group

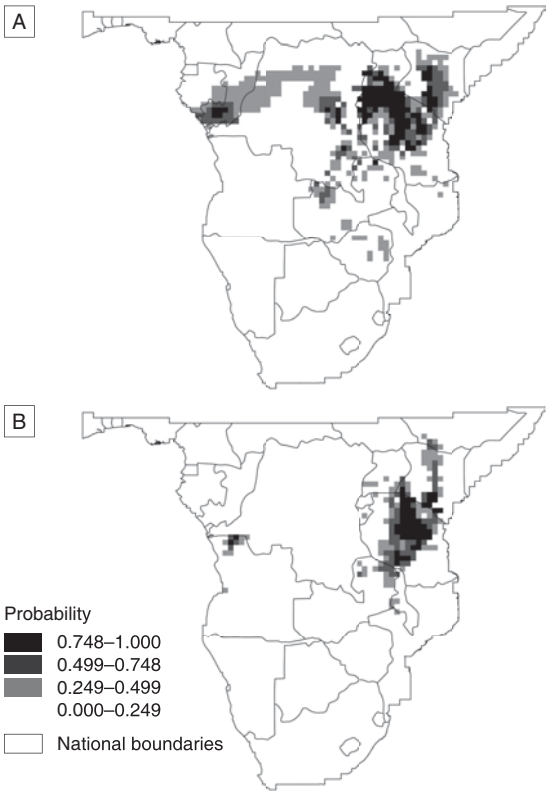

FIG. 15 *R. carnivoralis*

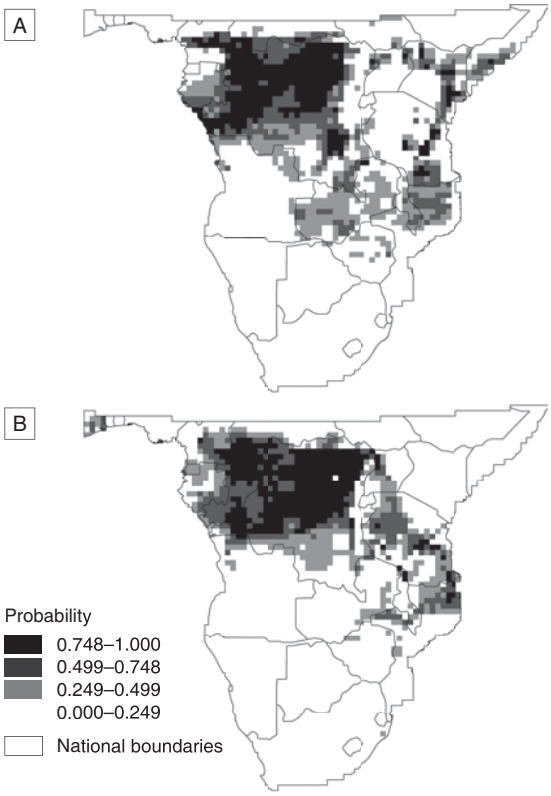

FIG. 16 *R. complanatus*

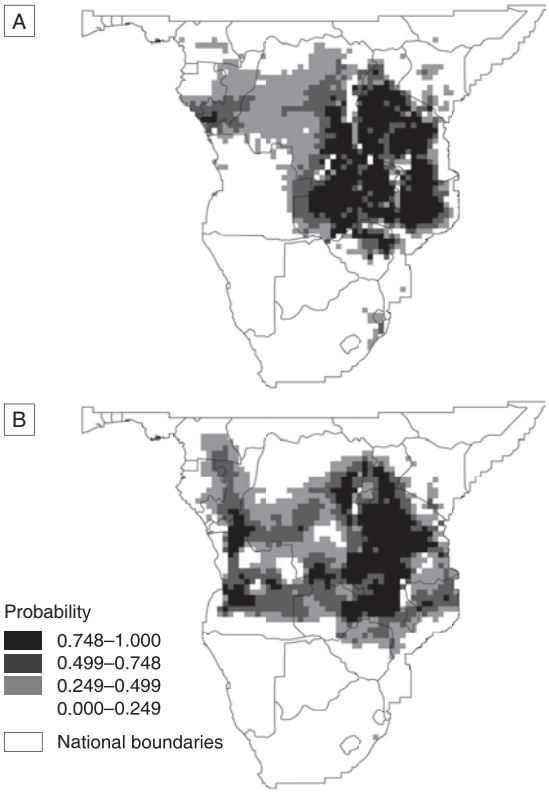

FIG. 17 *R. compositus*

FIG. 10–39 *Continued*

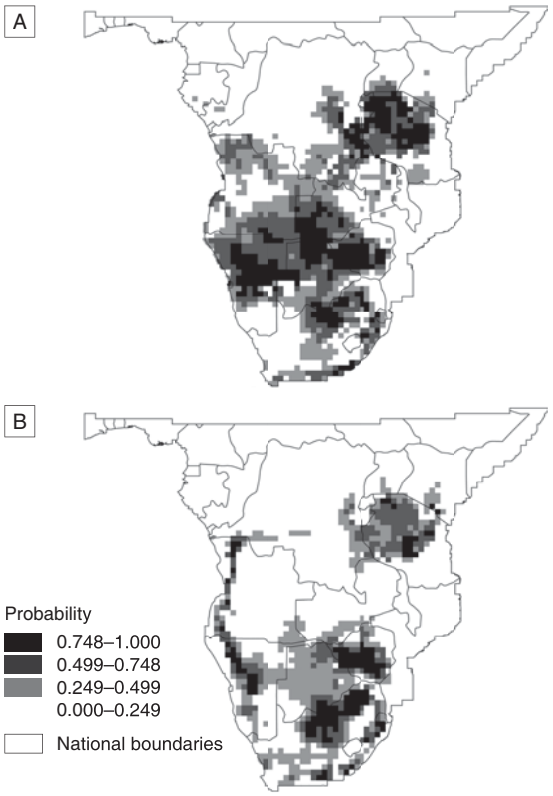

FIG. 18 *R. distinctus*

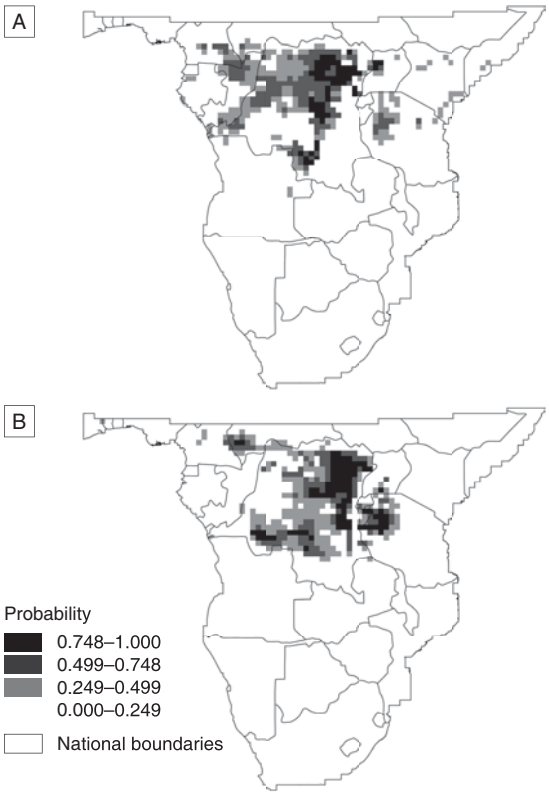

FIG. 19 *R. dux*

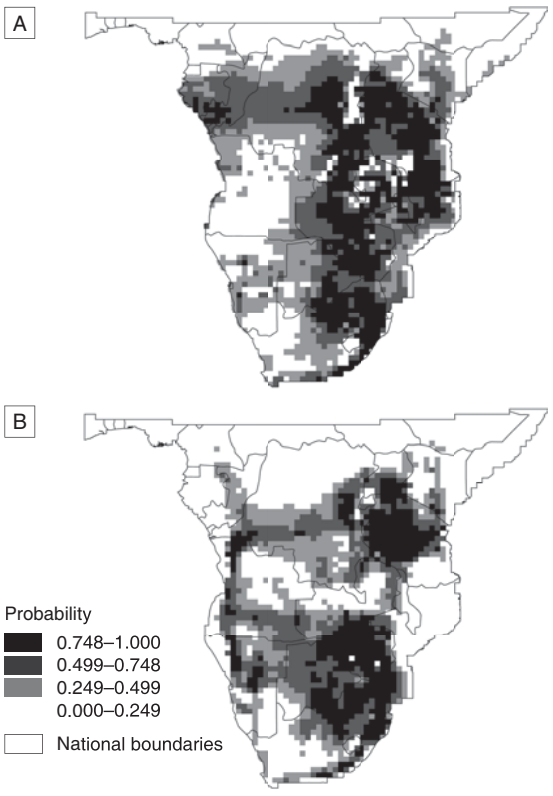

FIG. 20 *R. evertsi evertsi*

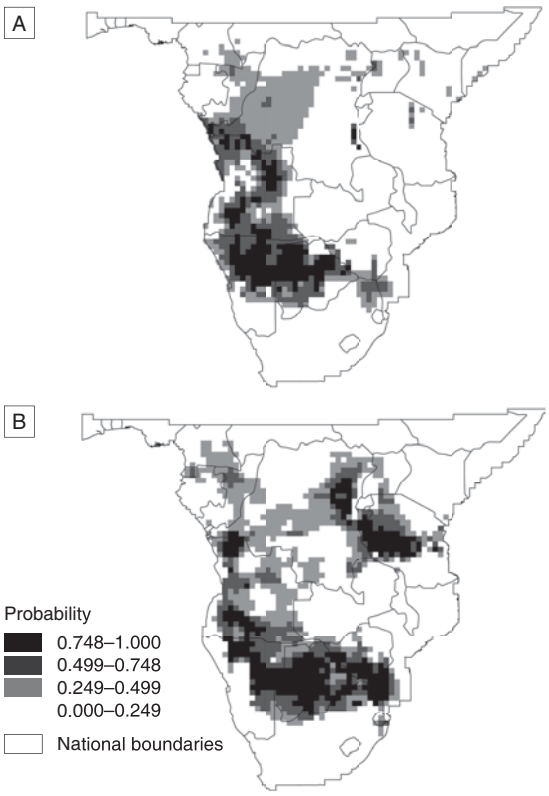

FIG. 21 *R. evertsi mimeticus*

FIG. 10–39 *Continued*

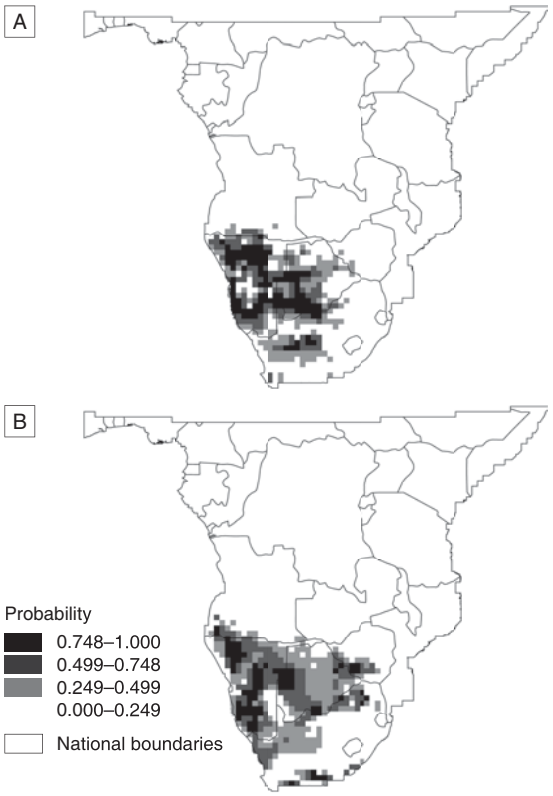

FIG. 22 *R. exophthalmos*

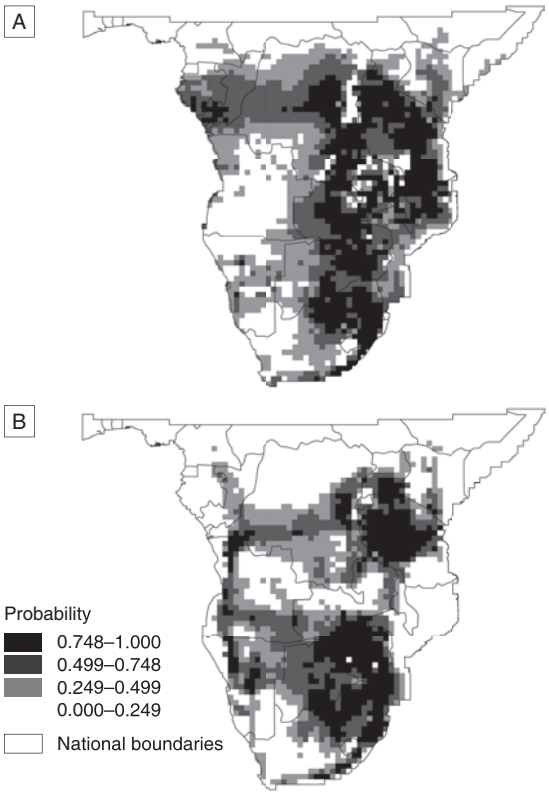

FIG. 23 *R. humeralis*

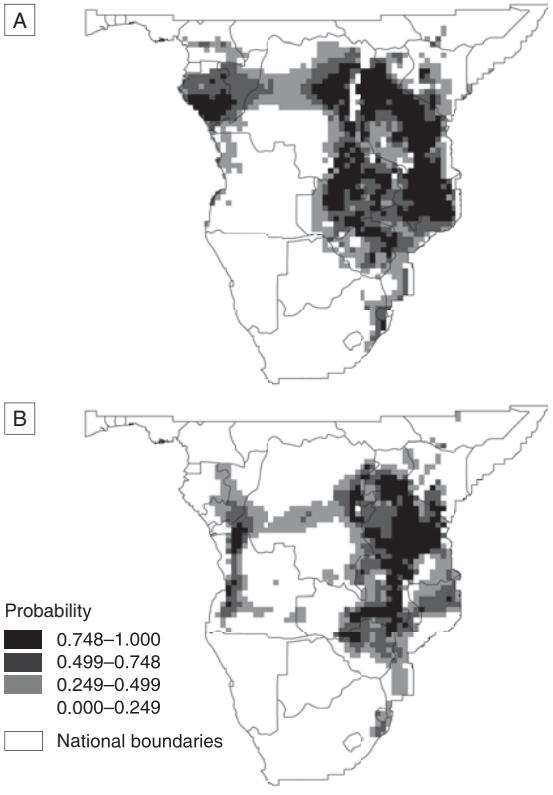

FIG. 24 *R. kochi*

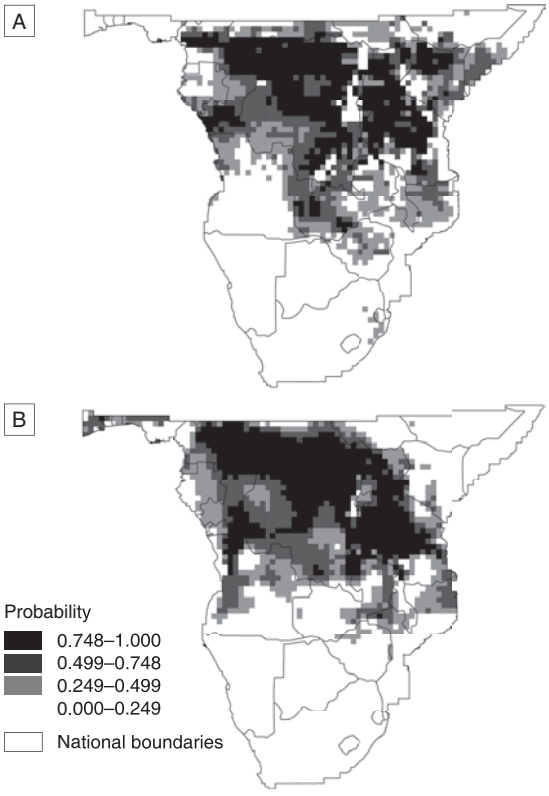

FIG. 25 *R. longus*

FIG. 10–39 *Continued*

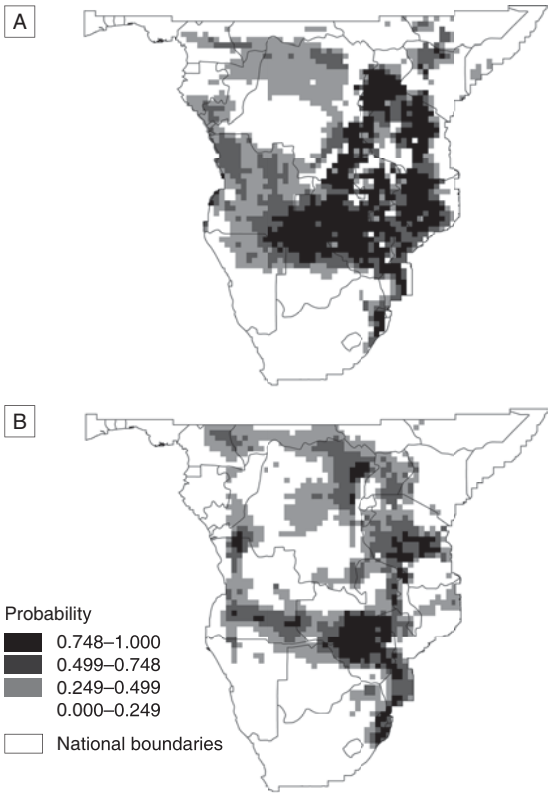

FIG. 26 *R. lunulatus*

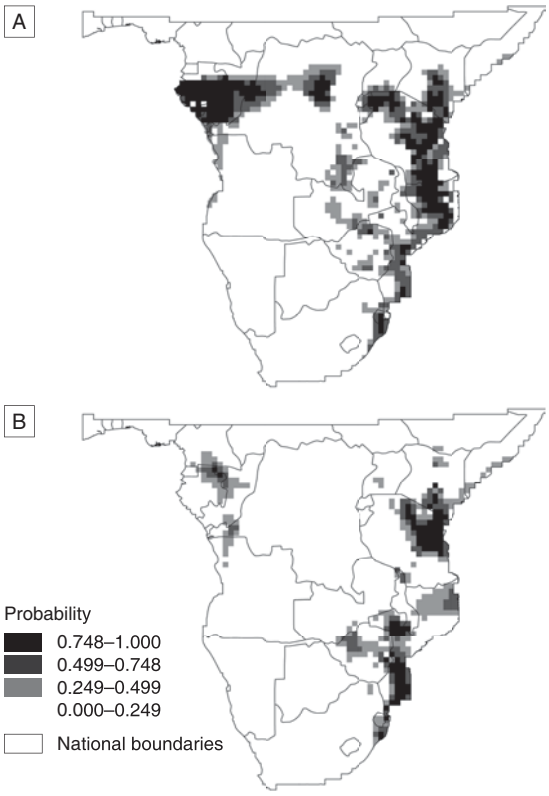

FIG. 27 *R. maculatus*

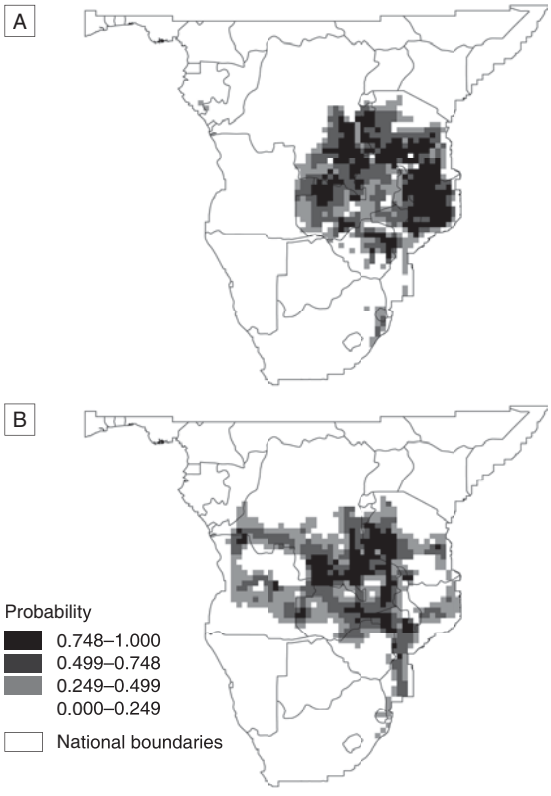

FIG. 28 *R. masseyi*

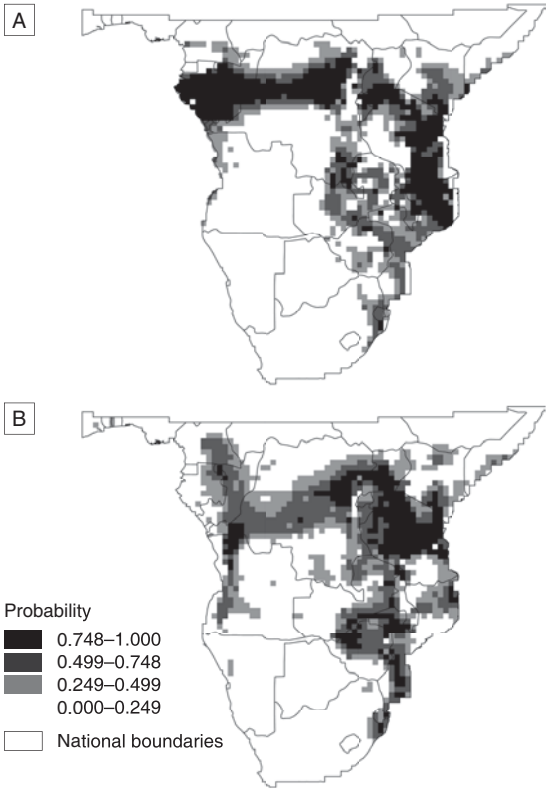

FIG. 29 *R. muehlensi*

FIG. 10–39 *Continued*

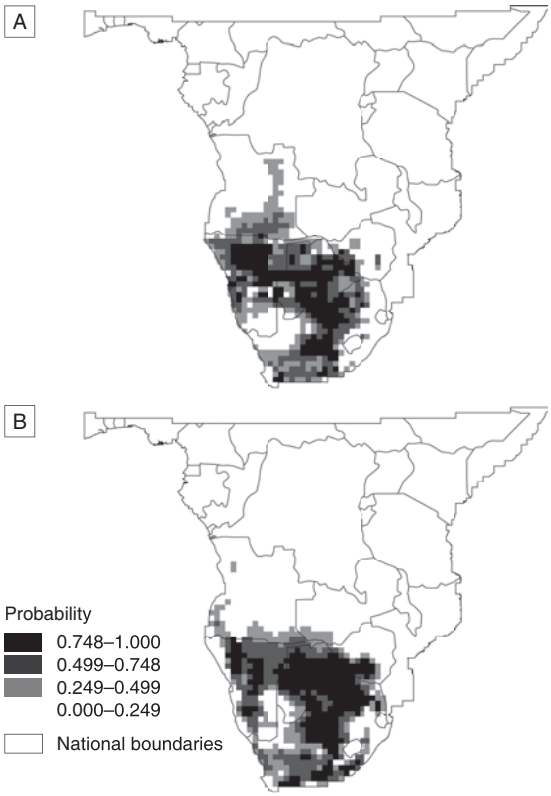

FIG. 30 *R. oculatus*

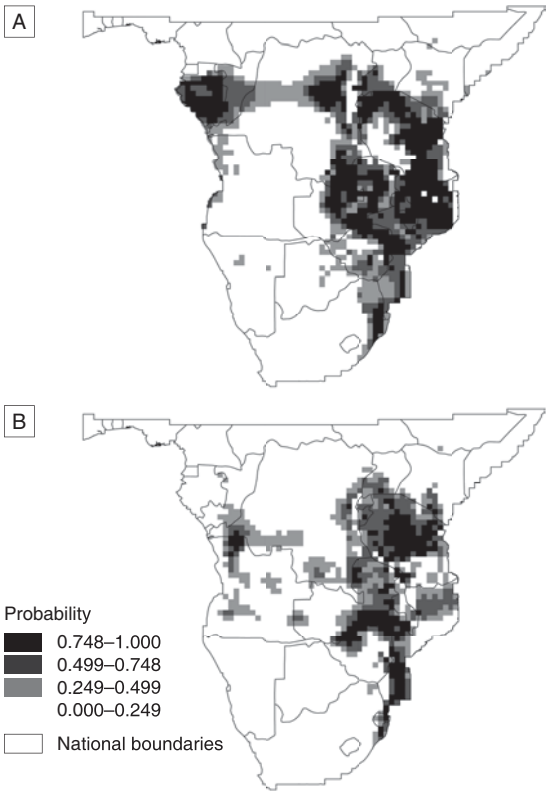

FIG. 31 *R. planus*

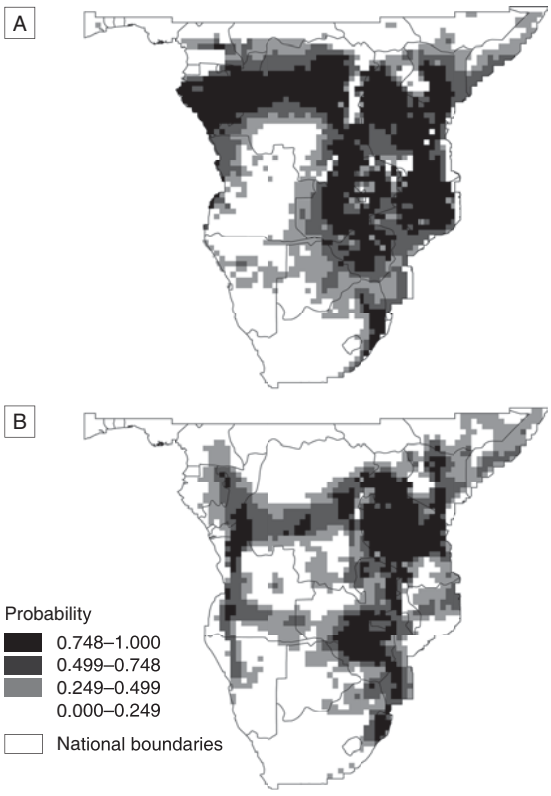

FIG. 32 *R. pravus*

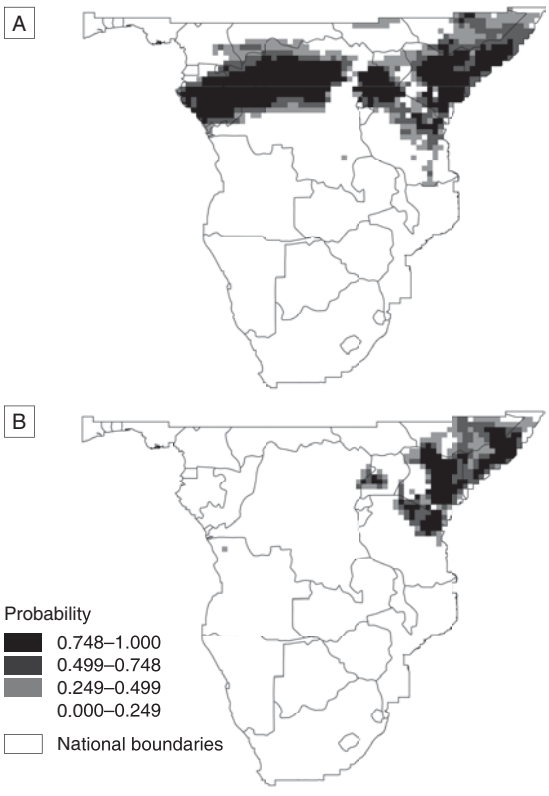

FIG. 33 *R. pulchellus*

FIG. 10–39 *Continued*

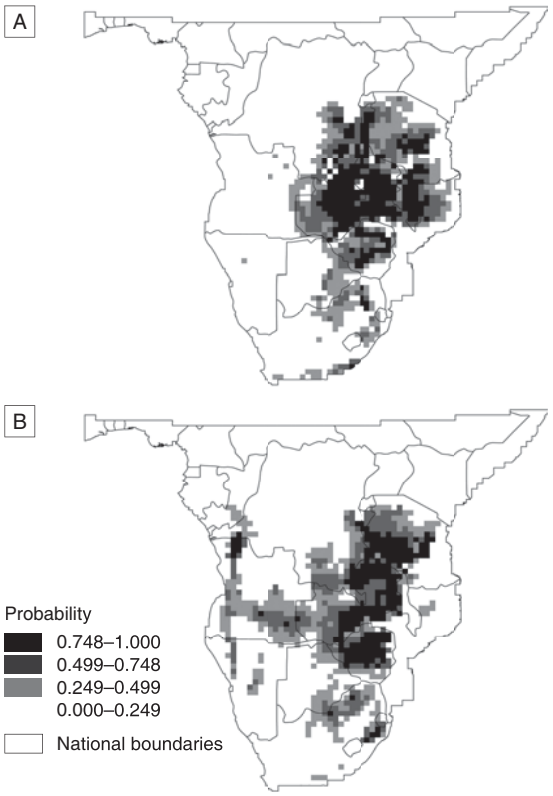

FIG. 34 *R. punctatus*

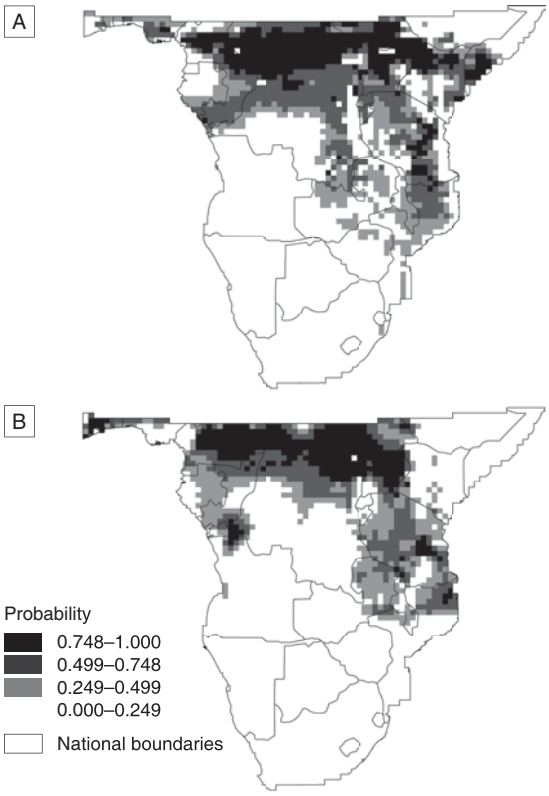

FIG. 35 *R. senegalensis*

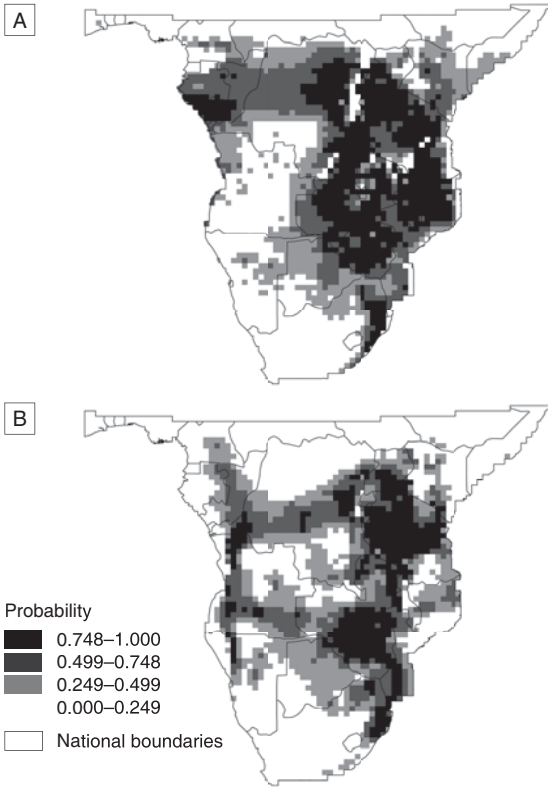

FIG. 36 *R. simus*

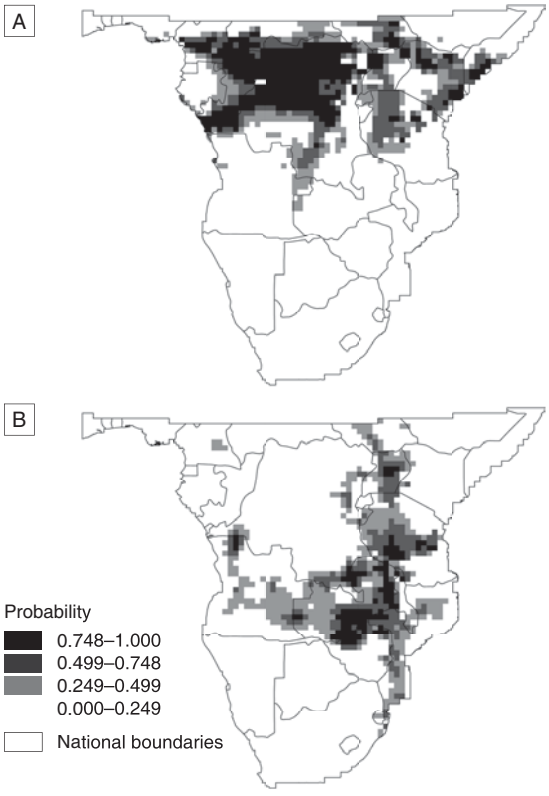

FIG. 37 *R. supertritus*

FIG. 10–39 *Continued*

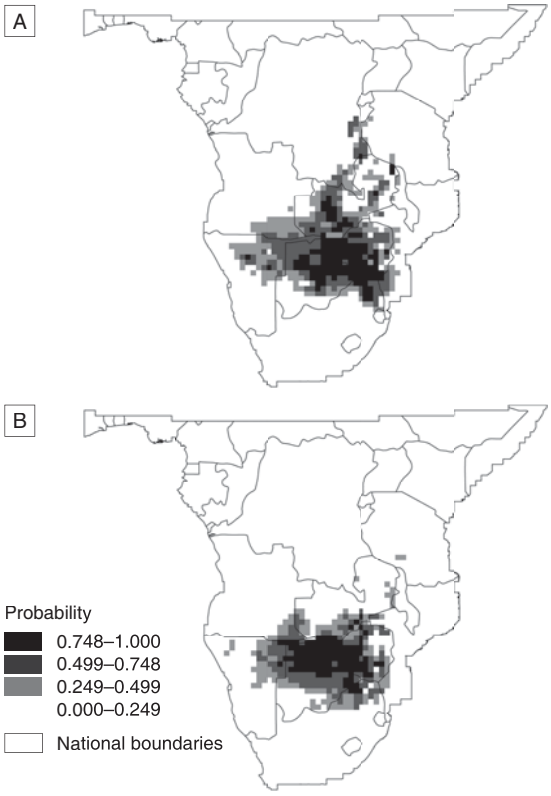

FIG. 38 *R. zambeziensis*

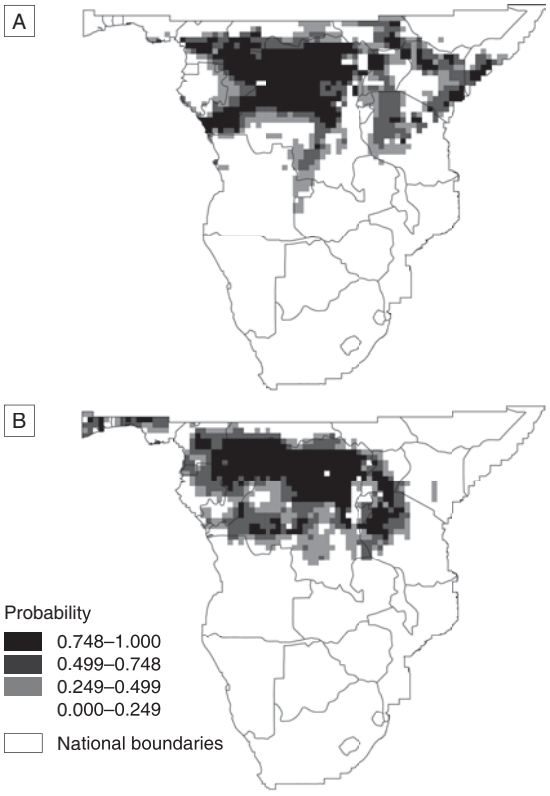

FIG. 39 *R. ziemanni*

is a highly significant differences between the two data sets (Kolmogorov-Smirnov test $P > 0.001$ was obtained for all variables. Also see Fig. 9). This difference was especially noticeable in the predictions for mean maximum temperature for January, and mean rainfall for January and July where the GCM data predicted hotter and drier climates than DARLAM.

The regional analysis of predicted tick distributions using DARLAM and GCM has revealed consistently broader ranges for DARLAM, except for South Africa where the GCM predictions are broader than DARLAM in 66% of the species studied. Of these species *R. capensis* is present in a winter rainfall region with hot and generally dry summers, whereas *R. evertsi mimeticus, R. exopthalmos* and *R. oculatus* are species that occupy arid and semi-arid areas in South Africa with an annual mean rainfall of 100–400 mm. The other two species for which GCM predictions were found to be broader than DARLAM are *R. compositus* and R. *muehlensi*. *Rhipicephalus compositus* is a central African species present in a variety of wooded habitats with rainfall varying between 700 to more than 1 600 mm per annum (Walker *et al*. 2000). On the other hand, *R. muehlensi* is present in all African countries with an eastern seaboard from Somalia to South Africa. It occurs in coastal mosaic and undifferentiated woodland with the rainfall generally between 500 and 1 100 mm per annum (Walker *et al*. 2000).

Proportional overlap tests between the GCM and DARLAM fields on a sub-Saharan scale yield overlap values ranging from 24–72%. Regional comparisons show moderate overlap between DARLAM and GCM predictions. The lowest average overlap in tick ranges is found in East Africa with a mean proportional overlap of 43%, while for the "general" ticks category the overlap is the highest at 52%. This result is expected to change as the area of analysis increases (Table 2).

DISCUSSION

Using models to predict tick distributions

This study employed a climate envelope model (Erasmus *et al.* 2000) and a regional climate model DARLAM (Engelbrecht *et al*. 2002) to predict the present and future distribution of some African species of the tick genus *Rhipicephalus*. A climate com-

piled from values from two GCMs was also used on a comparative basis with DARLAM for modelling future tick distributions. Earlier work (Olwoch *et al.* 2003) indicated high accuracy levels between the predicted and recorded distributions of *R. appendiculatus, R. capensis* group*, R. longus* and *R. zambeziensis* in Africa using DARLAM. With this as background we proceeded to predict the future distributions of certain African tick species. The perceived advantages of this approach over the previous studies include:

(i) The climate surfaces produced by DARLAM are capable of capturing climate at sufficiently fine scales relative to the range sizes of species, are entirely based on a simulation of climate processes and do not use any recorded meteorological data to generate climate surfaces (Engelbrecht *et al.* 2002). Furthermore, the 25, 8 or 6 km resolution of most long-term interpolated climate data sets gives a false picture because it depends on the original low-resolution point observations (for a comparison of different climate data sets see Olwoch *et al.* 2003).

(ii) The multivariate capabilities of a predictive species modelling procedure (Erasmus *et al.* 2000) and its ability to provide probabilities of occurrence as opposed to mere absent-present predictions gives a comparatively better picture especially when tackling species that have been poorly sampled. This model can also operate effectively using only presence records and any number of available climate variables. The model has been validated for bird species (Erasmus *et al.* 2000) and tested on four species of African ticks (Olwoch *et al.* 2003).

(iii) The use of satellite imagery (e.g. the use of NDVI) is gaining ground as a basis for predicting tick distributions, but only works for predicting current distributions and cannot capture NDVI for the future.

This paper relates the possible effect that predicted climate changes, without taking other factors into account, may have on tick distribution in sub-Saharan Africa. It would, however be naïve not to address the importance of some of these other factors. One of these is host species, particularly as climate change may drastically affect their distribution even more than it would that of the ticks. Ixodid ticks are obligate, albeit temporary parasites of mammals, birds or reptiles during their larval, nymph and adult stages. Several species attach to a very wide range of hosts, while others have a restricted range of hosts that they will attach to during their adult or immature stages. This part of the discussion is limited to those species of *Rhipicephalus* of which one of us (I.G.H) has considerable field experience, namely *R. appendiculatus*, *R. capensis* group, *R. distinctus*, *R. evertsi evertsi*, *R. evertsi mimeticus*, *R. exophthalmos*, *R. kochi*, *R. maculatus*, *R. muehlensi*, *R. oculatus*, *Rhipicephalus* spp. of the pravus group, *R. simus* and *R. zambeziensis.*

Ticks that have a wide host range can be considered as generalists, namely *R. appendiculatus*, *R. evertsi evertsi*, *R. evertsi mimeticus* and *R. zambeziensis.* In addition, their larvae and nymphs feed on the same domestic or wild ruminant or equine hosts as the adults (Walker *et al*. 2000), with the further proviso that the larger the host animal or species the greater the number of adult ticks it is likely to harbour (Horak, Boomker, Spickett & De Vos 1992; Horak, Boomker & Flamand 1995). Although wild ruminant or equine host species are likely to be affected by climate change, it is probable that there will still be domesticated animals around to act as hosts for the ticks.

Rhipicephalus maculatus and *R. muehlensi*, which both prefer coastal bush as habitat, can be considered restricted generalists in that all stages of development of the former tick prefer thick-skinned animals such as African buffaloes (*Syncerus caffer*), bushpigs (*Potamochoerus larvatus*) and rhinoceroses (*Ceratotherium simum* and *Diceros bicornis*) as hosts, and those of the latter tick tragelaphine antelope species such as kudus (*Tragelaphus* spp.), nyalas (*Tragelaphus angasii*) and bushbuck (*Tragelaphus scriptus*) (Horak *et al.* 1995; Walker *et al.* 2000). Climate change will thus not only affect the preferred coastal woodland habitat of the ticks, but also the distribution of their hosts and these could prove to be major constraints to the predicted future distributions of these ticks.

The preferred hosts of all stages of development of *R. kochi* are medium-sized and larger antelopes and scrub hares, and the preferred hosts of adult *R. exophthalmos* are medium-sized and larger domestic and wild ruminants and scrub hares (Walker *et al.* 2000). The preferred hosts of all stages of development of ticks of the *R. pravus* group are scrub hares, but their adults will also be found on medium-sized and larger domestic and wild ruminants (Walker *et al.* 2000). It would, however, appear as if elephant shrews are excellent hosts of the immature stages of each of the latter three ticks (Fourie, Horak & Woodall 2005). Depending on the extent of reliance that the immature stages have on elephant shrews compared to the larger animals as hosts,

the effect of climate change on the distribution of these small mammals may be greater than its predicted effect on the distribution of the tick species they harbour.

The host preferences of two of the more "specialist" group of ticks, namely *R. capensis sensu strictu* and *R. simus sensu strictu* are nearly identical, with their adults on equids, large carnivores and large bovids and their immature stages on murid rodents, but whereas *R. capensis sensu strictu* is a tick of the western, winter rainfall, coastal regions, *R. simus* is found mainly in the moister inland summer rainfall regions of South Africa (Walker *et al.* 2000). The predicted future distributions may thus be determined not only by the presence of large mammal and murine hosts for their adult and immature stages respectively, but also by the differences in their seasonal climate preferences. The remaining two ticks, namely *R. distinctus* and *R. oculatus* are both very specific in their host requirements with all stages of the former virtually exclusively infesting hyraxes and of the latter hares (Walker *et al.* 2000). Any predicted changes in these ticks' distributions will depend heavily upon changes in the distribution of their specific hosts.

The above analysis and the fact that different tick species prefer different ecological and climatic requirements imply that the effect of climate change on the distribution of one tick species will not necessarily reflect the manner in which other species would react, emphasizing the importance of assessing its effect on as many species as possible. It should also be noted that predicted data, figures and risk maps presented here in no way represent the current/future presence or absence of species, but rather an inclination to habitat suitability. Moreover, this study supports the view put forward by Randolph (2002) that if the objective of a risk map is to warn of potential threat, to alert control services and to direct attention to hitherto uncharted localities where the tick may be lurking, it may be better to err, within limits, on the side of false alarms than of false complacency. In the light of the foregoing this paper represents an attempt to produce maps, using a regional climate model, for the predicted future distribution of tick species belonging to a genus of considerable veterinary and medical importance on the African continent.

Predictive species modelling is particularly useful in Africa where field surveys on most ticks are not conducted on a regular basis and consequently species inventories are not updated as required. By using the recorded distributions of well-sampled tick species and models the gaps in the existing records of poorly sampled species can be filled in. Even if up-to-date field data on the distribution of tick species are available, studies on the future distribution of species will still depend on the use of models. Thus good data and predictive species modelling are complementary in the study of the distribution of species in a changing environment. Since some of the African tick species have been adequately sampled this data can be used as an input in a model and the response to climate change of lesser-sampled species can be obtained.

Implications of the findings

The predicted effect of climate change on the distribution of ticks varies by region and species, and several species are forecast to experience range alterations in the form of contractions, expansions or shifts. It is also envisaged that climate change will alter the overall pattern of tick species richness. Though range alterations are in some cases minimal, they nevertheless may prove catastrophic on small African farms if prior warnings are not issued. The extent to which these predicted changes coupled with possible landscape changes will translate into realized alterations in distributions will depend on numerous other factors. These may include the effect of climate change on the hosts as discussed above, acaricide usage, land degradation and human population increase. In the following paragraphs each of these predicted changes are analysed separately before general conclusions are made and, where possible the biological implications of the predicted range alteration are discussed.

Range expansions

As could be expected, not all tick species reacted to the predicted climate changes in a similar manner. However, specific information concerning how physiological tolerances and behavioural patterns influence species ranges is limited to a few African taxa and has not been researched sufficiently to allow for entirely accurate predictions (Van Jaarsveld, Chown, Erasmus, Kshatriya & Wessels 2002). More than half of the tick species studied expanded their ranges under predicted future climate conditions. This has implications for the time ahead, as some of these species are vectors of pathogens. The close correlation between climate variables and many vectors of disease has been pointed out by Rogers & Randolph (1993). Climate change may increase the reproductive rate of some pathogens or alter the selection pressures on others and possibly accelerate the rate

at which new pathogens evolve. Because of the number of new pathogens that may evolve, mutations will probably also increase and there are likely to be more disease cycles per year in a warmer world (Sutherst 1996).

The expected range expansions simulated for East African ticks could be in response to the predicted general decrease in maximum temperatures. Since temperature determines rates of invertebrate development, reproduction and mortality, a decrease in temperature could accelerate rates of population increase, especially in areas where these are currently limited by high temperatures (Sutherst 1996) through a reduction in the desiccation and death of eggs. DARLAM's predicted decrease in January maximum temperatures could increase the likelihood of egg survival and thus result in greater hatching percentages. These moderate temperatures are responsible for the expected general expansion of tick ranges in sub-Saharan Africa.

Climate changes predicted for the east African horn region and northern Kenya favour range expansion by *R. pulchellus*, which prefers harsh environmental conditions (Walker *et al.* 2000). Range expansion by this tick corresponds with field observations that indicate that it is already expanding its range in the northern parts of east Africa (J. Mukani, personal communication 2002). On the other hand the specific reasons behind the predicted range expansion of *R. bequaerti* are not clear since very little information exists in the literature on the ecological preferences of this species. Its range expansion may, however, be in response to the predicted increase in minimum temperatures accelerating development and shortening generation times, possibly leading to higher tick populations in some areas (Sutherst 1996). The predicted decrease in maximum temperatures at the same time may reduce the limiting effect on such development that excessively high temperatures may have had.

In Southern Africa, range expansions are predicted for those species that currently occupy the drier regions of the subcontinent, namely *R. evertsi mimeticus* and *R. exophthalmus*. Furthermore, the predicted decrease in maximum temperatures and increase in rainfall in Namibia may result in shorter generation times and therefore more tick generations per year and higher tick populations. The fact that extensive range expansions are predicted for some of the economically important tick species implies that a future climate may also be favourable for an increase in tick-borne diseases. Range expansions of ticks in South Africa in particular may be in response to the observed effect of temperature on the pre-hatch period of their eggs. Various authors (Londt 1977; Robertson 1981; Spickett & Heyne 1990) reported that the length of this period is inversely dependent on increased temperatures. They observed that eggs laid in late summer; autumn or winter for instance took longer to hatch than those laid in summer and that there was a synchronous hatching of these eggs that occurred as the temperatures increased in spring. This observation was also recently supported by the field data of Horak, Spickett & Braack (2000) for *Boophilus decoloratus* in the Kruger National Park (KNP) in South Africa. Any predicted range expansion for this tick will also be in agreement with the marked increase in the number of free-living ticks of this species collected from vegetation in the KNP in 1998, corresponding to the exceptionally warm temperatures recorded during that year. In fact, Horak *et al.* (2000) recorded a double seasonal peak in tick numbers in 1998 implying that an additional generation of ticks had been completed. This result is also in agreement with experimental data on the spread of the tick *Ixodes ricinus* in northern Europe (Lindgren, Talleklint & Polfeld 1998). A worrying aspect of these predicted range expansions is that, by implication, larger numbers of cattle will be exposed to certain economically important tick species thus increasing the encumbrance of effective tick control measures.

In the "restricted generalist" and "specialist" tick categories the distributions of *R. pravus* and *R. simus* respectively, that currently already occupy wide ranges, are predicted to expand further. However, a reason for the apparently wide current distributions of these two ticks could be due to the fact that it is only recently that their specific identities have been resolved; in the past and still today authors refer to them as ticks of the *R. pravus* and *R. simus* groups (Walker *et al.* 2000). It is probable that the distribution data used in this study also contain data on ticks of the latter broader groups, and consequently it is not possible to state whether the predicted distributions represent those of true *R. pravus* and *R. simus* or those of ticks belonging to these groups.

Range contractions

The ranges of nearly half the tick species studied displayed varying degrees of contraction. The degree of range contraction is usually of concern because of the known negative relationship between range size and the probability of extinction (Gaston 1994). However, in this case this aspect is not of

much concern considering the relatively small scale of contraction found in the species investigated. Compared to other species some may view the extinction of parasites as an advantage, but it may have unexpected consequences. In Cote d'Ivoire for instance Gouteux & Jarry (1998) examined five species of tsetse fly and found that each species occupied different habitats and that populations were displaced in time. Partial removal of *Glossina palpalis* resulted in the invasion of its territory by two less dominate species, namely *Glossina pallicera* and *Glossina nigrofusca* resulting in the continued transmission of trypanosomosis (Sutherst 2001). Additionally, the suppression of *B. decoloratus* in south-eastern African countries by chemical control, coupled with the warm, moist climate of these countries, has partially been responsible for the invasion of its habitat by its more vigorous relative *B. microplus* (Sutherst 2001). Although the latter is also subject to the same chemical control, this shows that in reality suppression of one parasite may result in unexpected consequences. Thus, a contraction in the distribution range of one parasite species may increase competition and initiate the invasion of its erstwhile range by another species, which may, as is the case with *B. microplus*, transmit economically more important diseases than the indigenous *B. decoloratus* (Sutherst 2001).

The general range contraction for most of the Central African tick species included in this study is in response to the predicted decrease in the July minimum temperatures over this region. Similarly, increase in January temperatures and intense desiccation predicted for Zimbabwe and some parts of South Africa may be detrimental to tick growth and development leading to contraction of tick ranges in this region. The "generalist" tick, *R. appendiculatus* that flourishes in areas of high rainfall and moderate temperature is forecast to lose ground under the predicted dehydration of most of the East African coast. These results are in agreement with field observations on the decrease of free-living *R. appendiculatus* in the KNP following the 1991/1992 drought (Horak *et al.* 2000). An explanation for these observations appear to be that an increase in the ratio of bare ground compared to ground cover in the years following the drought led to heat stress and dry stress, which adversely affected the free-living stages of *R. appendiculatus* and consequently resulted in a reduction in the population on the vegetation. An increase in maximum temperatures in Zimbabwe is likely to drive *R. appendiculatus towards* the cooler areas of East Africa. This forecast is in agreement with earlier predictions by Rogers & Randolph (1993) that under global warming South African ticks are likely to retreat to the mountainous eastern region near the border of South Africa with Mozambique and that this effect will be more noticeable near the peripheries of their present ranges. The contraction in the distribution of *R. appendiculatus* may be looked at with relief since it is the most important vector of tick-borne diseases on the African continent, transmitting the pathogen *Theileria parva* that causes East Coast fever and Corridor disease in cattle in South Africa. This could imply that areas currently showing Corridor disease as an emerging disease may become vector free in the future. However, the contraction is too small to affect livestock ranching.

Range shifts and species richness

The overall results indicate that climate change will result in an increase in species richness in the current western arid areas of the sub-continent. This is attributed to more favourable climatic conditions in the future. However, because of specific ecological requirements, this pattern is not common to all ticks. For instance *R. appendiculatus* demonstrates a clear west to east shift in its distribution range and therefore supports the west to east shift hypothesis (Erasmus *et al.* 2002).

Future climate predictions using DARLAM and GCMs

The notable differences between the predicted climate outputs of the two modelling approaches is reflected in the variations in tick distribution range predictions. The hotter and drier climates predicted by GCMs are expected to result in greater decreases in tick distribution ranges than those forecast by DARLAM, an indication of model output differences. One would have expected proportionally significant differences in the resultant distribution ranges predicted by the two models corresponding to the highly significant differences in the two climates that they predict. However, moderate to high proportional overlapping between the DARLAM and GCM predictions implies that there are other factors operating at local levels other than climate. Because DARLAM is a process driven model it is able to capture today's conditions and comparatively more local interactions at a higher spatial resolution. GCMs on the other hand operate at a very low spatial resolution and have been criticized for being unable to capture present day features of the global climate (Goodess & Palutikof 1993). Ticks are habitat specialists and spend more that 90% of their lives on the ground and are thus likely to be affected by local

variations in climate. In this regard climate simulations provided by a regional model such as DARLAM are intuitively more appropriate to use in such studies than the GCM outputs.

Tick-borne diseases and climate change

A warmer climate will favour the range expansion of some of the economically important ticks, and domestic stock in sub-Saharan Africa would thus experience increased infestation with ticks that act as vectors of disease. With its poor reaction capacity, the livestock industry in sub-Saharan Africa would be severely affected and effective chemical control may be applied too late. Tick-borne disease control measures used during and after outbreaks and epidemics have not always been successful as they are usually crisis management tactics that do not allow for the incorporation of untreated controls in their evaluation (Carpenter, Appel, Erickson & Novilla 1976; Burrows, Hofer & East 1994). Most of these approaches target the disease in the infected animal and ignore the importance of all other interacting organisms in maintaining the disease in the population in a stable state. In this regard a more holistic ecological approach to disease management may be called for. Nevertheless tick-borne disease control will still rely heavily on chemical control due to its accessibility and "quick-fix" results. However, for a more permanent and sounder management of these diseases the integration of our knowledge about vectors and hosts, climate and other requirements, both now and in the future is of paramount importance. The impact of climate change on these tick-host-disease systems can no longer be ignored.

Future direction

The results presented here are essentially based on a climate matching method that relies firstly on the model used and secondly on the available current distribution data for the species. When these variables are projected into the future, caution is advised. Moreover, the overall effect of climate change on tick distribution will also depend on how these changes affect the interactions between ticks, hosts and tick-borne parasites collectively. Equally complex models will be required to include all of these specific interactions. In the absence of suitable modelling approaches to accommodate all of these biotic and abiotic interactions, simple climate matching models offer the best means available for exploring likely future biological consequences. On the whole, the effects of climate change on ticks and tick-borne diseases in Africa are likely to be expressed in several ways, from short-term epidemics to long-term gradual changes in disease trends. Field studies in Kenya already support this in that climate variability accounts for up to 26 % of the anomalies in hospital-based highland malaria cases (Githeko, Lindsay & Confalonieri & Patz 2000). In most cases there are few published data that provide this essential information partly because the science of climate and health is as yet not well developed. The actual proportion of changes in vector-borne diseases attributable to climate change is therefore still unknown. Furthermore, there are also bureaucratic obstacles to evidence-based health policy change (Githeko *et al.* 2000).

These results would have benefited from data generated by regular interval long-term surveys of tick distribution in Africa so that local trends could be identified. Although some ticks in some areas have been properly sampled, this sampling needs to be intensified to include all regions and all species. Where it has been, as in the case of *R. pulchellus*, the results are in agreement with field surveys in the horn of Africa where this species is already expanding its range. In the absence of such surveys and more robust models, the present predictions serve as a starting point for understanding the broad scale climatic requirements of African ticks and how these may be influenced by climate change. The prediction that some economically important tick species will be favoured by climate change puts pressure on African governments and on vector control agencies to introduce measures that will integrate the tick's ecological requirements in the appropriate tick control measure. Predicted range expansions in East and South Africa should not be taken lightly because of the dependency of these regions on livestock production. Holistic ecological control measures should be developed and resources for field studies should be provided to validate these results. In addition, resources to promote the continued study of the science of climate change must be made available for future research.

In conclusion, this study has identified those areas on the African continent south of the Sahara that will be most vulnerable to disruption by certain ticks of the genus *Rhipicephalus* under climate change. This is an important first step in disease management because it provides a key to the direction future efforts should take and also to avoid much unproductive effort on systems that may be sensitive to change, but for which there are sustainable and robust adaptation options already available. However, with the resources at hand, it is still possible to

give guidance as to the current and future distribution of a number of tick species.

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CHAPTER 4

FREE-LIVING TICKS

Most ixodid ticks spend at least 90 % of their lives off their hosts. Some of this time is spent as detached engorged females prior to oviposition, then as eggs prior to hatching, and later, in the case of multi-host ticks, as detached engorged larvae or nymphs prior to moulting. However, a great deal of this off-host time is spent questing for hosts, either as larvae, nymphs or adults depending on whether the particular species is a one-, two- or three-host tick. Questing ticks can be collected from the vegetation by means of flannel strips that are dragged over and through it, and the species composition, geographic locality and seasonal occurrence of ticks that are collected in this way can be ascertained (Spickett, Horak, Braack & Van Ark 1991; Zieger, Horak & Cauldwell 1998a). Various studies on the species composition and seasonality of questing ticks have been conducted in the Kruger National Park, and during the course of these the effects of drought, a rodent explosion and of an unusually warm winter on their numbers were determined (Spickett, Horak, Heyne & Braack 1995; Horak, Spickett & Braack 2000b). One of my postgraduate students also conducted a study on the dynamics of free-living questing ticks on a game ranch in Central Province, Zambia (Zieger *et al*. 1998a), at the conclusion of which I was responsible for the identification of at least 90 % of the ticks that had been collected.

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DRAG-SAMPLING OF FREE-LIVING IXODID TICKS IN THE KRUGER NATIONAL PARK

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ABSTRACT

SPICKETT, A. M., HORAK, I. G., BRAACK, L. E. O. & VAN ARK, H., 1991. Drag-sampling of free-living ixodid ticks in the Kruger National Park. *Onderstepoort Journal of Veterinary Research*, 58, 27–32 (1991)

Free-living ticks were collected by means of drag-sampling in 32 of the 35 landscape zones of the Kruger National Park during a period of 1 calendar month. Of the 18 199 specimens collected, 99,53 % were larvae, 0,05 % nymphs and 0,42 % adults. Fourteen species were collected. *Amblyomma hebraeum* followed by *Boophilus decoloratus*, predominated, both in distribution and abundance.

Large variations were encountered between drags. There was no correlation between the numbers of larvae collected and time of day, temperature, grass length, vegetation biomass estimates and subzone type.

INTRODUCTION

The seasonal abundance of ixodid ticks on blue wildebeest, Burchell's zebras, warthogs, and impala and kudu, in the Kruger National Park (KNP) has already been determined (Horak, De Vos & Brown, 1983; Horak, De Vos & De Klerk, 1984; Horak, Boomker, De Vos & Potgieter, 1988; Horak, Boomker & De Vos, unpublished data). Incidental collections of ticks have also been made from bushbuck, nyala, eland, giraffe and several carnivore species in the KNP (Horak, Potgieter, Walker, De Vos & Boomker, 1983; Horak, Jacot Guillarmod, Moolman & De Vos, 1987). These findings are incomplete without data on the free-living ticks potentially available on the vegetation in the KNP. Such data would contribute to an understanding of tick bionomics under conditions with minimal human interference.

The KNP, which is 1 945 528 ha in extent, has been divided by Gertenbach (1983) into 35 landscape zones on the basis of geomorphology, climate, soil and vegetation patterns. These landscape zones are intended to be used as funtional management units (Gertenbach, 1983). This papter reports on a survey of free-living ticks conducted in 32 of the 35 landscape zones over a period of 1 calendar month.

MATERIALS AND METHODS

The survey was conducted during March, 1988. The collection method chosen was drag-sampling, as a means of recovering immature ticks questing on vegetation (Zimmerman & Garris, 1985; Petney & Horak, 1987).

Ten 1 000 × 100 mm flannel strips were attached adjacently with Velcro[1] tape to a 1 200 mm-long wooden spar. Each collection was made by an operator pulling this spar, by means of a twine harness attached to its ends, for a distance of 250 m over the vegetation. At the end of each drag the flannel strips were individually detached from the bar and the ticks were removed with fine-point forceps, placed in vials containing 70 % alcohol and later identified and counted. Drags were not done over dew-laden grass early in the morning or over grass after rain, as this wet the flannel strips and decreased their efficacy. A total of 345 drags were done in 32 of the 35 landscape zones defined by Gertenbach (1983). These zones have generally been numbered from the south to the north in the KNP.

Each of the landscape zones was considered as a functional unit. Geographically extensive zones were, however, divided into north and south sectors which were treated as individual zones. Zone 23 was divided into 3 portions representative of the dominant grass type present in each, i.e. *Setaria, Themeda* and *Bothriochloa*. Within each zone, 3 drags were performed in each of 3 representative subzones: open grassland, gully and woodland.

Because of logistical problems and their small size, zones 20, 26 and 27 were not sampled.

The time at which each drag was done as well as the temperature in the shade at ground level (measured with a maximum/minimum thermometer), were recorded throughout the survey. Other factors noted on a subjective scale at the time of each drag were cloud cover, grasscover, condition and average length of the grass and the game density. In addition, grass fuel loads were estimated with a disc pasture meter accoring to the method of Trollope & Potgieter (1986). The mean of 100 disc meter readings were extrapolated to an estimated fuel load in kg/ha, as an indication of the biomass of the grass sward in the particular subzone in which drags were done.

Because of the overdispersed nature of free-living ticks, all counts were logarithmically transformed [$\log_{10}$ (x+1)] for statistical analyses (Petney, Van Ark & Spickett, 1990). Analyses were done only with counts of $\log_{10}$ (x+1) >1, and these were realized with only 2 species, *Amblyomma hebraeum* and *Boophilus decoloratus*. The numbers of the other tick species collected per subzone were considered too low for valid analysis.

RESULTS AND DISCUSSION

Tick species collected

A total of 14 tick species was collected. The greatest number of species recovered from any one zone was 7 (Zone 2) (Table 1). *A. hebraeum* predominated in most zones, being present in all but the northern sector of zone 32, where no ticks were recovered (Table 2). Despite being absent from 7 of the zones surveyed (Table 1), *B. decoloratus* was the next most abundant species (Table 3), and in zones

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TABLE 1 Tick species and stages collected in the different landscape zones of the Kruger National Park (zones 1–9)

Landscape zones*	Tick species													
	Amblyomma hebraeum	*Amblyomma marmoreum*	*Amblyomma nuttalli*	*Boophilus decoloratus*	*Dermacentor rhinocerinus*	*Haemaphysalis leachi*	*Hyalomma marginatum turanicum*	*Rhipicephalus appendiculatus*	*Rhipicephalus evertsi evertsi*	*Rhipicephalus* sp. (near *R. punctatus*)	*Rhipicephalus simus*	*Rhipicephalus tricuspis*	*Rhipicephalus turanicus*	*Rhipicephalus zambeziensis*
1	L			L		A		N/A			A			A
2	L	L		L		A		A	L		A			
3	L	L		L										
4	L			L/A		A			L		A			
5	L										A			
6	L			L										
7	L			L						L				
8	L			L			A	L		L				
9	L			L					L					
10	L													
11	L			L						L				
12	L			L					L	L				
13	L	L		L	L						A			
14	L							L						
15	L					A				L	A			A
16	L									L				
17S	L	L		L		A			L		A			
17N	L			L										
18	L			L										A
19N	L	L		L		A			L		A			
19S	L/N		L	L		A		N	L		A			A
21	L			L						L				
22N	L			L/N										
22S	L			L										
23Se	L								L					
23B	L			L						L			A	
23T	L									L				A
24	L			L										
25	L			L						L	A			
28	L			L				N		L	L			
29S	L	L		L				A	L					
29N	L	L		L										
30	L			L				L		L				
31				L					L		L			
32	L									L		A		
33	L	L		L					L	L				
34	L	L		L					L					
35	L									L	A			

* Zones numbered according to Gertenbach (1983)
L=Larvae; N=Nymphs; A=Adults

19 North, 22 South and 31 predominated over *A. hebraeum*. In the presence of *A. hebraeum* and the absence of *B. decoloratus*, a *Rhipicephalus* sp. (near *R. punctatus*) was predominant in zones 35 and 16 and *Rhipicephalus evertsi evertsi* in zone 23 (*Setaria*).

Of the 18 199 specimens collected, 99,53 % were larvae, 0,05 % nymphs and 0,42 % adults. Most species were represented by larvae, as the sampling method used favours this stage of development (Zimmerman & Garris, 1985; Norval, Yunker & Butler, 1987). However, several adults of *Haemaphysalis leachi, Rhipicephalus appendiculatus, Rhipicephalus zambeziensis* and *Rhipicephalus simus* and 1 adult specimen each of *B. decoloratus, Rhipicephalus tricuspis* and *Hyalomma marginatum turanicum* were collected (Table 1, Table 3). The latter tick normally occurs in the Karoo (Howell, Walker & Nevill, 1978) and its presence in the KNP is probably due to an engorged nymph detaching from a migratory bird. The recovery of an adult male *B. decoloratus* from the vegetation confirms the collection by Wilkinson (1964) cited by Mason & Norval (1981) of *Boophilus* males from drag samples. These one-host ticks probably actively quest for a new host after detachment from the original host.

Two nymphs of *A. hebraeum*, 1 nymph of *B. decoloratus* and on 3 occasions, nymphs of *R. appendiculatus* attached to the flannel strips (Table 1, Table 3). The low incidence or complete absence of *R. appendiculatus* and *R. zambeziensis* larvae on the strips is attributable to seasonality (Short & Norval, 1981; Norval, Walker & Colborne, 1982). That of *H. leachi* and *R. simus* is ascribed to the questing behaviour of the immature stages, which favours contact with rodents rather than with large mammals (Howell *et al.*, 1978).

TABLE 2 The total numbers of ixodid ticks, mean numbers of larvae per drag, number of species and the predominant species per vegetation zone collected in the Kruger National Park

Zone	Number of drags	Total larvae	Mean larvae per drag	Total nymphs	Total adults	Number of species present	Predominant species
2	9	2 555	283,89	1	4	7	A.h.
17S	9	1 785	198,33	0	3	6	A.h.
17N	9	1 771	196,78	0	0	2	A.h.
4	9	1 293	143,67	0	10	5	A.h.
33	9	1 181	131,22	0	0	5	A.h.
*15	9	1 162	129,11	0	12	5	A.h.
29N	9	960	106,67	0	0	3	A.h.
12	9	785	87,22	0	0	4	A.h.
30	8	551	68,88	0	0	4	A.h.
1	9	559	62,11	3	29	6	A.h.
18	9	555	61,67	0	1	3	A.h.
19N	9	535	59,44	2	7	7	B.d.
*23T	9	523	58,11	0	1	2	A.h.
29S	9	430	47,78	0	4	5	A.h.
8	9	396	44,00	0	0	4	A.h.
6	9	381	42,33	0	0	2	A.h.
13	9	375	41,67	0	0	3	A.h.
*14	9	365	40,56	0	0	2	A.h.
22S	9	342	38,00	0	0	2	B.d.
22N	9	274	30,44	1	0	2	A.h.
19S	9	210	23,33	0	2	6	A.h.
3	9	189	21,00	1	0	5	A.h.
21	9	188	20,89	0	0	3	A.h.
28	10	195	19,50	0	0	3	A.h.
34	9	158	17,56	0	0	4	A.h.
*5	9	81	9,00	0	1	2	A.h.
11	9	72	8,00	0	0	3	A.h.
7	9	62	6,89	0	1	4	A.h.
*35	9	49	5,44	0	0	3	R.p.
25	9	38	4,22	0	1	4	A.h.
9	9	35	3,89	0	0	3	A.h.
24	9	24	2,67	0	0	2	A.h.
31	9	15	1,67	0	0	3	B.d.
23B	9	10	1,11	0	0	3	A.h.
*10	9	6	0,67	0	0	1	A.h.
*23Se	9	3	0,33	0	0	2	R.e.
*16	9	3	0,33	0	0	2	R.p.
*32S	6	2	0,33	0	0	1	A.h.
*†32N	6	0	0	0	0	0	

S =South; N = North; Se = *Setaria;* B = *Bothriochloa;* T = *Themeda*;
B.d. = *B. decoloratus;* R.p. =*Rhipicephalus* sp. (near *R. punctatus*);
R.e. =*R. e. evertsi;* A.h. = *A. hebraeum;** = *B. decoloratus* absent; † = *A. hebraeum* absent

TABLE 3 Numbers of larvae, nymphs and adults of the 9 main tick species collected from the vegetation in the Kruger National Park

Tick species	Total number of larvae	Mean number of larvae	Total number of nymphs	Total number of adults
Amblyomma hebraeum	15669	45,42	2	0
Boophilus decoloratus	1787	5,18	1	1
Rhipicephalus sp. (near *R. punctatus*)	301	0,87	0	0
Amblyomma marmoreum	263	0,76	0	0
Rhipicephalus evertsi evertsi	73	0,21	0	0
Rhipicephalus simus	15	0,04	0	27
Rhipicephalus appendiculatus	5	0,01	5	16
Haemaphysalis leachi	1	0,00	0	18
Rhipicephalus zambeziensis	0	0,00	0	15

Although the immature stages of *Hyalomma truncatum* do occur in the KNP in large numbers on scrub hares (Horak & Spickett, unpublished data) and adults on giraffes (Horak *et al.*, 1983), no *Hyalomma* spp. larvae were recovered. Rechav (1986), using a similar collection method, obtained small numbers of larvae of both *Hyalomma truncatum* and *Hyalomma marginatum rufipes* in a bush habitat in the western Transvaal. He gives no data on grass length, however, and this may affect larval attachment to the flannel strips. They are more likely to be collected from very short grass because they prefer rodents, hares and ground-feeding birds as hosts (Rechav, 1986; Horak & MacIvor, 1987). Only 1 larva of *Dermacentor rhinocerinus* and 1 of *Amblyomma nuttali* were collected (Table 1).

Time of day

The presence of heavy dew on the grass in the early mornings precluded most drags before 09:00 as the flannel strips became too wet. Most larvae were collected between 11:00 and 12:00 and fewest between 16:00 and 17:00 (Fig. 1). No drags were performed after 17:00. To determine whether there were significant differences in the numbers of larvae collected at different times of the day, it was assumed that equal numbers would be collected irrespective of the time of day. To accommodate conta-

gious distribution the means per drag for each time interval were transformed, indexed [$\log_{10}$ (mean/drag) × 10] and used as observed frequencies. The overall mean of the observed values was transformed and indexed [$\log_{10}$ (mean) × 10] to serve as expected frequencies. Chi-squared analysis of these observations, however, showed no significant difference (P=0,05) between the larval numbers collected at different times of the day.

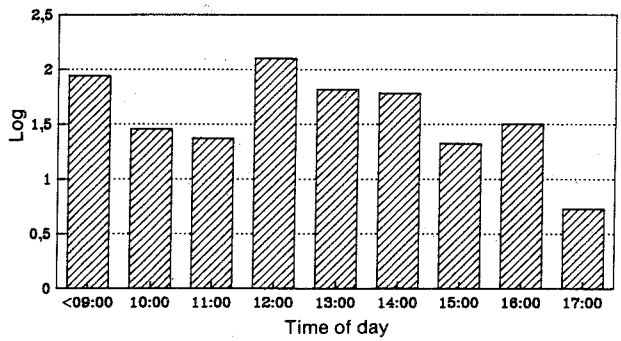

FIG. 1 Mean number [$\log_{10}$ (x+1)] of tick larvae collected per drag at various times of the day in different landscape zones of the Kruger National Park

These results are in contrast to those of Rechav (1979), who found more than 80 % of larvae of *A. hebraeum* (which constitute the majority of larvae collected in this survey), *R. appendiculatus* and *R. evertsi evertsi* on grass tips and 20 % on the ground at 06:00 and 09:00. He found only 50 % on grass tips at 12:00 and an 'increased number' towards evening, at a locality in the eastern Cape Province of South Africa.

Temperature

Temperature in the shade at ground level ranged from 25 °C–37 °C, while the numbers of *A. hebraeum* larvae collected [$\log_{10}$ (x+1)] ranged from 0–3,218, and those of *B. decoloratus* from 0–1,838. Neither the total numbers of larvae collected nor the numbers of *A. hebraeum* (Fig. 2) and *B. decoloratus* were temperature-dependant at the time of collection within the temperature range recorded. This probably indicates that the larvae of all species are active over the complete temperature range measured.

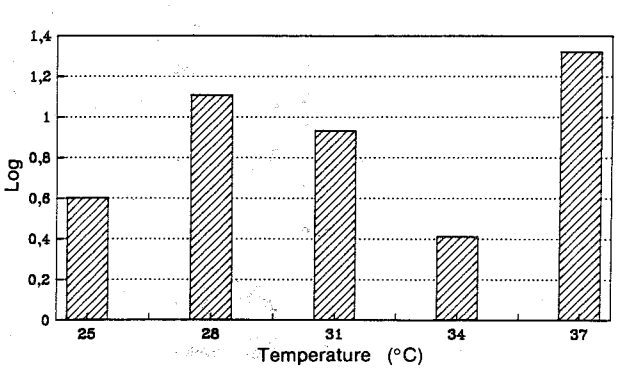

FIG. 2 Mean number [$\log_{10}$ (x+1)] of *Amblyomma hebraeum* larvae collected by drag-sampling at various temperatures in different landscape zones of the Kruger National Park

Vegetation biomass

Of the 62 observations where the numbers of *A. hebraeum* larvae [$\log_{10}$ (x+1)] ranged from 1–3,218 (SD=0,605), the corresponding biomass estimations ranged from 608–7541 kg/ha (SD=1403,442). There was a poor relationship between the numbers of larvae recovered and the biomass estimations, with a coefficient of correlation of r = 0,0425 for *A. hebraeum*.

Grass length

In laboratory experiments Londt & Whitehead (1972) found that *A. hebraeum* larvae prefer an 'optimal vegetation height' of 380 mm. In this study *A. hebraeum* larvae, ranging in numbers from 1–3,023, showed no significant correlation at 5 % (r = 0,0854) with the mean estimated length of the grass from which they were collected, which ranged from 250–1 000 mm (Fig. 3). *B. decoloratus* larvae, ranging in number from 1,041–2,702, also showed no significant correlation at 5 % (r = 0,3646) with the same range of grass lengths. However, most *B. decoloratus* larvae were collected from grass with a mean estimated length of between 700 and 900 mm (Fig. 4). Londt & Whitehead (1972) consider the 'optimal vegetation height' for this species to be 200 mm.

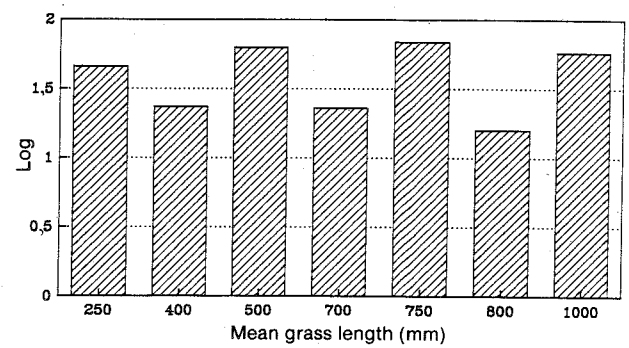

FIG. 3 Mean number [$\log_{10}$ (x+1)] of *Amblyomma hebraeum* larvae collected by drag-sampling from grass of various lengths in different landscape zones of the Kruger National Park

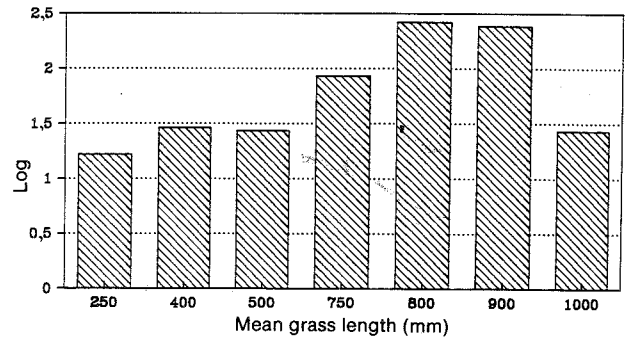

FIG. 4 Mean number [$\log_{10}$ (x+1)] of *Boophilus decoloratus* larvae collected by drag-sampling from grass of various lengths in different landscape zones of the Kruger National Park

Subzones

The mean numbers of *A. hebraeum* larvae collected were consistently greater than those of *B. decoloratus* in all 3 subzones when both species were present (Fig. 5). However, neither species occurred significantly more frequently than the other in any of the 3 subzones (chi-squared= 0,412 , P < 0,05).

In open grassland the numbers of *A. hebraeum* larvae collected ranged from 0,301–2,534, in gullies from 0,602–3,072, while woodland subzones yielded the highest numbers (0,301–3,146). *A. hebraeum* is commonly regarded as a species that is ecologically

dependent on tall grass and tree shade (Theiler, 1948; Londt & Whitehead, 1972; Norval, 1974), and substitution of bush with kikuyu grass pasture has been suggested as a method of reducing populations of this species (Spickett, 1987). Multiple comparison of means by the Bonferroni method, however, showed no significant differences between the numbers of larvae collected in the 3 subzones in this survey.

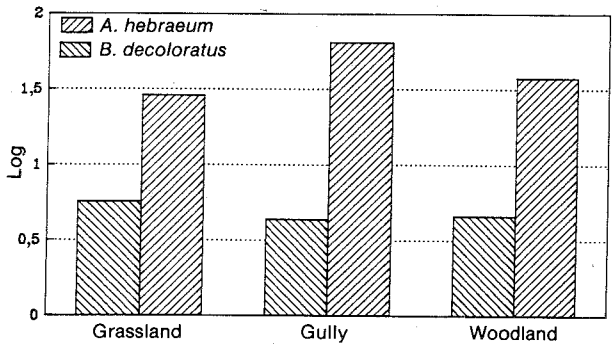

FIG. 5 Mean number [$\log_{10}$ (x+1)] of *Amblyomma hebraeum* and *Boophilus decoloratus* larvae collected by drag-sampling from 3 subzones within different landscape zones of the Kruger National Park

Corresponding ranges for *B. decoloratus* were open grassland 0,477–2,709; gullies 0,602–1,954, and woodland subzones 0,301–1,954 larvae. According to Londt & Whitehead (1972), *B. decoloratus* prefers protected vegetation (sheltered by neighbouring trees and bushes), as opposed to covered vegetation (under a complete canopy of trees) and open vegetation (not in the immediate vicinity of trees). Although open grassland yielded more larvae of this species than the other subzones, no significant differences in the numbers recovered from the 3 subzones could be demonstrated.

The vast variation in the vegetation typifying the different landscape zones would tend to obviate any experimental assumption of subzone homogeneity. A typical grassland subzone in a thicket landscape could resemble a typical woodland in a savanna landscape. The low numbers of larvae recovered, high variation between drags and the small number of drags performed per subzone, prevented valid analyses within individual landscapes.

To test whether the absence of any association between the 2 predominant tick species and any of the 3 subzones was due to incorrect experimental assumption, similar landscape zones were grouped to form larger vegetational zones. This attempt to increase the number of drags per subzone, while at the same time improving subzone homogeneity, provided no evidence of statistical correlation between the total number of larvae collected, or the numbers of *A. hebraeum* or of *B. decoloratus* larvae recovered and open grassland, woodland or gully subzones.

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The effect of severe drought on the abundance of ticks on vegetation and on scrub hares in the Kruger National Park

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Free-living ixodid ticks were collected monthly from August 1988 to July 1993 from the vegetation of landscape zones 17 (*Sclerocarya caffra/Acacia nigrescens* Savanna) and 4 (Thickets of the Sabie and Crocodile Rivers) in the south-east and south-west of the Kruger National Park respectively, and parasitic ticks from scrub hares in the latter landscape zone. Total tick collections from the vegetation of both landscape zones were lowest in the year following the drought year of August 1991 to July 1992, while the tick burdens of the scrub hares were lowest during the drought year itself.

Key words: ixodid ticks, abundance, landscape zones, scrub hares, drought.

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Introduction

The seasonal abundance of free-living ixodid ticks in the *Sclerocarya caffra/Acacia nigrescens* landscape zone in the south-eastern region of the Kruger National Park has been determined by monthly drag-sampling of the vegetation in this region (Spickett *et al.* 1992). Similar data for parasitic ticks have been obtained by monthly sampling of scrub hares (*Lepus saxatilis*) in the landscape zone described as Thickets of the Sabie and Crocodile Rivers in the south-west of the park (Horak *et al.* 1993). Thirteen ixodid tick species were recovered from the vegetation and 12 from the scrub hares.

The present paper records the total numbers of ticks collected annually by monthly drag-sampling of vegetation in two landscape zones in the Kruger National Park and monthly examination of scrub hares in one of these zones over a period of five years from August 1988 to July 1993. During this time exceptionally low rainfall was recorded for the period August 1991 to July 1992.

Materials and Methods

Study Sites

Free-living ticks were collected in the southern region of the Sclerocarya caffra/Acacia nigrescens Savanna landscape zone and in the Skukuza region of the Thickets of the Sabie and Crocodile Rivers landscape zone (Landscape Zones 17 and 4 respectively of Gertenbach 1983). Ticks were also collected from scrub hares shot in the latter zone.

Tick collection

Free-living ticks questing on vegetation were collected at monthly intervals from August 1988 to July 1993 by drag-sampling (Zimmerman & Garris 1985; Petney & Horak 1987). Detailed descriptions of our

collection methods are given in Spickett *et al.* (1991, 1992). Five scrub hares were shot each month and ticks collected from these animals as described by Horak *et al.* (1986) and Horak & Fourie (1991). All the ticks were identified and counted under a stereoscopic microscope.

Presentation of data

The total numbers of ticks collected each year from August to July in each of the landscape zones and from the scrub hares are graphically illustrated and compared. Similar comparisons are made for each of the major tick species.

Results

The vast majority of ticks recovered from vegetation were in the larval stage. The largest total number of ticks (Fig. 1b) and larvae of *Amblyomma hebraeum* (Fig. 1c), *Boophilus decoloratus* (Fig. 2a), *Rhipicephalus appendiculatus* (Fig. 2b) and *Rhipicephalus zambeziensis* (Fig. 2c) were collected from the vegetation of landscape zone 17 during the year of lowest rainfall from August 1991 to July 1992 (Fig. 1a). In each case a decrease in numbers was evident only during the following year, with the greatest decrease occurring in the total number of ticks (Fig 1b) and number of *A. hebraeum* larvae recovered (Fig. 1c).

The total number of ticks (Fig. 3a) recovered from the vegetation of landscape zone 4 during the drought year (August 1991 to July 1992) did not differ markedly from the numbers collected in preceding years. However, a considerable reduction in the total number of ticks recovered occurred in the year following the drought. This reduction resulted from a decrease in the numbers of larvae of the major species, namely *A. hebraeum* (Fig. 3b), *B. decoloratus* (Fig. 4a) and *R. zambeziensis* (Fig. 4b).

The smallest total number of ticks (Fig. 5a) was recovered from the scrub hares during the drought year. This was attributable to reduced numbers of larvae of *A. hebraeum* (Fig. 5b) and *Amblyomma marmoreum* (Fig. 5c), immature *Hyalomma truncatum* (Fig. 6a) and larvae of *R. zambeziensis* (Fig. 6b).

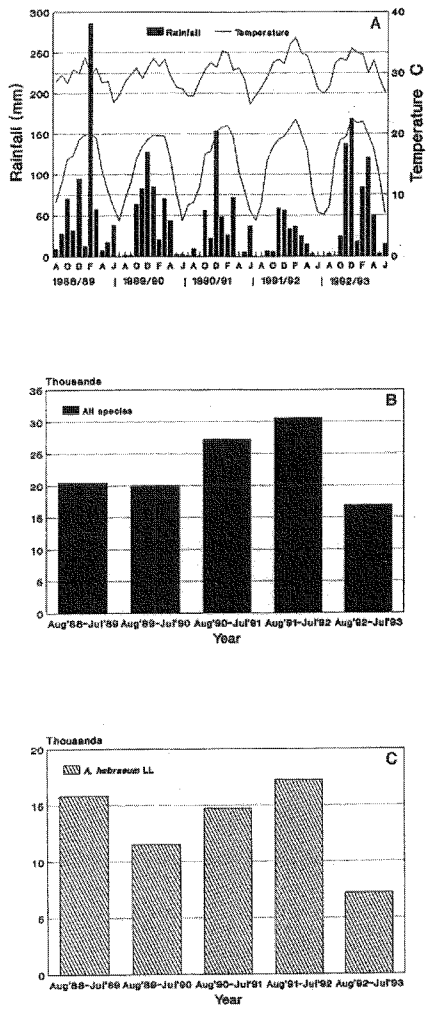

Fig. 1. A) Total monthly rainfall, and maximum and minimum temperature for Skukuza. B) Total numbers of ticks of all species. C) Total numbers of *Amblyomma hebraeum* larvae collected each year in landscape zone 17.

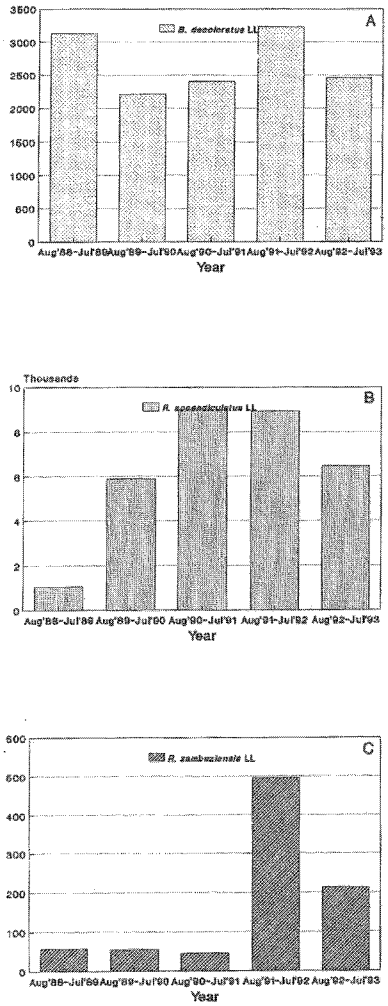

Fig. 2. Total numbers of larvae of A) *Boophilus decoloratus*; B) *Rhipicephalus appendiculatus*; and C) *Rhipicephalus zambeziens*is collected each year in landscape zone 17.

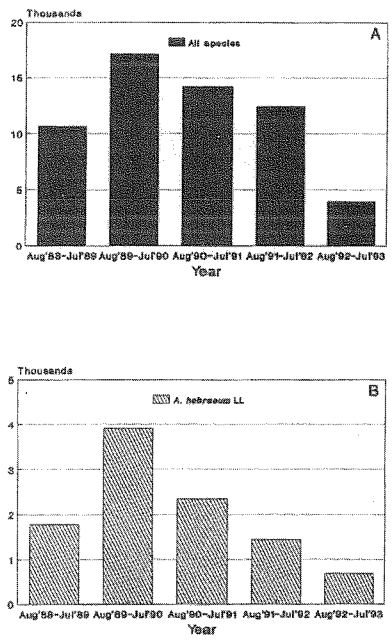

Fig. 3. Total numbers of A) ticks of all species; and B) *Amblyomma hebraeum* larvae collected each year in landscape zone 4.

Discussion

A number of explanations for the fluctuations in tick abundance during and after the drought can be proffered. These are, however, only speculative as the fluctuations are probably caused by a complex set of interactions and are not, therefore, easily explained.

The grass cover in that portion of landscape zone 17 in which we worked appeared to be amongst the most dense to be seen anywhere in the park—both before and during the drought year. The rainfall following the drought resulted in a visually apparent increase in the density and length of this grass cover. This could have had a diluting effect on tick density, resulting in the reduced numbers recovered during the year following the drought.

The grass and forb cover in that region of landscape zone 4 which we sampled was partially destroyed by fire during September

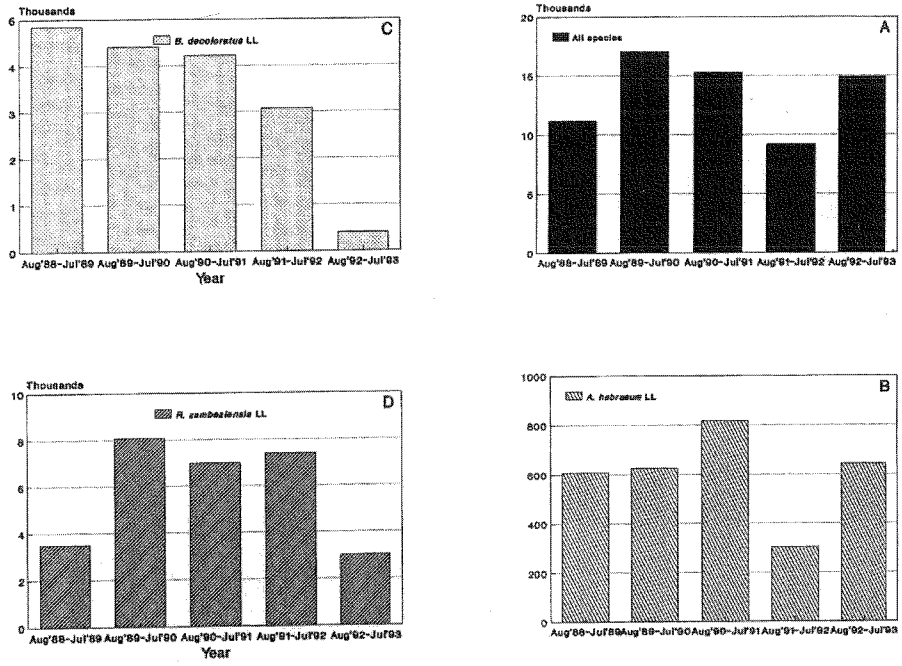

Fig. 4. Total numbers of larvae of A) *Boophilus decoloratus*; and B) *Rhipicephalus zambeziensis* collected each year in landscape zone 4.

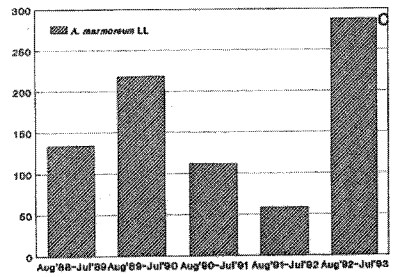

Fig. 5. Total numbers of A) ticks of all species; B) *Amblyomma hebraeum* larvae; and C) *Amblyomma marmoreum* larvae collected each year from scrub hares in landscape zone 4.

1990. Although the cover improved during the summer of 1990/1991 it was again severely affected by the drought of 1991/92 and, on a subjective assessment, large numbers of animals emigrated from this region. The rain following the drought resulted in a massive regrowth of forbs, weeds and to a lesser extent grass and it was only during the latter half of 1993 that the animals returned. The reduced animal population during 1991/92 and much of 1993 probably affected the tick population adversely, while the considerable regrowth of forbs and weeds following the rains could have diluted tick density, thus resulting in the small numbers recovered from the vegetation in the year following the drought.

The numbers of ticks recovered from the scrub hares examined in landscape zone 4 contradict the above theories. The drought seemed to result in an immediate and considerable reduction of the tick burdens of these animals. There is, however, an essential difference between the species found on the scrub hares and the free-living tick species recovered from the vegetation. The major tick on the hares was *H. truncatum* but this species was never recovered from

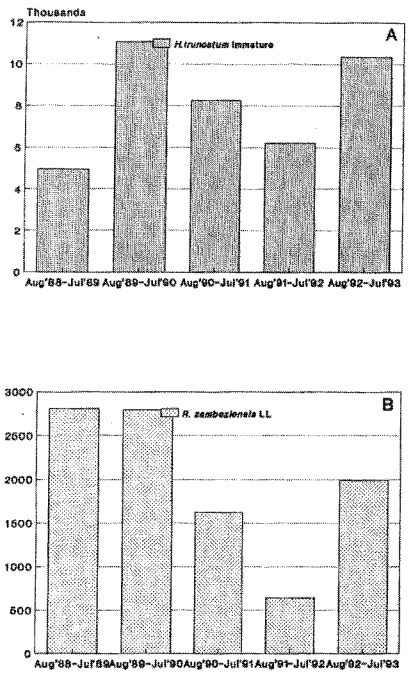

Fig. 6. Total numbers of A) *Hyalomma truncatum* immatures; and B) *Rhipicephalus zambeziensis* larvae collected each year from scrub hares in landscape zone 4.

the vegetation. Nevertheless, the larvae of *A. hebraeum*, *A. marmoreum* and *R. zambeziensis* all showed trends similar to those of *H. truncatum*.

Acknowledgements

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Dynamics of free-living ixodid ticks on a game ranch in the Central Province, Zambia

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ABSTRACT

ZIEGER, U., HORAK, I.G. & CAULDWELL, A.E. 1998. Dynamics of free-living ixodid ticks on a game ranch in the Central Province, Zambia. *Onderstepoort Journal of Veterinary Research,* 65:49–59

Free-living ixodid ticks were collected at monthly intervals from January to December 1996 by drag-sampling the vegetation of Mtendere Game Ranch in the Chisamba District of the Central Province, Zambia. Ticks belonging to 11 species were recovered. *Rhipicephalus appendiculatus* was most abundant, comprising 90 % of the total number collected. All life stages of this tick showed a definite seasonal pattern of activity. The adults were present mainly during the rainy season (February and March), the larvae during the cool and dry season (May to August), and the nymphs during the hot and dry season (August to October). Adults were most abundant in the wooded areas and nymphs in the open grasslands. Larvae of *Amblyomma variegatum* were only found from May to September, while larvae of *Boophilus decoloratus* were present throughout the year with peaks of abundance from January to February and again from August to November. *Rhipicephalus evertsi evertsi* larvae occurred throughout the year. Recent burning of the vegetation did not seem to affect the number of ticks collected. A possible burning regime to achieve a degree of tick control is discussed.

Keywords: Central Province, Zambia, drag-sampling, free-living ixodid ticks

INTRODUCTION

Ticks have been incriminated as a contributing factor to wildlife losses on some game ranches in southern Africa (Lightfoot & Norval 1981; Norval & Lightfoot 1982). The effects of heavy tick burdens on wild animals can include tick toxicosis, anaemia, metabolic disturbances and tick worry (O'Kelly & Seifert 1969; Seebuck, Springel & O'Kelly 1971). Secondary bacterial infections and myiasis of tick-bite wounds are also common (Howell, Walker & Nevill 1978). Blood parasites, such as *Theileria* spp, *Babesia* spp, *Anaplasma* spp, *Cytauxzoon* spp and *Cowdria ruminantium* can all be transmitted by ticks (Howell *et al.* 1978). Although endemic wild animals are usually not affected by these blood parasites, translocation of hosts and/or ticks into non-endemic areas can cause severe losses amongst susceptible animals (Lightfoot & Norval 1981; Meltzer 1993).

Commercial game ranching is a new and developing industry in Zambia. Many of the present game ranches are small, covering areas of less than 1 000 ha. Overstocking with wildlife is common, leading to a situation that lends itself to the build-up of high tick numbers (Horak 1980; Gallivan, Culverwell, Girdwood & Surgeoner 1995). Heavy tick infestations on wildlife on a game ranch in the Chisamba District of the Central Province of Zambia had previously been reported by the owner. In the present study the abundance of free-living ticks on this ranch was investigated. Data were collected concerning the tick species present on the ranch, their seasonal occurrence and abundance on the vegetation, their vegetation type preferences and the effects of recent burning of certain areas of the ranch on their subsequent numbers. The total tick burdens of a variety of large and small mammals and some birds on the

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ranch were also ascertained. However, the results of the latter studies will be published separately.

MATERIAL AND METHODS

Study area

The survey was conducted on Mtendere Game Ranch (15°05′S, 28°16′E), approximately 20 km north of Lusaka in the Chisamba District of the Central Province of Zambia. The altitude in this region varies from 1 100–1 200 m above sea level, and the annual rainfall from 800–900 mm (Hutchison 1974). Three distinct seasons occur. They are the warm and wet rainy season from December to April, the cool and dry season from May to August and the hot and dry season from September to November. The monthly mean temperatures are 20,0 °C in January, 15,0 °C in July and 22,5 °C in October (Ansell 1978). The vegetation of this region is classified as miombo woodland. It is dominated by trees of the genera *Brachystegia* and *Julbernardia* (Trapnell 1953). Miombo woodlands are typically interspersed with shallow, seasonally waterlogged drainage lines called dambos.

The ranch is 960 ha in size and has operated as a commercial game ranch since 1990. In January 1996 it contained some 570 larger ungulates. This is equivalent to 205 large stock units at a stocking rate of one large stock unit per 4,7 ha. The game included 34 Burchell's zebra *Equus burchellii;* ten warthog *Phacochoerus africanus;* 25 bushpig *Potamochoerus larvatus;* 135 impala *Aepyceros melampus;* 18 tsessebe *Damaliscus lunatus lunatus;* 48 Lichtenstein's hartebeest *Sigmoceros lichtensteinii;* four oribi *Ourebia ourebi;* 22 eland *Taurotragus oryx;* 35 bushbuck *Tragelaphus scriptus;* two sitatunga *Tragelaphus spekii;* 43 greater kudu *Tragelaphus strepsiceros*; 20 common duiker *Sylvicapra grimmia;* four roan antelope *Hippotragus equinus;* 30 sable antelope *Hippotragus niger;* 62 defassa waterbuck *Kobus ellipsiprymnus defassa;* 20 Kafue lechwe *Kobus leche kafuensis*; 36 puku *Kobus vardonii*; and 22 reedbuck *Redunca arundinum.*

Selection of sites

Ticks were collected monthly at eight sites. One site was situated in each of the four major vegetation types of the ranch: a grassland, a dambo, a miombo woodland and a munga woodland. The grassland area had been planted to Rhodes grass *Chloris gayana* in 1990 and is currently classified according to Edwards (1983) as a short closed grassland with a grass height of 0,5–1,0 m, and a tree and shrub crown cover of less than 0,1 %. The dambo site is dominated by *Setaria incrassata, Echinochloa colona* and *Hyparrhenia* spp. It is classified as a tall closed grassland with a grass height of 1,0–2,0 m and a tree and shrub crown cover of less than 0,1 %. The miombo woodland is dominated by the tree *Brachystegia spiciformis* and the grass *Andropogon gayanus.* This vegetation type is classified as a tall closed woodland with a total tree crown cover of 10,0–75,0% and a canopy height of 10,0–20,0 m. The munga woodland is typically found between dambo and miombo vegetation. It is dominated by grasses of the genera *Brachiaria*, *Stereochlaena* and *Setaria,* which are interspersed with *Combretum fragrans* trees. It is classified as a tall, closed woodland with a crown canopy cover of 1,0–10,0 % and a mean tree height of 11,0 m. None of these sites, subsequently called control sites, has been manipulated by the application of fire or bush clearing during the past 6 years. In addition, ticks were collected at four matching sites. In these matching sites, the vegetation had been manipulated previously. They are a grassland site that had been burnt in December 1995; a dambo site that had been burnt in October 1995; a miombo woodland site that had been burnt in August 1994 and in which undergrowth had regularly been cleared with heavy machinery during the 1980's; and a munga woodland site that had been burnt in August 1994.

Tick collection

Ticks questing on the vegetation were collected by drag-sampling (Londt & Whitehead 1972; Rechav 1982; Zimmerman & Garris 1985). The method used is described in detail by Spickett, Horak, Braack & Van Ark (1991). In addition, a 95-mm steel rod was sewn into the distal end of each flannel strip to keep it down on the vegetation while dragging. At each site, three replicate drags of 250 m each were done at monthly intervals. After each drag all the ticks present were removed from the flannel strips and stored in vials containing 70 % ethyl alcohol for later identification and counting. Drags were done during the first week of every calendar month from January 1996 to December 1996.

Rainfall

During the course of the study the total monthly rainfall was recorded using a standard rain gauge. This was located in the approximate centre of the ranch.

Presentation of data

The ticks collected each month from the three replicate drags per site were pooled. Because of the overdispersed nature of free-living ticks, all counts had to be transformed for statistical analysis (Petney, Van Ark & Spickett 1990). The natural logarithm [ln (number of ticks + 1)] of the raw data was found to be the best transformation, as the variance to mean ratio after transformation approximated the value of one, indicating a random distribution. Statistical tests

were done using the paired *t*-test on the transformed data only.

RESULTS

Rainfall

The monthly rainfall recorded during 1995/1996 is illustrated in Fig.1. Total rainfall for the 1995/1996 rainy season was 763 mm, which is slightly less than the modal variation of 800–900 mm (Hutchison 1974).

Tick species and abundance

The tick species recovered and their total numbers collected on Mtendere Game Ranch during the 12-month monitoring period are summarized in Table 1.

Ticks belonging to 11 species were recovered. By far the most abundant was *Rhipicephalus appendiculatus*, which constituted 90,0 % of the 39 713 ticks collected. This was followed by *Boophilus decoloratus* (5,6 %), *Rhipicephalus evertsi evertsi* (3,7 %) and *Amblyomma variegatum* (0,5 %). The other ticks were collected in small numbers only.

Amblyomma variegatum

The monthly total numbers of larvae collected from the four control sites are illustrated graphically in Fig. 2A.

Larvae were only found from May to September. The total number of larvae collected during the 12-month period from each of the four control sites and their respective manipulated sites are illustrated in Fig. 3A.

Although the number of larvae collected from the grassland and dambo control sites was higher than that from the miombo and munga woodland control sites, these differences were not statistically significant. Furthermore, no statistically significant differences in larval numbers were found between any of the control sites and their respective manipulated sites.

Boophilus decoloratus

Larvae were present throughout the year (Fig. 2B). They were most abundant from January to February and again from August to November. No statistically significant differences in the total numbers of larvae were found between the four vegetation types (Fig. 3B). However, the miombo woodland control site had a significantly higher number of larvae than the manipulated miombo woodland site ($P < 0,01$). Significantly more larvae were recovered from the vegetation of the manipulated munga woodland site than from the control site ($P < 0,05$).

Rhipicephalus appendiculatus

The monthly total numbers of larvae, nymphs and adults collected from the four control sites are illustrated in Fig. 4.

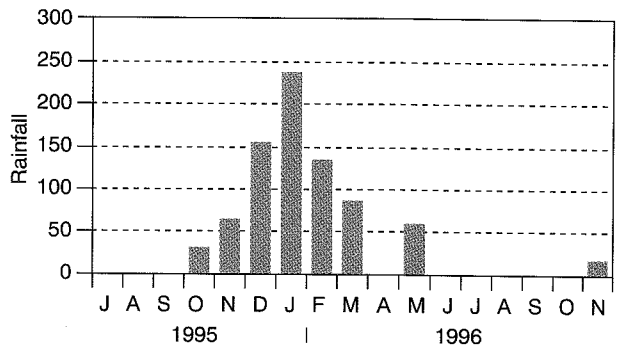

FIG. 1 The monthly rainfall (mm) recorded on Mtendere Game Ranch in the Central Province of Zambia from July 1995 to November 1996

TABLE 1 The species and number of ticks collected by monthly drag-sampling eight vegetation sites on Mtendere Game Ranch in the Central Province of Zambia during 1996

Tick species	Number of ticks collected				
	Larvae	Nymphs	Males	Females	Total
Amblyomma sp.	9	0	0	0	9
Amblyomma variegatum	192	2	0	0	194
Boophilus decoloratus	2 209	0	0	0	2 209
Hyalomma marginatum rufipes	2	0	0	0	2
Rhipicephalus appendiculatus	32 629	2 930	102	87	35 748
Rhipicephalus evertsi evertsi	1 481	0	0	1	1 482
Rhipicephalus lunulatus	0	0	10	5	15
Rhipicephalus sp. (like *R. pravus*)	23	0	0	0	23
Rhipicephalus sulcatus	0	0	4	4	8
Rhipicephalus turanicus	0	0	0	1	1
Rhipicephalus zambeziensis	21	1	0	0	22
Total number	36 566	2 933	116	98	39 713

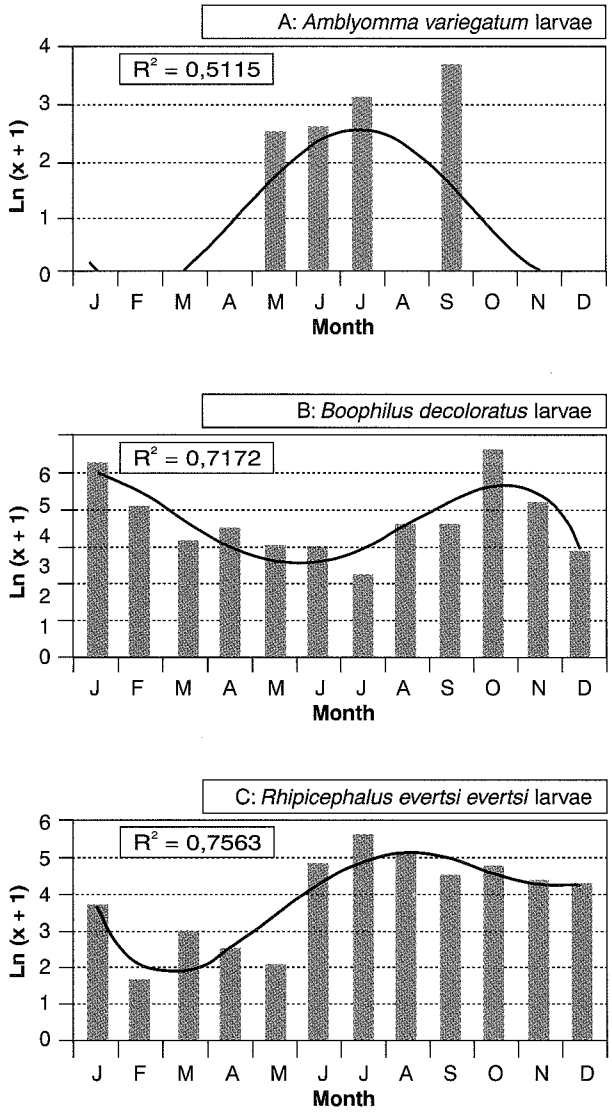

FIG. 2 The monthly number [Ln (x + 1)] of (A) *Amblyomma variegatum*, (B) *Boophilus decoloratus* and (C) *Rhipicephalus evertsi evertsi* larvae collected by drag-sampling the vegetation of four control sites on Mtendere Game Ranch in the Central Province of Zambia in 1996

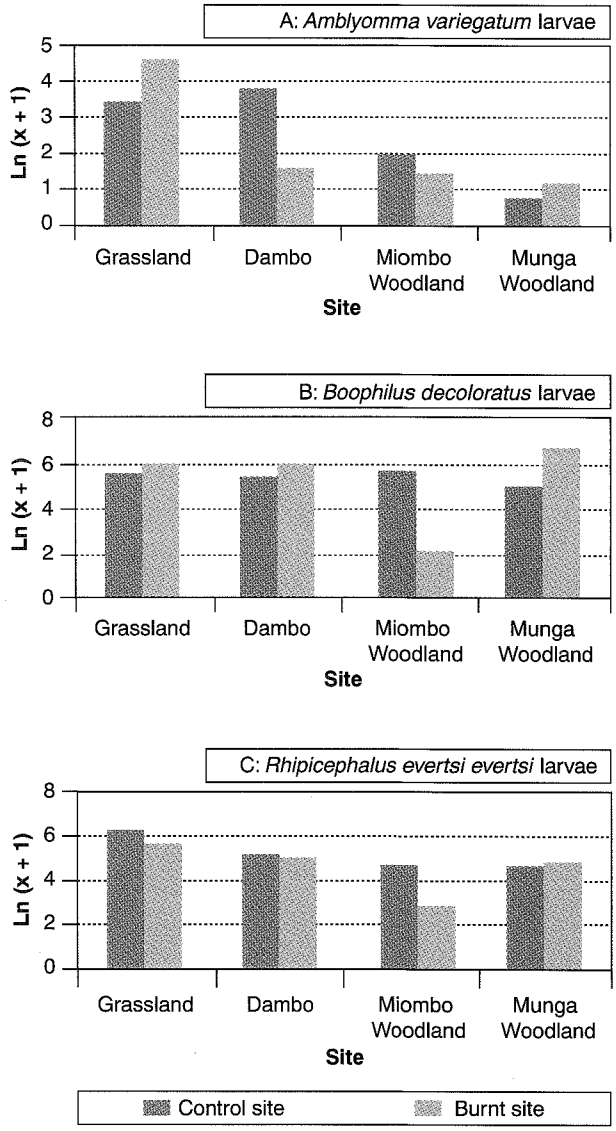

FIG. 3 The total number [Ln (x + 1)] of (A) *Amblyomma variegatum*, (B) *Boophilus decoloratus* and (C) *Rhipicephalus evertsi evertsi* larvae collected by drag-sampling the vegetation of control and burnt sites in four vegetation types on Mtendere Game Ranch in the Central Province of Zambia in 1996

Larvae were most active from May to August. Thereafter their numbers declined and they disappeared from the vegetation during December (Fig. 4A). Nymphs were most abundant from August to October (Fig. 4B). No nymphs were collected in March. Adults were recovered from January to June, with a peak in abundance during February and March (Fig. 4C), and total disappearance from the vegetation in July.

No statistically significant differences in larval abundance were found between the four vegetation types (Fig. 5A). Consistently lower numbers of larvae were recovered from the burnt dambo site than from its control site ($P < 0,01$). The number of larvae collected from the burnt munga woodland was twice as high as the number collected from its control site, although this difference was not statistically significant. There was a significant difference in the abundance of nymphs (Fig. 5B) between the grassland and the munga woodland sites ($P < 0,05$), between the dambo and the miombo woodland sites ($P < 0,05$) and between the dambo and the munga woodland sites ($P < 0,01$). Nymphs were more abundant in the burnt munga woodland than in the control munga woodland ($P < 0,05$). The total number of adults collected from the grassland site (Fig. 5C) was significantly lower than that collected from the three other

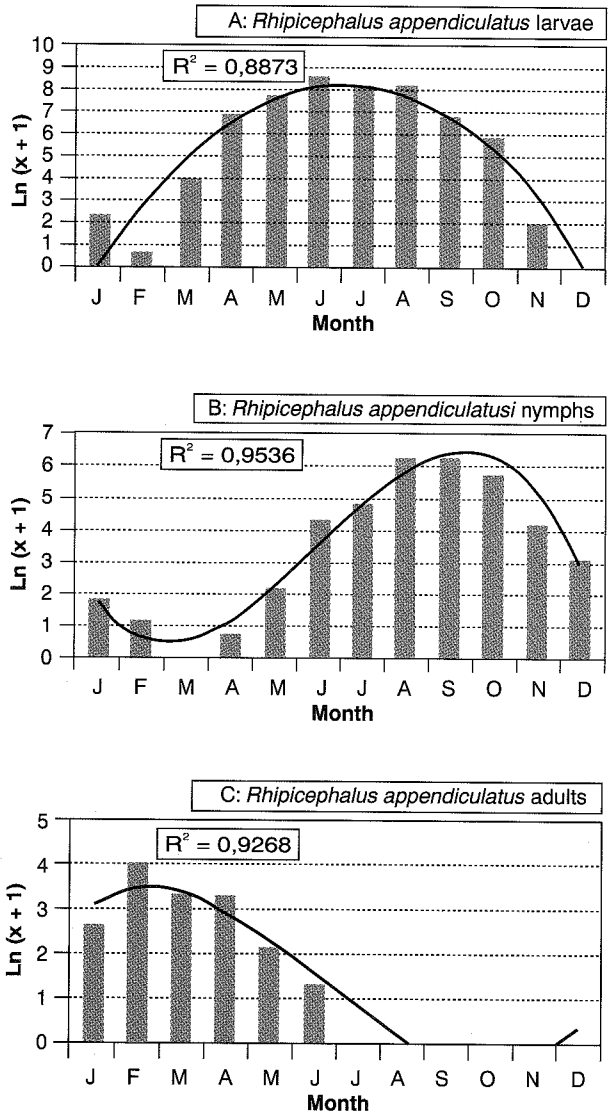

FIG. 4 The monthly number [Ln (x + 1)] of (A) larvae, (B) nymphs and (C) adults of *Rhipicephalus appendiculatus* collected by drag-sampling the vegetation of four control sites on Mtendere Game Ranch in the Central Province of Zambia in 1996

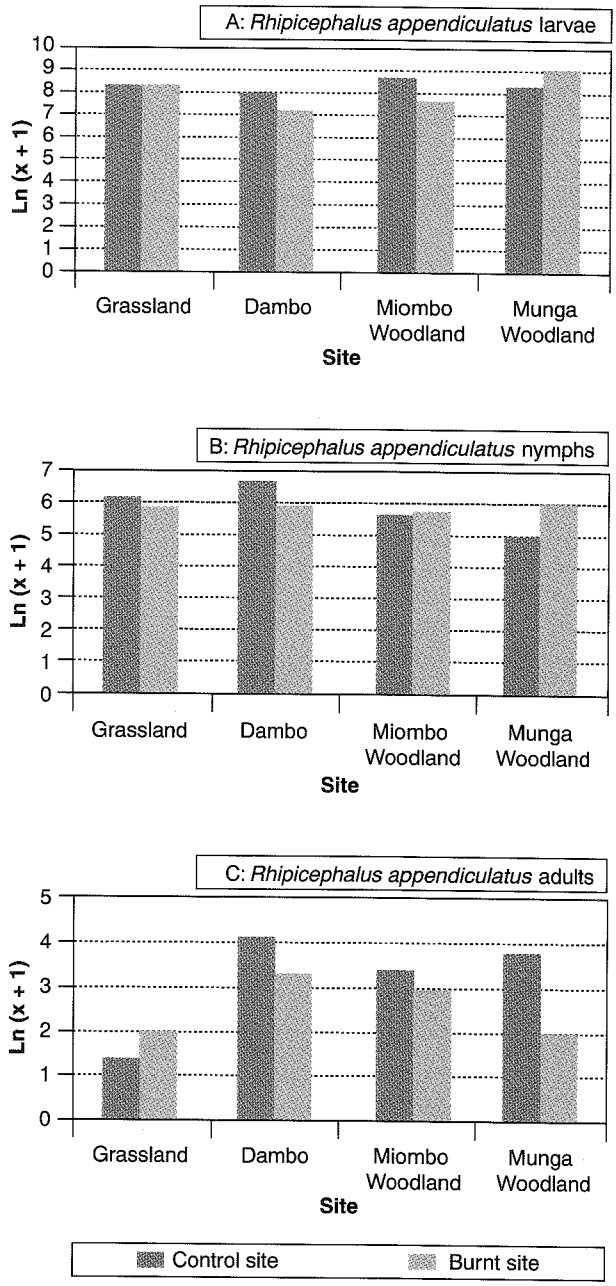

FIG. 5 The total number [Ln (x + 1)] of (A) larvae, (B) nymphs and (C) adults of *Rhipicephalus appendiculatus* collected by drag-sampling the vegetation of control and burnt sites in four vegetation types on Mtendere Game Ranch in the Central Province of Zambia in 1996

vegetation types ($P < 0,05$). No significant differences were found in the abundance of adults between the control and their respective manipulated sites.

Rhipicephalus evertsi evertsi

Larvae were collected throughout the year (Fig. 2C). They were more abundant during the dry period from June to November than at other times of the year. Significantly more larvae were recovered from the grassland site than from both the munga and the miombo woodland sites ($P < 0,01$). The burnt grassland site had significantly fewer larvae than its control site ($P < 0,05$).

Rhipicephalus lunulatus

Only 15 adults were recovered. One was collected in January, and the rest in December.

Rhipicephalus sp. (like *R. pravus*)

Larvae resembling those of *R. pravus* were found from May to September only.

Rhipicephalus zambeziensis

The few larvae collected were present from April to September.

DISCUSSION

Ticks

To our knowledge no study of this kind has previously been conducted in Zambia. However, similar surveys have been done in the south-eastern lowveld of Zimbabwe (Colborne 1988) and in the Eastern Cape Province (Rechav 1982) and in the Kruger National Park of South Africa (Spickett, Horak, Van Niekerk & Braack 1992; Spickett, Horak, Heyne & Braack 1995; Horak 1998). In none of these surveys was there such a marked dominance by one tick species as was the case with *R. appendiculatus* in this one. In his study in Zambia, MacLeod (1970) concluded that high stocking densities with cattle led to a shift in the tick composition and frequency on cattle. This shift favoured *B. decoloratus*, *R. appendiculatus* and *R. evertsi evertsi.* It is possible that the high stocking rate and the wildlife spectrum present on Mtendere Game Ranch have specifically favoured *R. appendiculatus*. If this were so, the tick species composition and the number of parasitic ticks present on the hosts should reflect the same trend. This aspect is currently under investigation, and the results will be published separately.

Tick numbers

A mean number of 138 ticks were recovered per individual drag per month. Horak (1998) collected a mean of 168 ticks per individual monthly drag over a 7-year period in an area of the Kruger National Park which, with the exception of *A. variegatum,* which was replaced there by *Amblyomma hebraeum,* contained a comparable spectrum of ticks. In Horak's study, however, ticks were collected not only from the flannel strips of the drag apparatus but also from the flannel leggings worn by the operator. Ticks of the three major species (*A. hebraeum, B. decoloratus* and *R. appendiculatus*) collected from the leggings, contributed approximately 28,0 % to the total number of ticks recovered (Horak, unpublished data 1992). When the ticks collected from the leggings are excluded from the counts, a mean number of 121 ticks were collected per drag-sample in the Kruger National Park. Although this comparison does not take the environmental differences between the two regions into account, the number of ticks questing on the vegetation on Mtendere Game Ranch is similar to that found in a natural South African wildlife area.

Amblyomma variegatum

In regions with a single annual rainy season *A. variegatum* completes one generation per year (Wilson 1950; Matthysse 1954). Adults are most active during the rainy season, with a peak of abundance on cattle in Zambia from November to January (Matthysse 1954; MacLeod 1970; MacLeod, Colbo, Madbouly & Mwanaumo 1977). All these reports, however, indicate that adults are always present, albeit in low numbers. With 65 days elapsing from the time of detachment of engorged females to the hatching of larvae (Walker 1956, cited by Petney, Horak & Rechav 1987), it is surprising that larvae were recovered only from May onwards in the present study. Most larvae are found on cattle in Zambia from March to May and the life cycle of this tick appears to be controlled by the time of oviposition (MacLeod & Colbo 1976; Pegram, Perry, Musisi & Mwanaumo 1986). In a normal rainfall year this means that the first larvae hatch in March. Total rainfall in the study area was normal during the 1995/1996 rainy season, but it was a rather cool and prolonged season with rains falling as late as May. It is possible therefore that these cool and wet climatic conditions may have led to a delay in the hatching of larvae.

Amblyomma variegatum has been reported from a wide variety of habitat types, particularly those with a good tree and/or bush or tall grass cover (Yeoman & Walker 1967; Yeoman 1968). In our study, however, hardly any larvae were recovered from the woodland areas. Burning of the dambo and grassland sites in October and December 1995 respectively did not significantly influence the number of larvae collected from the vegetation during the subsequent season of larval activity.

Boophilus decoloratus

This is a one-host tick and thus with rare exceptions, only larvae are recovered from the vegetation. Larvae were present throughout the year, with peaks of abundance during the height of the rainy season, and again during the hot and dry season. A similar seasonal pattern of abundance has been reported by MacLeod (1970) and MacLeod *et al.* (1977), who found peak numbers of adult *B. decoloratus* on cattle in the Southern and Central Provinces of Zambia during the rainy season, and again during the hot and dry season. In the Eastern Cape Province of South Africa, Rechav (1982) found two or three peaks of larval abundance on the vegetation. Based on Londt's (1977) results that at low temperatures the pre-oviposition period is long and egg development slow, Rechav (1982) concluded that the larval periodicity of *B. decoloratus* depended upon the prevailing ambient temperatures, and that this could lead to varying numbers of generations per annum. In Zimbabwe, Jooste (1966) speculated that four generations of *B. decoloratus* occurred per year, whereas in the KwaZulu-Natal and Mpumalanga Provinces of South Africa two peaks of abundance are usually recorded (Baker & Ducasse 1967; Horak, Boomker, Spickett & De Vos 1992).

No preference for vegetation type could be found in our study. The literature on this issue is, however, inconclusive. Rechav (1982) and Spickett *et al.* (1991) recovered greater numbers of larvae from open grassland than from other vegetation sub-zones, while Londt & Whitehead (1972) reported that *B. decoloratus* preferred the more protected types of vegetation. Neither burning of the grassland, nor of dambo sites 1 and 3 months respectively before the commencement of this study, influenced the numbers of larvae collected subsequently. This is consistent with the findings of Spickett, Horak, Van Niekerk & Braack (1992) who recorded a reduction in larval numbers immediately after a burn, to be followed by a rapid recovery and a subsequent period of overcompensation. In the present study few larvae were collected from the miombo woodland site, which was cleared of underbrush and which had been burnt regularly during the 1980's and again in 1994. The grass layer of this site is now dominated by unpalatable grasses such as *Zonotriche inamoena* and *Tristachia superba.* Lacking both palatable grazing and cover, this area is used infrequently by game. In contrast, more larvae were present in the munga woodland site that had been burnt in 1994, than in the unburned control site. The vegetation composition and structure of the latter two sites do not differ much. However, the burnt site was more heavily utilized by game, particularly so by a large breeding herd of sable antelope and a herd of Lichtenstein's hartebeest, both of which probably contributed to the larger number of ticks collected.

Rhipicephalus appendiculatus

All the developmental stages of *R. appendiculatus* showed a strict pattern of seasonal abundance, which reflects a single generation per annum. Adults were most abundant during the height of the rains, larvae during the cool and dry winter months, and nymphs at the end of the winter and during the hot and dry months. In this study adults disappeared completely from the vegetation for 6 months. This 1-year cycle has been well documented for several southern African countries: Malawi (Wilson 1946); Zimbabwe (Matson & Norval 1977; Short & Norval 1981; Colborne 1988); Zwaziland (Gallivan & Surgeoner 1995) and South Africa (Baker & Ducasse 1967; Horak 1982; Rechav 1982). In the Central Province of Zambia, MacLeod *et al.* (1977) found a distinct seasonal pattern with the highest numbers of adult *R. appendiculatus* occurring on cattle from December to March. However, smaller numbers of adults were present throughout the remainder of the year, as in the study of Matthysse (1954). It is unfortunate that MacLeod *et al.* (1977) pooled their results from the various farms, which they surveyed, thus making it impossible to determine in which region of the Central Province they had collected adult ticks all year round. The mean annual rainfall within this province varies from 1 100 mm in the north to 600 mm in the south along the lower Kafue River (Trapnell 1953). Pegram *et al.* (1986) also report that one generation of *R. appendiculatus* per year occurs in Zambia, with some inactive adults present on the vegetation during the dry months. These results indicate that *R. appendiculatus* generally completes a single life-cycle per annum in Zambia, but that at some localities adult ticks may be active throughout the year as in parts of East Africa (Yeoman & Walker 1967; McCulloch, Kalaye, Tungaraza, Suda & Mbasha 1968). The life cycle of *R. appendiculatus* is regulated by the adult life stage (Short & Norval 1981). Depending upon the prevailing climatic conditions, unfed adults may enter diapause and become active only when the combined influences of temperature, humidity and daylength are suitable. Four factors which initiate the activity period of *R. appendiculatus* adults have been proposed (Short & Norval 1981):

- > 10 mm of rainfall per month
- mean monthly minimum temperature of > 15 °C
- mean monthly maximum temperature of < 30 °C or > 30 °C only if rainfall exceeds 20 mm per month
- daylength of > 11 h of sunlight

On Mtendere Game Ranch the first condition was not met from June to the beginning of December 1996. Although the ambient temperatures were not recorded, it is likely that the second condition was not met from June to July and the third condition during November.

Free-living *R. appendiculatus* depend on adequate vegetation cover for their survival (Theiler 1949; Rechav 1982). The tick's spatial distribution within its preferred habitat is largely reliant upon the availability of suitable hosts and their distribution (Minshull & Norval 1982). In our study fewer adult *R. appendiculatus* were collected from the grassland site than from the three other vegetation types. Although this might be attributed to the sparse tree cover and short grasses in the grassland site, it seems more likely that the drop-off rhythm of the ticks and their hosts' behaviour influenced their distribution (Minshull & Norval 1982). Nymphs were most abundant during the hot and dry months of September and October. During this period most ungulates seek shade in woodland areas or in tall grass in the hot daytime hours. As engorged nymphs detach mainly between 12:00 and 18:00 (Minshull 1982), they would drop in these more shaded areas and moult there to the adult life stage. The opposite was observed for free-living nymphs in that more were collected from the grassland and the dambo areas than from the woodland vegetation types. Ungulates utilize the open areas throughout the daylight hours during the cold winter months when the larvae are most active. As engorged larvae detach from their hosts mainly between 10:00 and 14:00 (Minshull 1982), many would

drop in the grassland areas and moult there to nymphs. No distribution pattern related to vegetation type was observed for the larvae. This indicates that the various vegetation zones of the ranch were utilized evenly by ungulates during the rainy season, which coincides with the peak activity period of the preceding generation of adult ticks.

Fewer *R. appendiculatus* larvae were collected from the burnt dambo site than from its control. The dambo site was burnt in October 1995 during the period of peak abundance of free-living nymphs, and it is likely that the burn affected their numbers. However, there were no differences between the number of adults collected from the burnt and the unburned sites. It is generally believed that a burn causes direct mortalities among ticks, and that burning also makes the microclimate less favourable for their survival. These effects seem to be offset by the subsequent high concentration of host animals, which are attracted to the resprouting grasses in the freshly burnt area and thus introduce fresh infestation. This can lead to an increased number of ticks in the subsequent life stage at this site (Minshull & Norval 1982; Spickett *et al.* 1992). In the present study it appears likely that heavy rains caused the reduced number of larvae recovered from the burnt dambo site. This site, which is situated close to the middle of the drainage line, was waterlogged for a longer period than the control site. It is therefore possible that the egg batches and/or the newly hatched larvae had a lower chance of survival in the burnt dambo site than in its control.

Burning of the grassland site in December 1995 apparently had no effect on the number of ticks recovered subsequently. The direct effect of fire on ticks at this time is probably low, as the number of questing nymphs is declining rapidly and few adults are active. Two years after the August 1994 burn in the munga woodland, more larvae and nymphs were recovered from the burnt site than from the unburned site. As in the case of *B. decoloratus*, this is probably related to the subsequent heavy utilization of this area by game.

Rhipicephalus evertsi evertsi

All life stages of this tick are generally present throughout the year, but reports on its seasonality vary. Spickett *et al.* (1992) found no seasonal pattern for the free-living larvae in the Mpumalanga Lowveld of South Africa, but noted a 2-month cycle of high and low larval numbers. In the Eastern Cape Province of South Africa, Rechav (1982) recorded two peaks of larval abundance both for those questing on the vegetation and those on hosts. These peaks occurred from July to August and again from January to March. Collection of adult ticks from cattle in Zambia indicates peaks of abundance from March to May and again from September to October. There also is a single peak of larval abundance from September to October (MacLeod 1970). Adults occur in three waves per year in Zambia, or four waves per year in Zimbabwe (MacLeod 1975; Matson & Norval 1977). Larval numbers in our study were high during the cool and dry and during the hot and dry months. This seems to agree with MacLeod's (1970) results for ticks on cattle in Zambia. It appears that *R. evertsi evertsi* requires 2 months to complete a single generation under optimal climatic conditions (Rechav, Knight & Norval 1977). In contrast, a generation is completed in 6 months at winter temperatures (Matson & Norval 1977). Climatic variation will therefore influence the seasonal occurrence of this tick markedly, not only regionally but also between years (Rechav 1982). In our study larvae were more numerous in the open grassland area than in the other vegetation types. Similarly in Rechav's 1982 study this species was more abundant in open areas than in bushy habitat. On Mtendere Game Ranch the distribution of this tick possibly reflects the habitat preferences of the zebra, which clearly favoured the grassland areas of the ranch to the woodland ones. Zebra are the preferred hosts of all life stages of this tick (Horak, De Vos & De Klerk 1984; Horak 1998). Many engorged females consequently detach in the grassland and this subsequently leads to high larval numbers on the vegetation.

Consistently fewer larvae were collected from the burnt grassland site than from the control one. As larvae are active during December when this site was burnt, it is likely that they were affected directly. Zebra utilized this area extensively after the burn and it can therefore be assumed that many engorged females would have dropped here. This should have led to an increase in larval numbers. That this was not the case, is possibly because the plant litter had been removed by the burn and that the grasses were kept so short by heavy grazing that the microclimate had become unfavourable for the survival of these ticks (Gray 1961).

Rhipicephalus lunulatus

Only a few *R. lunulatus* adults were recovered. They were present in December and January. Pegram *et al.* (1986) recovered adult *R. lunulatus* from Zambian cattle only during the rainy season. No larvae or nymphs were collected from the vegetation in the present study.

Rhipicephalus sp. (like *R. pravus*)

These ticks are present on Mtendere Game Ranch in low numbers only. In the literature, *R. kochi, R. punctatus* and *R. pravus* are frequently referred to as the '*R. pravus* group' of ticks, as they are morphologically so similar, that differentiation between them is often very difficult. Both *R. neavei* (now known as *R. kochi)* and *R. punctatus* have previously been

recorded from cattle in the Central Province of Zambia. However, *R. pravus* has not yet been found (MacLeod *et al.* 1977). The seasonal occurrence of larvae seems to be restricted to the dry season.

Rhipicephalus zambeziensis

Rhipicephalus zambeziensis is closely related to *R. appendiculatus*, and their morphology and host related ecology are similar but their distributions differ (Norval, Walker & Colborne 1982). *R. zambeziensis* replaces *R. appendiculatus* in the hot, dry, low-lying areas of south-eastern Africa. Their distributions overlap where a gradual transition occurs between wet, high-lying and dry, low-lying areas. Such conditions occur in the Southern Province of Zambia, which borders the Zambezi Valley. *R. zambeziensis* does not appear to build up to such large numbers as does *R. appendiculatus*. The small number of *R. zambeziensis* larvae collected during the present study compared to the large number of *R. appendiculatus* larvae, indicates that the study site is probably situated at the northernmost limit of the distribution of the former tick along the Zambezi Valley. It also appears that the Chisamba District is more suited to *R. appendiculatus* than to *R. zambeziensis*. No *R. zambeziensis* adults were found on cattle in the Northern, Northwestern and Western Provinces of Zambia, whereas they were present in low numbers in the Central, Eastern and Southern Provinces (Pegram *et al.* 1986).

Control of ticks

Effect of burning

A grassland and a dambo site were burnt 1 and 3 months respectively before the start of our study in an attempt to control tick numbers. This objective was not achieved. The only tick that was reduced in numbers on the burnt grassland site was *R. evertsi evertsi,* which is a minor tick on the ranch. The burn did not affect populations of *R. appendiculatus*, the major tick species on the ranch. Although the efficiency of burning as a means of tick control has been questioned (Minshull & Norval 1982; Spickett *et al.* 1992), much of Zambia's vegetation requires periodic burning to remove moribund material. If these fires could be timed properly and if appropriate post-burn management could be applied, then it should be possible to effect a degree of tick control by burning the vegetation. To achieve a direct effect on questing ticks, a burn should, however, coincide with the peak activity period of the particular tick. For *R. appendiculatus* this would be from June to August to affect larvae and September or October to affect the nymphs. Whether burns at these times of year are ecologically advisable, will depend upon the type and condition of the vegetation and its moisture content. The influx of potential host animals into a recently burnt area tends to offset the initial reduction of tick numbers (Minshull & Norval 1982; Spickett *et al.* 1992). A long-term reduction in tick numbers can only be expected if animal concentrations in the burnt area can be avoided. On a game ranch, where rotational grazing such as that commonly employed with domestic animals cannot be applied easily, an overall low stocking rate can attempt to achieve this. In addition, if particular areas on a game ranch were to be burnt, these should be so large that the subsequent influx of animals does not lead to a high concentration of game on these burnt areas. A staggered burning programme, where fires are set in several areas at 2- to 3-week intervals, would also dilute host animal numbers and should result in a pattern of rotational grazing. If artificial watering points were in use, then those in the vicinity of the burnt areas can be closed to force game to move away (Du Toit 1996).

The use of cattle

The spatial and temporal distribution of *R. appendiculatus* can be exploited for tick control. In the present study, adults of this tick were most numerous in the woodland areas, whereas the nymphs were more abundant in the grassland and dambos. Cattle that are regularly treated with an acaricide are an efficient means of reducing the numbers of free-living ticks on the vegetation and parasitic ticks on game (Petney & Horak 1987; Mackie & Clarke 1992). If cattle were to be used for tick control on Mtendere Game Ranch, it is advocated that they be herded into the woodland areas during the rainy season and onto the grassland and dambo areas during the hot and dry season provided that sufficient grazing is available at these times. Cattle are excellent hosts of adult *R. appendiculatus* (MacLeod *et al.* 1977; Horak 1982) and should pick up large numbers of these ticks during the rainy season. These ticks will be killed each time that the cattle are treated with an acaricide.

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FLUCTUATIONS IN THE ABUNDANCE OF *BOOPHILUS DECOLORATUS* AND THREE *RHIPICEPHALUS* SPECIES ON VEGETATION DURING ELEVEN CONSECUTIVE YEARS

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Abstract. Free-living ticks were collected by drag-sampling the vegetation of a treed-savanna landscape zone in the south-eastern region of the Kruger National Park, South Africa. Commencing in August 1988 nine samples were collected each month for a period of 11 consecutive years. The larvae of *Boophilus decoloratus* reached peak abundance during various months within the period September to December during 10 of the 11 years. In 1998, however, a year with a particularly warm late summer and winter, they peaked during July and again during October. From August 1988 to July 1989 a total of 1,092 *Rhipicephalus appendiculatus*, including all stages of development, were collected from the vegetation. This number increased to more than 9,000 in both 1990/91 and 1991/92 and then decreased to only 76 in 1996/97, 5 years after a severe drought that occurred during 1991/92. The largest numbers of adult *Rhipicephalus simus* and *Rhipicephalus turanicus* were collected from the vegetation during 1995, approximately 8 months after the end of a rodent population explosion.

Key words: *Boophilus decoloratus*, *Rhipicephalus appendiculatus*, *Rhipicephalus simus*, *Rhipicephalus turanicus*, annual fluctuations.

Introduction

The seasonal and annual abundances as well as the geographic distributions of several ixodid tick species are not static. Both the abundance and the distribution of ticks can be determined by collecting free-living ticks from the vegetation or parasitic ticks from living or dead hosts in various habitats at regular intervals over a period of time. The blue tick, *Boophilus decoloratus*, is widespread in the moist, warm, eastern and southern regions of South Africa (Howell et al. 1978). The largest numbers are generally present on cattle from spring to autumn or winter (Rechav 1982, Baker et al. 1989, Dreyer et al. 1998). However, on wildlife and on the vegetation with which they are associated, peak burdens are usually recorded only in spring or early summer (Horak et al. 1984, 1992, Spickett et al. 1992).

The introduction, increase, spread and subsequent disappearance of *Rhipicephalus appendiculatus* in a large region of the south-eastern lowveld of Zimbabwe has been recorded by Norval & Perry (1990). The most important factor responsible for its disappearance from this locality appeared to be heat stress. Dry stress was probably a contributing factor and its effect was possibly cumulative over successive dry years.

The effect of the availability of hosts for the immature stages on ixodid tick population growth has been discussed by Norval (1979). He reported that in the absence of acaricidal treatment those species which made use of cattle during each of their stages of development showed large increases in abundance, whereas those species exhibiting small or moderate increases on untreated cattle utilised specific non ungulate hosts during their immature stages of development.

The present study details the numbers of *B. decoloratus* larvae, all stages of development of *R. appendiculatus*, and the adults of *Rhipicephalus simus* and *Rhipicephalus turanicus* collected by drag-sampling the vegetation of a treed-savanna landscape zone in the Kruger National Park (KNP), South Africa. Before and during the survey various biotic and abiotic changes were recorded in or close to the study site. In 1982/83, 6 years before the com-

mencement of the study, there was a sudden severe drought. A more prolonged dry period, commencing in 1990/91 and culminating in a very severe drought during 1991/92, occurred during the course of the study, and the late summer, autumn and winter months of 1998 were considerably warmer than the long-term average for these months. A suspected rodent population explosion during 1993 and 1994 was confirmed by trapping (Grobler et al. 1995).

Materials and methods

Lower Sabie and Crocodile Bridge are tourist rest camps in the south-eastern part of the KNP, which itself is located in the north-eastern lowveld of South Africa. Free-living ticks were collected from the vegetation adjacent to the eastern gravel road (±25°15'S, 32°05'E; Alt. ±200 m) which runs through a *Sclerocarya caffra/Acacia nigrescens* Savanna landscape zone between these two rest camps. Nine collections were made each month from August 1988 to July 1999 by drag-sampling the vegetation as described by Spickett et al. (1992).

Atmospheric temperatures and rainfall have been measured at Skukuza, a tourist rest camp situated approximately 40 km to the north-west of Lower Sabie, for more than 25 years. Rainfall is generally restricted to the spring, summer and autumn months, and annual rainfall is calculated from mid-winter (July) of one calendar year to mid-winter (June) of the next. Studies on myomorph rodents have been conducted in the KNP for various purposes since 1984 and trapping attempts were increased towards the end of 1993 and in 1994 during an outbreak of encephalomyocarditis-virus infection in African elephants (Grobler et al. 1995).

Results

The numbers of *B. decoloratus* larvae collected in June and July of each year, as well as the largest numbers collected in any one month of that year, and the months in which these large numbers were collected are summarized in Table 1.

During the 11 years of the survey the largest numbers of larvae were collected from the vegetation during various months within the period September to December of each year. From 1988 to 1997 these numbers varied between 201 larvae, collected in December 1994, to 1,048 larvae, collected in December 1991. In 1998, however, this number exceeded 2,500 larvae in October, and although not shown in the table, 2,400 in November. Similarly the numbers of larvae collected during June and July 1998 far exceeded the numbers of larvae collected in these months during any other year of the survey. The numbers of larvae collected a year later during June and July of 1999 were similar to those collected in the years prior to 1998. The 29-year average daily maximum atmospheric temperature at Skukuza between 1 March and 31 August is 27.9°C and the average minimum 10.8°C. During 1998 these temperatures were 30.0°C and 11.8°C, respectively.

The numbers of *R. appendiculatus* collected annually (August–July) from the vegetation of the study site from 1988 to 1999 are summarized in Table 2.

Tick numbers increased from slightly more than 1,000 during 1988/89 to more than 9,000 in both 1990/91 and 1991/92. A steady decline in numbers occurred thereafter and only 76 ticks were collected in the year ending July 1997. Although a total of only six *R. appendiculatus* were collected in the 9 months from August 1997 to March 1998 their numbers rose rapidly thereafter and 700 ticks were eventually collected during the year ending July 1998. Few ticks were collected in the following year.

The numbers of adult *R. appendiculatus*, *R. simus* and *R. turanicus* collected from the vegetation of the study site from January to December of each year from 1989 to 1998 are summarized in Table 3. This table also summarizes the total numbers of rodents collected at several trapping sites in the KNP during 1989, 1990, November 1993 and in the first 6 months of 1994.

The numbers of adult *R. simus* and *R. turanicus* increased considerably during 1995, approximately 8 months after the end of a rodent population explosion in the KNP and declined to the more usual levels during the years thereafter. No similar increase was recorded for adult *R. appendiculatus*.

Discussion

The effect of temperature on the pre-hatch period of the eggs of *B. decoloratus* has been determined under laboratory conditions by Londt (1977), while Spickett & Heyne (1990) did so under natural conditions. They found the length of this period to be inversely dependent on increased temperature. Londt (1977) also noted that relative humidity had no effect on the duration of the pre-hatch period. Robertson (1981) and Spickett & Heyne (1990) observed that eggs laid in late summer, autumn or winter took longer to hatch than those laid in summer and that there was a tendency for synchronous hatching of these eggs to occur as the temperature increased in spring. Although the long-term late summer to winter temperatures in the KNP are considerably warmer than those near East London or at

Table 1. Numbers of *Boophilus decoloratus* larvae collected during June and July and peak numbers collected each year (January–December) from the vegetation of a treed-savanna region in the Kruger National Park.

Year	No. of larvae collected in June of each year	No. of larvae collected in July of each year	Largest no. of larvae collected in any month	Months in which these large nos. of larvae were collected
1988	*	*	781	December
1989	153	46	556	December
1990	57	70	758	November
1991	26	244	1 048	December
1992	45	124	797	October
1993	13	76	359	September
1994	112	14	201	December
1995	24	33	467	September
1996	160	60	832	October
1997	200	38	501	November
1998	607	865	2 581	October
1999	9	30	**	**

Note: * collections only commenced in August 1988; ** no data available for collections made after July 1999.

Table 2. Total numbers of *Rhipicephalus appendiculatus* collected annually (August–July) from the vegetation of a treed-savanna region in the Kruger National Park.

Year	Numbers of *R. appendiculatus* collected				
	Larvae	Nymphs	Males	Females	Total
1988/89	1 047	39	2	4	1 092
1989/90	5 894	45	5	1	5 945
1990/91	8 990	159	16	24	9 189
1991/92	8 926	208	5	1	9 140
1992/93	6 455	40	3	0	6 498
1993/94	1 605	78	1	2	1 686
1994/95	485	24	0	0	509
1995/96	112	2	1	0	115
1996/97	73	3	0	0	76
1997/98	693	7	0	0	700
1998/99	148	39	10	15	212

Onderstepoort, where Robertson and Spickett and Heyne worked respectively, the same phenomenon seemed to occur. The large numbers of *B. decoloratus* larvae collected from the vegetation in the KNP during spring or early summer probably reflect the synchronous hatching of eggs that had accumulated since autumn. The exceptionally warm temperatures recorded from late summer to winter in 1998 resulted in large numbers of larvae hatching as early as June and July. The very large numbers of larvae collected in October and November of that year could well be the offspring of the adults resulting from these larvae, thus implying that an additional generation of ticks had been completed during 1998. The cooler temperatures experienced during 1999 resulted in the usual pattern of larval abundance on the vegetation during the winter months of this year.

Twelve adult male impalas, *Aepyceros melampus*, examined near Crocodile Bridge between January 1980 and January 1981 harboured a total of more than 16,000 *R. appendiculatus* in all stages of development. The first 5 years of drag-sampling in this region from August 1988 to July 1993, yielded a total of 31,864 ticks of this species. It thus seems safe to assume that the region surrounding the gravel road between the Crocodile Bridge and Lower Sabie rest camps is a suitable habitat for *R. appendiculatus* and that population fluctuations here are probably cyclical and gradual. These fluctuations would be influenced by climate, which would also affect vegetation cover as well as host density and species composition.

There appears to be a considerable lag-phase between low rainfall and the greatest decrease in the numbers of *R. appendiculatus* collected from the vegetation annually. The relatively low numbers col-

Table 3. Total numbers of adults of three *Rhipicephalus* spp. collected annually (January–December) from the vegetation of a treed-savanna region in the Kruger National Park.

Year	Tick species			No. of rodents caught per trap-night	Rodent trapping rate (%)
	R. appendiculatus	*R. simus*	*R. turanicus*		
1989	5	15	3	61/1 684	3.6
1990	6	19	5	45/1 534	2.9
1991	40	11	11		
1992	6	1	2		
1993	3	2	1	19/35	54.3
1994	3	12	13	530/947*	56.0*
1995	0	116	39		
1996	1	20	5		
1997	0	5	4		
1998	0	5	3		

Note: * rodent trapping after June 1994 was unsuccessful.

lected during 1988/89 could actually represent a recovery after the severe drought of 1982/83. The decline in numbers from 1992/93 onwards could be a consequence of the 1991/92 drought followed by a generally dry cycle. Analyses done at the time indicated that the greatest proportion of bare ground compared to vegetation cover occurred during 1996/97 when compared to previous years. This lack of cover probably led to both heat stress and dry stress adversely affecting the free-living stages of *R. appendiculatus* and to a consequent reduction in the population on the vegetation.

The immature stages of *R. simus* and *R. turanicus* are dependent on rodents or small mammals for their further development (Rechav 1982, Walker et al. 2000). The red veld rat, *Aethomys chrysophilus*, and the Natal multi-mammate rat, *Mastomys natalensis*, which are abundant in the KNP (Grobler et al. 1995), are good hosts of the immature stages of *R. simus* (Braack et al. 1996, Walker et al. 2000). The hosts of the immature stages of *R. turanicus* at this locality have not been determined but may well also be rodents. The rodent population explosion recorded towards the end of 1993 and during the first 6 months of 1994 supplied an abundance of hosts for the larvae and nymphs of *R. simus*, and possibly also *R. turanicus*. This was probably the reason for the marked increase in adult numbers on the vegetation in the following year. *Rhipicephalus appendiculatus*, of which the immature stages do not feed on rodents (Walker et al. 2000), did not show a similar increase.

The results of this survey indicate that monthly collections over a period of a year are not adequate for the determination of tick distribution or abundance in South Africa.

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CHAPTER 5

TICKS ON HUMANS

Most persons living in or visiting rural environments in sub-Saharan Africa are exposed to tick-bites. Our study entailed not only identifying the ticks that had bitten 194 people in South Africa during the past 41 years, but also related the season in which the incident had occurred to the seasonal abundance on its preferred host species of the tick species incriminated in the bite (Horak, Fourie, Heyne, Walker & Needham 2002a). It also explored the risk of being bitten in an environment heavily infested with free-living questing ticks of several species.

Adult bont-legged ticks, belonging to the genus *Hyalomma*, transmit the virus of Crimean-Congo haemorrhagic fever to humans. By matching the distribution of tick-associated human incidents of Crimean-Congo haemorrhagic fever in South Africa with those of the three *Hyalomma* species that occur here we were able to demonstrate that *Hyalomma marginatum rufipes* is the major vector of the virus in this country (Horak, Swanepoel & Gummow 2002c).

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Ixodid ticks feeding on humans in South Africa: with notes on preferred hosts, geographic distribution, seasonal occurrence and transmission of pathogens

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Abstract. This paper records the identities of 558 ixodid ticks feeding on 194 humans in South Africa. These ticks belonged to 20 species in six genera and those most frequently encountered were *Amblyomma hebraeum*, *Haemaphysalis leachi*, *Hyalomma marginatum rufipes*, *Hyalomma truncatum*, *Rhipicephalus appendiculatus*, *Rhipicephalus gertrudae* and *Rhipicephalus simus*. With the exception of the larvae of *R. appendiculatus*, the incidents of these ticks feeding on humans correlated well with their seasonal occurrences on preferred hosts. Ticks were also collected at monthly intervals, for 14 consecutive months, from the clothing of a game-guard providing protection for field-workers engaged in the collection, by means of flannel strips, of free-living ticks from the vegetation of four localities in the southern region of the Kruger National Park. In addition, with the exception of 3 months when the particular worker was absent, ticks that fed on one of the field-workers were collected over the same 14-month period. A total of 54,429 free-living ticks belonging to 14 species and six genera were collected from the vegetation at the four localities during this time and 3751 ticks belonging to 11 species and six genera from the clothing of the game-guard. The larvae of *A. hebraeum* and *Boophilus decoloratus* were the most numerous of the immature ticks, and *H. leachi* and *R. simus* of the adults on both the vegetation and the guard's clothing. Ticks fed on the field-worker on six occasions and 14 were collected, all of which were *A. hebraeum* larvae.

Key words: ticks, Ixodidae, humans, preferred hosts, geographic distribution, seasonal occurrence

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Introduction

Slightly more than 650 species of ixodid ticks, colloquially known as hard or shield ticks, have been recorded worldwide (Keirans, 1992; Camicas *et al.*, 1998), and more than 80 of these occur in South Africa (Walker, 1991). Each of these ticks has its preferred hosts, geographic distribution and seasonal occurrence and many are vectors of disease to humans or animals. The natural hosts of ixodid ticks are domestic and wild animals and humans are usually only bitten when they intrude upon the tick's habitat, particularly when it is questing for a host either from the vegetation or from the ground. The literature on ticks feeding on humans worldwide has recently been reviewed and this indicated that 24 ixodid species have frequently been collected from humans, while a further 48 species have been reported more rarely (Estrada-Peña and Jongejan, 1999). Only 14 of the 72 species recorded in this review occur in Africa, and only six of them belong to the genus *Rhipicephalus*. However, Walker *et al.* (2000) list an additional 24 African species of the genus *Rhipicephalus* that have been collected from humans and three of these, namely *Rhipicephalus appendiculatus* and *Rhipicephalus simus*, as well as *Rhipicephalus pulchellus*, listed by Estrada-Peña and Jongejan (1999) as occasionally feeding on humans, can probably now also be classified as frequently infesting humans with 18, 27 and 40 records, respectively.

There are four stages in the life cycle of an ixodid tick, namely egg, larva, nymph and adult, and each of the post-embryonic stages requires a blood-meal. The larvae of several species ascend grass stems and leaves on which they can be seen in dense clusters while they await hosts. It is thus not uncommon for a person to be bitten by several larvae at more or less the same time. The nymphs and adults of some species also use vegetation from which to quest for hosts. Many tourists visit, and also hike in national, provincial and privately owned nature reserves and on farms in South Africa, while a considerably larger number of people live and work there. Free-living ticks often abound in these localities and humans thus unwittingly become infested. Urban and peri-urban areas are often also heavily tick-infested, particularly where pets and livestock are allowed to roam freely and infestation can be acquired in either of these localities. The kennel or brown dog tick, *Rhipicephalus sanguineus*, is practically an exclusive parasite of domestic dogs and its life cycle is adapted to living in kennels or human dwellings with its dog host (Walker *et al.*, 2000). It is thus also possible for people to be bitten by ticks in the supposed safety of their own homes.

This report presents data on ixodid ticks that have fed on humans in South Africa or have been collected at regular intervals from the clothing of a game-guard and have subsequently been identified by us. The preferred hosts of

those most commonly feeding on humans are listed, as are their geographic distributions and the diseases they may transmit, while their seasonal occurrences have been graphically illustrated. This has been done to make persons aware of the ticks with which, and the places and times at which they could become infested.

Materials and Methods

Over the past 41 years ticks feeding on humans have been collected by several persons, including ourselves, and been identified by us. The identities, stages of development, numbers of these ticks and incidents of feeding have all been tabulated. At monthly intervals, from February 2001 to March 2002, free-living ticks were collected at four sites in the southern part of the Kruger National Park by dragging flannel strips over the vegetation. At each of two of the sites nine drag-samples monthly, each 250 m in length, were made with flannel strips and the collector also wore flannel leggings from which ticks were collected. At each of the other two sites 42 drag-samples monthly, each 200 m in length, were made with flannel strips and no collections from flannel leggings were made. During these excursions the field-workers were accompanied, for their own protection, by an armed game-guard and ticks were collected every month at each of the four collection sites from the guard's clothing by means of fine-tipped forceps and immediately transferred to vials containing 70% ethanol. In addition, with the exception of July, August and September 2001, when another worker took his place, ticks actually feeding on a particular field-worker (I.G.H.) were collected over the same 14-month period.

Results and Discussion

Between 1961 and 2002, 558 ticks feeding on 194 persons were collected. Each collection, irrespective of the number of ticks of a particular species involved, was considered a single incident of feeding by that species. If more than one species or more than one developmental stage fed simultaneously, these were also each considered as single incidents irrespective of the numbers involved. The tick species and the number of occasions on which a particular species or stage were collected are summarized in Table 1.

The comparatively small number of 194 collections taken from humans during the past 41 years reflects the tendency in South Africa for individuals and health-care personnel to discard attached specimens, and more

Table 1. Tick species feeding on humans in South Africa

Species	Number of ticks collected (number of occasions collected)					
	Larvae	Nymphs	Males	Females	Adults[a]	Total
Amblyomma hebraeum	327 (35)	10 (9)	5 (5)	3 (2)		345
Amblyomma marmoreum	2 (1)	3 (3)	3 (3)	0		8
Boophilus decoloratus	1 (1)	0	2 (2)	1 (1)		4
Haemaphysalis leachi	2 (1)	0	10 (10)	3 (3)		15
Haemaphysalis silacea	0	1 (1)	0	0		1
Hyalomma marginatum rufipes	0	0	6 (6)	1 (1)	1 (1)	8
Hyalomma truncatum	0	0	13 (13)	3 (3)	8 (2)	24
Hyalomma sp.	0	0	0	1 (1)		1
Ixodes pilosus group	0	5 (3)	0	5 (5)	2 (1)	12
Ixodes rubicundus	0	0	0	2 (2)		2
Rhipicephalus appendiculatus	6 (4)	9 (8)	3 (3)	4 (2)		22
Rhipicephalus evertsi evertsi	3 (2)	0	3 (3)	3 (3)		9
Rhipicephalus follis	0	0	1 (1)	2 (2)		3
Rhipicephalus gertrudae	0	1 (1)	20 (10)	16 (13)	2 (2)	39
Rhipicephalus glabroscutatum	0	0	1 (1)	0		1
Rhipicephalus maculatus	0	2 (1)	13 (4)	5 (2)		20
Rhipicephalus muehlensi	0	0	1 (1)	0		1
Rhipicephalus sanguineus	0	5 (2)	0	2 (2)	1 (1)	8
Rhipicephalus simus	0	0	17 (15)	15 (15)		32
Rhipicephalus warburtoni	0	0	1 (1)	1 (1)		2
Rhipicephalus zambeziensis	0	1 (1)	0	0		1
Total	341	37	99	64	14	558

[a] Sex not determined.

particularly larvae, once they have been removed. In addition a large proportion of persons living or working in rural environments in the eastern, central, north-eastern and northern regions of the country regard tick-bite as a normal occurrence and would seldom consider retaining specimens.

The 20 ixodid tick species collected represent six genera with species of the genus *Rhipicephalus* the most numerous. Most bites were inflicted by *Amblyomma hebraeum*, *Haemaphysalis leachi*, *Hyalomma marginatum rufipes*, *Hyalomma truncatum*, *R. appendiculatus*, *Rhipicephalus gertrudae* and *R. simus*. Whereas all stages of development of *A. hebraeum* and *R. appendiculatus* fed on humans, it was mainly adults of the other species

that did so. Further discussion will concentrate chiefly on the above-mentioned seven ticks with brief notes on the other species.

Amblyomma hebraeum, the South African bont tick, is a 3-host species and the adults, as its colloquial name infers, are brightly coloured. They prefer cattle and the very large wild herbivores as hosts. The larvae and nymphs feed on the same hosts as the adults as well as on a large variety of smaller animals including hares and guineafowls (Norval, 1983; Horak *et al.*, 1987a). Females can lay approximately 15,000 eggs and, provided hatching is successful, these give rise to thousands of larvae. The large number of larvae collected from humans attests not only to their abundance on the vegetation but also to their catholic taste for hosts. This tick is associated with tall grassveld and trees or bush and is not found in open savannah or steppes. It is present in the coastal region from the eastern half of the Eastern Cape Province northwards through KwaZulu-Natal and Swaziland into the lowveld and bushveld of the Mpumalanga, Limpopo, Gauteng and Northwest Provinces (Howell *et al.*, 1978).

The seasonal occurrence of all stages of development of *A. hebraeum* on greater kudus in the Eastern Cape Province and also in north-eastern Mpumalanga Province is graphically illustrated in Figure 1. In the south there is a tendency for larvae to be most numerous from late summer to winter and adults from spring to late summer. In the north there is no clear pattern of

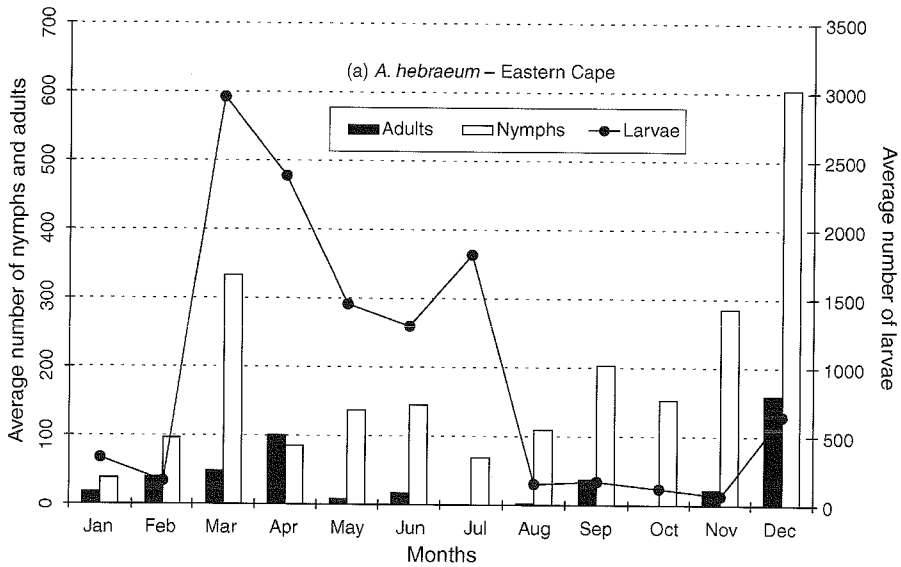
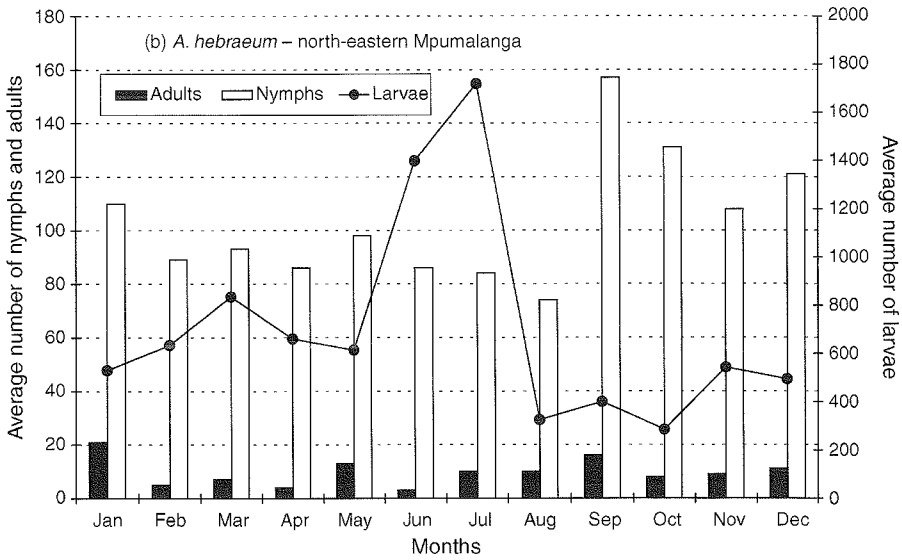


Figure 1. The seasonal occurrence of all stages of development of *A. hebraeum* on greater kudus in (a) the Eastern Cape Province, (b) north-eastern Mpumalanga Province [adapted from Horak *et al.* (1992)], and (c) feeding on humans.



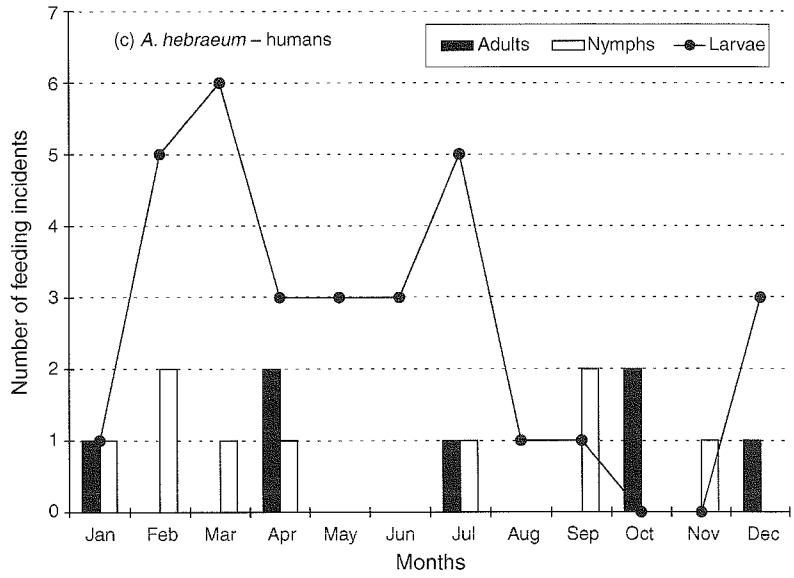


Figure 1. (continued)

seasonality and, with the exception of larvae that are most numerous during June and July, all stages of development are present in approximately the same proportions throughout the year. Most instances of larvae feeding on humans occurred between February and July and during December, while with the exception of May, June and August nymphs or adults fed on humans throughout the year (Figure 1(c)).

The CO_2 exhaled by animals activates free-living, unfed nymphs and adult *A. hebraeum* to search for a host in a haphazard fashion, and the directional response required for host location is elicited by a pheromone produced by male ticks that are already feeding (Norval *et al.*, 1989). These ticks are also stimulated by CO_2 exhaled by humans and it is while they are scuttling along the ground that they find and sometimes attach to a human host. *A. hebraeum* is a vector of *Rickettsia africae*, the etiological agent of African tick-bite fever in humans (Kelly, 2001). The long mouthparts of the nymphs and adults can cause deep wounds that may become secondarily infected with bacteria.

H. leachi is a 3-host tick, colloquially known as the yellow dog tick, and its name aptly implicates dogs as a preferred host. Its adults also infest the larger wild carnivores (Horak *et al.*, 2000) and it is possibly because of this preference for carnivores that they attach to humans because of the latter's carnivorous diet and signals that may be exuded by their monogastric digestive system. The immature stages feed on murid rodents, and provided rodent hosts are present this tick can occur virtually throughout South Africa. The seasonality of the adults varies considerably in different regions of the country and these differences are graphically illustrated in Figure 2. In the south-eastern, non-seasonal rainfall region they are most numerous on dogs from June to September and in the north-eastern, summer rainfall region from January to April. In the south-east most incidents of adults feeding on humans occurred during July and August (Figure 2(a)) and in the north incidents occurred from December to February and in June (Figure 2(b)).

Considerably more males than females were collected from humans, a tendency that was also evident for the two *Hyalomma* species (Table 1). *H. leachi* is a vector of *Rickettsia conori*, the cause of Mediterranean spotted fever in people (Kelly, 2001).

The coarse bont-legged tick, *H. marginatum rufipes*, is a large tick with a dark-brown body, long mouthparts, and long, red and white, banded legs from which it derives its common name. It is a 2-host tick and the adults parasitize domestic cattle and the very large wild herbivores, while the immature stages feed on hares as well as on ground-frequenting birds (Norval, 1982; Horak and Fourie, 1991). The adults actively hunt for hosts and, because of their large size, are easily seen scuttling along the ground from where they climb onto humans, on whom they usually attach in the hair of the head. They are most numerous on their preferred large herbivore hosts during December and January and most incidents of feeding on humans occurred during January (Figure 3(a)).

H. marginatum rufipes is widely distributed in South Africa, and appears to be absent only from the winter rainfall regions of the Western Cape Province and the cold mountainous areas of KwaZulu-Natal, as well as from

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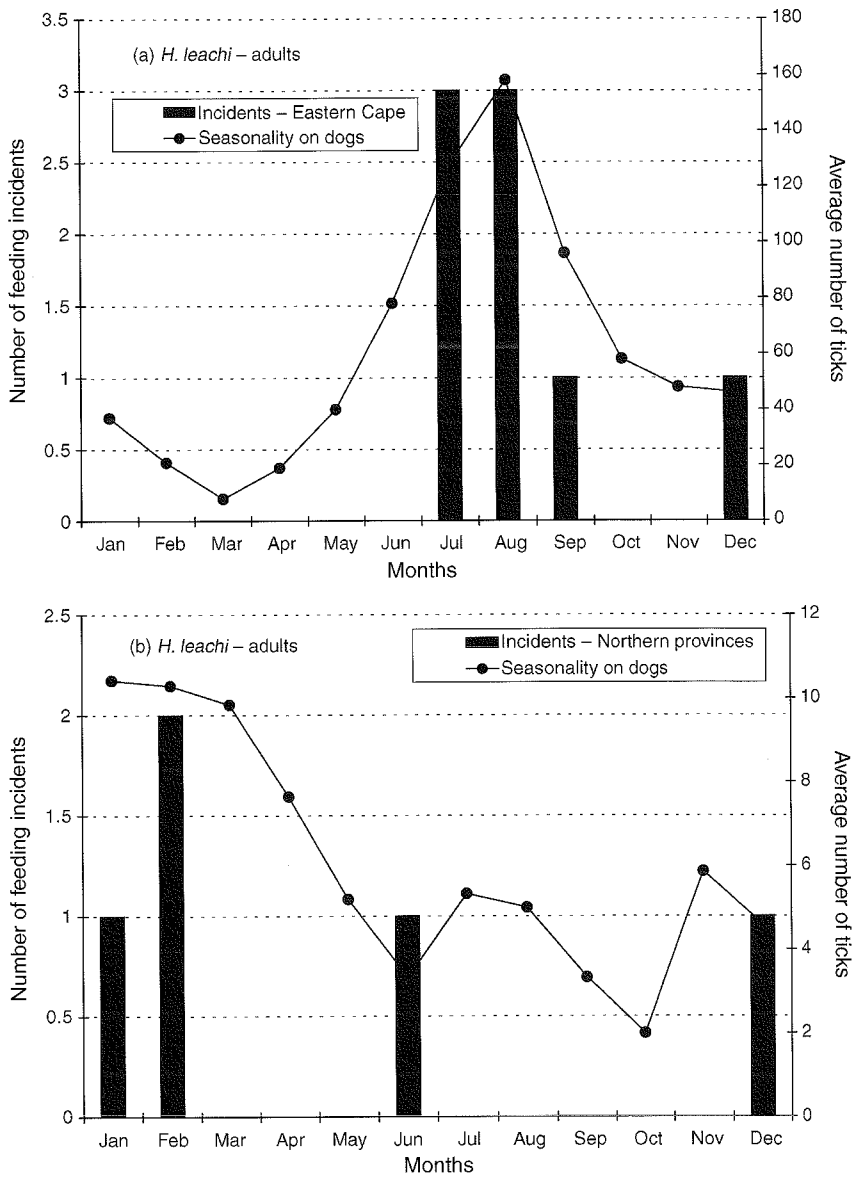

Figure 2. The seasonal occurrence of adult *H. leachi* on dogs in (a) the Eastern Cape Province and (b) north-eastern KwaZulu-Natal [adapted from Horak *et al.* (1987b, 2001)], and feeding on humans in (a) the Eastern Cape Province and (b) the more northerly provinces.

the more humid east coast and inland north-eastern regions (Howell *et al.*, 1978). Recent surveys have shown that it is particularly prevalent in the central and western Free State and eastern Northern Cape Provinces.

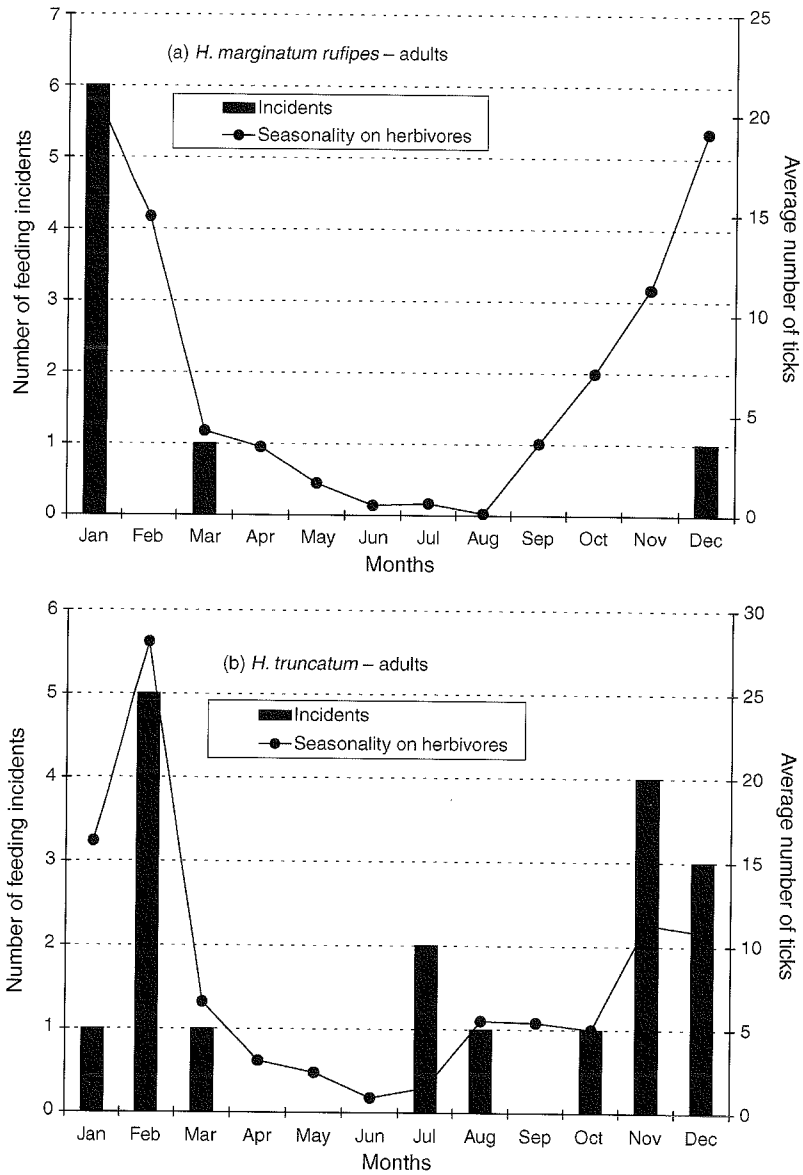

Figure 3. The seasonal occurrence of adult (a) *H. marginatum rufipes* and (b) *H. truncatum* on cattle and large wild herbivores at various localities in South Africa (adapted from seven surveys), and of these ticks feeding on humans.

H. marginatum rufipes is an important vector of the virus causing Crimean-Congo haemorrhagic fever (CCHF) in South Africa (Shepherd *et al.*, 1989).

H. truncatum is also a 2-host species and is known as the smooth bont-legged tick. Large herbivores are the preferred hosts of the adults, and hares

and rodents of the immature stages (Horak *et al.*, 1991). The adults are most numerous on large herbivores during February, and most instances of feeding on humans have been recorded during this month and November and December (Figure 3(b)). *H. truncatum* occurs throughout the western and northern parts of South Africa, but is absent from the moister regions of the Western and Eastern Cape, Free State and KwaZulu-Natal Provinces, and also from the eastern coastal strip (Howell *et al.*, 1978). It has been incriminated as a vector of the virus of CCHF (Shepherd *et al.*, 1989).

A total of 6 males and 1 female *H. marginatum rufipes* and 13 males and 3 female *H. truncatum* were collected from humans in the present survey (Table 1). This preponderance of males, if taken in conjunction with the 12 males and no female *H. truncatum* recorded by Swanepoel *et al.* (1987) from humans, seems unlikely to be fortuitous. It could hardly be because males spend a longer time on hosts than do females, as suggested by Swanepoel *et al.* (1987), as this would presuppose that female ticks that were present with the males had engorged on the humans (a process that takes approximately 7–10 days) and detached before the male ticks were collected. It could be that, like *A. hebraeum*, male ticks attach first and because of their size and the irritation they cause are easily detected and collected before the females even attach. The preponderance of *H. truncatum* over *H. marginatum rufipes* on humans (Table 1) could well reflect genuine host preferences of these species as suggested by Swanepoel *et al.* (1987).

R. appendiculatus is known as the brown ear tick because of the colour of the males and unfed females and the adults' propensity to attach to the ears of its large domestic and wild ruminant hosts. The adults of this 3-host tick are frequently seen questing for hosts on blades of grass from mid to late summer. The immature stages feed on the same hosts as the adults as well as on smaller ruminants and also on scrub hares (Walker *et al.*, 2000). In South Africa a single life cycle is completed annually. Adults are most numerous on greater kudus and other preferred hosts during summer (January or February to April), larvae from late summer to winter (March or April to June or July) and nymphs in the winter and early spring (June or July to October or November) (Figure 4(a) and (b)). All incidents of larvae feeding on humans occurred from July to September and most incidents of nymphs feeding from June to August, and of adults during March (Figure 4(c)).

R. appendiculatus survives best in woodland and woodland savannah regions with good vegetation cover. It tends to disappear if overgrazing occurs and it does not survive on open plains. In South Africa it occurs as far south and west as the central southern regions of the Eastern Cape Province, and northwards along the coast of KwaZulu-Natal to the Mpumalanga, Gauteng, Limpopo and Northwest Provinces (Walker *et al.*, 2000).

R. gertrudae has no colloquial name and is a 3-host tick of which the adults feed on domestic cattle, sheep and dogs as well as several large wildlife

species (Walker *et al.*, 2000). It also seems to have a preference for feeding on primates. Large infestations have caused mortalities in young baboons in Namibia (Brain and Bohrmann, 1992), and 21 incidents of ticks feeding on humans were recorded in the present survey (Figure 5(a) and (b)). Males and females were collected in approximately equal numbers. The immature

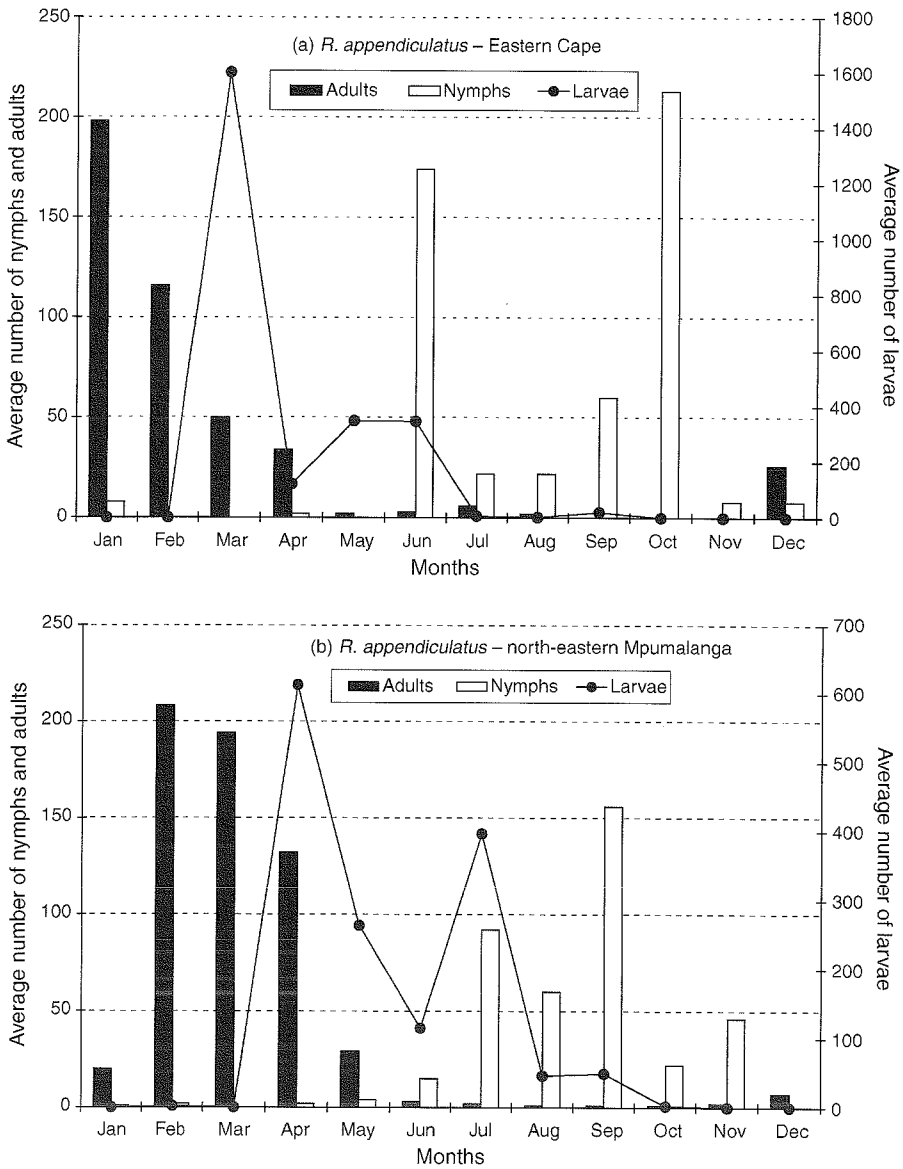

Figure 4. The seasonal occurrence of all stages of development of *R. appendiculatus* on greater kudus in (a) the Eastern Cape Province, (b) north-eastern Mpumalanga Province [adapted from Horak *et al.* (1992)], and (c) feeding on humans.

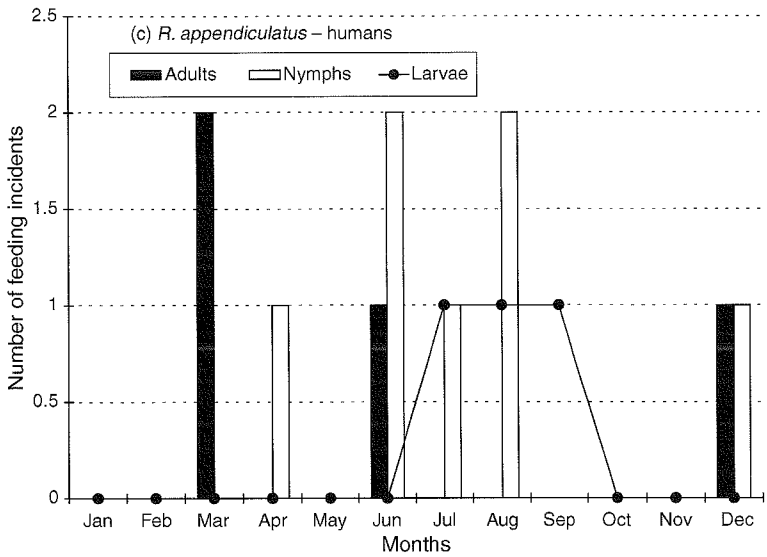

Figure 4. (continued)

stages feed on murid rodents (Fourie *et al.*, 1992). *R. gertrudae* replaces *R. simus* in the drier southern and western regions of South Africa from approximately 28°S and 27°E to the southern and western coastal regions

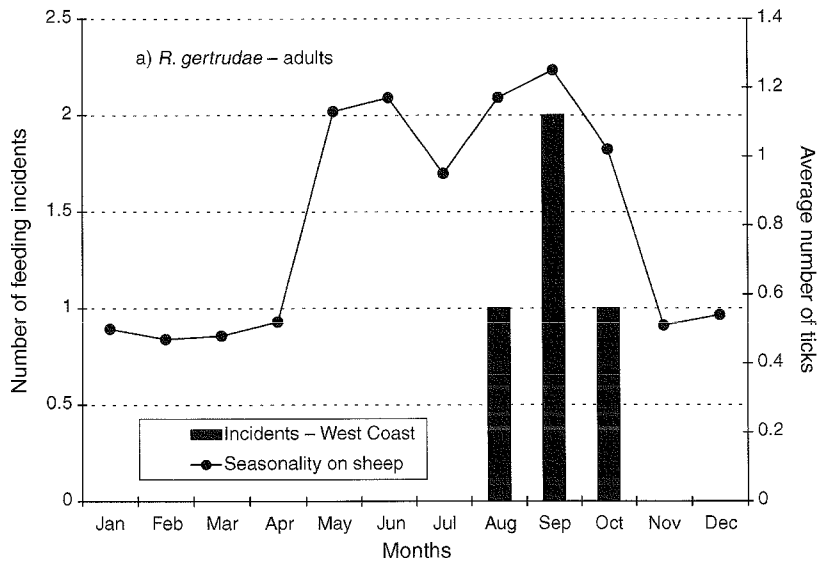

Figure 5. The seasonal occurrence of adult *R. gertrudae* on (a) sheep in the western regions of South Africa and (b) cattle in the Free State Province [adapted from Horak and Fourie (1992) and Fourie *et al.* (1996)], and feeding on humans at these localities.

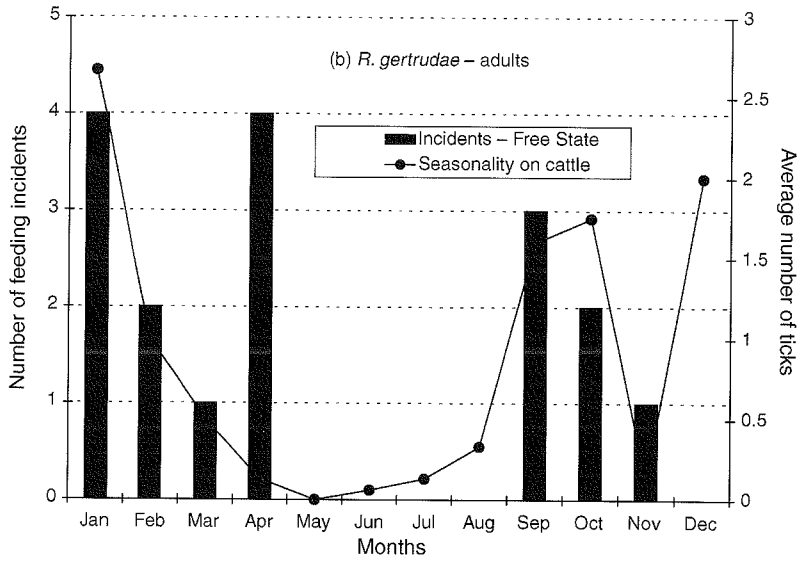

Figure 5. (continued)

in the south and west (Walker *et al.*, 2000). It is most numerous on sheep in the southern and western coastal regions from May to October (Horak and Fourie, 1992), and on cattle in the south-western Free State from September to February (Fourie *et al.*, 1996) (Figure 5). The four instances in the southern and western coastal regions in which humans were parasitized occurred between August and October, while those in the central and south-western Free State took place during the period September to April (Figure 5(a) and (b)).

R. simus is locally known as the glossy brown tick because of the smooth, shiny, dark-brown shield of the male. The preferred hosts of the adults of this 3-host tick are monogastric animals such as domestic and wild carnivores, equids and suids. However, cattle and African buffaloes and to a lesser extent sheep also serve as hosts (Walker *et al.*, 2000). It is possible that signals exuded by humans' monogastric digestive system and their carnivorous diet make them attractive to the tick, and are consequently responsible for the large number of infestations by both male and female ticks. The immature stages feed on murid rodents. In South Africa *R. simus* is common in the eastern tall grassveld from the Eastern Cape Province north through KwaZulu-Natal into the subtropical evergreen, deciduous and thorn forests of Mpumalanga and Limpopo Provinces. It is also present in the provinces of Gauteng and the Northwest (Walker *et al.*, 2000). In the south-east of the country it is most numerous on dogs from September to January, and in the north from January to March (Figure 6(a) and (b)). In both regions most

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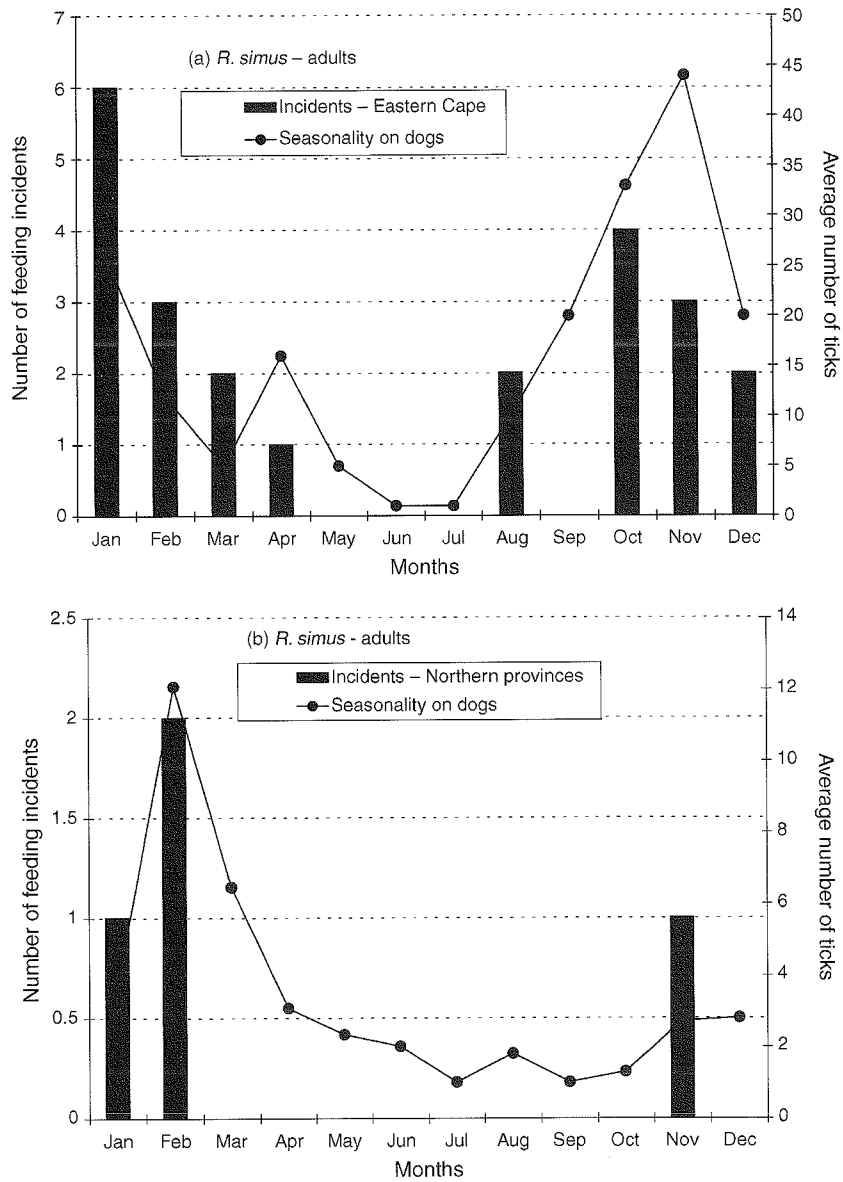

Figure 6. The seasonal occurrence of adult *Rhipicephalus simus* on dogs in (a) the Eastern Cape Province and (b) north-eastern KwaZulu-Natal [adapted from Horak *et al.* (1987b, 2001)], and feeding on humans in (a) the Eastern Cape Province and (b) the more northerly provinces.

instances of ticks feeding on humans were recorded during the period of their peak occurrence on their preferred hosts. *R. simus* is a vector of *R. conori* the cause of Mediterranean spotted fever in humans (Kelly, 2001).

A brief review of the other species feeding on humans follows. *Amblyomma marmoreum* is known as the South African tortoise tick because all stages feed on these animals (Walker, 1991). However, the immature stages, and particularly the larvae, also feed on a large variety of warm-blooded hosts, including carnivores (Horak *et al.*, 1987a, 2001). With the possible exception of *Rhipicephalus evertsi evertsi*, *Boophilus decoloratus* is the most widespread ixodid tick in South Africa and its larvae are often present in large numbers on the vegetation (Spickett *et al.*, 1992). Yet only four incidents of its feeding on humans in South Africa were recorded (Table 1). The collection of adult ticks in three of these indicates that they may have been attached for at least 15 days as the larva and nymph of this 1-host tick each require 7 days before they moult to the following stage. Adult ticks of this species may, however, transfer to other hosts, as has been recorded for *Boophilus microplus* (Mason and Norval, 1981), and could thus also infest humans. *Haemaphysalis silacea* and *Rhipicephalus glabroscutatum* are parasites of greater kudus in the Valley Bushveld regions of the Eastern Cape Province (Horak *et al.*, 1992). Ticks of the *Ixodes pilosus* group are chiefly present in the south and south-eastern regions of the country and parasitize domestic and wild ruminants and carnivores (Horak *et al.*, 1987b; Walker, 1991). *Ixodes rubicundus*, or the Karoo paralysis tick, is so named because of its geographic distribution and the severe outbreaks of paralysis it causes in sheep and goats during autumn and winter (Spickett and Heyne, 1988). The red-legged tick *R. evertsi evertsi* is the most widespread rhipicephalid tick in Africa, feeding particularly on equids and also on a wide range of ruminants (Walker *et al.*, 2000). The virus of CCHF has been isolated from this tick (Swanepoel *et al.*, 1983), and the females produce a toxin that causes paralysis in spring-born lambs (Hamel and Göthe, 1978; Howell *et al.*, 1978). *Rhipicephalus follis* belongs to the same group of ticks as *R. gertrudae*, but is present in the cooler eastern regions of the country (Walker *et al.*, 2000). *Rhipicephalus maculatus* and *Rhipicephalus muehlensi* occur in the coastal bush regions of KwaZulu-Natal, where the preferred hosts of the former are African elephants, rhinoceroses, bushpigs and African buffaloes, and nyalas of the latter (Walker *et al.*, 2000). *Rhipicephalus sanguineus*, also known as the kennel tick or brown dog tick, is nearly exclusively a parasite of dogs as well as the kennels and homes in which they live (Walker *et al.*, 2000). Thirty-three percent of 161 dogs tested in the greater Bloemfontein area, Free State Province were seropositive for *Ehrlichia chaffeensis* antigen (Pretorius and Kelly, 1998), and ehrlichiosis has been confirmed serologically in a patient in this city (Annemarie Pretorius, personal communication, 1999). The most likely vector is *R. sanguineus*, which is a proven vector of *Ehrlichia canis* the causative organism of canine ehrlichiosis (Van Heerden, 1992). *Rhipicephalus warburtoni* is a tick that has only recently been described and

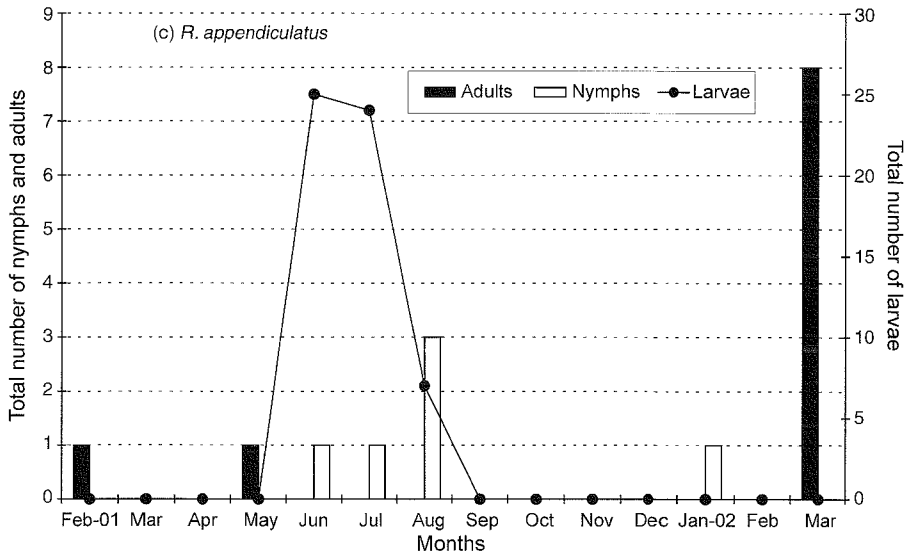

Figure 7. (continued)

rhinoceroses in the southern regions of the Kruger National Park and the free-living adults of their large, brightly coloured, orange and dark-brown ticks can easily be collected by hand from thicker grass stems from which they quest for hosts. The tick's abundance in the survey region and the monogastric nature of the game-guard's digestive system, similar to that of rhinoceroses, possibly account for the presence of these ticks on his garments. Adults have never been collected from the flannel strips used at monthly intervals for nearly 14 years to collect free-living ticks from the vegetation in the south of the Park. Two females have, however, been collected from the flannel leggings worn by the person responsible for dragging the flannel strips. It would thus appear as if these ticks are rapidly able to distinguish between living and inanimate objects. Because the immature stages feed on various rodent species, and possibly also on elephant shrews, they quest for hosts from the ground and are thus rarely collected by drag-sampling the vegetation with flannel strips (Horak and Cohen, 2001).

Adult *R. turanicus* is a parasite occasionally collected from dogs and wild carnivores in the north-eastern regions of South Africa, while it is regularly present on scrub hares in north-eastern KwaZulu-Natal (Horak *et al.*, 1995, 2000, 2001). It is most numerous on the vegetation in the south-east of the Kruger National Park during February and March (Horak *et al.*, 2001), and the five ticks on the game-guard's clothing were collected during February, March and April in this region of the Park.

Table 4. Ticks feeding on a field-worker during monthly tick collections in the Kruger National Park from February 2001 to March 2002

Species	Number of ticks collected					No. of collections
	Larvae	Nymphs	Males	Females	Total	
Amblyomma hebraeum	14	0	0	0	14	6

The ticks feeding on the field-worker (I.G.H.) in the Kruger National Park are summarized in Table 4 and have also been included in Table 1. Ticks fed on him on six occasions in the time he spent in the field during 11 months of the 14-month survey period, and all of these were larvae of *A. hebraeum*, of which 14 were collected. In addition an *A. hebraeum* nymph and a male and female *R. simus* attached to a co-worker during the February 2002 collection period in the Park. Despite the fact that 8002 *B. decoloratus* larvae were collected from the vegetation of the four survey localities in the Park, and 1023 from the clothing of the game-guard, none attached to the field-worker, confirming the observation made earlier that this species does not readily feed on humans.

The actual tick challenge on the clothing of the field-worker cannot be compared to that on the game-guard's. He only occasionally accompanied the guard into the vegetation from which the ticks were being collected with flannel strips, and mostly remained near the vehicle removing ticks from the flannel strips as they were brought in by the collectors. He did, however, spend as much time as the guard outside the vehicle and much of this was spent standing in grass that was tick-infested as the majority of the flannel strip samples were taken off-road. Of necessity several ticks, and particularly larvae, escaped detection as they climbed from the flannel strips onto his clothing or unprotected skin and consequently provided an additional challenge of free-living ticks.

In general, adult ticks do not use trees or tall vegetation to drop onto unsuspecting humans, but the frequency with which they are found attached on the head has misled people to believe this. In fact, ticks get onto skin or clothing and crawl upwards to find a suitable attachment site. Thus ticks ascending the outer surface of clothing would find the head and neck as their first sites for possible attachment. Exceptions are *Ixodes* species in the *pilosus* group, *R. gertrudae* and *Rhipicephalus maculatus* that all may ascend tall woody vegetation and thus make their first contact with a person's upper body (I.G. Horak, personal observations, 1990–1993), and *Hyalomma* spp., that although questing for hosts from the ground, prefer to attach within the hair on the head of humans.

Conclusions

Although many free-living adult and immature ixodid ticks are present in tick-infested habitats, only a small proportion of these climb onto the clothing of persons working or walking in these localities and an even smaller proportion of the latter are likely to actually attach. The chances of a person being bitten by a tick of a particular species are related to that species' inclination to feed on humans as well as the seasonal occurrence of its questing, free-living life stages on the vegetation or on the ground.

Acknowledgements

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THE DISTRIBUTION OF HYALOMMA SPP. AND HUMAN CASES OF CRIMEAN-CONGO HAEMORRHAGIC FEVER IN SOUTH AFRICA

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Abstract

Three *Hyalomma* ticks, namely *Hyalomma marginatum rufipes*, *Hyalomma marginatum turanicum* and *Hyalomma truncatum* occur in South Africa. In the 20 years since 1981, when the first case of Crimean Congo haemorrhagic fever (CCHF) was recognised in this country, human infections have been more frequently associated with these ticks than with any other cause. Since 1981 all confirmed human cases of CCHF have been recorded and the actual or potential sources of infection and the localities at which infection occurred noted. Ticks have been collected from a variety of domestic and wild animals across the country and the intensity of infestation with *Hyalomma* spp. on these animals determined. Large mammals are the preferred hosts of adult ticks and scrub hares of the immature stages. The mean burdens of *H. marginatum rufipes* on all host species and the proportion of animals infested are greater in the central semi-arid regions of the country than in the moister east or more arid western regions. The distribution of human cases of CCHF follows that of the higher intensities of infestation with this tick species. The concurrence of the highest intensities of infestation with ticks, a high prevalence of antibodies in preferred host animals, and the greatest number of CCHF cases in humans in the central, semi-arid regions, support the contention that *H. marginatum rufipes* is the major vector of the virus in South Africa.

Introduction

The first case of Crimean-Congo haemorrhagic fever (CCHF) to be recognised in South Africa was diagnosed in a child who had attended a nature study course (veld-school) in a nature reserve in the North West Province during February 1981. Surveys to detect virus in ticks and animals and antibodies in animals and humans in the reserve and its vicinity were conducted soon thereafter (Swanepoel *et al.*, 1983), and the seasonal activity of ixodid ticks and their host preferences in the reserve were determined by and Rechav *et al.*, (1987). Despite the disease being diagnosed in South Africa for the first time only in 1981, there is little doubt that it was present in the country long before then as antibodies were found in sera that had been in cold storage since 1964 (Swanepoel 1994).

The distributions of the three *Hyalomma* ticks occurring in South Africa, namely *Hyalomma marginatum rufipes*, *Hyalomma marginatum turanicum* and *Hyalomma truncatum* have been plotted by Theiler (1956) and illustrated by Howell *et al.*, (1978), and their hosts listed by Theiler (1962) and Walker (1991). These ticks are widespread in South Africa and the greatest concentrations occur in semi-arid in-land regions extending to the western coast with few if any ticks present in the eastern and southern coastal areas. The preferred hosts of the adult ticks are large animals such as zebras, eland, domestic cattle, African buffaloes, rhinoceroses, giraffes and ostriches (Norval 1982; Walker 1991; Horak *et al.*, 1991; Theiler 1962). Sheep and goats are also frequently infested but their tick burdens are usually small (Fourie *et al.*, 1988; Fourie and Horak 1991; Horak and Fourie 1992). The preferred hosts of the immature stages of all three ticks are scrub hares, (Horak and MacIvor 1987; Rechav *et al.* 1987; Horak and Fourie 1991). The immature stages of both subspecies of *H. marginatum* also infest ground-frequenting birds and those of *H. truncatum* infest rodents (Norval 1982; Rechav *et al.* 1987; Walker 1991; Horak *et al.* 1991).

Materials and methods

Since the first recognised case of CCHF in humans in South Africa in 1981 all confirmed cases have been recorded and the actual or potential sources of infection and the localities at which infection occurred noted. The geographic distribution of these cases has been summarised in the same tables as the tick distribution.

Cattle, sheep, goats and large wild animals as well as hares have been examined for ixodid ticks at several localities in South Africa. The numbers of *Hyalomma* ticks harboured by these animals are summarized in three tables, and are based

on the average numbers of ticks collected from infested animals. Where actual numbers of ticks and animals examined and infested have been supplied in the various publications consulted these have been used in the tables. If not these numbers have been calculated as accurately as possible from the materials and methods and graphic illustrations in these publications. The numbers of ticks collected have been arranged by host and by degree of latitude from west to east to support the gist of this communication.

Results and discussion

A total of 158 cases of CCHF have been diagnosed in humans in southern Africa during the 20 years since the disease was recognised in South Africa in 1981 for the first time. One of these infections occurred in Zaire, one in Tanzania, ten in Namibia and the rest in South Africa. The sources and potential sources of infection for these patients are summarized in Table 1.

Table 1: Sources or potential sources of human infection with CCHF virus in southern Africa from 1981 to 2000

No. of cases	Sources or potential sources of human infection			
	Tick bite	Blood or tissues of stock or ticks	Blood or fomites of patients	Lived in or visited rural environment
158	67 (42.4%)	66 (41.8%)	7 (4.4%)	18 (11.4%)

Marginally the largest group of cases (42,4%) originated from tick bite, while a similar number (41,8%) arose from known or potential contact with fresh blood or other tissues of livestock and/or ticks. Most patients were employed in the livestock industry, and males constitute 129 of all cases of the disease diagnosed to date. The case fatality rate fluctuated around 30% for the first few years after CCHF was initially recognised in southern Africa (Swanepoel *et al.*, 1987). It has now declined to 23,4% (37/158), probably because greater awareness of the disease has led to earlier recognition and better management of patients in most instances (Swanepoel, 1994; Swanepoel, 1998; Unpublished laboratory records).

The average numbers of adult *Hyalomma* spp. collected from infested cattle, zebras, gemsbok, eland and giraffes, and from smaller stock such as sheep and goats, as well as immature ticks collected from scrub hares, and on two

occasions from Cape hares, are summarized in Tables 2-4. With the exception of one set of sheep, no animals were examined between latitudes 21°E and 24°E.

Table 2: Average numbers of *Hyalomma marginatum rufipes* collected from infested domestic and wild animals and human cases of CCHF in South Africa in relation to degrees latitude

Hosts	Numbers of ticks collected and human cases of CCHF				
	1621°E	2124°E	2427°E	2730°E	3033°E
Large animals (867/1698)*	<1	No collections	31	7	3
Sheep and goats (339/2330)*	0	0	2	1	0
Hares (225/885)*	0	No collections	20	21	0
CCHF cases	10	24	46	21	10

* = No. infested/total no. examined

The larger the host species the greater the proportion infested with adult ticks and the greater the number of adult ticks harboured. Wherever scrub hares were examined within the distribution ranges of the ticks a large proportion of these hares were infested and the infested animals generally had large burdens. While some *H. marginatum rufipes* have been recovered from eland in the arid north-western part of the country (Table 2), none have been collected from scrub hares or other animals in the moister, south-western region (Horak *et al.*, 1986; Horak and Fourie 1992; Table 1). Very few adult and no immature *H. marginatum rufipes* were collected from large mammals or scrub hares respectively in the east of the country, which is generally moist and warm. The greatest numbers of this species were encountered on the largest variety of hosts between 24°E and 27°E. But for its southern coastal area, where no *H. marginatum rufipes* was recovered, this region is considered semi-arid.

Table 3: Average numbers of *Hyalomma marginatum turanicum* collected from infested domestic and wild animals and human cases of CCHF in South Africa in relation to degrees latitude

Hosts	Numbers of ticks collected and human cases of CCHF		
	1621°E	2124°E	2427°E
Large animals (27/27)*	No collections	No collections	48
Sheep and goats (10/987)*	1	1	No collections
Scrub hares (16/53)*	0	No collections	167
CCHF cases	10	24	46

* = No. infested/total no. examined

Table 4: Average numbers of *Hyalomma truncatum* collected from infested domestic and wild animals and human cases of CCHF in South Africa in relation to degrees latitude

Hosts	Number of ticks collected and human cases of CCHF				
	1621°E	2124°E	2427°E	2730°E	3033°E
Large animals (411/1725)*	99	No collections	20	7	5
Sheep and goats (374/3041)*	4	1	2	1	0
Hares (537/911)*	19	No collections	50	27	53
CCHF cases	10	24	46	21	10

* = No. infested/total no. examined

With the exception of a single *H. marginatum turanicum* from a sheep in the north-western region between latitudes 16°E to 21°E, and a few collected from sheep in the south between 21°E and 24°E (Horak, and Fourie 1992), this tick was recovered only in the Eastern Cape Province between 24°E and 27°E (Table 3). The latter collections were all taken from wildlife in the Mountain Zebra National Park (Horak *et al.* 1991). This park is situated in a semi-arid region with vegetation classified as Karroid Mountain Veld replaced by Karoo.

Hyalomma truncatum was present on both large and small wild and domestic animals wherever these were examined from 16°E to 30°E. The six giraffes examined in the north-eastern regions of Mpumalanga Province were all

infested, and large numbers of immature ticks were also collected from scrub hares in this region and in north-eastern Northern Province between latitudes 30°E and 33°E (Table 4).

Several surveys in South Africa and Zimbabwe during which small mammals and birds were examined, confirm that hares, and especially scrub hares, are the preferred hosts of the immature stages of the three *Hyalomma* occurring in South Africa (Norval 1982; Horak *et al.* 1986; 1991; Rechav *et al.* 1987). Wherever immature *Hyalomma* of a particular species were collected from scrub hares in the present surveys, adults of the same species were invariably present on larger hosts (Tables 2-4).

Although the geographic distributions of the ticks have obvious implications for the occurrence of Crimean-Congo haemorrhagic fever, the seasonal occurrence of adult ticks is probably equally important. Most adult *H. marginatum rufipes*, *H marginatum turanicum* and *H. truncatum* are present on cattle or large wild herbivores from October to March.

CCHF virus has been isolated from at least 30 species of ticks, both argasids and ixodids, but only members of three ixodid genera, namely *Dermacentor*, *Hyalomma* and *Rhipicephalus* have been shown to be capable of transmitting infection transstadially and transovarially (Swanepoel 1998). However, the bulk of the evidence suggests that *Hyalomma* spp. are the principal vectors, and the known distribution of the virus broadly coincides with the global distribution of these ticks (Hoogstraal 1956; Swanepoel 1998). Infection with the virus is acquired by *Hyalomma* spp. feeding on an infected host. This could be a hare, but possibly also a bird, in the case of the immature ticks, or a large herbivorous mammal or an ostrich in the case of the adults (Swanepoel 1998; Swanepoel *et al.*, 1998). In turn these animals can themselves acquire infection from infected ticks.

The geographic distribution of confirmed cases of CCHF in humans is summarized with the tick numbers in Tables 2-4. The distribution of these cases more closely corresponds to that of the two *H. marginatum* subspecies, and more especially to the regions in which the heaviest concentrations of *H. marginatum rufipes* have been recorded, than with the distribution of *H. truncatum*. It is particularly noticeable that no human cases of CCHF have been reported in regions south of the southern mountain ranges in the Eastern and Western Cape Provinces, where only *H. truncatum* is found and no *H. marginatum rufipes* is present (Howell *et al.* 1978). The prevalence of

antibodies in cattle in these southern regions was also lower than in other parts of the country where both ticks are present (Swanepoel *et al.* 1987).

Although *Hyalomma* ticks, their hosts and the presence of viral antibodies in the hosts are widely distributed in South Africa the few confirmed cases of disease in humans imply that there are barriers to infection. One of these is a difference in the competence of the vector species, with *H marginatum rufipes* being the most efficient. Another the regional abundance of the competent vector species with the greatest numbers of *Hyalomma* spp., and particularly *H. marginatum rufipes*, present in the semi-arid central regions of the country where human density is generally low. A third is a low concentration of virus particles in vector adult ticks, and a fourth the preference of these ticks for large herbivores and not for humans. Furthermore for human infection to occur via a tick, the tick would, during its immature stages of development, have had to feed on a hare with a sufficiently high viral titre for it to become infected (Shepherd *et al.*, 1989b). Viraemia in scrub hares and rodents lasts approximately one week, but only in a proportion scrub hares does it appear to reach an intensity sufficient to infect feeding immature ticks (Shepherd *et al.* 1989b). Viraemia in large mammals and in ostriches is also of short duration (Shepherd *et al.*, 1998).

The three South African *Hyalomma* spp. are two-host ticks. The larvae and the nymphs of *H. marginatum rufipes*, that together spend about three weeks on their hosts, have a better chance of being present on a viraemic host than the adults, that spend approximately only 10 to 14 days on their hosts. However, the probability of a large proportion of immature or adult ticks becoming infected from their preferred hosts is low.

Theoretically the control of *H. truncatum* should be less complex than that of either of the *H. marginatum* subspecies. The hare and rodent hosts of the immature stages of *H. truncatum* have restricted home ranges and efficient long-term tick control on domestic livestock should simultaneously reduce the number of immature stages on the small mammal hosts on the same property. Although efficient long-term control on livestock will also reduce the number of immatures of the two *H. marginatum* subspecies on hares and birds at the same locality, new ticks can be reintroduced at any time by birds that have large home ranges or are migratory.

Human infestation with *Hyalomma* ticks can be prevented by various precautionary measures. Firstly these ticks are active mainly in the warmer summer months, and particular care should be taken by hikers to regularly

examine themselves for ticks. Clothing can also be sprayed with preparations that will repel or kill ticks. Resting or sleeping in places where large domestic or wild animals regularly congregate is unwise as considerable numbers of adult ticks are often present at these sites. Sleeping on the ground in summer within the distribution range of the ticks is ill advised. Ticks should not be removed from large stock with the naked fingers, nor should ticks be squashed between the fingers. Particular care must be taken when performing necropsies on recently dead large animals as *Hyalomma* frequently detach from the carcass and may then reattach in the hair of the scalp of the operator, or in the beard, if one is worn. Contact with the fresh blood or tissues of healthy young cattle, sheep or goats during slaughter, or that of older animals that have died from a tick-borne disease and that are potentially coincidentally infested with CCHF infected *Hyalomma* spp. should be avoided by wearing gloves. Ostriches, and if possible also cattle, destined for abattoirs should be kept free of ticks for at least two weeks prior to slaughter.

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CHAPTER 6

TICKS ON DOMESTIC ANIMALS

I have conducted, or been involved in, a large number of surveys on ticks that infest domestic animals. In these the seasonal abundance and/or species composition of ticks infesting cattle in the Free State and Eastern Cape Provinces (Fourie & Horak 1990; Horak 1999), sheep in the Free State, and Eastern, Western and Northern Cape Provinces (Fourie, Horak & Marais 1988; Horak, Williams & Van Schalkwyk 1991a; Horak & Fourie 1992), goats in the Free State, Eastern Cape and Limpopo Provinces (Fivaz, Horak & Williams 1990; Fourie & Horak 1991; Horak, Knight & Williams 1991d; Boomker, Horak & Ramsay 1994; Horak, MacIvor & Greeff 2001a), and dogs in Gauteng, North-West, KwaZulu-Natal, Western Cape and Eastern Cape Provinces and in southern Mozambique (Horak 1995; Bryson, Horak, Höhn & Louw 2000; Horak, Emslie & Spickett 2001b; Horak & Matthee 2003; Neves, Afonso & Horak 2004; Nyangiwe, Horak & Bryson 2006) have been determined.

I am considered an authority on the identification of the immature stages of ixodid ticks that occur in South Africa. Hence my publications contain more accurate numeric and host preference data on the immature stages of the various tick genera than one would find in the works of researchers who are less confident in this field.

With the exception of the studies of Fourie *et al*. (1988), Fourie & Horak (1990, 1991) and Nyangiwe & Horak (2007), in which I identified some of the ticks, and Horak *et al*. (2001a), in which K. MacIvor identified all the ticks, and I the other parasites, I was responsible for the identification of all the ticks in the publications on ticks of domestic animals.

Cattle

The species proportion of ticks recovered from cattle in Free State Province (Fourie & Horak 1990), differed considerably from that recorded on sheep and goats examined on the same farm, with *Hyalomma marginatum rufipes* the major species on cattle. The species composition of the ticks on these cattle was also, with a few exceptions, completely different from that of the ticks infesting cattle on grass pastures or in Valley Bushveld in the Eastern Cape Province (Horak 1999). *Rhipicephalus appendiculatus* was the dominant species on the cattle on the pastures, while *Amblyomma hebraeum*, *Haemaphysals silacea*, *R. appendiculatus* and *Rhipicephalus glabroscutatum* were predominant on the cattle in Valley Bushveld.

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PARASITES OF CATTLE IN THE SOUTH WESTERN ORANGE FREE STATE

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ABSTRACT

A number of young Friesian oxen were slaughtered (one at a time) for parasite recovery for 12 consecutive months, from April 1987 to March 1988, on a farm in the Fauresmith district of the south western Orange Free State. A total of 5 ixodid and one argasid tick species, 2 lice species, plus one nematode species and one cestode species, were recovered.

Peak numbers of adult *Hyalomma marginatum rufipes* were present from November 1987 to February 1988, while the largest numbers of *Hyalomma truncatum* were recovered during September 1987 and from November 1987 to January 1988. Adult *Ixodes rubicundus* were recovered only during April and June 1987. Adult ticks of a *Rhipicephalus* sp. near *R. punctatus* were present during April and from September to November 1987 and in January 1988. No pattern of seasonal abundance was evident for the other tick species, the lice or the helminths.

Key words: Seasonal abundance, ixodid ticks, cattle, lice, nematodes

Fourie L.J.; Horak I.G. **Parasites of cattle in the south western Orange Free State.** *Journal of the South African Veterinary Association* (1990) 61 No. 1, 27-28 (En.) Department of Zoology and Entomology, University of the Orange Free State, 9301 Bloemfontein, Republic of South Africa.

INTRODUCTION

One of the objectives of integrated pest management, is the maintenance of parasite populations below levels causing economic loss[8]. In order to determine economic thresholds of parasitism, production losses related to pest densities must be ascertained. The first step in such an approach should be the gathering of quantitative and qualitative data on the burdens of the economically important parasite species.

In the south western Orange Free State, cattle constitute a tertiary agricultural resource after woolled and non-woolled sheep. About 21 000 cattle are farmed in 6 districts (Fauresmith, Jagersfontein, Philippolis, Trompsburg, Bethulie and Edenburg) within this area. No data on the parasite burdens of cattle within this region have been published. This paper records the numbers of external and internal parasites recovered from free-ranging Friesian cattle run on a farm in the Fauresmith district.

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MATERIALS AND METHODS

Study Area

Parasite collections were carried out on the farm "Preezfontein", which is situated 10 km from Fauresmith (29°46'S; 25°19'E) in the south western Orange Free State. A 72 ha camp, consisting of level as well as hilly areas, was chosen on this farm as the survey locality. The vegetation of this region is classified as False Upper Karoo[1]. The mean annual rainfall during the period 1980-86 was 360 mm, of which 69 percent fell during the summer. Due to the irregularity of the rainfall, mild to severe droughts occur periodically. During the study period, rainfall was measured at Fauresmith.

Survey animals

Young Friesian oxen under 16 months of age were used as survey animals and were maintained at a constant stocking density of 1 animal/6 ha during the survey period (April 1987-March 1988). In order to pre-infest the survey camp, particularly with nematodes, the cattle were placed in it during November 1986, 5 months prior to the actual start of sampling. From the end of April 1987, one animal was slaughtered each month for 12 consecutive months. Each of these animals had been dosed with the anthelmintic febantel (Rintal, Bayer, Animal Health) at 15 mg kg^{-1} live mass one month prior to slaughter. This implied that the nematodes recovered at slaughter had been acquired in the survey camp only during the preceding month.

Parasite recovery

After the collection of all easily visible ticks, one half of the skin covering the head and the neck, body and upper legs and one front and one back lower leg and foot was processed for ectoparasite recovery[4]. The lungs, mucosa of the abomasum and the contents of the abomasum, small and large intestines were processed for helminth recovery[4]. The parasite burdens of the animals were determined by examining the material collected, or in the case of the helminths representative samples, equivalent to 1/50 thereof, under a stereoscopic microscope[4]. The nematodes were identified, using a standard light microscope.

RESULTS

The numbers of ectoparasites collected from each of the animals are summarised in Table 1.

Five species of ixodid ticks and one argasid tick were recovered. Four of the ixodid tick species exhibited fairly clear patterns of seasonal abundance. All the animals were infested with *Damalinia bovis* and some with *Linognathus vituli.*

Only 3 animals were infested with helminths. The bovines slaughtered during October and December 1987, harboured *Cooperia oncophora* (600, fourth stage larvae and 5700 adults; and 450 adults respectively). The scolices and strobila of 3 *Thysaniezia giardi* were recovered from the animal killed during February 1988.

DISCUSSION

Ticks

The adults of *Amblyomma marmoreum* prefer tortoises as hosts, but the immature stages are found on reptiles, birds and mammals[7]. Their presence on the cattle is thus not surprising.

The peak in seasonal abundance of *Hyalomma marginatum rufipes* on the cattle (November - February) is similar to that observed on Merino sheep (December - March) on the same farm during the previous year[3]. It also closely corresponds to that recorded on cattle in the northern Transvaal (December - February)[6].

Although 20 sheep on "Preezfontein"

Table 1: Ectoparasites recovered from 12 Friesian cattle on the farm "Preezfontein" in the south western Orange Free State

Month	Ixodid and argasid ticks										Lice			Rainfall (mm)
	Amblyomma marmoreum		*Hyalomma marginatum rufipes*		*Hyalomma truncatum*		*Ixodes rubicundus*		*Rhipicephalus* sp. (near *R. punctatus)*		*Otobius megnini*	*Damalinia bovis*	*Linognathus vituli*	
	L	N	♂	♀	♂	♀	♂	♀	♂	♀	N	N + Ad	N + Ad	
April 1987	136		2				1	4	3	3	74	44685	2	10,6
May			4	1							12	138	12	1,0
June							2	4				771	30	11,3
July												5026	2	23,3
August												4227	65	14,9
September					3	3			1	5		606	5	88,7
October			3	3					2	3		2058	11	21,8
November			15	5	4	1			2	9		611	12	58,2
December			18	4	5	2					12	104	6	43,3
January 1988	2	4	30	2	1	4			2	2	120	12		12,1
February			29	3		1					1	209		394,2
March	8		3	1								15		89,1
TOTALS	**146**	**4**	**104**	**19**	**13**	**11**	**3**	**8**	**10**	**22**	**219**	**58462**	**145**	**768,5**

L = larvae N = nymphs Ad = adults

were examined for ticks each week from February 1986 to January 1987, a total of only 4 adult *Hyalomma truncatum* were recovered[3]. The 12 cattle examined in the present survey, harboured a total of 24 adult *H. truncatum*. The peak in seasonal abundance of these ticks (September, and November - January) was earlier than that observed on cattle in the northern Transvaal (January - March)[6].

Only 2 of the survey cattle became infested with adults of *Ixodes rubicundus* during April and June. This falls within the period April - September during which *I. rubicundus* was present on the sheep on the farm in the previous year[3].

The small number of ticks of this species recovered, could imply either that cattle are not suitable as hosts or that they did not utilise the hilly areas in their camp. Since *I. rubicundus* is confined mainly to rocky outcrops and hills[9], its acquisition by the cattle would require that they frequent these areas.

During the previous year, adults of *Rhipicephalus* sp. (near *R. punctatus)* [then referred to as *Rhipicephalus* sp. (near *R. pravus*)] were recovered from sheep on "Preezfontein" mainly during the spring and the late summer months[3]. Although they were only present in small numbers on the cattle, their seasonal abundance corresponds to that seen on the sheep.

The most important host for the immature stages of this tick is the rock elephant shrew, *Elephantulus myurus*[2]. Hence it is reasonable to assume that the adult ticks will be confined to rocky outcrops and hills. The small number of ticks found on the cattle, means either that they are not suitable as hosts or that they did not utilise the areas in their camp where the ticks were concentrated. This tick has been incriminated as a cause of paralysis in Angora goats in the south western Orange Free State[2].

Only the larvae and the nymphs of *Otobius megnini* are parasitic and they are found in the outer ear canals of a variety of hosts[5]. Infestation is usually associated with kraals[5] and hence with hosts that are confined in these kraals for shorter or longer periods of time. The cattle in this survey were raised in kraals on the farm, from where they were introduced into the survey camp at least 3 months prior to slaughter. The immature stages of this tick spend several months in their hosts' ears[5] and we assume that the cattle acquired the infestation in the kraals in which they were raised.

All the cattle were infested with *D. bovis*, but no pattern of seasonal abundance was evident. Small numbers of *L. vituli* were recovered from the animals examined from April to December 1987.

The small numbers of helminths recovered and the low percentage of animals infested, is probably due to the fact that only 12 animals ran in the 72 ha camp at one time, and that the period of pre-contamination (5 months) was too short. The semi-arid nature of the region is also not conducive to the survival of the free-living stages of most helminths.

The period of exposure of one month is shorter than the developmental periods of both *Bunostomum phlebotomum* and *Oesophagostomum radiatum*. The immature stages of these worms, had they been present, may have been missed on examination of the intestinal contents.

ACKNOWLEDGEMENTS

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Parasites of domestic and wild animals in South Africa. XXXVII. Ixodid ticks on cattle on Kikuyu grass pastures and in Valley Bushveld in the Eastern Cape Province

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ABSTRACT

HORAK, I.G. 1999. Parasites of domestic and wild animals in South Africa. XXXVII. Ixodid ticks on cattle on Kikuyu grass pastures and in Valley Bushveld in the Eastern Cape Province. *Onderstepoort Journal of Veterinary Research*, 66:175–184

Individual calves, exposed to infestation for 14 d on dry-land Kikuyu grass pastures on the coast near Alexandria, were slaughtered at approximately monthly intervals over a period of 2 years and examined for ticks. Although seven species were recovered total tick burdens were for the most part low. Changing the acaricide with which other cattle on the farm, but not the survey calves, were treated from an organophosphate-based compound to a synthetic pyrethroid resulted in a marked sustained reduction in the number of ticks on the calves.

Successive pairs of yearling cattle exposed to infestation on a farm in Valley Bushveld were slaughtered at monthly intervals over a period of 2 years and examined for ixodid ticks. Eleven species were recovered, of which *Amblyomma hebraeum, Haemaphysalis silacea, Rhipicephalus appendiculatus* and *Rhipicephalus glabroscutatum* were the most abundant and prevalent. Adult *A. hebraeum* were generally most numerous from early to late summer, adult *R. appendiculatus* from mid to late summer, and adult *R. glabroscutatum* from spring to mid-summer.

Keywords: Acaricidal effect, cattle, Eastern Cape Province, ixodid ticks, Kikuyu grass pastures, seasonal abundance, Valley Bushveld

INTRODUCTION

Various surveys on the ixodid ticks parasitizing domestic animals on farms in the Eastern Cape Province have been published. These include studies on both coastal and inland farms. Robertson (1981) and Rechav (1982) have determined the seasonal abundance of ticks on cattle on a coastal farm close to East London. While Rechav (1982), Horak, Williams & Van Schalkwyk (1991a) and Horak, Knight & Williams (1991d) have done so for cattle, sheep and goats on inland farms.

Several studies on the ixodid ticks parasitizing domestic and wild animals on the farm "Bucklands" as well as wildlife in the adjacent Andries Vosloo Kudu Reserve, situated in Valley Bushveld in the Eastern Cape Province, have been published. These studies include cattle (Rechav 1982), Dorper sheep (Horak, Williams & Van Schalkwyk 1991a), Angora goats (Rechav 1982; Horak, Knight & Williams 1991d), greater kudus (Knight & Rechav 1978; Horak, Boomker, Spickett & De Vos 1992), scrub hares (Horak & Fourie 1991), four-striped grass mice (Rechav 1982) and helmeted guineafowls (Horak, Spickett, Braack & Williams 1991c). The seasonal abundance of questing tick larvae on the vegetation of the farm has also been ascertained (Rechav 1982; Petney & Horak 1987).

The present paper describes the abundance of ticks on dairy calves on the farm "Glendye", a coastal farm near Alexandria, and the seasonal abundance of

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ticks on young beef cattle on the farm "Bucklands", north of Grahamstown. This research was conducted a number of years ago, but for various reasons has not been published. The survey on Glendye" clearly demonstrates the "rub-off" effect of synthetic pyrethroid acaricides, while that on "Bucklands" was carried out simultaneously with some of those already published for other domestic and wild animals on this property and thus deserves recording for completeness sake.

GENERAL MATERIALS AND METHODS

TICK RECOVERY

After exposure to infestation on the farms the survey animals from "Glendye" and from "Bucklands" were transported to Grahamstown where they were slaughtered. The skin of the head, body and tail, as well as the lower legs and feet with skin attached, were removed from the carcasses and processed for tick recovery as described by Horak *et al.* (1992) for greater kudus.

TICK IDENTIFICATION AND COUNTS

Ticks were collected from the processed material, identified and counted under a stereoscopic microscope. The numbers of female ticks that were completing engorgement, and were therefore likely to detach within the next 24 h, were determined for each species using some of the idiosomal lengths suggested by Horak, Fourie, Novellie & Williams (1991b). The seasonal abundances of several of the tick species have been graphically illustrated using a square-root transformation of the data.

SURVEY ON "GLENDYE"

MATERIALS AND METHODS

Study site

The farm "Glendye" (33°45'S, 26°29'E; Alt. 137 m) is 232 ha in extent and is situated approximately 3000 m from the coast south of Alexandria, Eastern Cape Province. With the exception of some indigenous coastal forest retained as windbreaks and shelter, virtually the entire farm has been planted to Kikuyu grass, *Pennisetum clandestinum*, and divided into paddocks approximately 1 ha in size. These paddocks are not irrigated and are used mainly as grazing for dairy cattle. Rainfall is non-seasonal and the long-term mean annual total is 830 mm, virtually equally distributed between the first and second halves of the year. Total precipitation is supplemented by heavy coastal mists. At the time of the survey the farm was stocked with approximately 200 Friesland cows, 90 replacement heifers, 30 beef cattle and 40 mutton-breed sheep.

Four ha of the pastures were allocated to the study and were divided into four fenced paddocks, each approximately 1 ha in size. Prior to fencing this particular piece of pasture had been grazed by cattle and horses. Subsequent to the fencing five Friesland calves were rotated through the four paddocks and on occasion also dairy cows. All cattle were removed from the paddocks during November 1982. On 1 December 1982 15, 9-month old Friesland heifer calves were placed in one of the four paddocks and thereafter were rotated through these paddocks as the vegetation was grazed down.

From 29 November 1982 to 7 June 1983 the 15 heifers, as well as other cattle on the farm, were plunge-dipped in the acaricide chlorfenvinphos [Disnis: Agricura Animal Care (Sanvet)] at approximately 14-d intervals. From 21 June 1983 until the conclusion of the survey in November 1984 all the cattle were dipped at approximately 14 to 21-d intervals in the acaricide cyhalothrin [Librekto: Milborrow Animal Health (Sanvet)]. The heifers were artificially inseminated and removed from the paddocks shortly before they were due to calve. The last heifers were removed from the paddocks during September 1984. As the heifers were removed from the paddocks other dairy cattle were rotated through them.

Survey animals

Once every 28 d from December 1982 to January 1984, separate pairs of approximately 4-month old Friesland bull calves, raised under tick and worm-free conditions, were placed with the 15 heifers in the paddocks for a period of 14 d. Once every calendar month from February 1984 onwards, the pairs of calves were placed with the heifers or other cattle in the four paddocks for periods of 14 d. With the exception of one calf, which was accidentally plunge-dipped in chlorfenvinphos 2 d prior to its slaughter during April 1983, none of these calves was treated with an acaricide.

At the conclusion of their 14-d periods of exposure the bull calves were transported to Grahamstown. On the following day one was killed and processed for ecto- and endoparasite recovery. The other calf was killed 21 d later and processed only for the collection of endoparasites. The endoparasite burdens of the calves will be reported separately.

RESULTS AND DISCUSSION

The species and total numbers of ixodid ticks collected from the calves on "Glendye" are summarized in Table 1.

TABLE 1 Ixodid ticks collected from 25 Friesland bull calves on the farm "Glendye", Eastern Cape Province

Tick species	Total numbers recovered					No. of calves infested
	Larvae	Nymphs	Males	Females	Total	
Amblyomma hebraeum	40	0	0	0	40	6
Boophilus decoloratus	16	21	6	0	43	8
Haemaphysalis silacea	36	20	11	4	71	10
Ixodes sp.	2	0	0	0	2	1
Rhipicephalus appendiculatus	4 181	210	105	136 (5)	4 632	15
Rhipicephalus evertsi evertsi	188	158	6	1 (1)	353	9
Rhipicephalus glabroscutatum	17	4	0	0	21	2

( ) = number of engorging female ticks that could detach within the next 24 h

Seven species were recovered, with *Rhipicephalus appendiculatus* being the only species present in substantial numbers. The dominance of this tick on "Glendye" was possibly due to the clumps of indigenous trees retained on the pastures for shelter, which then provided a suitable habitat for its free-living stages. Although not illustrated here, the larvae of *R. appendiculatus* were most abundant from February to May 1983, the nymphs from April to June and in August 1983 and the adults from December 1982 to March 1983.

From the first week of June 1983 onwards, just before the acaricide used on the resident farm cattle on "Glendye" was changed from chlorfenvinphos to cyhalothrin, there was a marked decline in the total number of ticks acquired by the bull calves in the survey. This decrease persisted until the end of the study and is graphically illustrated in Fig. 1.

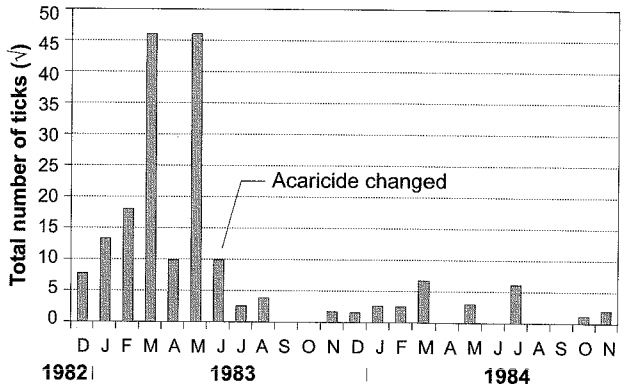

FIG. 1 The combined abundance of all stages and all species of ixodid ticks on individual calves on coastal Kikuyu grass pastures, Eastern Cape Province. One animal was examined at the beginning of August 1983 and another at the end of the same month and their average burden has been plotted

The organophosphate, chlorfenvinphos, initially used on "Glendye", had very little residual acaricidal effect on the cattle and probably no "rub-off" effect between cattle in the same paddock. In contrast the synthetic pyrethroid acaricides usually have a 7–10 d residual effect as well as a "rub-off" effect. Thus, although the survey calves themselves were not treated with either of the acaricides, some of the synthetic pyrethroid may have rubbed off on to them when they came into contact with the treated heifers and later with other cattle in the same paddocks. In addition, the high efficacy of the latter acaricide, combined with its residual effect, would not only have killed the ticks on the treated cattle on the farm, but would ultimately have led to a reduction in the numbers of free-living ticks on the pastures and consequently also on the survey calves.

Two studies with results similar to those recorded on "Glendye" have been published. The first was conducted on "Bucklands" and the adjacent Andries Vosloo Kudu Reserve (Horak & Knight 1986). In that study, with the exception of the various species of domestic animals used for survey purposes, all the cattle on "Bucklands" were treated with a synthetic pyrethroid acaricide at 2 to 4-weekly intervals and the sheep and goats at monthly intervals. This resulted in a significant reduction in the numbers of *A. hebraeum* on the vegetation as well as on greater kudus, scrub hares and helmeted guineafowls on the farm compared to those on the vegetation and the same wild animals on the adjacent reserve (Horak & Knight 1986; Petney & Horak 1987). Not one of the other tick species was similarly affected.

The second study was conducted on "Mubanga", a mixed cattle and wildlife farm, and on "Mtendere Game Ranch", a nearby wildlife farm, in the Central Province, Zambia (Zieger, Horak, Cauldwell, Uys & Bothma 1998). The cattle on "Mubanga" were treated with a synthetic pyrethroid acaricide at weekly intervals during summer and at 2-weekly intervals during winter. This resulted in a significant reduction in the numbers of *Amblyomma variegatum, R. appendiculatus* and *R. evertsi evertsi* on the vegetation as well as on impalas on the farm compared to those on the nearby "Mtendere Game Ranch" (Zieger *et al.* 1998). Those tick species which parasitized mainly wildlife on the farm were not affected by this treatment regime.

The significant reductions in tick numbers on the wild animals on both "Bucklands" and "Mubanga" could not be ascribed to the "rub-off" effect of the acaricides used on the domestic livestock as there would have been no contact between these animals and the wildlife. Rather they were due to the high efficacies of the remedies as well as their residual acaricidal effects on the domesticated hosts. This would have resulted in a disruption of the life cycles of the ticks on these hosts and consequently have led to reduced pasture contamination, ultimately resulting in reduced host infestation.

It thus appears possible to reduce the levels of tick infestation on all animals on a farm by the regular treatment of only some animals with an efficient acaricide with a residual effect. This option could have certain advantages in that the surviving tick population may provide sufficient challenge to maintain endemic stability to the tick-borne diseases prevalent at a particular locality and yet be too small to cause tick damage.

SURVEY ON "BUCKLANDS"

MATERIALS AND METHODS

Study site

The farm "Bucklands" (33°06'S, 26°41'E; Alt. 335–538 m) is 5 480 ha in extent and is situated along the banks of the Great Fish River, Eastern Cape Province. The vegetation is classified as Valley Bushveld (Acocks 1988). Rainfall is non-seasonal and the long-term mean annual total is 484 mm, of which slightly more than 300 mm falls from October to March. At the time of the survey the farm supported approximately 185 cattle, 300 Dorper sheep, 4 000 Angora goats, 300 greater kudus and large numbers of small antelopes, scrub hares and helmeted guineafowls. The domestic stock were regularly treated with the acaricide fenvalarate [Sumitik Cattle Dip: Shell SA (Pty) Ltd].

Survey animals

Four, approximately 12-month-old, beef-type oxen, which ran together, but separately from the other cattle on the farm, were not treated with an acaricide unless they were very heavily infested with ticks. At monthly intervals two yearling oxen were treated with a synthetic pyrethroid acaricide and kept under tick-free conditions for 7 d. They were then placed in the same camp on the farm as that in which the four normally untreated animals were grazing at that particular time.

After 1 month the two introduced cattle were removed from the camp, killed and processed for tick recovery. On the same day two more oxen of approximately the same age, and prepared in the same way as the previous two, were placed in the camp where they remained for a month before being killed for tick recovery. With the exception of December 1985 and January 1986, when only one animal was slaughtered on each occasion, this procedure was repeated for 24 consecutive months. Although the cattle were confined to the camps by fences these did not prevent greater kudus or smaller antelopes as well as other wildlife from entering the camps.

RESULTS AND DISCUSSION

The species and numbers of ixodid ticks collected from the cattle on "Bucklands" are summarized in Table 2.

Eleven tick species were recovered. Of these *Amblyomma hebraeum, Haemaphysalis silacea, Rhipicephalus appendiculatus* and *Rhipicephalus glabroscutatum* were the most abundant and all animals were infested with the latter three species. Adult ticks

TABLE 2 Ixodid ticks collected from 46 cattle on the farm "Bucklands", Eastern Cape Province

Tick species	Total numbers recovered					No. of cattle infested
	Larvae	Nymphs	Males	Females	Total	
Amblyomma hebraeum	6 769	366	778	314 (78)	8 227	45
Amblyomma marmoreum	1 796	13	0	0	1 809	29
Boophilus decoloratus	179	197	95	83 (38)	554	19
Haemaphysalis silacea	18 674	2 512	630	441 (224)	22 257	46
Hyalomma marginatum rufipes	0	0	21	16 (1)	37	10
Rhipicephalus appendiculatus	10 223	1 456	932	312 (95)	12 933	46
Rhipicephalus evertsi evertsi	1 354	916	55	19 (2)	2 344	33
Rhipicephalus exophthalmos	0	0	223	75 (22)	298	19
Rhipicephalus glabroscutatum	16 889	3 975	1 076	649 (66)	22 589	46
Rhipicephalus simus	0	0	28	20 (4)	48	15
Rhipicephalus sp.	2	5	0	0	7	4

( ) = number of engorging female ticks that could detach within the next 24 h

accounted for a substantial proportion of the total tick population and large numbers of females were completing engorgement on the cattle.

Fifteen tick species have already been collected from cattle, Dorper sheep, Angora goats, greater kudus, four-striped grass mice, scrub hares and helmeted guineafowls examined on "Bucklands" (Knight & Rechav 1978; Rechav 1982; Horak & Fourie 1991; Horak *et al.* 1991a, c, d; 1992).

Four of these 15 species were not recovered in the present survey. One of these four was *Rhipicephalus oculatus,* which parasitizes hares almost exclusively (Keirans, Walker, Horak & Heyne 1993) and occurs in large numbers on scrub hares on "Bucklands" (Horak & Fourie 1991). The other three missing species were *Haemaphysalis leachi, Hyalomma truncatum* and *Ixodes pilosus. H. leachi* is a carnivore tick, but feeds on certain murid rodents and also on carnivores during its immature stages (Hoogstraal 1956; Norval 1984). Hence its absence on the cattle is not surprising. On the other hand cattle are one of the preferred hosts of adult *H. truncatum* (Hoogstraal 1956; Norval 1982). It was absent on the survey animals, despite the fact that a few of its immature stages were collected from scrub hares examined at the same time (Horak & Fourie 1991). This suggests that "Bucklands" lies at the limits of this tick's distribution in this region of the Eastern Cape Province. The same probably applies to both *I. pilosus* and *Hyalomma marginatum rufipes.* The latter tick was, however, collected from the survey cattle in small numbers.

The seasonal abundances of *A. hebraeum, Amblyomma marmoreum, H. silacea, R. appendiculatus* and *R. glabroscutatum* are graphically illustrated in Fig. 2–6.

Amblyomma hebraeum

The parasitic and free-living populations of *A. hebraeum* on "Bucklands" were considerably reduced by the regular acaricidal treatment of the resident domestic stock (Horak & Knight 1986; Petney & Horak 1987). The 8 227 and 199 ticks collected from the 46 cattle and from the nine greater kudus respectively examined on "Bucklands" compared with the 36 293 *A. hebraeum* collected from the 16 kudus examined on the adjacent Andries Vosloo Kudu Reserve during the same time period confirm this (Table 2; Horak *et al.* 1992). The tick burdens on the survey cattle would undoubtedly have been lower had they grazed with the other cattle on the farm and not been kept separately in camps with the four untreated cattle on which only emergency acaricidal treatment was permitted. The fairly large adult burdens recorded on the cattle during the summer months substantiates the preference of this life stage for cattle and for other large hosts (Theiler 1962; Norval 1983; Horak, MacIvor, Petney & De Vos 1987a).

Despite the reduced numbers of *A. hebraeum* it was still possible to determine a pattern of seasonal abundance on the cattle (Fig. 2). The larvae were most abundant during the period March to May (autumn) and the adults during the period October to May (summer to autumn). No clear pattern of seasonality was evident for the nymphs. The larval and adult abundance corresponds to that observed on greater kudus in the same vicinity by Knight & Rechav (1978) and by Horak *et al.* (1992) and on cattle in the same region (Rechav 1982), as well as on cattle in thornveld in southern KwaZulu-Natal (Baker & Ducasse 1967). The abundance of adults from early to late summer also corresponds to that observed on cattle in the Northern Province of South Africa and in southern Zimbabwe (Horak 1982; Norval 1983).

This pattern of abundance, which is probably controlled by climate, strongly suggests that at least the majority of the population completes a single life cycle annually at these localities. In regions where the winters are warmer, such as the north-eastern lowveld of the KwaZulu-Natal and Mpumalanga Provinces, there is little indication of a pattern of seasonal abundance with all stages of development being present simultaneously (Horak *et al.* 1992; Horak, Boomker & Flamand 1995). In these regions it seems possible that the life cycle may even be shorter than 1 year. In Norval's (1977) initial research on *A. hebraeum* in the Eastern Cape Province he stated that the life cycle is normally of 3 years duration. Rechav (1982), however, disagreed and suggested that his own research in this province indicated that many ticks completed a 1-year life cycle, with a few cohorts having a life cycle of 15–18 months. The present results tend to confirm Rechav's findings.

Amblyomma marmoreum

All parasitic stages of this tick prefer tortoises, and probably more particularly leopard tortoises as hosts (Theiler 1962; Norval 1975b; Dower, Petney & Horak 1988). However, the larvae and sometimes the nymphs commonly also infest carnivores, equids, ruminants, lagomorphs and the larger ground-frequenting birds (Norval 1975b; Horak *et al.* 1987a; Horak, Jacot Guillarmod, Moolman & De Vos 1987b). During the period of the present study cattle, sheep, goats, greater kudus, scrub hares and helmeted guineafowls were concurrently examined on "Bucklands" (Horak & Fourie 1991; Horak *et al.* 1991a, b, c; 1992). The prevalence of infestation on the ruminants varied between a low of 47,9 % on sheep and a high of 63,0 % on cattle, while 25,5 % of scrub hares and 78,4 % of guineafowls were infested.

The peak period of larval abundance from January to April or May on the above-mentioned animals

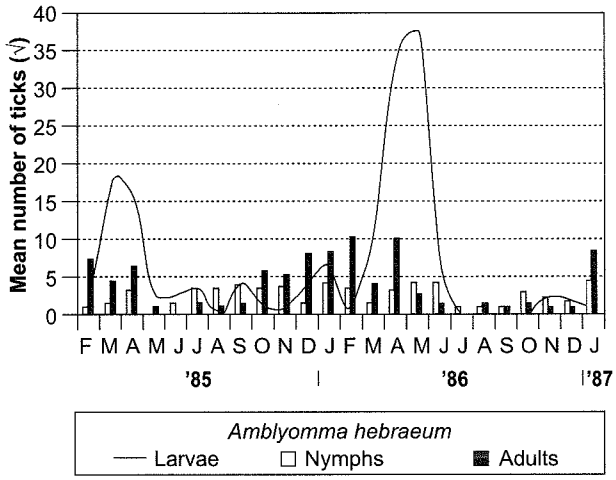

FIG. 2 The seasonal abundance of *Amblyomma hebraeum* on yearling cattle in Valley Bushveld, Eastern Cape Province

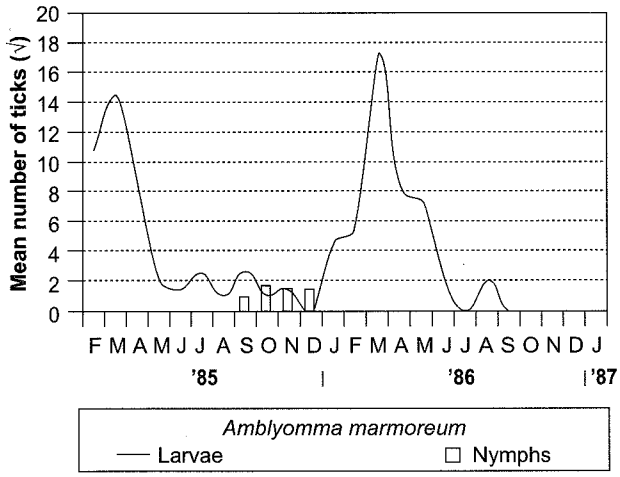

FIG. 3 The seasonal abundance of *Amblyomma marmoreum* on yearling cattle in Valley Bushveld, Eastern Cape Province

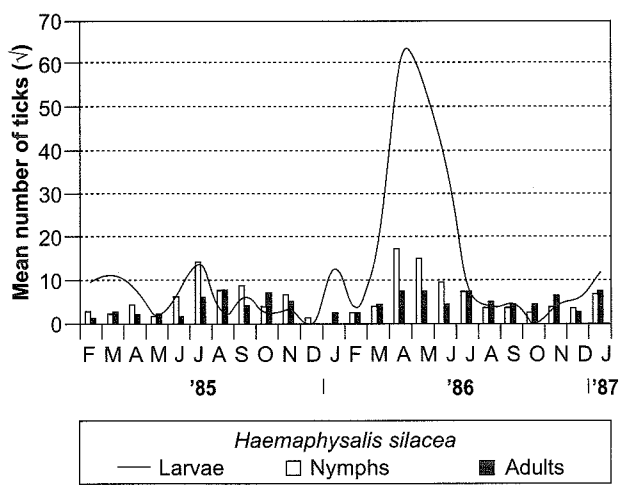

FIG. 4 The seasonal abundance of *Haemaphysalis silacea* on yearling cattle in Valley Bushveld, Eastern Cape Province

would seem to indicate a 1-year life cycle for this tick (Fig. 3). On the preferred tortoise hosts a cycle as short as this seems unlikely as larvae may remain attached for as long as 30–104 d, nymphs 47–51 d and females 60–73 d (Norval 1975b; Dower *et al.* 1988). The parasitic portion of the life cycle on tortoises could thus theoretically last 228 d, making it improbable that the total life cycle could be completed within 1 year. Norval (1975b) has suggested that the life cycle of *A. marmoreum* in the Eastern Cape Province can be 1 or 2 years long depending on whether the nymphs feed on tortoises during spring or during mid-summer. However, should the immature stages feed on sheep, and probably other warm-blooded animals, this may only take between 6 and 12 d for the larvae and between 8 and 20 d for the nymphs (Norval 1975b). This eventuality would reduce the parasitic phase of the life cycle, and possibly the length of the whole life cycle, considerably.

Boophilus decoloratus

Cattle and greater kudus are excellent hosts of this tick (Hoogstraal 1956; Baker & Ducasse 1967; Mason & Norval 1980; Horak *et al.* 1992). The small numbers collected from the cattle in the present survey, and from greater kudus on "Bucklands" and in the adjacent Andries Vosloo Kudu Reserve during the concurrent surveys on the latter animals (Horak *et al.* 1992), indicate that this farm and its environs are not a suitable habitat for *B. decoloratus.* This is confirmed by the fact that Rechav (1982) collected large numbers of this tick from cattle on the farm "Beaconsfield", scarcely 45 km to the south of "Bucklands", whereas he found none on cattle examined on "Bucklands" at the same time. Whether these differences were due to climatic, vegetational or other dissimilarities between the two farms could not be determined within the scope of this survey.

Haemaphysalis silacea

This tick was the second most numerous on the cattle and many of the females were completing engorgement. On greater kudus examined concurrently in the adjacent Andries Vosloo Kudu Reserve 27,8% of males, 59,5% of females and 84,8% of females completing engorgement were attached to the tails of the animals (Horak *et al.* 1992). In the present study 18,6% of the males, 31,5% of the females and 22,3% of engorging females were attached to the tails of the cattle. These differences could be due to the vastly different structures and pilosities of the tails of these two hosts, with the short bushy tails of the kudus affording greater protection to the adult ticks. Besides cattle, all stages of development may be found on sheep and goats as well as on various antelope species and also, rarely, on dogs. The immature stages have been found on small wild carnivores, scrub hares and helmeted guineafowls (Norval 1975a; Horak *et al.* 1987b; Walker 1991).

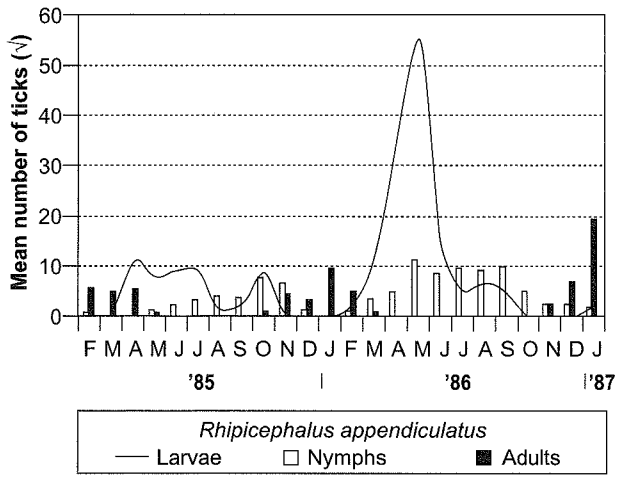

FIG. 5 The seasonal abundance of *Rhipicephalus appendiculatus* on yearling cattle in Valley Bushveld, Eastern Cape Province

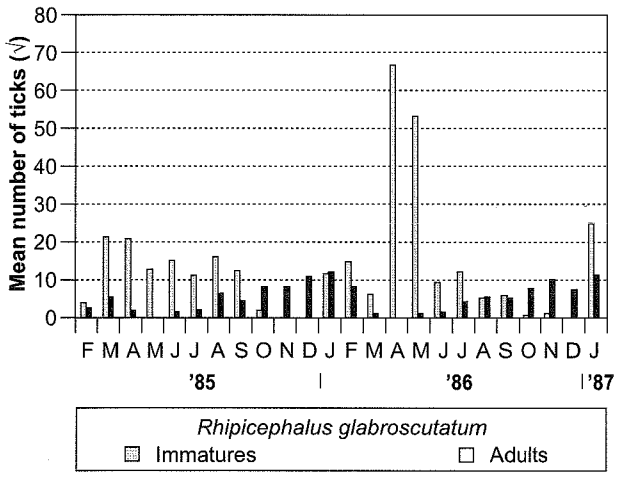

FIG. 6 The seasonal abundance of *Rhipicephalus glabroscutatum* on yearling cattle in Valley Bushveld, Eastern Cape Province

Apparently the life cycle continues throughout the year but with peaks of larval abundance occurring from late summer to winter, nymphs from autumn to spring and adults in spring and in late summer (Norval 1975a; Rechav 1982; Horak *et al.* 1991d; 1992; Fig. 4).

Haemaphysalis silacea is found only in parts of South Africa. Even here it is confined to localized areas of Fish River Bush along the hot and dry river valleys in the Eastern Cape Province as well as to the subtropical and deciduous bush complex along the coast (Theiler 1945; Norval 1975a; Rechav 1982). It is also present in KwaZulu-Natal, especially in the Hluhluwe, Umfolozi and St Lucia regions (Baker & Keep 1970; Horak, Keep, Flamand & Boomker 1988; Horak *et al.* 1995), in vegetation types classified as Valley Bushveld, Lowveld and Coastal Forest and Thornveld (Acocks 1988).

Rhipicephalus appendiculatus

All stages of development prefer cattle and the larger wild bovids as hosts (Yeoman & Walker 1967; Walker 1974; Norval, Walker & Colborne 1982). The immature stages are also found on the smaller antelopes as well as on carnivores and on hares (Clifford, Flux & Hoogstraal 1976; Norval *et al.* 1982; Horak & Fourie 1991).

Although the seasonal abundance of *R. appendiculatus* in the present survey was typical for this species in the Eastern Cape Province adult numbers were nevertheless relatively low in the late summer of 1985 and during the subsequent summer of 1985/1986 (Fig. 5). The larval and nymphal numbers were also low during the autumn to spring months of 1985. However, larval numbers increased considerably during 1986, commencing in February and peaking at several thousand during May and continuing until September. The numbers of nymphs collected during 1986 also considerably exceeded those collected during 1985. These were followed by the greatest numbers of adults collected during the entire survey from the cattle examined during January 1987.

Short & Norval (1981) state that the seasonal occurrence of the larvae and the nymphs of *R. appendiculatus* is determined by the pattern set by the adults. According to them the activity of the latter life stage is influenced by rainfall, temperature and daylength. Randolph (1993), on the other hand, believes that it is the timing of the questing activity of the dessication-vulnerable larvae that determines the pattern of the tick's seasonal activity. She suggests that the timing of nymphal and adult activity is determined by temperature-dependent development rates as well as the delaying phenomenon of photo-period sensitive diapause. She also thinks that the timing and duration of this diapause have evolved to achieve maximum tick survival by ensuring the presence of eggs and larvae during optimal climatic conditions.

The proposals by Short & Norval (1981) and Randolph (1993) are not necessarily mutually exclusive. They probably complement one another. In the current survey both larval and nymphal activity commenced approximately 2 months earlier during 1986 than during 1985 and greater numbers of both stages were collected. The increase in numbers during 1986 may, however, not have been due to more favourable climatic conditions, but rather to the fact that by that time hardly any acaricide had been used on the four cattle kept permanently in the survey camps. The absence of control could have resulted in an overall increase in tick numbers.

"Bucklands" is situated fairly close to the western extremity of the distribution of *R. appendiculatus* in the Eastern Cape Province. At Grahamstown, 30 km to the south-west, it occurs in mixed infestations with *Rhipicephalus nitens* (Horak *et al.* 1987b). On the

farm "Sidbury", situated in Eastern Province Thornveld interspersed with macchia (fynbos), 60 km to the south-west of "Bucklands", it is virtually entirely replaced by *R. nitens* (Horak *et al.* 1991a), while in the Addo Elephant National Park, in Valley Bushveld 100 km to the south-west, both ticks are absent (Horak *et al.* 1992).

Rhipicephalus evertsi evertsi

All stages of development of this two-host tick prefer equids and eland as hosts, on which they may occur in large numbers (Hoogstraal 1956; Norval 1981; Horak *et al.* 1991b). Cattle are frequently infested but seldom harbour the same large numbers of any stage of development as do the former animals (Rechav 1982; Baker, Ducasse, Sutherst & Maywald 1989). Few ticks were collected at "Bucklands", and all stages of development generally preferred the warmer months from November to April. This pattern of abundance agrees with the findings of Rechav (1982) on the farms "Beaconsfield" and "Luembe" in the Eastern Cape Province and those of Baker & Ducasse (1967) in southern KwaZulu-Natal. In localities with warmer winters, such as in Zimbabwe and Zambia, *R. evertsi evertsi* can apparently complete more than one generation annually and successive "waves" of adult activity can be detected (MacLeod, Colbo, Madbouly & Mwanaumo 1977; Matson & Norval 1977).

Rhipicephalus exophthalmos

This tick, which has frequently been confused with *Rhipicephalus oculatus,* with which it often occurs sympatrically on scrub hares, has only recently been described (Keirans *et al.* 1993). Unlike *R. oculatus,* however, which virtually exclusively parasitizes hares, *R. exophthalmos* is encountered on domestic and wild ungulates as well as on hares (Keirans *et al.* 1993). The largest collections to date are those from the two calves examined on "Bucklands" during January 1987. They harboured 85 males, 12 females and 76 males, 24 females respectively. Until recently the only known hosts of the immature stages were scrub hares [Horak & Fourie 1991, as *Rhipicephalus* sp. (near *R. oculatus*)], but they have now also been collected from various species of elephant shrews (Fourie & Horak, unpublished data). Ticks were present on the cattle from February to April 1985, December 1985 to February 1986, and from August 1986 until the termination of the survey in January 1987.

R. exophthalmos is widely distributed in Namibia and in the southern regions of the Eastern and Western Cape Provinces, South Africa (Keirans *et al.* 1993).

Rhipicephalus glabroscutatum

Although this was the most prevalent and abundant tick on cattle on "Bucklands", these animals are not necessarily its preferred hosts. Greater kudus examined at the same time as the cattle on the farm harboured considerably larger numbers of ticks (Horak *et al.* 1992). Other antelopes such as eland and mountain reedbuck are also good hosts (Horak *et al.* 1991b). Large numbers of adult ticks have also been collected from Angora and Boer goats in flocks on which no acaricide was used (MacIvor & Horak 1987). *R. glabroscutatum* is of considerable economic importance on goats in that it has been associated with the occurrence of foot abscesses in these animals (MacIvor & Horak 1987).

This is a two-host tick (Du Toit 1941) and the seasonality of its immature stages, from late summer to spring and its adults from spring to late summer throughout its distribution range, indicate that a single life cycle is completed annually (Horak, Sheppey, Knight & Beuthin 1986; MacIvor & Horak 1987; Horak *et al.* 1991b, d; Fig. 6). *R. glabroscutatum* is found only in South Africa and then only in the Eastern and Western Cape Provinces (MacIvor 1985; Walker 1991).

Rhipicephalus simus

Adults prefer large bovids, such as cattle and African buffaloes, as well as equids, suids and the larger wild carnivores as hosts (Norval & Mason 1981; Walker 1991). The immature stages parasitize various species of murid rodents (Norval & Mason 1981), of which the four-striped grass mouse appears to be particularly favoured (Rechav 1982). Adult *R. simus* are never very numerous and are generally most abundant during the spring and summer months (Baker & Ducasse 1967; Norval & Mason 1981; Horak *et al.* 1987b). The larvae are most numerous on four-striped grass mice in autumn and early winter and the nymphs from early winter to spring (Rechav 1982). The very small numbers of adults collected in the present survey probably indicate that the prevailing climate on "Bucklands" is too arid for this tick, which generally prefers the moister regions of the country (Walker 1991).

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Sheep

The proportional species representation of the ticks collected from sheep in south-western Free State Province (Fourie, Horak & Marais 1988), differed considerably from that recorded on cattle and goats examined on the same farm, with *Ixodes rubicundus* the major species on the sheep. The tick species recovered from sheep examined in north-eastern Free State (Horak, Williams & Van Schalkwyk 1991a), on which *Rhipicephalus evertsi evertsi* was the dominant species, also differed markedly from those collected from sheep examined in the south-west of the province (Fourie *et al*. 1988). The major species infesting sheep in the Valley Bushveld of the Eastern Cape Province were *Haemaphysalis silacea*, *Rhipicephalus appendiculatus* and *Rhipicephalus glabroscutatum*, while *R. evertsi evertsi* and *Rhipicephalus nitens* were the major species on sheep grazing vegetation classified as Eastern Province Thornveld (Horak *et al*. 1991a). On the other hand *Hyalomma truncatum*, *I. rubicundus*, *R. evertsi evertsi* and *Rhipicephalus gertrudae* were most numerous on sheep examined in the Northern Cape Province and north-western Western Cape Province (Horak & Fourie 1992).

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THE SEASONAL ABUNDANCE OF ADULT IXODID TICKS ON MERINO SHEEP IN THE SOUTH-WESTERN ORANGE FREE STATE

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ABSTRACT

With the exception of October, when no collections were made, adult ticks were collected at weekly intervals from February 1986 to January 1987 from 20 randomly selected sheep out of a flock of 60. *Ixodes rubicundus* was the most abundant tick and was present from April to September with a peak during May. *Hyalomma marginatum rufipes* was the next most numerous tick. It was recovered throughout the year with peak burdens being recorded from November to April. Small numbers of a *Rhipicephalus* sp.(near *R. pravus*) were also collected. These exhibited a major peak during February and a minor peak during August.

A dipping programme to prevent the paralysis caused by *I. rubicundus* and the *Rhipicephalus* sp. (near *R. pravus*) is suggested.

Key words: Seasonal abundance, *Hyalomma marginatum rufipes*, *Ixodes rubicundus*, *Rhipicephalus* sp. (near *R. pravus*), Merino sheep

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INTRODUCTION

Six species of ixodid ticks are important parasites of sheep in South Africa. These are *Amblyomma hebraeum*, which can transmit *Cowdria ruminantium*, the cause of heartwater in sheep, goats and cattle[17]; *Hyalomma* spp. which, because of their long mouthparts and tendency to form clusters, can cause severe tissue damage and necrosis[9]; *Ixodes rubicundus* and *Rhipicephalus evertsi evertsi*, both of which transmit toxins causing paralysis[4 16], known as Karoo paralysis and spring lamb paralysis respectively; and *Rhipicephalus glabroscutatum*, which with *A. hebraeum* can cause tissue damage giving rise to foot abscesses in sheep and goats[12].

The distributions of 4 of these ticks, namely, *Hyalomma* spp., *I. rubicundus* and *R. evertsi evertsi* include the south-western Orange Free State[9]. A fifth tick, *Rhipicephalus* sp. (near *R. pravus*), has recently been recorded in this region[3]. This tick seems to be the likely cause of paralysis in Angora goat kids[3] and would probably have the same effect on lambs.

With the exception of *I. rubicundus*[16], no research on the seasonal abundance of ticks on sheep has been done in South Africa. The seasonal abundance of *Hyalomma* spp. and of *R. evertsi evertsi* on cattle and Cape mountain zebras, *Equus zebra zebra*, and eland, *Taurotragus oryx*, has however, been determined[5 6 8].

The present paper describes the seasonal abundance of *Hyalomma marginatum rufipes*, *I. rubicundus* and the *R. pravus*-like tick on Merino sheep on a farm in the south-western Orange Free State.

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MATERIALS AND METHODS

Study area

The farm "Preezfontein" is situated 10 km from Fauresmith (29° 46'S; 25° 19'E) in the south-western Orange Free State and topographically it consists of flat as well as hilly areas. The vegetation is defined as False Upper Karoo[1]. Sixty nine per cent of the annual rainfall (total 360 mm; long term mean for 1980-1986) occurs during the summer months. Due to the irregularity of rainfall, mild to severe droughts occur periodically. The air temperature exhibits major circadian and seasonal fluctuations with a long-term (1980-1986) mean maximum temperature ranging between 32,2°C in January and 17,2°C in June. The mean minimum temperature varies between 16,4°C in January and 1,3°C in July. The mammal and bird species trapped or shot on "Preezfontein", and which may act as hosts for ixodid ticks have been listed in a previous publication[3].

The monthly rainfall in the survey camp and monthly mean minimum and maximum atmospheric temperatures are graphically illustrated in Fig. 4-5. The highest rainfall was recorded during March and November whereas the highest temperatures were recorded during January 1987.

Survey animals

Sixty, young adult Merino sheep were confined to a camp, 190 ha in extent, which encompassed hilly as well as flat terrain. From the beginning of February 1986, 20 randomly selected sheep were examined once a week for ticks. Whole body searches were conducted by two experienced persons and the ticks collected from each animal were placed in separate labelled bottles. With the exception of October 1986, when sampling was discontinued because of treatment of the breech regions of the sheep against fly strike, this procedure was followed until the end of January 1987.

The ticks recovered from each sheep were counted and identified using a stereoscopic microscope.

RESULTS

The total number and relative abundance of the ixodid ticks collected from the sheep are summarised in Table 1. Six ixodid ticks species were recovered from the sheep. The most prevalent and abundant tick was *I. rubicundus* followed by *H. marginatum rufipes*. Using the number of ticks collected each month, the seasonal abundance of *H. marginatum rufipes*, *I. rubicundus* and *Rhipicephalus* sp. (near *R. pravus*) is graphically illustrated in Fig. 1-3.

DISCUSSION

Hyalomma spp.

H. marginatum rufipes was the dominant species in this genus recovered. This is not surprising as the south-western Orange Free State lies almost at the centre of its geographic distribution[9]. It was present throughout the year and its peak period of adult activity at "Preezfontein" (November-April), corresponds closely to that observed on cattle in the northern Transvaal (October-April)[5] and to that of the closely related *Hyalomma marginatum turanicum* on Cape mountain zebras and eland in the Karoo (November-March)[6 8].

The immature stages of *H. marginatum rufipes* prefer scrub hares, *Lepus saxatilis*, and ground-frequenting birds, such as helmeted guinea fowl, *Numida meleagris*, as hosts[8 14]. They are virtually never found on sheep or any of the other domestic or wild ruminants.

The south-western Orange Free State is close to the limit of the distribution range of *Hyalomma truncatum*[9] and this may explain the small numbers collected in the present survey.

Ixodes rubicundus

Although information in the literature is scant, it seems as if the length of the activity period of adult *I. rubicundus* decreases from the south to the north of South Africa. At latitudes greater than 31°S the activity period of the adult ticks extends from February or March to October or November[16]. Cases of paralysis caused by this tick may occur as early as February at these latitudes[15]. At "Preezfontein" (29°46'S) the adult ticks are active from April to September with a peak in May and the first cases of paralysis are usually recorded during April. At latitudes less than 26°S the first cases of paralysis

Table 1: **The ixodid ticks collected from Merino sheep on the farm "Preezfontein"**

Ticks	Males	Females	Total	Relative abundance	Percentage of sheep infested
Hyalomma marginatum rufipes	501	421	922	16,30	34,92
Hyalomma truncatum	3	1	4	0,07	0,50
Ixodes rubicundus	1 562	3 090	4 652	82,22	45,18
Rhipicephalus sp. (near *R. pravus*)	30	47	77	1,36	5,38
Rhipicephalus evertsi evertsi	0	1	1	0,02	0,13
Rhipicephalus evertsi mimeticus	2	0	2	0,04	0,25

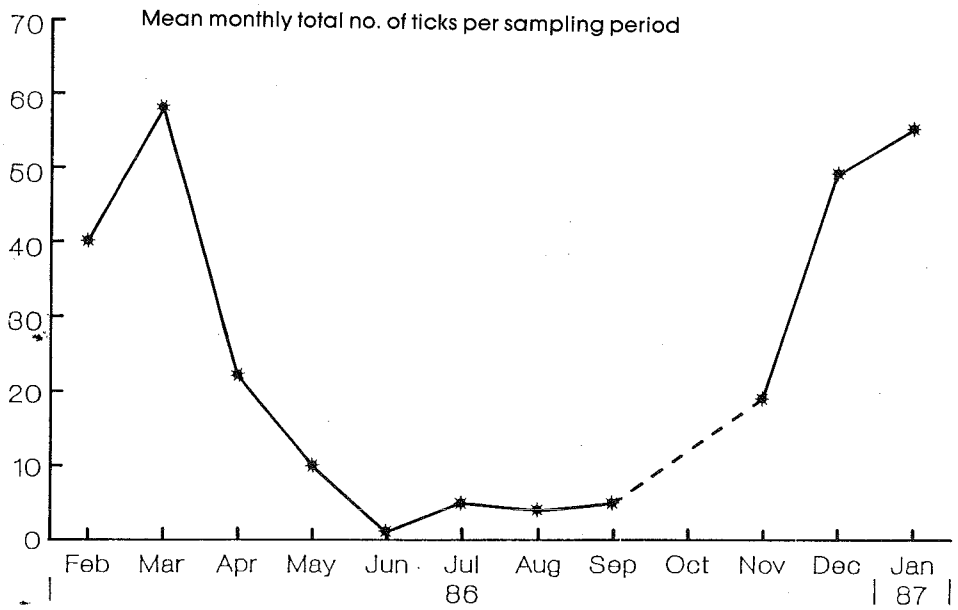

Fig 1: The seasonal abundance of *Hyalomma marginatum rufipes* on Merino sheep on the farm "Preezfontein"

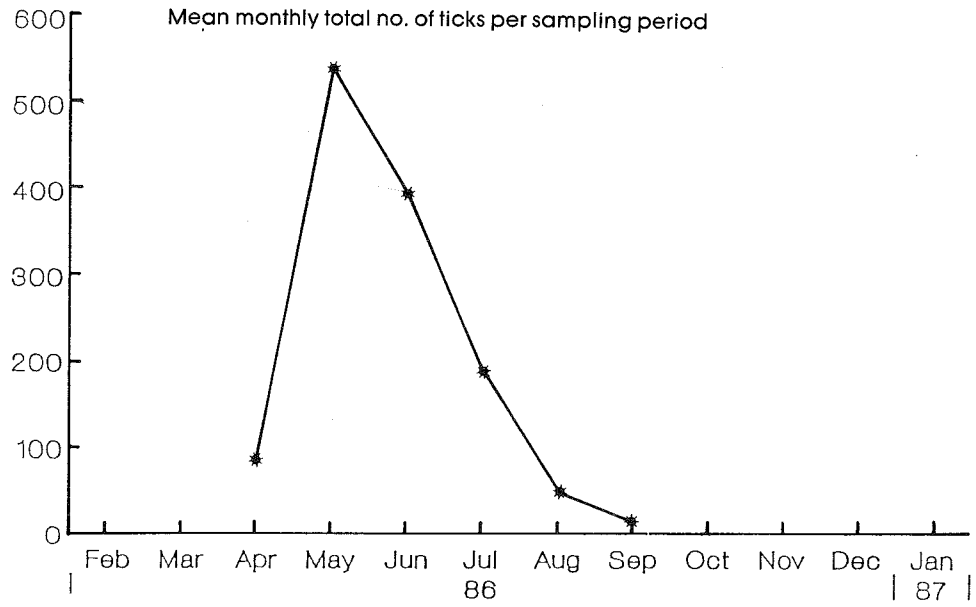

Fig 2: The seasonal abundance of *Ixodes rubicundus* on Merino sheep on the farm "Preezfontein"

are only seen during June (A. Spickett, Veterinary Research Institute, Onderstepoort, personal communication 1987).

This pattern of occurrence of paralysis has definite control implications. Sheep should be treated with an acaricide at least during the month when the first cases of paralysis are expected, but preferably the month before. Treatment should also be repeated during the period of tick activity. Thus in the south of the country treatment should commence in January or February and continue until September. At latitudes similar to "Preezfontein", treatment should commence in March or April and continue till July, whereas at Belfast in the Transvaal, the northernmost latitude at which *I. rubicundus* is found[9], a single treatment in May or June should suffice.

The dispartity in the sex ratio (♂♂ : ♀♀ = 1:2) of *I. rubicundus* is to be expected. Males are rarely parasitic on the host and during a series of observations it was found that 76% of females are mated off the host (Fourie, unpublished data). A similar disparity in sex ratios (♂♂ : ♀♀ = 1:3) exists for the closely related *I. pilosus*[1,3].

No immature *I. rubicundus* were recovered. This is hardly surprising as the preferred hosts of the immature stages are elephant shrews, *Elephantulus* spp.[16] and red rock rabbits, *Pronolagus rupestris*[7,16], although nymphae have occasionally been collected off sheep[16].

Rhipicephalus evertsi

The south-western Orange Free State lies close to the edge of the distribution of *R. evertsi evertsi* in this region[9] and this may explain its virtual absence in the present survey.

R. evertsi mimeticus is found in the drier regions of South West Africa/Namibia and in western Botswana[9]. Its presence on "Preezfontein" could possibly be due to the introduction of animals from the former regions and the establishment of a small focus of infestation.

Rhipicephalus sp. (near *R. pravus*)

This tick has recently been incriminated as a possible cause of paralysis in Angora goat kids in the south-western Orange Free State[3]. The peak period of adult abundance in February, with a minor peak in August, corresponds to the times at which paralysis was observed in the kids. The kids, however, harboured considerably more ticks than did the sheep in this survey. Acaricidal treatment of the heads of animals, particularly the ears, where these ticks prefer to attach, during January/February and August/September, could reduce the incidence of paralysis caused by this tick.

The fact that a smaller number of males than females was collected from the sheep, is probably due to the collecting method employed. Collections of the smaller tick species and the smaller life stages of ticks from live animals do not always accurately reflect the total number of ticks present[11]. The males, being generally smaller than the females, are more easily overlooked in such collections[11].

The immature stages of this tick prefer the rock elephant shrew, *Elephantulus myurus*, while the adults are frequently found on scrub hares[3]. The absence of immature ticks on the sheep is thus to be expected.

The use of host animals to gather infor-

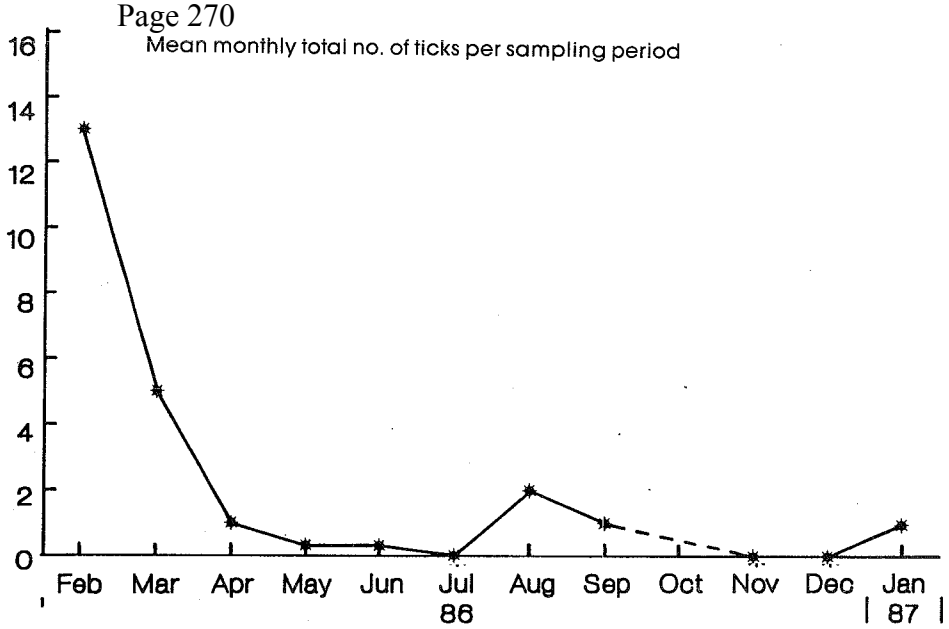

Fig 3: The seasonal abundance of a *Rhipicephalus* sp. (near *R. pravus*) on Merino sheep on the farm "Preezfontein"

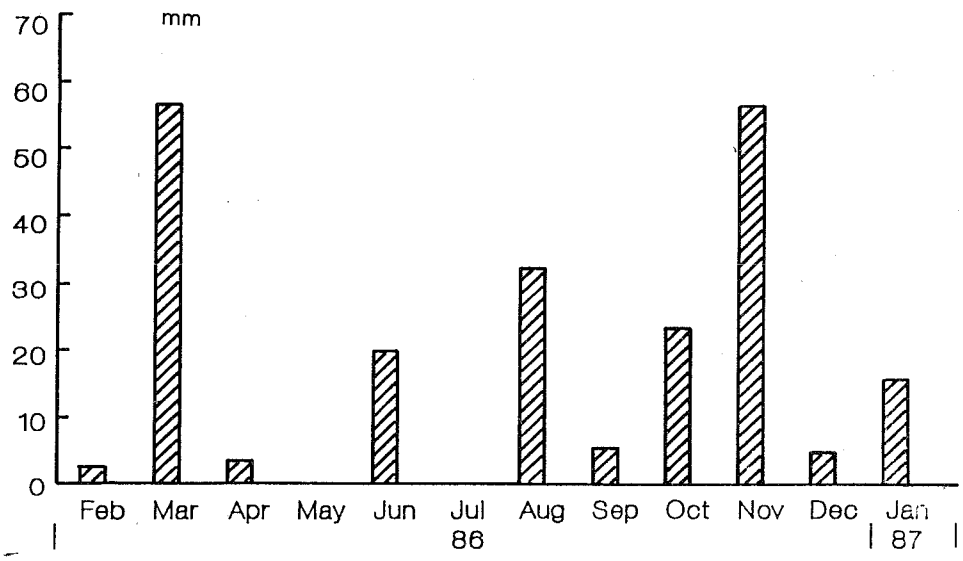

Fig 4: Total monthly rainfall measured at the farm "Preezfontein"

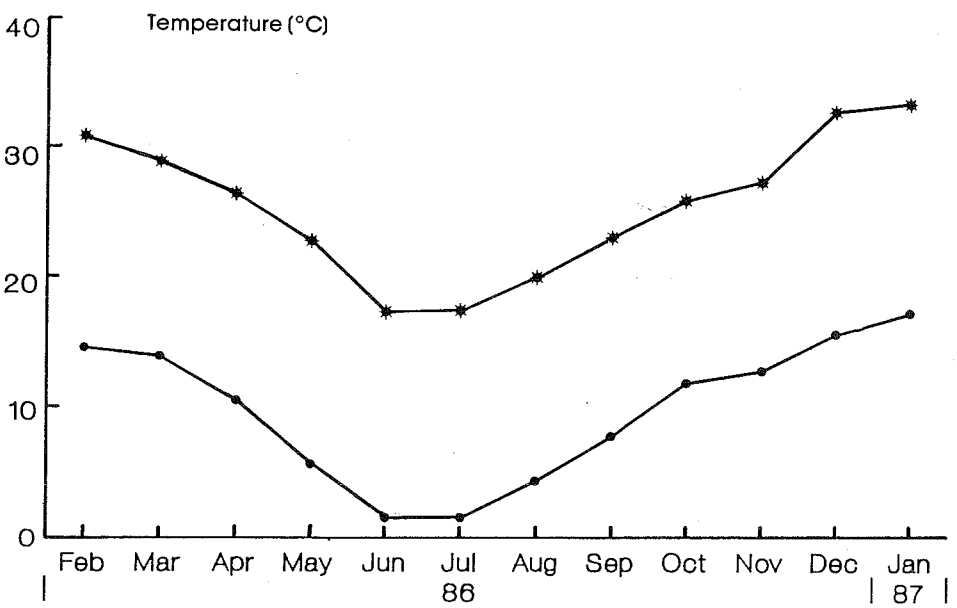

Fig 5: Mean monthly minimum and maximum atmospheric temperatures recorded at Fauresmith 10 km south-west of the farm "Preezfontein"

mation on the seasonal activity of ticks has obvious disadvantages. This is particularly true where the survey locality is very varied in topography and vegetation types. Ticks are associated with certain vegetation or habitat types and domestic stock do not utilise forage areas in a random manner[2]. It therefore seems evident that tick-host contact is a product of the temporal and spatial congruencies in the activity patterns of ticks and their domestic hosts. Age and sex-related differences in bovine behaviour exist[10] which if applicable to sheep could either increase or decrease the probability of tick-host contact. A more meaningful approach would be to survey specific habitat types as well as considering possible host, sex and age-related differences in the tick burdens acquired by the survey animals.

ACKNOWLEDGEMENTS

We wish to thank Mr. J. van Niekerk of the farm "Preezfontein" for the loan of the survey sheep and the use of the facilities on his farm. Messrs. J. and U.J. Mayegiso assisted with the collection of ticks from the sheep.

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Book Review/Boekresensie

PLANT POISONINGS AND MYCOTOXICOSES OF LIVESTOCK IN SOUTHERN AFRICA

T S KELLERMAN, J A W COETZER, T W NAUDE

Oxford University Press, Cape Town. 1988, 243 pp, illustrations 600, Price R180,00 (ISBN 0-1957-0488-6)

In the foreword of this new publication, Dr R D Bigalke emphasises the diversity and beauty of the South African flora and the many plant toxins occuring in this subcontinent. Plant toxins and mycotoxins have a major influence on animal production in Southern Africa. Therefore research into the various facets of toxicology has been encouraged over many years. The last textbook to consolidate the known information, was published by Prof Douw Steyn in 1934. For many years the need for a new textbook has been expressed by practitioners as well as teachers of veterinary toxicology. The appearance of Poisoning and Mycotoxicoses of Livestock in Southern Africa is the answer to this need.

The authors have many years of experience in plant toxicology and pathology. On studying the references given in the text, the reader is immediately struck by the contribution of these three scientists which indicates the tremendous influence they have had on toxicological research in South Africa.

This hard-cover book is exceptionally well illustrated mainly with coloured photographs illustrating plants, symptoms of poisoning and lesions, caused by the poison. These illustrations are of great benefit and the publishers must be congratulated on the quality of the reproductions.

The book is divided into different chapters, each dealing with a different organ system. Each system is then subdivided, sometimes according to the lesions and symptoms or by chemical grouping of plants that may affect the particular system. Thus in the first chapter, the toxicology affecting the liver is divided into hepatoxicoses with and without photosensitivity. Conditions with photosensitivity, are then subdivided into toxins primarily damaging the liver parenchyma and those affecting mainly the biliary system. This is a very useful classification but in a few instances there may be differing opinions about specific classifications. The authors have classified plants or fungi according to their major effect. In many instances there is more than one toxic principle in a plant, in which case other effects are mentioned under the appropriate heading and cross referenced.

For each type of poisoning, a brief description of the plant or fungus involved is given with photographs showing either the whole plant or certain parts. In cases where plants have a more specific area of distribution, this is indicated on a map. The chemical structures of some known toxins are given with a description of their mechanism of action. Full descriptions are given of the clinical symptoms and lesions and these are further highlighted with photographs. Treatment and prevention for poisoning by each individual plant is given where applicable.

The very extensive bibliography at the end of each chapter and the many references to unpublished information in the text, underline the thorough research and effort which went into this book.

This publication will be of great importance to practising veterinarians, students and agriculturists, not only in southern Africa but also in other African countries and far beyond the African continent.

A Immelman

Onderstepoort J. vet. Res., 58, 115–123 (1991)

PARASITES OF DOMESTIC AND WILD ANIMALS IN SOUTH AFRICA. XXV. IXODID TICKS ON SHEEP IN THE NORTH-EASTERN ORANGE FREE STATE AND IN THE EASTERN CAPE PROVINCE

I. G. HORAK[1], E. J. WILLIAMS[2] and P. C. VAN SCHALKWYK[3]

ABSTRACT

HORAK, I. G., WILLIAMS, E. J. & VAN SCHALKWYK, P. C., 1991. Parasites of domestic and wild animals in South Africa. XXV. Ixodid ticks on sheep in the north-eastern Orange Free State and in the eastern Cape Province. *Onderstepoort Journal of Veterinary Research*, 58,115–123 (1991)

The tick burdens of 115 Merino sheep, slaughtered over a period of 15 consecutive months on a farm in the north-eastern Orange Free State, were determined. A total of 7 ixodid and 1 argasid tick species were recovered and the seasonal abundances of *Boophilus decoloratus, Hyalomma marginatum rufipes, Margaropus winthemi* and *Rhipicephalus evertsi evertsi* were determined.

One hundred and forty-nine Merino sheep were slaughtered over periods varying from 10 to 25 months on 3 farms in Eastern Province Thornveld in the eastern Cape Province and their tick burdens determined. Fourteen ixodid tick species were recovered from these animals and the seasonal abundances of *Amblyomma marmoreum, B. decoloratus, Haemaphysalis silacea, R. evertsi evertsi* and *Rhipicephalus nitens* were ascertained.

On a farm in Valley Bushveld in the eastern Cape Province, 2 Dorper sheep were slaughtered each month for a period of 24 consecutive months. These 48 sheep harboured 10 ixodid tick species and the seasonal abundances of *A. marmoreum, H. silacea, Rhipicephalus appendiculatus* and *Rhipicephalus glabroscutatum* were determined.

A total of 17 ixodid tick species, of which 12 had reached the adult stage, where recovered from the sheep on the 5 farms.

INTRODUCTION

Many ixodid tick species have already been recovered from sheep. Theiler (1962) records a total of 46 species as having been recovered in the adult stage from sheep in Africa south of the Sahara, while Yeoman & Walker (1967) recorded the adults of 14 species from sheep in Tanzania and Walker (1974) those of 21 species from sheep in Kenya. Six species of ixodids are listed by Fourie, Horak & Marais (1988) as important parasites of sheep in South Africa. These are *Amblyomma hebraeum, Hyalomma* spp., *Ixodes rubicundus, Rhipicephalus evertsi evertsi* and *Rhipicephalus glabroscutatum.*

In this country, the total tick burdens of 24 Dorper sheep on a farm in Valley Bushveld in the eastern Cape Province have been determined and the adults of 4 species recovered (Horak & Knight, 1986). The seasonal abundance of adult *I. rubicundus* has been recorded on sheep in the Karoo (Stampa, 1959) and in the south-western Orange Free State where, in addition, that of *Hyalomma marginatum rufipes* and a *Rhipicephalus* sp. (near *R. punctatus*), has been ascertained (Fourie *et al.*, 1988).

The present paper describes the burdens and seasonal abundance of ixodid ticks on Merino sheep in the north-eastern Orange Free State and in Eastern Province Thornveld and on Dorper sheep in Valley Bushveld in the eastern Cape Province. The findings for the Dorpers are an amplification of those recorded by Horak & Knight (1986) plus those from another 24 of these sheep.

MATERIALS AND METHODS

Survey animals

The sheep slaughtered in the 5 surveys reported here were all also processed for the recovery of helminths. The various periods of exposure to infestation prior to slaughter were dictated by the data desired from the helminth surveys. The shortest period of exposure was approximately 1 month, which we consider more than adequate to acquire representative tick burdens. None of the sheep were treated with an acaricide for at least 12 weeks prior to slaughter.

Parasite recovery

After slaughter half the skin of the head and of the body (excluding the heavily woolled portions) of each sheep, plus 1 front and 1 back leg, were processed for tick recovery as described by Horak, Meltzer & De Vos (1982). In addition a 100 × 100 mm piece of skin, with wool attached, was excised from just behind the shoulder on 1 side of each sheep. This piece of skin was examined *in toto* under a stereoscopic microscope and the ticks collected, identified, counted and added to the burdens which had been calculated from the processed material, as described by Horak, Potgieter, Walker, De Vos & Boomker (1983).

Many of the tick larvae collected in the surveys had already died prior to the sheep being processed for tick recovery. These larvae were nevertheless counted, identified and considered part of the total tick burden of each sheep.

SURVEYS ON INDIVIDUAL FARMS

"Tweespruit"

The farm "Tweespruit" (27° 25′ S, 29° 32′ E) is situated 35 km east of Vrede in the north-eastern Orange Free State. The vegetation is classified as Themeda Veld to Cymbopogon/Themeda Veld Transition (Acocks, 1975). This is a summer rainfall region with regular frost during winter. The Merino sheep grazed the natural vegetation and during droughts were fed concentrates and lucerne hay. There were also approximately 100 cattle and 12 horses on the farm.

Except in October 1983, when no older lambs were slaughtered, 3 to 6 lambs which had run on the farm "Tweespruit" since birth were slaughtered each month from November 1982 to February 1984. In addition 1 to 3, 2 to 5-month old lambs, that had been raised under worm-free conditions at a laboratory and then exposed to infestation with the

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TABLE 1 Total numbers of ticks recovered from 115 Merino sheep on the farm "Tweespruit" in the north-eastern Orange Free State from November 1982 to February 1984

Species	Total numbers recovered					Number of sheep infested
	Larvae	Nymphs	Males	Females	Total	
Amblyomma hebraeum	1	1	0	0	2	2
Boophilus decoloratus	1 595	153	88	60 (19)	1 896	109
Haemaphysalis sp.	2	0	0	0	2	1
Hyalomma marginatum rufipes	3	0	5	2	10	9
Margaropus winthemi	78	0	0	0	78	16
Rhipicephalus evertsi evertsi	8 761	584	818	300 (85)	10 463	115
Rhipicephalus sp.	1	1	0	0	2	2
Otobius megnini	2	3	0	0	5	4
Total	10 443	742	911	362 (104)	12 458	

( ) = Number of maturing female ticks, i.e. idiosoma of *B. decoloratus* > 4,0 mm; *R. evertsi evertsi* > 6,0 mm in length

flock on "Tweespruit" for a month, were slaughtered each month from December 1982 to February 1984.

Seven species of ixodid ticks and 1 argasid were collected (Table 1). *Rhipicephalus evertsi evertsi* was the most numerous and all sheep were infested. Most sheep were also infested with *Boophilus decoloratus,* which was the next most abundant tick.

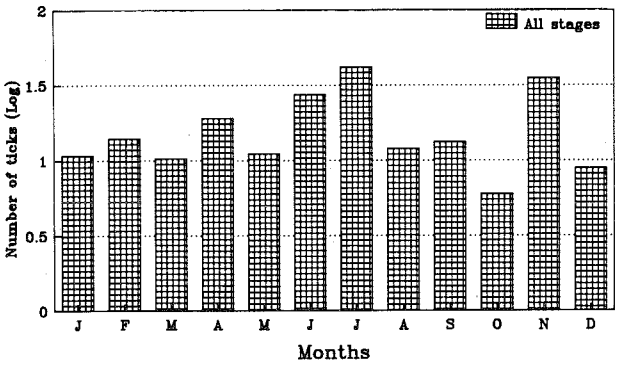

FIG. 1 The mean monthly mean abundance of *Boophilus decoloratus* on Merino sheep on the farm "Tweespruit"

Peak mean monthly mean burdens of *B. decoloratus* were present during June, July and November (Fig. 1). The largest mean monthly mean numbers of immature *R. evertsi evertsi* were recovered during March and June and of adults from March to May with a minor peak in October and November (Fig. 2).

Larvae of *M. winthemi* were present from June to September 1983. A few adult *Hyalomma marginatum rufipes* were recovered from March to May 1983.

"Reed Valley", "Sidbury" and "Grasmere"

The farms "Reed Valey" (33° 33′ S, 26° 02′ E) 14 km south-east of Paterson, "Sidbury" (33° 25′ S, 26° 11′ E) at Sidbury and "Grasmere" (33° 31′ S, 25° 53′ E) 12 km south-west of Paterson are all situated in a vegetation zone classified as Eastern Province Thornveld (Acocks, 1975) in the eastern Cape Province. Mean maximum air temperatures range between approximately 20 °C during winter and 30 °C during summer and mean minima between approximately 8 °C during winter and 18 °C during summer. Mean annual rainfall in this region is approximately 500 mm and is non-seasonal, with the major portion falling during spring and summer. In addition to Merino sheep the farms "Reed Valley" and "Sidbury" each ran a herd of dairy cattle while the farm "Grasmere" aslo ran a herd of beef cattle and a flock of Angora goats.

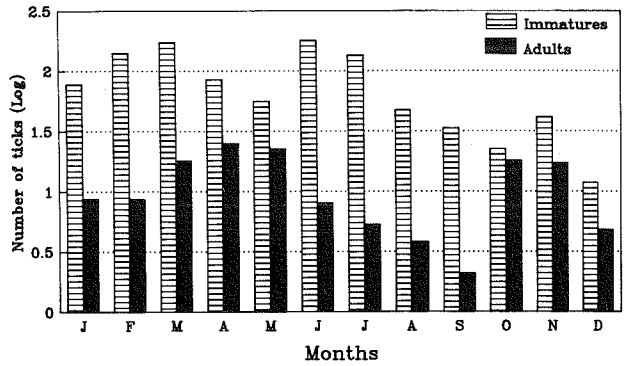

FIG. 2 The mean monthly mean abundance of *Rhipicephalus evertsi evertsi* on Merino sheep on the farm "Tweespruit"

On the farms "Reed Valley" and "Sidbury", 4 and 3, 10–14 month-old Merino lambs respectively, originating from neighbouring farms, were exposed to infestation at monthly intervals with resident flocks of Merino sheep for a month before slaughter. The survey ran for 13 consecutive months (March 1983 to March 1984) on "Reed Valley" and 25 months (March 1986 to March 1988) on "Sidbury". On the farm "Grasmere" 2 autumn-born Merino lambs, running with a flock of ewes and lambs, were slaughtered each month from 1 day of age until they were 9 months old from May 1986 to February 1987.

The total numbers of *B. decoloratus* recovered from the sheep on "Reed Valley" and "Sidbury" have been combined and mean monthly mean burdens calculated and illustrated in a single figure (Fig. 3). The burdens of *R. evertsi evertsi* of the same sheep have been treated in a similar fashion (Fig. 4).

Peak burdens of *B. decoloratus* were present during July and November. The largest numbers of immature *R. evertsi evertsi* were recovered during January and October and of adults during November.

Twelve species of ixodid ticks, of which *R. evertsi evertsi* was the most numerous and prevalent, were present on "Reed Valley" (Table 2).

The largest numbers of larvae of *A. marmoreum* were present from March to May and nymphs during November.

TABLE 2 Total numbers of ixodid ticks recovered from 52 Merino sheep on the farm "Reed Valley" in the eastern Cape Province from March 1983 to March 1984

Species	Total numbers recovered					Number of sheep infested
	Larvae	Nymphs	Males	Females	Total	
Amblyomma hebraeum	56	8	0	0	64	17
Amblyomma marmoreum	374	10	0	0	384	20
Boophilus decoloratus	414	8	8	14 (4)	444	35
Haemaphysalis silacea	12	0	8	0	20	9
Hyalomma marginatum rufipes	30	0	0	0	30	4
Hyalomma truncatum	0	0	2	0	2	1
Ixodes pilosus	18	4	0	2	24	10
Rhipicephalus appendiculatus	0	2	0	0	2	1
Rhipicephalus evertsi evertsi	2 324	60	126	42 (6)	2 552	50
Rhipicephalus glabroscutatum	8	2	0	0	10	4
Rhipicephalus nitens	42	6	4	6 (2)	58	10
Rhipicephalus simus	0	0	10	4	14	5
Total	3 278	100	158	68 (12)	3 604	

( ) = Number of maturing female ticks, i.e. the idiosoma of *B. decoloratus* > 4,0 mm; *R. evertsi evertsi* > 6,0 mm; *R. nitens* > 5,0 mm

TABLE 3 Total numbers of ixodid ticks recovered from 75 Merino sheep on the farm "Sidbury" in the eastern Cape Province from March 1986 to March 1988

Species	Total numbers recovered					Number of sheep infested
	Larvae	Nymphs	Males	Females	Total	
Amblyomma hebraeum	848	30	34	4(2)	916	32
Amblyomma marmoreum	366	8	0	0	374	38
Boophilus decoloratus	4 722	112	28	44(22)	4 906	58
Haemaphysalis leachi	6	0	0	0	6	2
Haemaphysalis silacea	146	88	8	12(4)	254	12
Hyalomma truncatum	0	0	2	0	2	1
Ixodes pilosus	54	30	0	0	84	10
Rhipicephalus appendiculatus	0	38	0	2	40	15
Rhipicephalus evertsi evertsi	57 012	1 564	542	292(70)	59 410	75
Rhipicephalus glabroscutatum	28	0	0	0	28	3
Rhipicephalus nitens	35 616	3 566	494	370(52)	40 046	74
Rhipicephalus simus	0	0	2	4	6	1
Total	98 768	5 466	1 110	728(150)	106 072	

( ) = Number of maturing female ticks, i.e. idiosoma of *A. hebraeum* > 9,0 mm; *B. decoloratus* > 4,0 mm; *H. silacea* > 5,0 mm; *R. evertsi evertsi* > 6,0 mm; *R. nitens* > 5,0 mm

Twelve tick species, of which *R. evertsi evertsi* and *R. nitens* were the most numerous and prevalent, were recovered from the sheep on "Sidbury" (Table 3, Fig. 5).

The larvae of *R. nitens* peaked during autumn, and the nymphs during late winter and spring. The largest numbers of adults were present during mid-summer.

The lambs on "Grasmere" were infested with 6 tick species, of which *R. evertsi evertsi* was the most numerous and, together with *Haemaphysalis silacea*, the most prevalent (Table 4). Because the lambs were slaughtered over a period shorter than a year no definite conclusions on the seasonal abundance of the ticks can be drawn. However, the larvae of *H. silacea* were present from mid-summer to spring, the nymphs from winter to mid-summer and the adults in mid-winter and mid-summer.

"Bucklands"

The farm "Bucklands" (33° 06′ S, 26° 41′ E) is situated 28 km north-east of Grahamstown in the eastern Cape Province in a vegetation zone classified

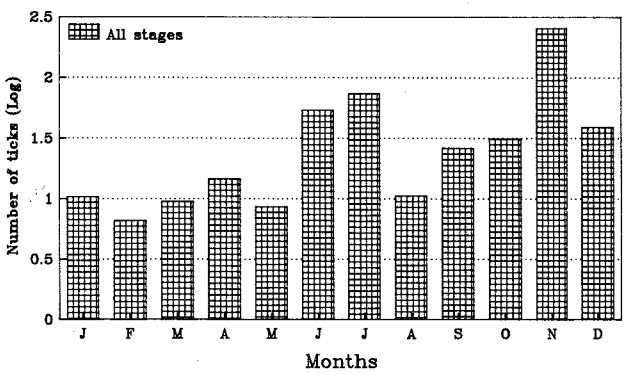

FIG. 3 The combined mean monthly mean abundance of *Boophilus decoloratus* on Merino sheep on the farms "Reed Valley" and "Sidbury"

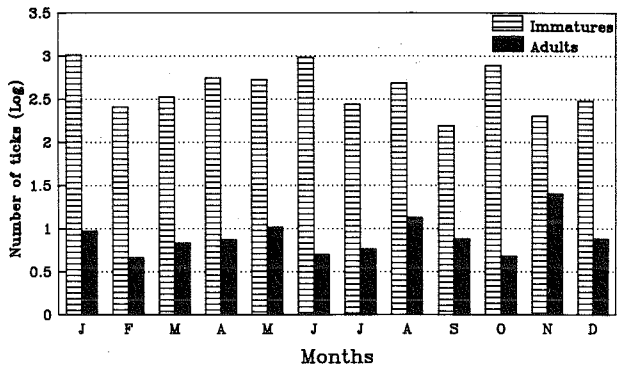

FIG. 4 The combined mean monthly mean abundance of *Rhipicephalus evertsi evertsi* on Merino sheep on the farms "Reed Valley" and "Sidbury"

TABLE 4 Total numbers of ixodid ticks recovered from 22 Merino lambs on the farm "Grasmere" in the eastern Cape Province from May 1986 to February 1987

Species	Total numbers recovered					Number of sheep infested
	Larvae	Nymphs	Males	Females	Total	
Amblyomma hebraeum	8	20	2	2	32	6
Boophilus decoloratus	8	0	0	0	8	2
Haemaphysalis silacea	288	181	20	10(2)	499	22
Ixodes pilosus	133	42	6	2	183	14
Rhipicephalus evertsi evertsi	3 613	96	44	54(12)	3 807	22
Rhipicephalus sp.	10	0	0	0	10	3
Total	4 060	339	72	68(14)	4 539	

( ) = Number of maturing female ticks, i.e. idiosoma of *H. silacea* > 5,0 mm; *R. evertsi evertsi* > 6,0 mm

TABLE 5 The total numbers of ticks recovered from 48 Dorper sheep on the farm "Bucklands" in the eastern Cape Province from February 1985 to January 1987

Species	Total numbers recovered					Number of sheep infested
	Larvae	Nymphs	Males	Females	Total	
Amblyomma hebraeum	120	90	10	8(4)	228	22
Amblyomma marmoreum	392	12	0	0	404	23
Boophilus decoloratus	6	0	0	0	6	2
Haemaphysalis silacea	2 030	700	40	10(2)	2 780	43
Hyalomma marginatum rufipes	0	0	0	2	2	1
Rhipicephalus appendiculatus	4 934	290	2	4(2)	5 230	32
Rhipicephalus evertsi evertsi	98	46	4	8(2)	156	21
Rhipicephalus glabroscutatum	3 262	154	106	62(18)	3 584	45
Rhipicephalus sp. (Near *R. oculatus*)	0	0	2	0	2	1
Rhipicephalus simus	0	0	2	2	4	1
Total	10 842	1 292	166	96(28)	12 396	

( ) = Number of maturing female ticks, i.e. idiosoma of *A. hebraeum* > 9,0 mm; *H. silacea* > 5,0 mm; *R. appendiculatus* > 5,0 mm; *R. evertsi evertsi* > 6,0 mm; *R. glabroscutatum* > 4,5 mm

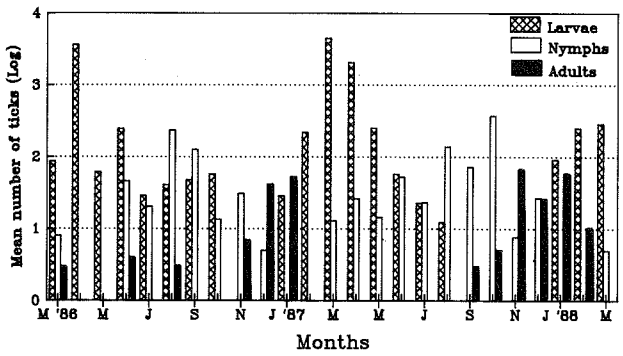

FIG. 5 The seasonal abundance of *Rhipicephalus nitens* on Merino sheep on the farm "Sidbury"

as Valley Bushveld (Acocks, 1975). Rainfall is non-seasonal and the long-term mean annual total is 484 mm of which slightly more than 300 mm falls from October to March. At the time of the survey the farm grazed approximately 300 Dorper sheep, 4 000 angora goats and 185 cattle plus approximately 300 free-ranging kudu and numerous smaller antelope.

At "Bucklands" 2, 8–12 month-old Dorper (Dorset Horn × Blackhead Persian) lambs, which ran with a flock or Dorper sheep, were slaughtered each month for a period of 24 consecutive months from February 1985 to January 1987.

Rhipicephalus appendiculatus, followed by *R. glabroscutatum* and *H. silacea* were the most abundant ticks. *R. glabroscutatum* was also the most prevalent (Table 5, Fig. 6–8)

Peak numbers of immature *H. silacea* were present during May and July 1985 and April and May 1986, while few adults were recovered. The largest numbers of *R. appendiculatus* larvae were collected from March or May to July and nymphs from April or May to September. Only 6 adults were recovered. Immature *R. glabroscutatum* were recovered in peak numbers from April to September 1985 and during April and May 1986. Adults preferred the months September or October to February or March.

The largest numbers of larvae of *A. marmoreum* were generally present from February to May and nymphs during September and October.

General

A total of 17 ixodid tick species were recovered from all the sheep, irrespective of locality. *R. evertsi*

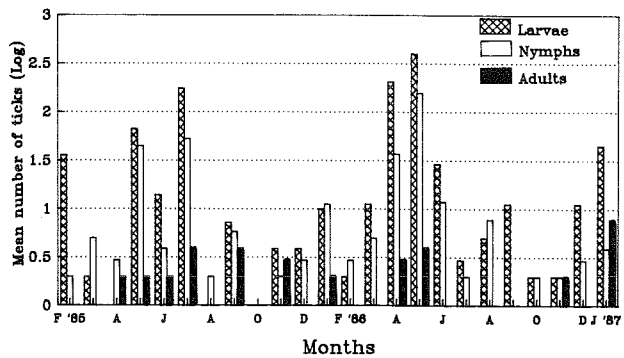

FIG. 6 The seasonal abundance of *Haemaphysalis silacea* on Dorper sheep on the farm "Bucklands"

TABLE 6 Total numbers of ixodid ticks recovered from 312 sheep examined in the north-eastern Orange Free State and the eastern Cape Province

Species	Total numbers recovered				
	Larvae	Nymphs	Males	Females	Total
Amblyomma hebraeum	1 033	149	46	14(2)	1 242
Amblyomma marmoreum	1 132	30	0	0	1 162
Boophilus decoloratus	6 745	273	124	118(45)	7 260
Haemaphysalis leachi	6	0	0	0	6
Haemaphysalis silacea	2 476	969	76	32(8)	3 553
Haemaphysalis sp.	2	0	0	0	2
Hyalomma marginatum rufipes	33	0	5	4	42
Hyalomma truncatum	0	0	4	0	4
Ixodes pilosus	205	76	6	4	291
Margaropus winthemi	78	0	0	0	78
Rhipicephalus appendiculatus	4 934	330	2	6(2)	5 272
Rhipicephalus evertsi evertsi	71 808	2 350	1 534	696(175)	76 388
Rhipicephalus glabroscutatum	3 298	156	106	62(18)	3 622
Rhipicephalus nitens	35 658	3 572	498	376(54)	40 104
Rhipicephalus simus	0	0	14	10	24
Rhipicephalus sp. (near *R. oculatus*)	0	0	2	0	2
Rhipicephalus sp.	11	1	0	0	12
Total	127 389	7 936	2 417	1 322(304)	139 064

( ) = Number of maturing female ticks, i.e. idiosoma of *A. hebraeum* > 9,0 mm; *B. decoloratus* > 4,0 mm; *H. silacea* > 5,0 mm; *H. marginatum rufipes* > 7,5 mm; *I. pilosus* > 5,0 mm; *R. appendiculatus* > 5,0 mm; *R. evertsi evertsi* > 6,0 mm; *R. glabroscutatum* > 4,5 mm; *R. nitens* > 5,0 mm; *R. simus* > 6,0 mm

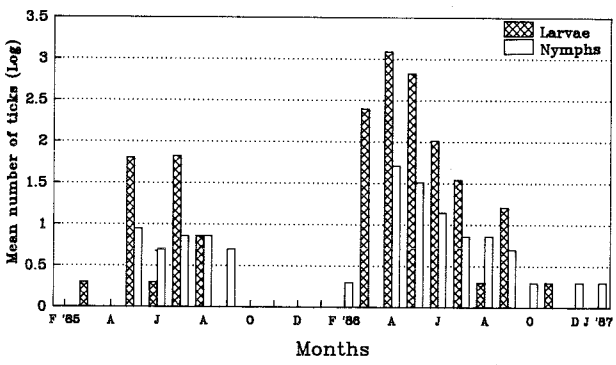

FIG. 7 The seasonal abundance of *Rhipicephalus appendiculatus* on Dorper sheep on the farm "Bucklands"

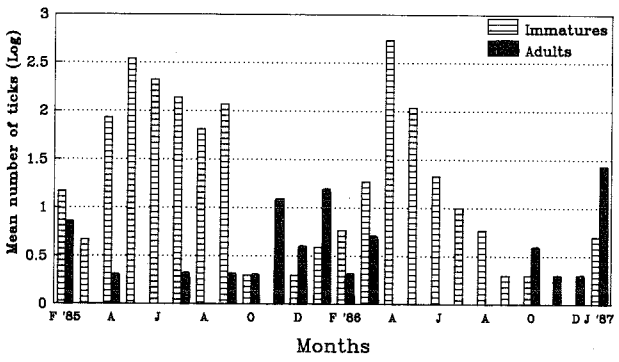

FIG. 8 The seasonal abundance of *Rhipicephalus glabroscutatum* on Dorper sheep on the farm "Bucklands"

evertsi was the most abundant tick folowed by *R. nitens* and *B. decoloratus* (Table 6). The adults of 12 of these species were present on the sheep.

DISCUSSION

General observations

Probably one of the most notable findings of these surveys was that, although numerous larvae of many tick species were recovered from the sheep, many of them had already died before the animals were processed for tick recovery. The reason for the death of the larvae is possibly either suffocation in the wool-fat or the residual effects of acaricide which had been applied several months previously.

The dead larvae that remained on the sheep contributed to the imbalance between the larval, nymphal and adult numbers. The total numbers of ticks, irrespective of species, recovered in each stage of development were 127 389 larvae, 7 936 nymphs and 3 739 adults (Table 6), a ratio of 34,1:2,1:1,0. These proportions indicate that sheep are not good hosts of nymphs or adults. The nymph to adult ratio indicates that, with the exception of a few species, sheep are as good hosts of adult ticks as they are of nymphs. In addition 304 ticks of the total female population of 1 322 had reached a size which indicated that they were engorging successfully and would probably detach within the next 24 to 48 h. This high proportion of engorging female ticks implies that virtually all female ticks on sheep will successfully engorge and detach.

Amblyomma hebraeum

The larvae and nymphs of this tick utilize a large variety of small and large mammals and some ground-nesting birds as hosts (Theiler, 1962; Norval, 1983; Horak, MacIvor, Petney & De Vos, 1987). It is thus not surprising that they should also be recovered from sheep. The adults prefer large hosts such as cattle, kudu, eland, buffalo and giraffe (Horak, Potgieter, Walker, De Vos & Boomker, 1983; Horak, MacIvor, Petney & De Vos, 1987) and the small numbers recovered from the sheep reflect this preference.

The Valley Bushveld region of the eastern Cape Province is a particularly good habitat for *A. hebraeum* (Knight & Rechav, 1978; Rechav, 1982; MacIvor & Horak, 1984; Horak & Knight, 1986). The relatively small numbers recovered from the Dorper sheep on the farm "Bucklands" are the survivors of prolonged, regular acaricidal treatment

aimed specifically at this tick (Horak & Knight, 1986; Petney & Horak, 1987). The north-eastern Orange Free State is not a recognized habitat of *A. hebraeum* (Howell, Walker & Nevill, 1978), and the 2 ticks recovered from the sheep on "Tweespruit" had possibly been transported there in a previous stage of development on either domestic stock or on migratory birds.

No pattern of seasonal abundance was evident on the sheep examined in the eastern Cape Province. All stages were present in small numbers throughout the year.

In South Africa *A. hebraeum* is the most important vector of *Cowdria ruminantium,* the cause of heartwater in sheep, goats and cattle (Bezuidenhout, 1987). Thus sheep may act not only as a source of ticks but also of *C. ruminantium* for goats or cattle, and *vice versa,* on farms where all 3 are grazed.

Amblyomma marmoreum

All stages of this tick, commonly known as the South African tortoise tick, feed on tortoises (Norval, 1975; Dower, Petney & Horak, 1988). The immature stages also have a wide range of alternative hosts (Theiler, 1962; Norval, 1975; Horak, MacIvor, Petney & De Vos, 1987), hence their recovery from sheep is not unexpected.

Compared with *A. hebraeum,* relatively large numbers of larvae of *A. marmoreum* were recovered from the sheep on "Reed Valley" and "Bucklands", indicating that the acaricidal treatment regimes practised on these farms for the control of the former tick did not affect *A. marmoreum* to the same extent. This is not surprising as its adults are found almost exclusively on tortoises (Theiler, 1962; Norval, 1975; Petney, Horak & Rechav, 1987). It also implies that these farms, and "Sidbury", are suitable habitats for tortoises, particularly the leopard or mountain tortoise, *Geochelone pardalis,* which seems to be a preferred host of the adults (Theiler, 1962; Norval, 1975; Dower *et al.*, 1988).

On "Reed Valley" and "Bucklands" the larvae were present mainly during late summer and autumn and the nymphs during spring, a seasonal pattern previously observed by Norval (1975) and Horak & Williams (1986). On "Sidbury" the larvae were recovered throughout the year apart from December and January.

Boophilus decoloratus

Large numbers of this 1-host tick are frequently recovered from its preferred wild hosts, namely giraffe, eland, kudu, bushbuck and Burchell's zebras, on which the ratio of larvae to nymphs to adults is approximately 4:2:1 (Horak, Potgieter, Walker, De Vos & Boomker, 1983; Horak, De Vos & De Klerk, 1984). The survey sheep harboured relatively small burdens, but this could have been due to acaricidal treatment of other stock on the farms suppressing the overall populations. The ratio of 27,9 larvae to 1,1 nymph to 1 adult on sheep (Table 6) is closest to that on blue wildebeest (8,9:1,7:1), which are considered to be naturally resistant to infestation with *B. decoloratus* (Horak, De Vos & Brown, 1983). On these antelope the marked decrease in numbers between the larval and nymphal stage is probably due to an immune response of the host similar to that observed in cattle resistant to *Boophilus microplus* (Wagland, 1979). On sheep it is probably mainly due to an accumulation of dead larvae suffocated by wool-fat or killed by the residual effects of an acaricide and trapped in the fleece. Once the larvae reach the nymphal stage on sheep further development to adults appears to be unhindered as does the engorgement of the females.

The seasonal abundance of *B. decoloratus* on the sheep, with peaks during July and November, resembles that on cattle in the eastern Cape Province (Rechav, 1982) and blue wildebeest and Burchell's zebras in the north-eastern Transvaal (Horak, De Vos & Brown, 1983; Horak *et al.*, 1984). However, the peaks on the latter 3 host species were all approximately 1 month earlier than those on the sheep. The spring or early summer peak (September–November) is probably due to the synchronous hatching of eggs that had accumulated during the winter months (Robertson, 1981).

B. decoloratus is a vector of *Babesia bigemina,* the cause of African redwater or babesiosis in cattle (Potgieter, 1977). The infection passes transovarially in the ticks and is not lost even if the tick should feed on a refractory host (Gray & Potgieter, 1981). Consequently sheep should be considered as reservoirs of infected ticks on any farm on which there has been an outbreak of babesiosis in cattle.

Haemaphysalis leachi

Small numbers, of larvae only, were recovered. These are accidental infestations originating from adult ticks, carried by either wild carnivores or domestic dogs on the farms. The immature stages are usually found on rodents (Hoogstraal, 1956; Norval, 1984), and the sheep probably became infested by lying down on questing larvae.

Haemaphysalis silacea

This tick is associated with well-wooded ravines and river valleys in the eastern Cape Province and, to a lesser extent, Natal (Howell *et al.,* 1978). Thus considerably greater burdens were recovered from the Dorper sheep on "Bucklands", with its dense bush and tree cover, than from the sheep on the other farms in the eastern Cape Province which had a more open type of thornveld.

The surveys conducted by Knight & Rechav (1978) on kudu, and by Rechav (1982) on Angora goats and cattle in Valley Bushveld on and near "Bucklands", also indicated considerable variation in the seasonal abundance of this tick. The prolonged presence of larvae and nymphs and the summer and winter peaks of adult abundance (Rechav, 1982; "Grasmere") indicate that more than 1 life cycle can be completed annually.

***Hyalomma* spp.**

The 3 ticks of this genus found in South Africa all prefer the drier regions of the country (Howell *et al.*, 1978). Hence quite large numbers were recovered by Fourie *et al.* (1988) from Merino sheep in the semi-arid south-western Orange Free State compared with the small numbers on the sheep in the present surveys, all of which were conducted on farms with moister climates. Fourie *et al.* (1988) recorded peak burdens of adult *H. marginatum rufipes* on sheep

from November to April. The very few adult ticks of this species that we recovered were present from March to May.

The preferred hosts of the adult ticks are large animals such as cattle, eland and zebras (Hoogstraal 1956; Rechav, 1986; Horak, Knight & De Vos, 1986), on which they occur during the summer months. Scrub hares are the preferred hosts of the immature stages of all 3 *Hyalommas* (Rechav, 1986; Horak & MacIvor, 1987), while ground-nesting birds may be infested with the 2 subspecies of *H. marginatum* (Horak & Williams, 1986; Horak & Knight, 1986). The 33 larvae of *H. marginatum rufipes* recovered from the sheep on the farms "Tweespruit" and "Reed Valley" must be considered accidental infestations.

Ixodes pilosus

This tick is found in sourveld regions, particularly in wooded ravines and vegetation bordering streams, along the coast from Port Shepstone in southern Natal to Cape Town in the south-western Cape Province (Howell *et al.*, 1978). The farms "Reed Valley", "Sidbury" and "Grasmere" are situated within 40 km of the southern coast-line and hence probably lie within the distribution range of *I. pilosus*. The small numbers recovered indicate either that sheep are not good hosts, or that the farms lie at the limits of the tick's distribution. Horak, Sheppey, Knight & Beuthin (1986), Horak, Jacot Guillarmod, Moolman & De Vos (1987) and Horak, Keep, Spickett & Boomker (1989) consider grey rhebuck, caracal and bushbuck to be some of the preferred hosts of *I. pilosus*.

Margaropus winthemi

This 1-host tick is recorded almost exclusively in the Republic of South Africa and Lesotho, where it prefers higher-lying regions with cold winters (Howell *et al.*, 1978). Its preferred hosts are equids, among them Cape mountain zebras, on which very large numbers may be encountered during winter (Horak, Knight & De Vos, 1986). Sheep are obviously not good hosts as development does not proceed beyond the larval stage. Even though very few larvae were recovered from the sheep, these were present from June to September (winter to early spring), confirming the preference of this tick for the colder months. The infestation on "Tweespruit" was probably maintained by horses and cattle.

Rhipicephalus appendiculatus

Howell *et al.* (1978), making use of Theiler's (1962) distribution data, show *R. appendiculatus,* as occurring in the south-western Cape Province. Horak, Sheppey, Knight & Beuthin (1986) suggest that this tick does not occur in this region and that its southern distribution probably does not extend west much past 25° E. The findings on "Bucklands", "Reed Valley" and "Sidbury" confirm this supposition. At "Bucklands" (26° 41 ′ E) large numbers of *R. appendiculatus* were recovered, whereas at "Sidbury" (26° 11′ E) and "Reed Valley" (26° 02′ E), *R. appendiculatus* had virtually disappeared and had been replaced by *R. nitens.* This finding indicates that the distribution of *R. appendiculatus* probably does not extend west along the southern coast beyond 26° E.

The seasonal abundance of the larvae and nymphs on the Dorper sheep at "Bucklands" is similar to that observed a few years earlier by Rechav (1982) on Angora goats and cattle on the same farm. The small number of adults recovered from the sheep indicate that they are not good hosts of this stage of development. Angora goats, and particularly cattle, examined on "Bucklands" at the same time as the Dorper sheep, harboured considerably greater numbers of adults (Horak & Knight, 1986).

Rhipicephalus evertsi evertsi

This 2-host tick has a widespread distribution covering most of the eastern as well as the south-western portion of the country (Howell *et al.*, 1978). It was recovered from sheep on each of the 5 farms surveyed and, with the exception of "Bucklands", was the most abundant and prevalent tick.

The preferred hosts of all stages of development are equids (Hoogstraal, 1956; Norval, 1981). Horak *et al.*, (1984) and Horak, Knight & De Vos (1986) recovered large numbers from Burchell's and Cape mountain zebras, on which the ratio of larvae to nymphs to adults was 7,9:4,0:1,0. On the sheep this ratio was 32,2:1,1:1,0 (Table 6). It is thus obvious that many larvae die on the sheep before moulting to nymphs. This is supported by the fact that a large proportion of the larvae were recovered from the legs and bodies of the sheep, whereas the preferred site of attachment on the definitive hosts is the ear canal, where moulting to the nymphal stage occurs (Howell *et al.*, 1978).

The life stage ratios on zebras indicate that 1 of 4 nymphs may eventually give rise to an adult on the same host species. Thus 3 of the 4 ticks either die or find another host during this process. The approximate parity between nymphs and adults on sheep indicates that a fairly large number of nymphs must have fed on other hosts (probably horses, cattle or hares) on the farms and then infested sheep in the adult stage. Sheep must be considered one of the preferred hosts of adult *R. evertsi evertsi* as several animals harboured more than 30 ticks. Although this tick is widely destributed the adults are rarely abundant except on equids, on which they occur in large numbers, and 30 must be considered a fairly heavy burden.

The engorging females of *R. evertsi evertsi* transmit a toxin that causes paralysis in sheep (Hamel & Gothe, 1978), commonly known as spring lamb paralysis. The occurrence and severity of this paralysis is dependent upon the number of engorging female ticks simultaneously reaching a mass of 15–21 mg in relation to the mass of the lamb (Gothe & Bezuidenhout, 1986). In spring there is a rapid rise in adult numbers (MacLeod, Colbo, Madbouly & Mwanaumo, 1977; Londt, Horak & De Villiers, 1979), probably because large numbers of overwintering nymphs moult synchronously. Sheep may thus be infested by both sexes simultaneously, which increases the possiblility of paralysis occurring (Gothe & Budelmann, 1980). If very young lambs are present they may become heavily infested and because of their small body mass the chances of paralysis are further enhanced. With the exception of "Bucklands", where few *R. evertsi evertsi* were recovered after winter, adult tick numbers rose during October or November on all the survey farms. No cases of paralysis were seen as all the survey sheep, including the autumn-born (May) lambs on "Grasmere", were fairly large by that time.

The presence of several peaks in immature and adult abundance on the sheep during the course of the surveys indicate that 2 or more life cycles can be

completed annually, as suggested by Matson & Norval (1977) and Horak, Knight & De Vos (1986).

Rhipicephalus glabroscutatum

The geographic distribution of this 2-host tick has been illustrated by MacIvor (1985). The inland Valley Bushveld region in the eastern Cape Province is 1 of its preferred localities, and it was on "Bucklands" that substantial numbers of ticks were recovered.

Kudu are the preferred hosts of all stages of development of *R. glabroscutatum,* while cattle and Angora goats are better hosts than are Dorper sheep (Horak & Knight, 1986). Substantial numbers of immatures may also be recovered from scrub hares (Horak & Knight, 1986). On kudu on and around "Bucklands" the ratio of larvae to nymphs to adults was 11,2:6,0:1,0, whereas the ratio on Angora goats on the farm was 3,2:2,8:1,0 (Horak & Knight, 1986). On the Dorper sheep in the present survey it was 19,4:0,9:1,0 (Table 5). As in the case of *R. evertsi evertsi* on the Merino sheep, large numbers of *R. glabroscutatum* larvae died or detached before moulting to nymphs on the Dorper sheep. Consequently a large proportion of the adults on these sheep must have originated from nymphs that had fed on other animals, notably kudu and scrub hares.

The presence of the immature stages from late summer to spring, with a peak in numbers from April to September, and of adults from spring to late summer, is virtually identical to that recorded for this tick on goats running in Valley Bushveld near Uitenhage (MacIvor & Horak, 1984). This pattern of seasonal abundance indicates that only 1 life cycle is completed annually.

Rhipicephalus nitens

According to Morel (1969) *R. nitens* is restricted to the south-western Cape Province. In our experience its destribution extends to the south-eastern Cape Province at least as far as Grahamstown (26° 32′ E) (Horak, Jacot Guillarmod, Moolman & De Vos, 1987). The recovery of *R. nitens* from sheep on the farms "Reed Valley", and more particularly "Sidbury", further confirms this. We suggest that the distribution of this tick is associated with vegetation described as macchia or fynbos even though this may be dominated by other vegetation types. On both "Reed Valley" and "Sidbury" fynbos-like vegetation is present.

In the Bontebok National Park in the south-western Cape Province all stages of development can be found on bontebok, grey rhebuck and scrub hares and the mean ratio of larvae, to nymphs to adults is 16,3:5,6:1,0 (Horak, Sheppey, Knight & Beuthin, 1986). On the sheep at Sidbury the ratio is 41,2:4,1:1,0, indicating a considerable reduction in numbers between the larval and nymphal stages. This is probably partly because numerous larvae die on the sheep, as discussed earlier. The Bontebok Park results may also have been biased in favour of a low larval ratio as the animals were slaughtered at 2-monthly intervals and the month of peak larval abundance could have been missed. Sheep must be considered good hosts of adult *R. nitens* as all animals harboured more than 30 ticks during the periods of peak adult abundance and approximately 1/7 of all female ticks recovered were maturing.

Horak, Sheppey, Knight & Beuthin (1986) remarked that in the Bontebok Park male *R. nitens* outnumbered females on their hosts early in the season of adult activity while the converse was true later in the season. The same was true at "Sidbury" during January 1987 (late season) (70 males:100 females) but not January 1986 (108 males:48 females).

In the Bontebok Park, where rain falls mainly from autumn to spring, larvae reached peak numbers during April, nymphs during August and adults from December to February (Horak, Sheppey, Knight & Beuthin, 1986). At "Sidbury", where most of the rain falls from spring to autumn the larvae peaked during March/April, the nymphs during August to October and the adults from November to January. Seasonal abundance at the 2 localities was thus fairly similar despite the difference in rainfall patterns.

Rhipicephalus simus

Too few ticks were present for any meaningful conclusions to be drawn. However, all the ticks recovered were found on the lower legs and feet of the sheep.

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Miss Andrea van Niekerk of the Veterinary Research Institute, Onderstepoort drew the figures.

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PARASITES OF DOMESTIC AND WILD ANIMALS IN SOUTH AFRICA. XXXI. ADULT IXODID TICKS ON SHEEP IN THE CAPE PROVINCE AND IN THE ORANGE FREE STATE

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ABSTRACT

HORAK, I. G. & FOURIE, L. J., 1992. parasites of domestic and wild animals in South Africa. XXXI. Adult ixodid ticks on sheep in the Cape Province and in the Orange Free State. *Onderstepoort Journal of Veterinary Research*, 59, 275–283 (1992)

Four to 10 Dorper sheep on each of 12 farms in the Cape Province and 3 farms in the Orange Free State were examined for adult ixodid ticks at approximately 2- to 4-weekly intervals over periods varying from 4 to 18 months, commencing during January, February or April 1989. The farms in the Cape Province were located in the north-west, south-west and south of the province. Those in the Orange Free State were situated in the north-east and in the south.

The sheep in the Cape Province harboured 10 species of ixodid ticks and the seasonal abundances of *Ixodes rubicundus, Rhipicephalus evertsi evertsi, Rhipicephalus gertrudae* and *Hyalomma truncatum* were determined. The animals in the Orange Free State were infested with 7 tick species and the seasonal abundances of *I. rubicundus, R. evertsi evertsi* and *Hyalomma marginatum rufipes* were determined.

INTRODUCTION

Sheep in sub-Saharan Africa may harbour adults of many different ixodid ticks (Theiler, 1962; Yeoman & Walker, 1967; Walker, 1974; Fourie, Horak & Marais, 1988b; Horak, Williams & Van Schalkwyk, 1991). They are, however, good hosts of only a few species.

Three studies on ticks infesting sheep in South Africa have recently been published. Fourie *et al.* (1988b) recovered the adults of 6 species from sheep in the south-western Orange Free State and described the seasonal abundances of *Hyalomma marginatum rufipes, Ixodes rubicundus* and *Rhipicephalus punctatus* [then identified as *Rhipicephalus* sp. (near *R. pravus)*]. Horak, Williams & Van Schalkwyk (1991) recovered 7 ixodid tick species, including the adults of 3 of them, from sheep in the north-eastern Orange Free State, and 15 species, including the adults of 12, from the eastern Cape Province. They determined the seasonal abundances of *Amblyomma marmoreum, Boophilus decoloratus, Haemaphysalis silacea, H. marginatum rufipes, Rhipicephalus appendiculatus, Rhipicephalus evertsi evertsi, Rhipicephalus glabroscutatum* and *Rhipicephalus nitens* on these animals. In the third study Walker (1990) described *Rhipicephalus lounsburyi* and *Rhipicephalus neumanni* and also plotted their distributions. The latter 2 species parasitize the feet of sheep and other ungulates.

The present paper describes a survey of adult ticks on Dorper sheep on 12 farms in the Cape Province and 3 farms in the Orange Free State. This survey was conducted within the distribution range of *I. rubicundus,* with the specific intent of determining the commencement and peak of activity of this tick at various latitudes in South Africa. The opportunity was also taken to collect data on the distribution and seasonal abundance of other ticks parasitizing sheep.

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MATERIALS AND METHODS

Survey localities

The farms on which the sheep were examined, the regions within which these farms are located and the vegetation types of these regions are summarized in Table 1.

Survey animals

Four to 10 Dorper sheep, which were individually identified, ran with commercial flocks of this breed on each of the 15 survey farms. The camps in which the sheep grazed encompassed hilly and/or mountainous as well as level terrain.

Tick collections

The marked sheep were examined at approximately 2- to 4-weekly intervals for periods ranging from 4 to 18 months, commencing in January, February or April 1989. Whole body searches for adult ixodid ticks were conducted on these sheep by the owner, or a State Veterinarian, or a stock inspector. Ticks from each sheep were collected separately and placed in 70 % alcohol in marked vials.

All the ticks were identified and counted under a stereoscopic microscope. The total numbers recovered of the major tick species have been summarized in separate tables for each species. The 3 *Hyalommas* have been dealt with in a single table and the minor species have been combined in another table. Where collections were made at sufficiently regular intervals the seasonal abundances of the major tick species are graphically illustrated. If collections were irregular, or particular species occurred only in small numbers, seasonal trends for these species are mentioned in the text.

RESULTS AND DISCUSSION

General

Certain aspects of the methods employed in this survey can be criticized. Firstly various collaborators were used to collect the ticks from the sheep, secondly the proposed collection intervals were not strictly adhered to, thirdly the total length and timing of the collection periods were biased in favour of the seasonal occurrence of *I. rubicundus,* and finally no

TABLE 1 The regions in which ixodid ticks were collected from Dorper sheep

Farm	Co-ordinates	Nearest town	Vegetation type	Collection period
Far north-western Cape Province				
Bovlei	30° 12′ S, 18° 05′ E		Mountain Renosterbosveld	Jan.–Oct. 89
Olienfontein	30° 14′ S, 18° 00′ E	Kamieskroon	Mountain Renosterbosveld	Jan.–Jul. 89
Outuin	30° 10′ S, 18° 02′ E		Mountain Renosterbosveld	Jan.–Dec. 89
North-western Cape Province				
Diepvlei	31° 40′ S, 18° 50′ E		Succulent Karoo	Jan.–Jul. 89
Gifberg	31° 47′ S, 18° 40′ E	Vanrhyns-dorp	Succulent Karoo	Jan.–Oct. 89
Kantoorshoek	31° 47′ S, 18° 45′ E		Succulent Karoo	Jan. 89–Feb. 90
South-western Cape Province				
Pienaarskloof	33° 13′ S, 20° 02′ E	Touwsrivier	Macchia	Jan. 89–Jun. 90
Rheeboksfontein	33° 44′ S, 20° 32′ E	Barrydale	Karroid Broken Veld	Apr. 89–Jun. 90
Sandfontein	34° 05′ S, 20° 03′ E	Bonnievale	Karroid Broken Veld	Jan. 89–Feb. 90
Southern Cape Province				
Dieniedouw	33° 27′ S, 23° 52′ E		False Macchia	Jan.–May 89
Klipfontein	33° 20′ S, 23° 19′ E	Willowmore	Karroid Broken Veld	Feb.–May 89
The Knolls	33° 26′ S, 23° 40′ E		False Macchia	Feb.–Jun. 89.
Southern Orange Free State				
Goedemoed	30° 35′ S, 26° 20′ E	Bethulie	False Upper Karoo	Feb. 89–Jan. 90
North-eastern Orange Free State				
Driefontein	28° 09′ S, 27° 59′ E		*Cymbopongon-Themeda* Veld	Feb.–Nov. 89
Palmietfontein	28° 19′ S, 27° 57′ E	Paul Roux	*Cymbopogon-Themeda* Veld	Feb.–Nov. 89

attempt was made to collect immature ticks. Nevertheless valuable data on adult ticks infesting sheep in several regions of South Africa were obtained. These include new locality records for a number of species, the commencement of activity and months of peak abundance of *I. rubicundus* at different latitudes, and the determination of the seasonal abundance of adult *Rhipicephalus gertrudae* in this country.

A total of 10 ixodid tick species were recovered from the sheep in the Cape Province. Of these *I. rubicundus, R. evertsi evertsi, R. gertrudae* and *Hyalomma truncatum* can be considered major species. The sheep in the Orange Free State harboured 7 tick species of which *I. rubicundus, R. evertsi evertsi* and *H. marginatum rufipes* were the most numerous. Fourie *et al.* (1988b), Walker (1990) and Horak, Williams & Van Schalkwyk (1991) recorded a total of 22 species on sheep in the Cape Province and the Orange Free State during their recent investigations. To these can now be added *Hyalomma marginatum turanicum, Rhipicephalus follis* and *R. gertrudae.*

Ixodes rubicundus

The preferred domesticated hosts of adults of this species are sheep (Stampa, 1959; Fourie & Horak, 1991) while the wild hosts are mountain reedbuck, eland and caracals (Horak, Moolman & Fourie, 1987). The preferred hosts of the immature stages are rock elephant shrews and red rock rabbits and possibly also caracals (Stampa, 1959; Horak *et al.*, 1987; Fourie, Horak & Van den Heever, 1992). The numbers of ticks recovered from the sheep on the various farms in the present survey are summarized in Table 2.

The greatest total numbers of ticks were recovered from sheep on farms in the far north-western, the north-western and the southern Cape Province.

The distribution of this tick has recently been reviewed by Spickett & Heyne (1988). The farms in the current survey lie within or on the fringes of its previously known distribution range. It may be introduced to new localities by the large-scale transportation of sheep from infested regions to biotically suitable, uninfested regions in the autumn and winter months when the adult ticks are present on the animals.

With the possible exception of the north-eastern Orange Free State, the numbers of ticks recovered from sheep from one or more farms in each of the regions sampled indicate that these localities are all suitable for *I. rubicundus.* Excluding the south-western Cape Province and the north-eastern Orange Free State, *I. rubicundus* was the numerically dominant species in each of the regions. The disparity in the sex ratio (562 males to 2 449 females) is characteristic for this species, in which mating generally occurs off the host (Fourie *et al.*, 1988b). In addition those males which may be present on the host are seldom attached, and hence could have been overlooked during sampling.

The seasonal abundances of *I. rubicundus* on sheep on "Bovlei" plus "Outuin" in the far north-western Cape Province; on all 3 farms in the north-western Cape Province; on all 3 farms in the south-western Cape Province; and on "Goedemoed" in the southern Orange Free State are illustrated in Fig. 1.

TABLE 2 The geographic distribution, abundance and seasonal activity of *Ixodes rubicundus* recovered from Dorper sheep

Farm	No. of ticks recovered			Activity commenced	Activity period	Peak abundance
	Males	Females	Total			
Far N.W. Cape Province						
Bovlei	29	244	273	4th wk, March	March–October	June
Olienfontein*	1	13	14	3rd wk, May	May–July	July
Outuin	128	452	580	2nd wk, March	March–September	June
N.W. Cape Province						
Diepvlei*	8	42	50	3rd wk, May	May–July	June
Gifberg	63	396	459	1st wk, April	April–October	June
Kantoorshoek	54	248	302	3rd wk, April	April–November	May, June
S.W. Cape Province						
Pienaarskloof	34	144	178	5th wk, March	March–September	April, June, July
Rheeboksfontein	2	15	17	4th wk, March	March–August	July
Sandfontein	5	60	65	1st wk, April	April–December	June
S. Cape Province						
Dieniedouw*	0	9	9	4th wk, April	April and May*	April
Klipfontein*	36	149	185	4th wk, February	February–May*	April
The Knolls*	175	437	612	4th wk, February	February–June*	June
S. Orange Free State						
Goedemoed	18	116	134	1st wk, April	April–September	April
N.E. Orange Free State						
Driefontein	6	89	95	4th wk, April	April–June	May
Palmietfontein	3	35	38	1st wk, February	February–June	February

* Sheep examined only until May, June or July 1989

Activity commenced in March or April and continued until October, November or even December. Peak activity was recorded during April in the southern Orange Free State and during May or June in the north-western Cape Province. Fourie *et al.* (1988b) recorded the commencement of activity during April on sheep in the south-western Orange Free State and peak activity during May. On goats at the latter locality activity in 1988 commenced in April and peaked during May and in 1989 commenced during March and peaked during April (Fourie & Horak, 1991). Data on seasonal activity in the north-western and south-western Cape Province has not previously been published.

There is considerable variation in the commencement of seasonal activity of the tick even on nearby farms. This may be a result of differences in host behaviour, such as preferences for either hilly or level terrain, particularly in topographically variable regions or camps (Fourie & Kok, 1992).

Presently available information suggests that in the summer rainfall regions of the Cape Province and the Orange Free State the tick is usually active until only September or October, while in the winter rainfall regions it is active till November or December (Stampa, 1959; Fourie, Petney, Horak & De Jager, 1989; Fourie & Horak, 1991). Possibly, therefore, rainfall in winter enhances its ecological lifespan. These data seem to support the current concept that the adults can remain active for only one season.

Sheep are the most important livestock species affected by paralysis associated with *I. rubicundus* infestation (Stampa, 1959; Spickett & Heyne, 1988). Goats and cattle can also be affected, as well as wild herbivores (Stampa, 1959; Fourie & Horak, 1987; Fourie & Vrahimis, 1989).

Rhipicephalus evertsi evertsi

The preferred hosts of all stages of development are equids and eland (Norval, 1981; Horak, Fourie, Novellie & Williams, 1991). Sheep are also efficient hosts of the adults (Horak, Williams & Van Schalkwyk, 1991) and scrub hares of the immature stages (Horak & Fourie, 1991). The numbers of ticks recovered from sheep in this survey are summarized in Table 3.

The largest numbers were present on sheep in the north-western Cape Province, in Succulent Karoo, and the north-eastern Orange Free State, in *Cymbopogon-Themeda* Veld (Acocks, 1988). According to Howell, Walker & Nevill (1978), increasing aridity, with a critical annual rainfall of 250–280 mm, is the chief factor limiting the spread of *R. evertsi evertsi.*

The seasonal abundances of this tick on "Diepvlei", "Gifberg" and "Kantoorshoek" in the north-western Cape Province, and on "Driefontein" plus "Palmietfontein" in the north-eastern Orange Free State are graphically illustrated in Fig. 2.

In the Cape Province the greatest numbers were present during March and April compared with February to April in the Orange Free State. Substantial numbers were also present during October and November in the latter province. At both localities activity was markedly reduced during the cooler months from June or July to August or September. On Merino sheep on a farm near Vrede, which lies further to the north and east than the 2 farms in the present survey in the Orange Free State, peak adult activity was recorded from March to May, but other-

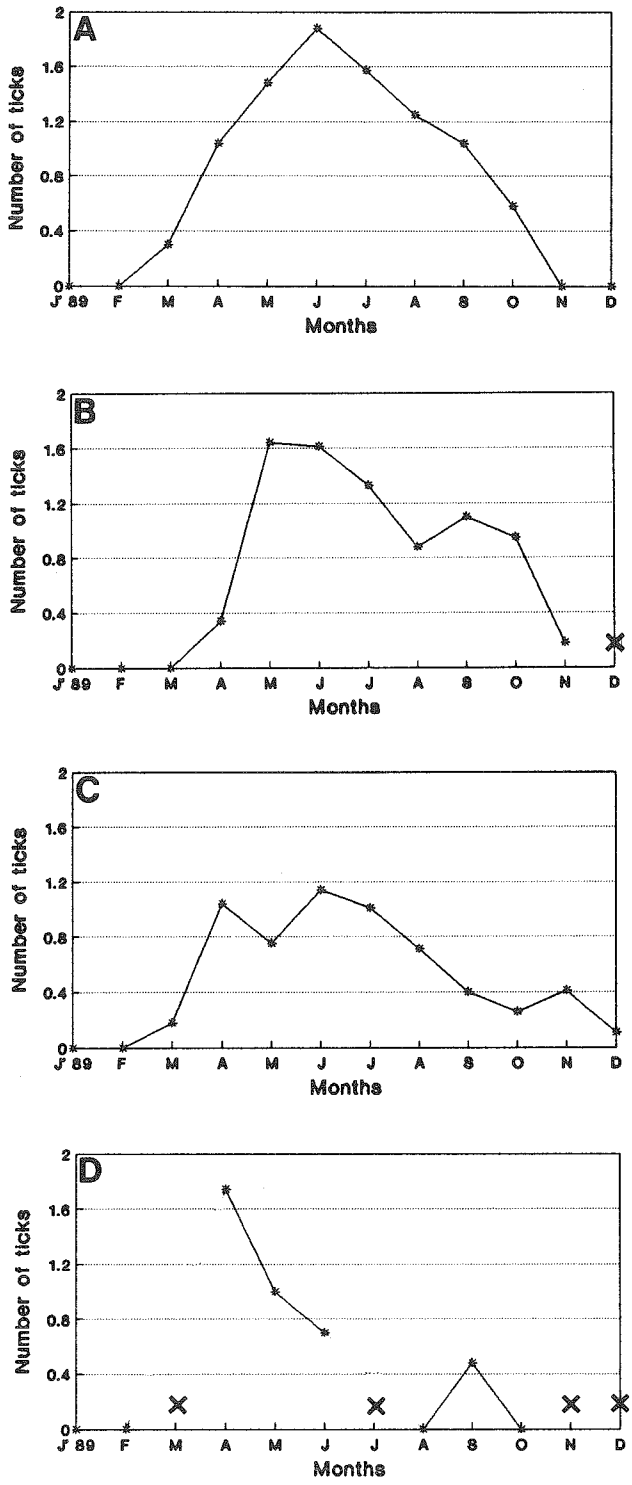

FIG. 1 The monthly mean total numbers of adult *Ixodes rubicundus* [$\log_{10}(x+1)$] collected from Dorper sheep in
(A) the far north-western Cape Province
(B) the north-western Cape Province
(C) the south-western Cape Province
(D) the southern Orange Free State
× = no collections made

TABLE 3 The geographic distribution and abundance of *Rhipicephalus evertsi evertsi* recovered from Dorper sheep

Farm	No. of ticks recovered			Period of major activity
	Males	Females	Total	
Far N.W. Cape Province				
Olienfontein*	0	1	1	
N.W. Cape Province				
Diepvlei*	98	57	155	January–May
Gifberg	200	157	357	February–May
Kantoorshoek	71	53	124	March–July, September, October
S.W. Cape Province				
Pienaarskloof	0	1	1	
Sandfontein	66	37	103	January, March, April
S. Orange Free State				
Goedemoed	3	3	6	
N.E. Orange Free State				
Driefontein	277	179	456	February–April, October, November
Palmietfontein	693	323	1 016	February–June, October, November

* Sheep examined only until July 1989

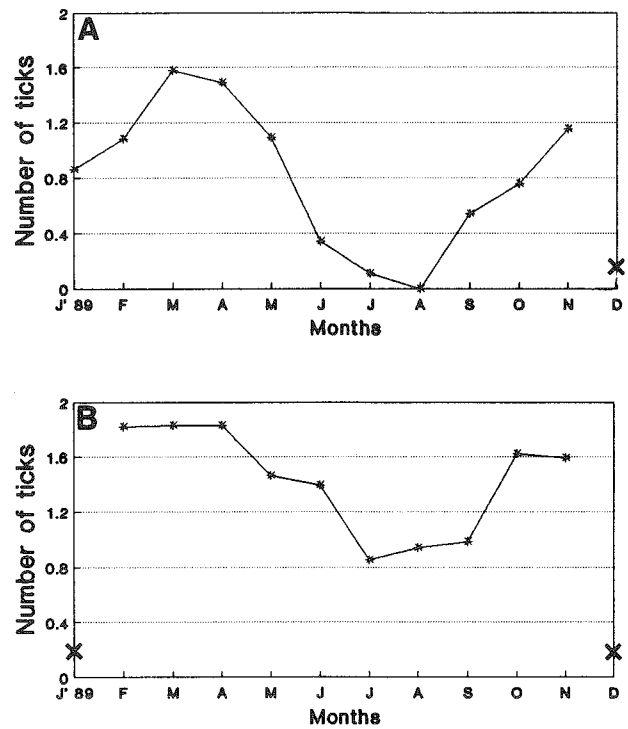

FIG. 2 The monthly mean total numbers of adult *Rhipicephalus evertsi evertsi* [$\log_{10}(x+1)$] collected from Dorper sheep in
(A) the north-western Cape Province
(B) the north-eastern Orange Free State
× = no collections made

wise the pattern of seasonal abundance was virtually identical to that observed on the latter farms (Horak, Williams & Van Schalkwyk, 1991). The continual, or almost continual, presence of adult ticks indicates that more than 1 life cycle can be completed annually as suggested by Matson & Norval

(1977) and Horak, Knight & De Vos (1986).

Engorging females of this tick can cause paralysis in sheep (Hamel & Göthe, 1978). This usually occurs in young, spring-born lambs in the Highveld of the Transvaal and the Orange Free State (Howell *et al.*, 1978), probably owing to large numbers of overwintering nymphs moulting synchronously to adults in spring. The lambs are thus infested by many adults of both sexes simultaneously, and this increases the possibility of paralysis occurring (Göthe & Budelmann, 1980).

Rhipicephalus gertrudae

The adults of this tick prefer large herbivores and have been recorded from cattle, sheep, goats and horses (Biggs & Langenhoven, 1984; Walker, 1991; Fourie & Horak, 1991). Wild herbivores from which it has been recovered include mountain zebras (Walker, 1991), grey rhebok and bontebok (Horak, Sheppey, Knight & Beuthin, 1986) and gemsbok (Fourie, Vrahimis, Horak, Terblanche & Kok, 1991). The numbers of *R. gertrudae* recovered from sheep in the present survey are summarized in Table 4.

TABLE 4 The geographic distribution and abundance of *Rhipicephalus gertrudae* recovered from Dorper sheep

Farm	No. of ticks recovered			Period of major activity
	Males	Females	Total	
Far N.W. Cape Province				
Bovlei	1	6	7	
Olienfontein*	1	0	1	
Outuin	192	147	339	May–October
N.W. Cape Province				
Diepvlei*	28	21	49	May, June
Gifberg	46	76	122	May–August
Kantoorshoek	45	49	94	March–October
S.W. Cape Province				
Rheeboksfontein	89	145	234	May–October
Sandfontein	50	55	105	May–June
S. Cape Province				
The Knolls*	4	4	8	
S. Orange Free State				
Goedemoed	9	8	17	

* Sheep examined only until June or July 1989

The sheep examined in all the western regions of the Cape Province were most heavily infested. According to Walker (1991), *R. gertrudae* is widely distributed in the Cape Province, from which it extends northwards into Namibia in the west and into the southern and central Orange Free State in the east. The small numbers of ticks recovered from goats and gemsbok in the Orange Free State (Fourie & Horak, 1991; Fourie *et al.*, 1991), and from sheep in the southern part of this province and of the Cape Province in the present survey, indicate that this species prefers the more arid far western regions of this country.

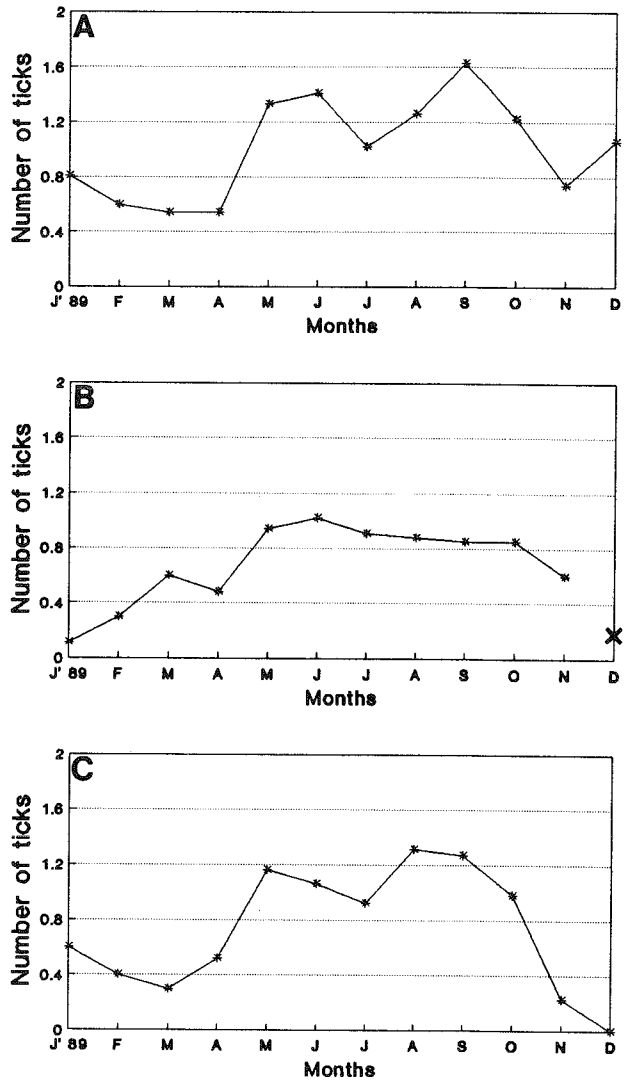

FIG. 3 The monthly mean total numbers of adult *Rhipicephalus gertrudae* [$\log_{10}(x+1)$] collected from Dorper sheep in
(A) the far north-western Cape Province
(B) the north-western Cape Province
(C) the south-western Cape Province
x = no collections made

The seasonal abundances of *R. gertrudae* on "Outuin" in the far north-western Cape Province; on all 3 farms in the north-western Cape Province, and on the 2 farms in the south-western Cape Province are graphically illustrated in Fig. 3.

In each of these localities the largest numbers of ticks were recovered from May to October. Biggs & Langenhoven (1984), who were unable to distinguish *R. gertrudae* consistently from another *R. capensis* group tick occurring on cattle in their survey near Windhoek, Namibia, recorded the largest numbers of these ticks from November to March.

Hyalomma spp.

The preferred hosts of the adults of the 3 ticks of this genus occurring in South Africa are large herbivores, such as cattle, eland and zebras (Horak,

1982; Rechav, Zeederberg & Zeller, 1987; Horak, Fourie, Novellie & Williams, 1991). It would, however, appear that when sheep are farmed in regions in which these ticks abound that they too are fairly good hosts of the adults. The immature stages of all 3 ticks prefer scrub hares as hosts (Horak & MacIvor, 1987; Rechav *et al.*, 1987; Horak & Fourie, 1991). These stages of the 2 subspecies of *H. marginatum* also infest ground-nesting birds and those of *H. truncatum* certain rodents (Walker, 1991; Horak, Fourie, Novellie & Williams, 1991).

The distributions and abundances of the 3 *Hyalomma* ticks are summarized in Table 5.

According to Howell *et al.* (1978) *H. marginatum rufipes* is more widely distributed in the Orange Free State than *H. truncatum*, while the converse is true for the Cape Province. The results of the present and other surveys indicate that, where their distributions overlap in the 2 provinces, *H. marginatum rufipes* is generally more numerous in the Orange Free State and *H. truncatum* in the Cape Province (Fourie *et al.*, 1988b; Fourie & Horak, 1990, 1991; Horak & Fourie, 1991; Fourie *et al.*, 1991).

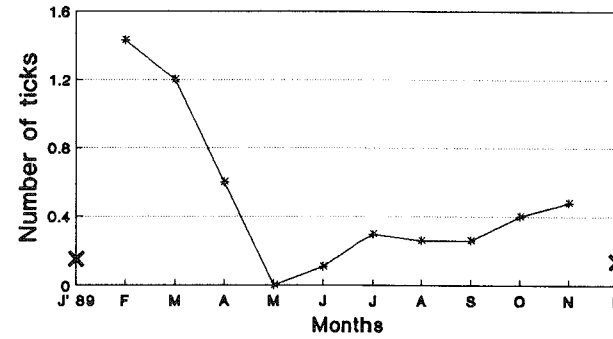

FIG. 5 The monthly mean total numbers of adult *Hyalomma marginatum rufipes* [$\log_{10}$ (x +1)] collected from Dorper sheep in the north-eastern Orange Free State
× = no collections made

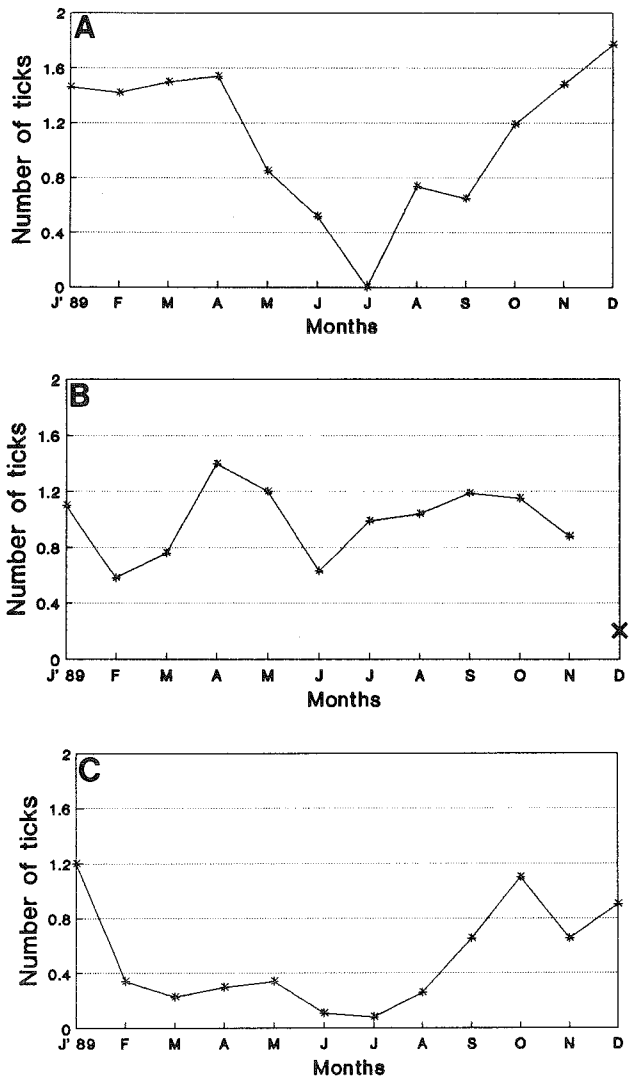

FIG. 4 The monthly mean total numbers of adult *Hyalomma truncatum* [$\log_{10}$ (x +1)] collected from Dorper sheep in
(A) the far north-western Cape Province
(B) the north-western Cape Province
(C) the south-western Cape Province
× = no collections made

The distribution of *H. marginatum turanicum* partially overlaps those of both the other ticks (Howell *et al.*, 1978). The recovery of a single specimen of this tick from a sheep on "Outuin", in the far north-western Cape Province, lies outside its previously known distribution range and possibly indicates the limit of the tick's distribution. However, it could have been transported there by a bird.

The seasonal abundances of *H. truncatum* on sheep on "Outuin" in the far north-western Cape Province, as well as on the 3 farms in the north-western Cape Province, and on the 3 farms in the south-western Cape Province are summarized in Fig. 4.

On "Outuin" the largest numbers were present from January to April and during November and December; in the north-western Cape Province they were present during April; and during January and October in the south-western Cape Province. These months of major abundance lie within the period spring to autumn and correspond to previous observations made for this tick in the Karoo regions of the Cape Province (Horak, Fourie, Novellie & Williams, 1991), the south-western Orange Free State (Fourie & Horak, 1990) and the south-western and northern Transvaal (Londt, Horak & De Villiers, 1979; Rechav *et al.*, 1987). The immature stages may be present on scrub hares in the largest numbers at any time from mid-summer to late winter (Horak & MacIvor, 1987; Rechav *et al.*, 1987; Horak & Fourie, 1991).

The combined seasonal abundance of *H. marginatum rufipes* on sheep on "Driefontein" and "Palmietfontein" in the north-eastern Orange Free State is illustrated in Fig. 5.

The survey on these farms commenced during February and ended during November (Table 1). The largest numbers of ticks were present during February and March, and few were recovered there-

TABLE 5 The geographic distribution and abundance of *Hyalomma truncatum, Hyalomma marginatum rufipes* and *Hyalomma marginatum turanicum* recovered from Dorper sheep

Farm	No. of *H. truncatum* recovered				No. of *H. marginatum turanicum*		
	Males	Females	Total	Period of major activity	Males	Females	Total
Far N.W. Cape Province							
Bovlei	33	23	56	Jan			
Olienfontein*	55	37	92	Jan–Apr			
Outuin	313	160	473	Jan–Apr, Nov–Dec	1	0	1
N.W. Cape Province							
Diepvlei*	238	123	361	Jan, Apr, May, July			
Gifberg	86	35	121	Sept & Oct			
Kantoorshoek	76	32	108	Jan, Feb, Apr			
S.W. Cape Province							
Pienaarskloof	50	16	66				
Rheeboksfontein	30	20	50	Sept & Oct			
Sandfontein	58	9	67	Jan, Feb, Nov, Dec			
S. Cape Province							
Dieniedouw*	2	4	6		1	1	2
Klipfontein*					2	0	2
The Knolls*	3	6	9		6	5	11

Farm	No. of *H. marginatum rufipes* recovered			
	Males	Females	Total	Period of major activity
S. Orange Free State				
Goedemoed	16	4	20	Feb
N.E. Orange Free State				
Driefontein	91	81	172	Feb & March
Palmietfontein	22	6	28	Feb, July–Nov

* Sheep examined only until May, June or July 1989

after. On sheep and cattle in the south-western Orange Free State the largest numbers were present from December to March and November to February respectively (Fourie *et al.,* 1988b; Fourie & Horak, 1990).

Certain strains of adult *H. truncatum* produce a toxin causing a condition known as sweating sickness in cattle (Howell *et al.,* 1978). On sheep the adults frequently attach around the feet and the damage caused by the long mouthparts may lead to secondary bacterial infections followed by foot abscess and lameness.

The results for the less abundant tick species are summarized in Table 6.

Boophilus decoloratus

The recovery of a few adults in the present survey probably indicates the presence of cattle on the farms on which the ticks were collected as these animals are amongst the preferred domestic hosts of this species (Howell *et al.,* 1978). Large numbers of larvae and smaller numbers of nymphs and adults of this tick have been recovered from Merino sheep in the north-eastern Orange Free State and from some farms in the eastern Cape Province by Horak, Williams & Van Schalkwyk (1991). The differences between the adult tick numbers recorded in the present survey compared with those in the earlier survey in the north-eastern Orange Free State could be due to the different recovery techniques employed, or breed or habitat dissimilarities.

Rhipicephalus follis

The problems surrounding the identification of this tick have been discussed by Walker (1991). In the Karoo eland appear to be the preferred hosts of the adults, while Cape mountain zebras, black wildebeest and springbok examined at the same locality as the eland were also infested (Horak, Fourie, Novellie & Williams, 1991). Adults have also been recovered from bushbuck (Horak, Keep, Spickett & Boomker, 1989), gemsbok (Fourie *et al.,* 1991) and bushpigs (Horak, Boomker & Flamand, 1991). Cattle are the most frequently recorded domestic hosts (Baker, Ducasse, Sutherst & Maywald, 1989; Walker, 1991).

Except on eland, *R. follis* never occurs in large numbers. Nevertheless it is widely distributed in the south-eastern Transvaal, central Orange Free State, Natal and the south-eastern and southern Cape Province (Walker, 1991). In the present survey it was recovered from sheep within this distribution range.

Rhipicephalus glabroscutatum

The domestic hosts of all stages of this 2-host tick are cattle, sheep and goats (MacIvor, 1985; Horak & Knight, 1986). The preferred wild hosts are common duikers, gemsbok, kudus, eland and mountain reedbuck (Horak, Potgieter, Walker, De Vos & Boomker, 1983; MacIvor & Horak, 1987; Horak, Fourie, Novellie & Williams, 1991). The immature stages are also found on scrub hares (Horak & Fourie, 1991). Very few ticks were recovered from sheep in the current survey and then only in the southern and south-western Cape Province.

According to MacIvor (1985) *R. glabroscutatum* is found mainly in the south-eastern Cape Province, with a few records from the central and southern parts of the province. The farms on which the tick was recovered in the present survey all lie within the latter region. Although too few adults were recovered to determine a pattern of seasonal abundance all these ticks were collected during the period De-

TABLE 6 The abundance and geographic distribution of various ixodid tick species recovered in small numbers from Dorper sheep

Tick species	No. of ticks recovered			Farm	Region
	Males	Females	Total		
Boophilus decoloratus	0	1	1	Sandfontein	S.W. Cape
	0	9	9	Palmietfontein	N.E. O.F.S.
Rhipicephalus follis	4	14	18	Dieniedouw*	S. Cape
	2	1	3	The Knolls*	S. Cape
	1	0	1	Palmietfontein	N.E. O.F.S.
Rhipicephalus glabroscutatum	0	2	2	Pienaarskloof	S.W. Cape
	0	1	1	Sandfontein	S.W. Cape
	1	15	16	Dieniedouw*	S. Cape
	3	5	8	Klipfontein*	S. Cape
	3 nymphs		3	The Knolls*	S. Cape
Rhipicephalus neumanni	9	1	10	Bovlei	Far N.W. Cape
	1	0	1	Klipfontein*	S. Cape
Rhipicephalus sp. (near *R. oculatus*)	6	10	16	Klipfontein*	S. Cape
Rhipicephalus punctatus	3	6	9	Goedemoed	S. O.F.S.
	4	2	6	Driefontein	N.E. O.F.S.

* Sheep examined only until May or June 1989

cember to March. MacIvor & Horak (1987) recorded the largest numbers of adults from various hosts at several localities from July or August to February. The adults attach around and between the claws of their hosts' hooves and are a major contributory cause of foot abscess, and hence lameness, in goats. This condition is most frequently seen during the above-mentioned months (MacIvor & Horak, 1987).

Rhipicephalus neumanni

Sheep are the most commonly recorded hosts of this tick, whose adults also attach between the claws of the hooves and are a contributory cause of foot abscess and lameness (Walker, 1990).

Both localities at which *R. neumanni* was presently recovered lie outside its originally recorded distribution range. It is, however, common in southern Namibia (Walker, 1990) and its distribution probably extends into the far north-western Cape Province. The recovery of a specimen on the farm "Klipfontein" in the southern Cape Province supports the suggestion by Walker (1990) that it may be commoner in the Karoo than her records indicate.

All the ticks were collected during late January and during February.

Rhipicephalus sp. (near *R. oculatus)*

The species diagnosis of this tick and of *Ripicephalus oculatus sensu stricto* have been discussed by Walker (1991). It has been recovered from cattle, sheep and goats (Horak & Knight, 1986; Walker, 1991) and from gemsbok, kudu, springbok and scrub hares (Horak & Knight, 1986; Walker, 1991; Horak & Fourie, 1991). In South Africa this tick has previously been recorded only in the south-eastern Cape Province (Walker, 1991). The farm "Klipfontein" in the southern Cape Province, on which ticks were found in the current survey, lies further to the west.

Rhipicephalus punctatus

The confusion surrounding the identity of this tick in South Africa has been addressed by Walker (1991). In this country the adults have been recovered from goats (as a *Rhipicephalus pravus*-like tick), sheep [as *Rhipicephalus* sp. (near *R. pravus*)] and on cattle [as *Rhipicephalus* sp. (near *R. punctatus*)] (Fourie, Horak & Marais, 1988a,b; Fourie & Horak, 1990). It has also been recorded on various wild herbivores (Walker, 1991; Fourie *et al.*, 1991). All stages feed on scrub hares (Horak & Fourie, 1991) and only the immature stages on rock elephant shrews (Fourie *et al.*, 1988a; 1992).

In South Africa *R. punctatus* has been recorded in the western, northern and north-eastern Transvaal, the central and south-western Orange Free State and the adjacent north-eastern Cape Province (Fourie *et al.*, 1988a,b; 1991; Walker, 1991; Horak & Fourie, 1991). Its presence in the north-eastern Orange Free State in this survey constitutes a new record.

This tick has been associated with paralysis in Angora goat kids in the south-western Orange Free State (Fourie *et al.*, 1988a).

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Goats

Very few ticks were collected from Angora goats on fenced irrigated pastures within the Valley Bushveld region of the Eastern Cape Province (Fivaz, Horak & Williams 1990). However, goats browsing Valley Bushveld in the same area were more heavily infested, with *Haemaphysalis silacea*, *Rhipicephalus appendiculatus* and *Rhipicephalus glabroscutatum* being the dominant species (Horak, Knight & Williams 1991d). Other goats in Valley Bushveld, further towards the west in the province, were very heavily infested, and *Amblyomma hebraeum* and *R. glabroscutatum* were most numerous on these animals. [See MacIvor & Horak (2003) in the section on sympatric wild and domestic animals in Chapter 7)].

The dominant species on goats, examined on the same farm as cattle and sheep in south-western Free State Province, was *Rhipicephalus warburtoni* (then referred to as *Rhipicephalus punctatus*) (Fourie & Horak 1991). In Limpopo Province, where few ticks were recovered from goats, the immature stages of *A. hebraeum* and the adults of a tick belonging to the *Rhicephalus pravus* group of species, were most numerous (Boomker, Horak & Ramsay 1994), while in the southern Karoo, Eastern Cape Province, *R. glabroscutatum* was the dominant tick species (Horak, MacIvor & Greeff 2001a).

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HELMINTH AND ARTHROPOD PARASITES OF ANGORA GOATS ON IRRIGATED KIKUYU GRASS PASTURES IN THE EASTERN CAPE PROVINCE

B H FIVAZ*, I G HORAK** and E J WILLIAMS*

ABSTRACT

Angora goat kids and yearlings grazing irrigated Kikuyu (*Pennisetum clandestinum)* grass pastures in the eastern Cape Province, became heavily infected with *Teladorsagia circumcincta* and *Trichostrongylus rugatus,* leading to high mortality in both age groups. Peak burdens of the former were recorded during March and May, and of the latter during May and June. Larger numbers of the cestode *Moniezia expanza,* occurred in the kids than in the yearlings. Despite the stress of high helminth burdens, no clinical cases of coccidiosis were seen.

Both groups of goats were infested with small numbers of immature stages of the tortoise tick, *Amblyomma marmoreum,* and the yellow dog tick, *Haemaphysalis leachi.* Infestation with the biting louse, *Damalinia limbata,* occurred within 2 d of birth, but never reached very large numbers. Larvae of the nasal botfly, *Oestrus ovis,* were present only from January to July.

Key words: Angora goats, irrigated artificial pastures, *Teladorsagia circumcincta, Trichostrongylus rugatus, Moniezia exapansa, Damalinia limbata, Oestrus ovis*

Fivaz B.H.; Horak I.G.; Williams E.J. **Helminth and arthropod parasites of Angora goats on irrigated Kikuyu grass pastures in the eastern Cape Province.** *Journal of the South African Veterinary Association* (1990) 61 No. 3, 112-116 (En.) Tick Research Unit, Department of Zoology and Entomology, Rhodes University, 6140 Grahamstown, Republic of South Africa.

INTRODUCTION

Angora goats are farmed extensively in the drier regions of the Cape Province of South Africa. Stock losses caused by severe winters, tick-borne disease and predation by caracal *(Felis caracal)* may be high under extensive conditions and therefore there has been a shift towards the intensification of Angora goat farming on artificial pastures. While there is some information on the occurrence of internal and external parasites of Angora goats grazing various natural veld types[2 7 8 12], little is known of the prevalence of these parasites in or on goats on artificial pastures.

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This paper records the results of a survey of the parasites of Angora goats on irrigated Kikuyu grass *(Pennisetum clandestinum)* pastures on a property north of Grahamstown in the Great Fish River Valley, eastern Cape Province.

MATERIALS AND METHODS

Study site

The farm "Kranzdrift" (33°08'S; 26°31E; Alt 340 m) with a mean annual rainfall of 375 mm, is 5 000 ha in extent and situated 19 km north of Grahamstown in a vegetation zone classified as Valley Bushveld[1]. Fifteen ha is planted with Kikuyu grass and this is regularly irrigated by means of a centre-pivot sprinkler system.

Pastures

The pastures on which the survey animals grazed, consisted of 4x2 ha paddocks, planted with Kikuyu grass. These paddocks had been grazed intermittently throughout the year for a number of years by 20 to 30 stud goats, but remained ungrazed on occasions for periods of 1 to 2 months. The paddocks were irrigated at 1 to 2 weekly intervals throughout the year, depending on rainfall and usage. All the goats in the survey were run together and grazed rotationally in each camp for periods of 1 to 2 weeks.

Goats

Twenty-five Angora goat ewes, with new-born kids at foot and 48 yearling goats that had previously grazed Valley Bushveld camps, were transferred to the Kikuyu grass pastures during October 1987. All stock, except the new-born kids, were dipped in a pyrethroid-containing dip (Sumifleece, Shell Chemicals), and drenched with morantel citrate (Banminth, Pfizer Laboratories) at 12,5 mg kg^{-1} just prior to transfer.

In order to serve as tracers of infestation on the pastures, 4 yearling goats (tracers) were drenched with ivermectin (Ivomec liquid, Logos Agvet) at 0,2 mg kg^{-1} and niclosamide (Lintex L, Bayer SA) at 50 mg kg^{-1}. No post-drenching faecal examinations were conducted to determine the efficacy of the drugs. These goats grazed the pastures for 30 d prior to slaughter. Commencing from October and December 1987 respectively, 2 of the untreated young kids and the 4 tracer yearlings were slaughtered at monthly intervals. With the exception of the consecutive groups of 4 tracer animals, it was inteded that the survey goats remain untreated. However, a considerable increase in internal parasite burdens necessitated the treatment of all the remaining yearlings on 4 separate occasions (approximately 2 months apart) during the trial period. These animals were treated with ivermectin and morantel citrate alternately at dosages of 0,2 and 12,5 mg kg^{-1} respectively. The young kids were not treated at all.

As all the yearlings had died from severe helminth infection by May 1988, they were replaced by 20 others, which had in turn all died by September 1988. Goats which died, were excluded from

Table 1: **Mean faecal nematode egg and coccidial oocyst counts, and numbers of helminths recovered from suckling Angora goat kids on irrigated Kikuyu grass pastures**

Month	No of goats	Age at slaughter	Mean numbers of helminths recovered: *Haemonchus contortus* Adult	*Nematodirus spathiger* 4L	*Nematodirus spathiger* Adult	*Teladorsagia circumcincta* 4L	*Teladorsagia circumcincta* Adult	*Trichostrongylus rugatus* 4L	*Trichostrongylus rugatus* Adult	*Moniezia expansa* scoleces	Mean nematode egg count	Mean faecal oocyst count
Oct 1987	2	0	0	0	0	0	0	0	0	0	0	0
Nov	2	1	0	0	0	0	0	0	0	0	0	50
Dec	2	2	0	12	50	463	813	338	300	1	0	25 425
Jan 1988	2	3	1	150	188	475	2 163	25	4 925	5	1 400	32 200
Feb	2	4	1	100	12	825	3 600	100	3 838	4	3 500	25 850
Mar	3	5	1	401	141	2 036	5 146	773	21 678	7	4 800	8 750

4L = 4th Stage larvae

Table 2: **Mean faecal nematode egg and coccidial oocyst counts, and numbers of helminths recovered from yearling Angora goat tracers on irrigated Kikuyu grass pastures**

Month	No. of goats	Mean numbers of helminths recovered: *Haemonchus contortus* Ad	*Nematodirus spathiger* 4L	*Nematodirus spathiger* Ad	*Teladorsagia circumcincta* 4L	*Teladorsagia circumcincta* Ad	*Trichostrongylus rugatus* 4L	*Trichostrongylus rugatus* Ad	*Trichuris sp.* Ad	*Moniezia expansa* scoleces	Mean nematode egg count	Mean faecal oocyst count
Dec 1987	4	0	144	50	525	1 019	100	550	2	0	125	953
Jan 1988	4	0	506	556	513	3 144	156	9 813	0	0	1 225	2475
February	4	0	31	75	44	1 281	19	670	0	0	433	2 150
March	4	4	37	0	2 644	7 825	644	31 650	0	0	2 850	2 516
April	4	10	431	331	238	4 094	1 094	16 704	0	1	1 762	2 050
May	3	6	0	0	1 362	7 875	1 475	48 237	2	0	2 300	2 400
June	4	7	231	6	1 631	3 126	7 256	42 050	1	2	3 920	4 308
July	3	0	163	163	175	494	1 844	19 325	1	2	1 416	1 283
August	4	0	400	175	481	1 881	813	2 019	8	0	187	6 157
September	3	0	8	0	167	550	42	83	0	0	83	6 666

4L = 4th Stage larvae

the survey and were not processed for parasite recovery.

Necropsy

At slaughter the carcasses were skinned, decapitated and eviscerated and the skins, heads, lungs and gastro-intestinal tracts placed in separate plastic bags and transported to the laboratory for examination.

Faecal worm egg- and oocyst counts: Approximately 10 faecal pellets were collected from the rectum of each slaughtered goat and pooled in a composite sample. The pooled faecal pellets were thoroughly crushed and mixed in a mortar and pestle after which 4 g were weighed out and added to 46 ml of a 40% sucrose solution. This was followed by a further mix in a mortar and pestle, after which the contents were placed in a bottle and repeatedly inverted. Egg counts were carried out in the conventional manner, using a McMaster slide.

Helminth recovery and counting

Two 1/50 representative samples of the contents of both the abomasum and small intestine were sieved on a sieve with 38 μm apertures and 2, 1/50 representative samples of the contents of the large intestine were sieved on a sieve with 150 μm apertures. The mucosae of the abomasum, small intestine and large intestine were scraped separately and the scrapings were digested with pepsin/HCl prior to sieving on a sieve with 38 μm apertures. The contents of the sieves were collected, preserved with formalin and stored. Total worm burdens were calculated from the worms counted in the various representative samples and in the digested material.

Ectoparasite recovery and counting

The skins were processed for the recovery of arthropod parasites and the latter were counted and identified as previously described[5 6]. Nasal botfly larvae were recovered from the nasal passages and paranasal sinuses, identified to stage of development and counted[10].

RESULTS

The survey was intended to run for 1 year in both groups of goats. Hówever, all the kids had died after 5 months and all the yearlings, including the 20 that had been added to their number, after 11 months on the pastures.

Helminths and coccidia

Suckling kids

The worm burdens and faecal oocyst counts of the kids are summarised in Table 1. None of the kids slaughtered at a few days or at 1 month of age was infected. Thereafter nematode burdens, consisting mainly of *T. circumcincta* and *T. rugatus* increased steadily to reach approximately 30 000 worms in the last suckling kids slaughtered.

When kids from the survey group started dying at 3 months of age, during January 1988, the total burdens of the slaughtered kids, comprised approximately 8 000 worms.

Although the faecal oocyst counts reached fairly high levels, no cases of clinical coccidiosis occurred.

Tracer yearling goats

The worm burdens and faecal oocyst counts of the tracer yearling goasts are summarised in Table 2. The total worm burdens increased erratically from December 1987 (when the first tracers were slaughtered), to May and June 1988. The decreased thereafter to reach the lowest

levels in the last goats slaughtered during September 1988. As in the case of the suckling kids, *T. circumcincta* and *T. rugatus* were the dominant parasites, with the former reaching peak levels during March and May, and the latter during May and June 1988. There were several mortalities amongst the yearling goats once the total burdens in those yearlings that served as tracers had reached approximately 40 000 worms during March 1988.

The faecal worm egg counts (excluding *Nematodirus spathigher)* of the slaughtered yearling tracer goats, corresponded fairly closely with their total adult worm burdens (Fig. 1). The faecal oocyst counts of the tracers never reached very high levels (Table 2).

Arthropods

Suckling kids

The numbers of ixodid ticks, lice and larvae of the nasal botfly, *Oestrus ovis,* recovered from the suckling kids are summarised in Table 3.

A single larva of the tortoise tick, *Amblyomma marmoreum,* and 7 larvae and a single nymbph of the yellow dog tick, *Haemaphysalis leachi,* were recovered. The lice burdens rose steadily to reach the highest level in the last group of goats slaughtered during March 1988. Larvae of *O. ovis* were first recovered during February 1988 when the kids were 4 months old.

Tracer yearling goats

The ectoparasite burdens of the tracers are summarised in Table 4. Larvae of *A. marmoreum* reached peak numbers from April to June 1988 and a single nymph was collected during December 1987. Three larvae only of *H. leachi* were recovered. Peak burdens of lice were present during May and August 1988, and the larvae of *O. ovis* from January to July 1988.

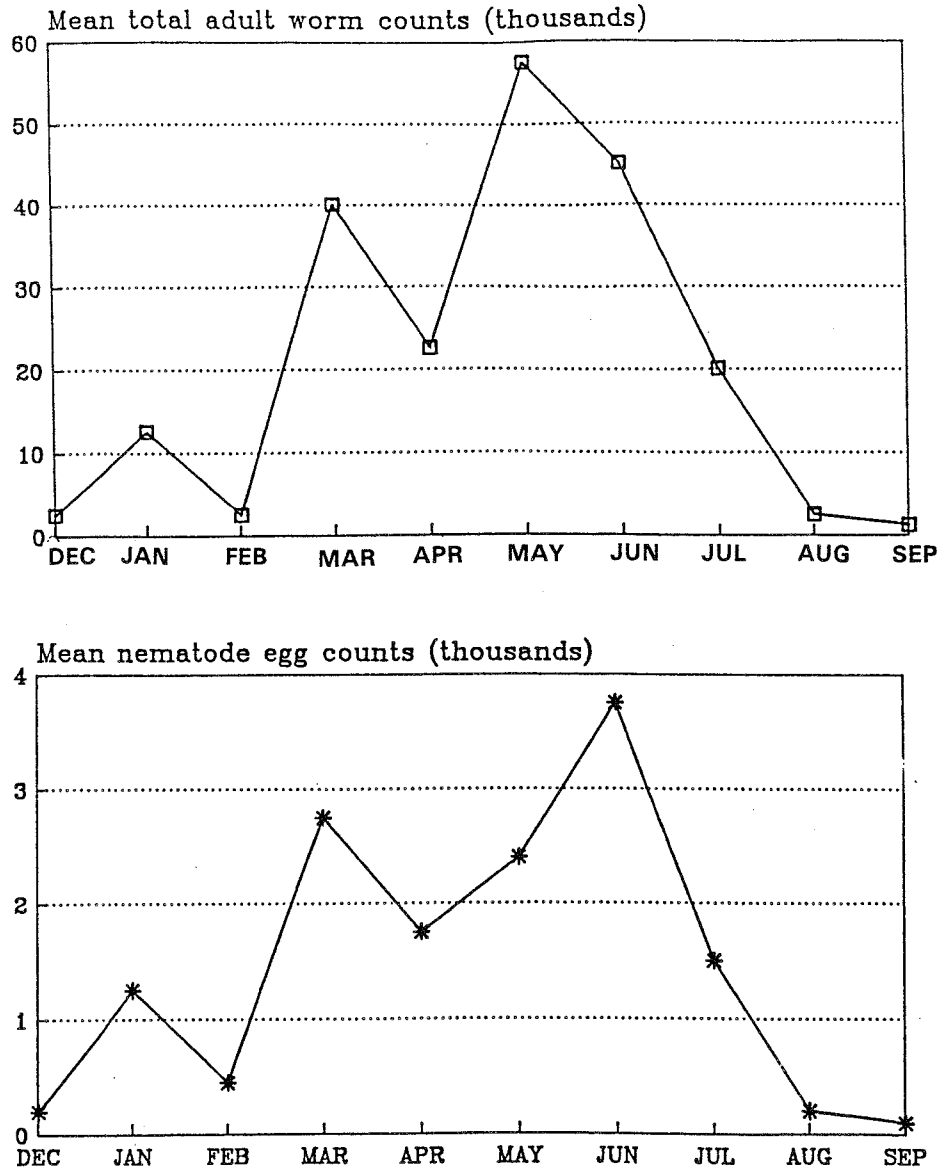

Fig. 1: **A comparison of the mean total adult worm burdens and mean faecal nematode egg counts of yearling Angora goat tracers grazing irrigated Kikuyu grass pastures**

DISCUSSION

Helminths

Nematodes

Low worm burdens have previously been recorded in Angora goat kids and adults reliant on natural browse for their nutritional requirements[2 7 8]. Horak[7 8] has recorded total worm burdens below 500 and 300 per head, respectively, in untreated Angora kids from birth to either 7 or 18 months running on 2 farms, one close to "Kranzdrift" in the Valley Bushveld, and the other in Noorsveld, in the Karoo. The dominant parasites in these kids were *T. rugatus* and *Strongyloides papillosus* in the Valley Bushveld and *N. spathiger* in the Karoo[7 8].

In the case of adult Angora goats, 2 surveys were conducted in Valley Bushveld, with *N. spathiger, T. circumcincta* and *Trichostrongylus pietersei* dominant in one[2], and *T. circumcincta* and *T. rugatus* in the other[7], which, incidentally had been conducted on a farm close to "Kranzdrift". Individual total burdens in these animals exceeded 5 000 worms in only 5 of the 72 goats examined.

The high total burdens encountered in the present surveys are undoubtedly closely related to absence of browse, the high stocking density, lush vegetation and regular irrigation. Despite these factors favourable for the survival and increase of nematode populations, only 3 species, namely *N. spathiger, T. circumcincta* and *T. rugatus* occurred in substantial numbers. It seems strange that *Haemonchus contortus,* which normally favours these conditions, never reached very large numbers, an observation also applying to Angora goats and sheep running in Valley Bushveld on a nearby farm[7]. One is left to speculate whether the macro-climate for this region, which seems inimical to the establishment of *H. contortus,* overrides the advantages of the micro-climate created by regular irrigation of artificially established pastures. Suppression of *H. contortus* by the large *T. circumcincta* infection, is a further possibility[15].

As could be expected, there appeared to be a direct relationship between the size or age of the goats and the size of the worm burdens which caused mortality[3]. The kids died when their total worm burdens exceeded approximately 8 000, the yearlings when these numbers exceeded 40 000 worms, and none of the adult ewes running with the kids died. Despite the death of all the experimental goats before the survey had run for one year, it was

Table 3: **Total numbers of ectoparasites recovered from suckling Angora goat kids on irrigated Kikuyu grass pasture**

Month	No. of goats	Age at slaughter (months)	Total numbers of ectoparasites recovered: Ixodid ticks *Amblyomma marmoreum* L	*Amblyomma marmoreum* N	*Haemaphysalis leachi* L	*Haemaphysalis leachi* N	Lice *Damalinia limbata* N	*Damalinia limbata* Ad	Oestrid larvae *Oestrus ovis* L 1, 2, 3
Oct 1987	2	0	1	0	1	0	4	22	0
Nov	2	1	0	0	4	1	202	70	0
Dec	2	2	0	0	0	0	366	138	0
Jan 1988	2	3	0	0	2	0	904	380	0
Feb	2	4	0	0	0	0	2236	1344	3
Mar	3	5	0	0	0	0	6588	5394	14

L = Larvae; N = Nymphs; Ad = Adults; L1, 2, 3 = Larval stages

Table 4: **Total numbers of ectoparasites recovered from yearling Angora goat tracers on irrigated Kikuyu grass pastures**

Month	No. of goats	Total numbers of ectoparasites recovered: Ixodid ticks *Amblyomma marmoreum* L	*Amblyomma marmoreum* N	*Haemaphysalis leachi* L	*Haemaphysalis leachi* N	Lice *Damalinia limbata* N	*Damalinia limbata* Ad	Oestrid larvae *Oestrus ovis* L 1, 2, 3
Dec 1987	4	1	1	2	0	1 816	3192	0
Jan 1988	4	0	0	0	0	2 576	2176	11
Feb	4	0	0	0	0	10 652	5380	2
Mar*	4	2	0	0	0	4 168	5580	18
April	4	80	0	0	0	4 188	4352	12
May**	3	35	0	1	0	11 103	10551	12
June	4	17	0	0	0	3 716	3124	12
July	3	3	0	0	0	2 397	2736	6
Aug	4	1	0	0	0	15 280	18036	0
Sept	3	2	0	0	0	6 486	4434	0

**Hyalomma* sp. 1 female
***Rhipicephalus simus* 1 L
L = Larvae; N = Nymphs; Ad = Adult; L1, 2, 3 = Larval stages

possible to ascertain seasonal abundance in the yearling goats during the 10 months of the survey. As both *T. circumcincta* and *T. rugatus* (the major parasites) exhibited similar trends in their seasonal abundance, they will be discussed together.

Worm burdens of the tracer yearling goats, rose erratically but steadily to reach a peak in May and June 1988. Thereafter they declined to reach the lowest levels during September 1988, when the investigation was terminated (Fig 1). The most favourable time for the acquisition of infection appeared to be from late summer (March) to early winter (June). This corresponds to the concept that these worm genera, generally prefer cooler conditions[13]. It contrasts, however, with the findings of 2 other surveys conducted on Angora goats running in Valley Bushveld. In these surveys, total worm burdens were generally higher from August or September to January then were those from February to July[2 7]. It would thus appear as if the micro-climatic conditions pertaining on the irrigated pastures, overrode those of the macro-climate for the region, resulting in an altered pattern of seasonal abundance for *T. circumcincta* and *T. rugatus* in contrast to *H. contortus,* for which the converse seemed to be true.

The mean total faecal worm egg counts (excluding *N. spathiger)* closely corresponded to the mean total adult worm burdens of the tracer yearling goats. In this instance, faecal worm egg counts could therefore be used as an indicator of total adult worm burdens and also of pasture contamination. If, however, large numbers of worms are arrested in their development in the host animal because of previous climatic stimuli, or where older hosts are used and a degree of immunity is present, worm egg counts do not accurately reflect the total worm burdens.

Cestodes

During surveys conducted on Angora goat kids in Valley Bushveld on a farm near "Kranzdrift" and on another in the Karoo, the kids became infected with *Moniezia expansa* during January when they were 3 or 4 months old[7 8]. The kids in Valley Bushveld were accidentally

treated with a cestocide during February, while those in the Karoo, spontaneously lost their infection by April. In the present survey, the kids were first infected in December 1987 at the age of 2 months and infection was still present during March 1988 when the survey ended. Several of the tracer yearling goats were also infected (Table 2), whereas in the Karoo only 1 of 90 yearling goats harboured a single *M. expansa*[7]. Immunity to cestodes in the former yearling goats, may have been affected by the stress induced by the large nematode burdens.

Arthropods

Ixodid ticks

Adult *A. marmoreum* prefer tortoises as hosts, while the immature stages can be found on reptiles, birds and mammals[9 14]. There are large numbers of tortoises in the Valley Bushveld region in which the survey was conducted and most mammal species in this area are infested with the immature stages of *A. marmoreum*[9]. It is quite probable that tortoises also feed on the irrigated pastures at "Kranzdrift" and that the tick larvae on the goats, originate from adult ticks that have detached from the tortoises. The seasonal pattern of larval abundance on the yearling goats, corresponds to that observed by Norval[11] for *A. marmoreum* in the eastern Cape Province.

The immature *H. leachi* on the goats, probably originate from adult ticks on the sheep-dogs used to herd the stock.

Lice

With the possible exceptions of May and August 1988 (Table 4), the burdens of *D. limbata* were never very large on any of the goats and no clear pattern of seasonal abundance could be discerned. The kids were already infested at 2 d of age.

Oestrid fly larvae

The kids became infested with the larvae of *O. ovis* for the first time at 4 months of age, during February 1988. Infestation was, however, already present during January, as evidenced in the yearling goats. The seasonal pattern of infestation in the latter goats from January to July, differs from that observed in sheep slaughtered at the Pretoria Municipal Abattoir, where infestation mainly occurred from October to May or June[4].

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THE SEASONAL ACTIVITY OF ADULT IXODID TICKS ON ANGORA GOATS IN THE SOUTH WESTERN ORANGE FREE STATE

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ABSTRACT

Adult ixodid ticks were collected at 2-weekly intervals for a period of 23 consecutive months from 15 to 20 Angora goats on a farm in the south western Orange Free State. A total of 6 ixodid tick species were recovered. *Rhipicephalus punctatus* was the most abundant and prevalent tick. It was present from spring to late summer. *Ixodes rubicundus* was the next most abundant tick and was present mainly from March or April to July with peak numbers present in April or May. The onset of this tick's activity appeared to be stimulated by low atmospheric temperatures.

Key words: Angora goats, ixodid ticks, seasonal activity

Fourie L.J.; Horak I.G. **The seasonal activity of adult ixodid ticks on Angora goats in the south western Orange Free State.** *Journal of the South African Veterinary Association* (1991) 62 No. 3, 104-106 (En.) Department of Zoology and Entomology, University of the Orange Free State, 9301 Bloemfontein, Republic of South Africa.

INTRODUCTION

Although sheep and cattle comprise the major portion of the livestock industry in the southern Orange Free State, about 60 000 Angora goats are also farmed in this province. Some research on tick infestation of Angora goats has been done in the eastern Cape Province[6 7 8] and the mortality of Angora goats caused by a paralysis-inducing tick species occurring in the southern Orange Free State has been recorded[2]. The present paper describes the seasonal activity of adult ixodid ticks on Angora goats on a farm in the south western Orange Free State. Similar studies on sheep and cattle on this farm have already been published[3 5].

MATERIALS AND METHODS

The study was conducted on the farm "Preezfontein", which is situated 10 km from the town of Fauresmith (29° 46'S; 25° 19'E) in the south western Orange Free State. The farm comprises an area approximately 6 000 ha in extent and topographically consists of flat as well as hilly ground. The vegetation in the area is defined as False Upper Karoo[1]. A fenced camp on the farm, encompassing 190 ha of vegetation typical of the region, was selected for this study.

The climate is semi-arid, with 69% of the annual rainfall occurring during the summer months. Mild to severe droughts occur periodically. Air temperatures exhibit major circadian and seasonal fluctuations with absolute temperatures varying between 39°C and -6,3°C. Total monthly rainfall during the study period was recorded at "Preezfontein" and mean maximum and minimum temperatures were obtained from a weather station at Fauresmith.

Four age and sex class categories of Angora goats were used, namely adult ewes, adult wethers, young wethers (7 months old) and kids. Each group initially consisted of 10 animals. Because tick-induced paralysis and other causes resulted in mortality, the groups of young goats and kids eventually contained between 5 and 10 animals each. The study on adult and young goats started during March 1988. During October 1988, the ewes on the farm kidded and their kids became the fourth group. During March 1989 the young wethers were excluded from the study and the kids born during the previous year were then considered as the young goat group. Angora ewes on the farm kidded again during December 1989, and the first observations on the second group of kids were made during January 1990.

Five animals belonging to each of the 3 or 4 survey groups were examined for ticks at 2-weekly intervals from March 1988 to January 1990. Each body region was carefully searched by parting the hair and visually inspecting the epidermis. All the adult ixodid ticks found were collected, placed in labelled bottles, identified and counted using a stereoscopic microscope. Burdens were expressed in terms of infestation density (numbers of ticks per kg host mass) and results presented in tabular and graphical form. To test for significant differences between sex ratios a Chi-squared test was used. Where reference is made to tick activity, it is inferred that these ticks actively quest for hosts either from the ground or from vantage points on the vegetation and then enter the parasitic phase of their life cycles.

In order to quantify seasonal abundance, the tick infestation densities of the various groups of goats were pooled. Except for *I. rubicundus* and *R. punctatus*, the numbers of the other tick species were too low to determine seasonal tendencies.

RESULTS

Total monthly rainfall and mean atmospheric temperatures are graphically illustrated in Fig. 1 & 2.

The total numbers and relative abundance of adult ixodid ticks collected from the goats are summarised in Table 1. Except for *Rhipicephalus evertsi evertsi* and *Rhipicephalus gertrudae*, where the sample sizes were too small, there were significant differences ($p < 0,05$) in the sex ratios of male to female ticks. With the exception of *I. rubicundus*, more male than female ticks were present on the goats.

The seasonal abundances of *I. rubicundus* and *R. punctatus* are graphically illustrated in Fig. 3 & 4.

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Table 1: **Adult ixodid ticks collected from Angora goats on the farm "Preezfontein"**

Tick species	Numbers recovered: Males	Females	Total	Relative abundance	% goats infested
Hyalomma marginatum rufipes	33	8	41	0,69	3,6
Hyalomma truncatum	45	27	72	1,21	4,7
Ixodes rubicundus	897	1155	2052	34,34	36,2
Rhipicephalus evertsi evertsi	3	0	3	0,05	1,4
Rhipicephalus gertrudae	16	10	26	0,44	0,4
Rhipicephalus punctatus	2084	1698	3782	63,29	53,6

the long term, differentially affect the epidemiology of the toxicoses caused.

Hyalomma truncatum was the most abundant of the 2 *Hyalomma* species collected. Most (>65%) of these ticks were collected during the summer months (January - March). The relatively low number collected from goats in the present study, suggests either that these animals are poor hosts of these ticks or that Angora goats minimise contact with the ticks through behavioural patterns. Both *H. marginatum rufipes* and *H. truncatum* seek hosts from the ground and not from the vegetation and this may affect tick/host contact.

Although free-living, newly moulted adult *I. rubicundus* are already present during December or January (summer), this tick is parasitic virtually only during the winter months, and it is reasonable to assume that low temperatures stimulate the onset of tick activity. A comparison of mean minimum temperatures for 1988 and 1989 shows that those for the 3 months preceding tick activity (January-March) were lower during 1989 than during the 1988 season. During March 1989

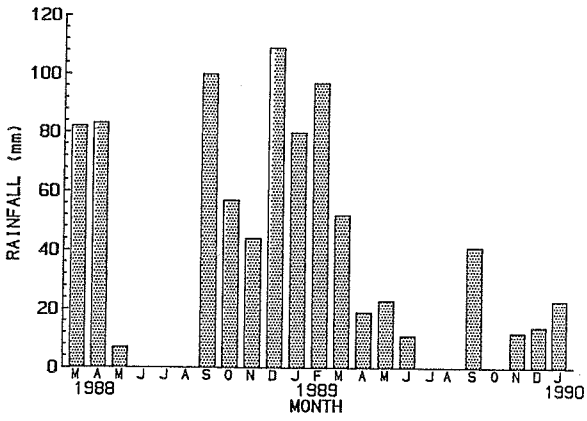

Fig. 1: **Total monthly rainfall on the farm "Preezfontein" from March 1988 to January 1990**

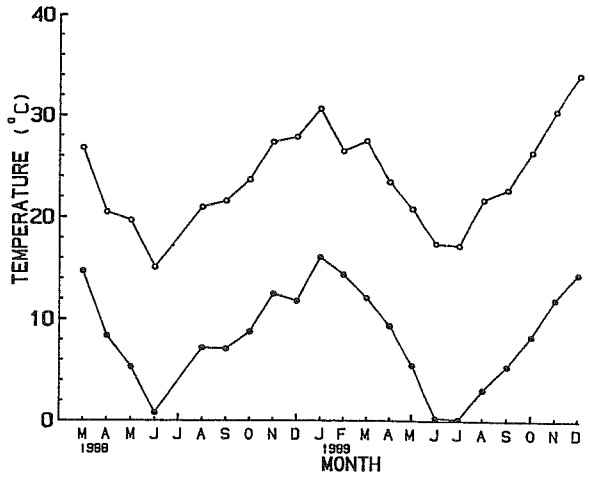

Fig. 2: **Mean monthly minimum and maximum temperatures at Fauresmith for the period March 1988 to December 1989**

DISCUSSION

There are some differences in the relative abundance of adult ticks of the various species infesting the goats and those recovered from sheep and cattle examined on the same farm in previous surveys. The relative abundances of the 4 major tick species recovered from the 3 host species on the farm, are summarised in Table 2.

Hyalomma marginatum rufipes was proportionately most abundant on cattle, *I. rubicundus* on sheep and *R. punctatus* on the goats. *H. marginatum rufipes* was least abundant on the goats, *Hyalomma truncatum* on the sheep and *I. rubicundus* on the cattle. These differences in relative abundance are probably due either to host preference of the ticks, to habitat preference of the ticks or hosts, or to behavioural differences of the hosts which may affect tick-host contacts. Accordingly, depending on the number and type of hosts frequenting a specific area, the numbers of ticks within this area may increase because of the greater availability of suitable hosts. Since *H. truncatum, I. rubicundus* and *R. punctatus* can all cause tick toxicosis[2,4], stocking densities may, in minimum temperatures fell below 10°C on 6 occasions, compared to only once during March 1988. This may explain why infestation occurred about one month earlier during 1989 than in 1988.

The variation in the commencement of tick activity and peak activity periods between years is significant. In an earlier survey on sheep *I. rubicundus* became active on "Preezfontein" during April 1987 and reached a peak during May[3]. In both surveys, tick burdens reached a peak within 4 weeks after the commencement of the activity.

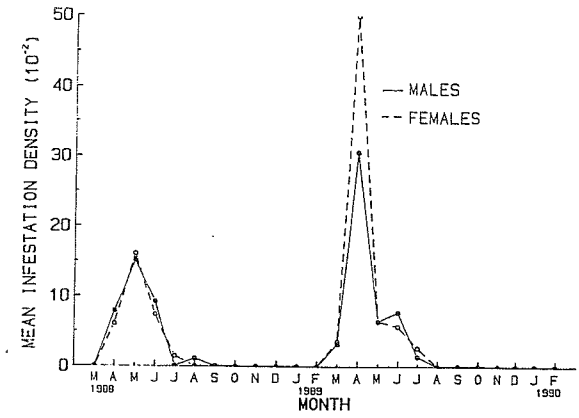

Fig. 3: **The seasonal abundance of adult *Ixodes rubicundus* on Angora goats on the farm "Preezfontein" in the south western Orange Free State (infestation density = number of ticks per kg host body mass)**

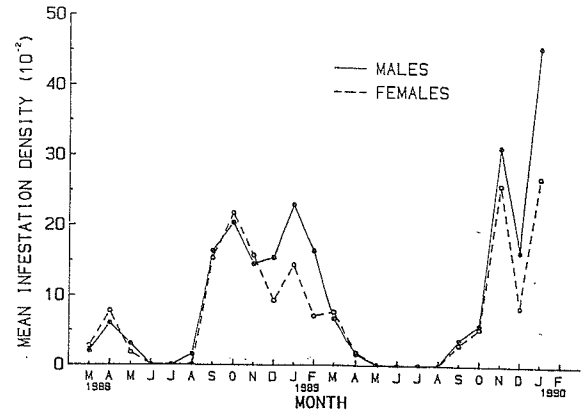

Fig. 4: **The seasonal abundance of adult *Rhipicephalus punctatus* on Angora goats on the farm "Preezfontein" in the south western Orange Free State (infestation density = number of ticks per kg host body mass)**

It is important to know when the ticks become active in order to remove stock from infested camps or apply acaracidal treatment before peak burdens are reached. On farms in the southern Orange Free State and parts of the Karoo, where these precautions were not taken during 1989, the earlier than expected activity of the ticks caused severe stock losses, with reports of up to 100 small stock mortalities on a single property not uncommon. The development of a weather-based model in order to predict the onset of tick activity is therefore regarded as a high priority and is currently receiving attention.

Unlike *I. rubicundus* the period of activity of *R. punctatus* commenced one month later in 1989 than during 1988. One could speculate that as this tick normally prefers the warmer temperatures of spring and summer, the colder winter of 1989 delayed the onset of its activity during that year.

ACKNOWLEDGEMENTS

We wish to thank Mrs C Human and Messrs L Barkhuisen, M van Straatten and J van Niekerk. This research was funded by the Wool and Meat Boards, the Foundation for Research Development, Bayer Animal Health and Shell Animal Health.

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Table2 : **The relative abundance of the major tick species recovered from goats, sheep and cattle on the farm "Preezfontein"**

Tick species	Relative abundance (%) on: Goats	Sheep	Cattle
Hyalomma marginatum rufipes	0,7	16,3	36,2
Hyalomma truncatum	1,2	0,1	7,1
Ixodes rubicundus	34,3	82,2	3,2
Rhipicephalus punctatus	63,3	1,3	9,4
Other species	0,5	0,1	44,1

Onderstepoort J. vet. Res., 58, 253–260 (1991)

PARASITES OF DOMESTIC AND WILD ANIMALS IN SOUTH AFRICA. XXVIII. HELMINTH AND ARTHROPOD PARASITES OF ANGORA GOATS AND KIDS IN VALLEY BUSHVELD

I. G. HORAK[1], M. M. KNIGHT[2] and E. J. WILLIAMS[2]

ABSTRACT

HORAK, I. G., KNIGHT, M. M. & WILLIAMS, E. J., 1991. Parasites of domestic and wild animals in South Africa. XXVIII. Helminth and arthropod parasites of Angora goats and kids in Valley Bushveld. *Onderstepoort Journal of Veterinary Research*, 58, 253–260 (1991)

Two adult Angora goats were slaughtered each month for 24 consecutive months on a farm in Valley Bushveld in the eastern Cape Province. On the same farm 2 Angora goat kids were slaughtered each month for 2 consecutive years from the time they were 1 week old until they reached 12 months of age. All these goats were processed for the recovery of helminth and arthropod parasites.

Fourteen nematode species, 2 nematode genera and 1 cestode species were recovered. Worm burdens were generally low in the adult goats. Nematode burdens increased erratically in the kids reaching the greatest numbers when they were 1 year old. The tapeworm, *Moniezia expansa*, was present in kids at 3 or 4 months of age and had usually disappeared by the time they reached 7 months of age.

The goats harboured 12 species of ixodid ticks, 1 louse species and the larvae of an oestrid fly. The seasonal abundances of 4 of the tick species were determined.

INTRODUCTION

Angora goats are farmed extensively in the Karoo and Valley Bushveld regions of the eastern Cape Province. They are mainly browsers (Aucamp, 1979), but will graze when placed on artificial pastures.

A number of studies on the parasites of these animals in the Valley Bushveld have already been published. Horak (1987a) and Boomker, Horak & MacIvor (1989) have examined the internal parasites, MacIvor & Horak (1984), Horak (1987b) and Fivaz, Horak & Williams (1990) have reported on both the helminth and arthropod parasites, and Rechav (1982), Horak & Knight (1986) and MacIvor & Horak (1987) on the ticks infesting Angora goats. Horak (1987b) and Fivaz *et al.* (1990) have also recorded the parasite burdens of kids from 1 week to 5 or 6 months of age. The research of Fivaz *et al.* (1990) was conducted on goats grazing irrigated Kikuyu grass pastures on a farm in the Valley Bushveld region, while the other surveys were done on goats browsing natural vegetation in this region.

Numerous surveys of parasites of domestic and wild animals have already been conducted on the farm "Bucklands", the locality of the present survey. These include kudu (Knight & Rechav, 1978; Boomker, Horak & Knight, 1991), Angora goats and cattle (Rechav, 1982), Dorper sheep, Angora goats, cattle, kudu, scrub hares and helmeted guineafowls (Horak & Knight, 1986), scrub hares (Horak & MacIvor, 1987), cattle (MacIvor & Horak, 1987), Angora goat kids (Horak, 1987b), Dorper sheep (Horak, Williams & Van Schalkwyk , 1991) and helmeted guineafowls (Horak, Spickett, Braack & Williams, 1991). Two studies on the seasonal abundance of free-living tick larvae have also been conducted on the farm (Rechav, 1982; Petney & Horak, 1987).

The present paper records the abundance of nematode and arthropod parasites of adult Angora goats slaughtered at monthly intervals over a 24 month period on the farm "Bucklands". It also describes the parasite burdens of Angora goat kids from the time they were 1 week of age until they were 12 months old, during 2 consecutive years. The results presented in this paper are a direct extension of those reported by Horak & Knight (1986) and Horak (1987a,b).

MATERIALS AND METHODS

Study site

The farm "Bucklands" (33° 06′ S, 26° 41′ E) is 5 480 ha in extent and is situated 28 km north-east of Grahamstown in the eastern Cape Province. The vegetation is classified as Valley Bushveld (Acocks, 1988). A more detailed description of it has been given by Rechav (1982). At the time of the survey there were approximately 185 cattle, 300 Dorper sheep, 4 000 Angora goats and 300 free-ranging kudu on the farm.

Survey animals

Two 4–6 year old Angora goats, that had not been treated with an anthelmintic or an acaricide during the preceding 3 months, and which ran with a flock of adult Angora goats, were slaughtered at monthly intervals from February 1985 to January 1987. Except for August 1988 when no kids were slaughtered, 2 Angora goat kids, born during September of 2 consecutive years (1986 and 1987), were slaughtered at approximately monthly intervals from the time they were 1 week old until they were 12 months of age. These kids ran with their dams until weaning and thereafter with goats of their own age. With the exception of the kids born during September 1986, which were accidentally treated with a cestocide during January 1987 and with a nematocide in April 1987, no other antiparasitic treatments were administered.

Parasite recovery

The lungs, liver, abomasum, small intestine and large intestine of each goat were processed for helminth recovery as described by Boomker *et al.* (1989). Two aliquots, each representing $^1/_{50}$th of the volume of the ingesta of the latter 3 organs, were made. These aliquots and the other material were examined under a stereoscopic microscope and the worms counted. Adult worms and larvae were collected, cleared in lactophenol and identified under a standard microscope.

The skins of the goats were processed for ectoparasite recovery as described by Horak, Meltzer &

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TABLE 1 Helminths recovered from 48 adult Angora goats on the farm "Bucklands" in Valley Bushveld

Helminth species	Total numbers of worms recovered			Number of animals infected
Nematodes	4th stage	Adults	Total	
Cooperia pectinata	0	700	700	7
Haemonchus contortus	0	1 277	1 277	19
Nematodirus spathiger	1 767	4 092	5 859	31
Oesophagostomum venulosum	0	126	126	19
Skrjabinema sp.	49 825 (all stages)		49 825	45
Strongyloides papillosus	25	10 525	10 550	37
Ostertagia/Teladorsagia spp.	636	—	636	18
Ostertagia ostertagi	—	5	5	1
Teladorsagia circumcincta	—	16 277	16 277	47
Teladorsagia trifurcata	—	160	160	3
Trichostrongylus spp.	87	—	87	5
Trichostrongylus axei	—	5 370	5 370	35
Trichostrongylus colubriformis	—	125	125	2
Trichostrongylus pietersei	—	764	764	10
Trichostrongylus rugatus	—	73 944	73 944	46
Trichuris sp.	0	6	6	4

TABLE 2 Helminths recovered from 50 Angora goat kids on the farm "Bucklands" in Valley Bushveld

Helminth species	Total numbers of worms recovered			Number of animals infected
Nematodes	4th stage	Adults	Total	
Cooperia spp.	25	—	25	1
Cooperia pectinata	—	375	375	7
Cooperia punctata	—	150	150	1
Haemonchus contortus	0	202	202	12
Namatodirus helvetianus	0	25	25	1
Nematodirus spathiger	1 100	3 825	4 925	21
Oesophagostomum venulosum	0	132	132	18
Skrjabinema sp.	47 825 (all stages)		47 825	31
Strongyloides papillosus	0	5 400	5 400	27
Teladorsagia circumcincta	25	901	926	9
Trichostrongylus spp.	5 985	—	5 985	10
Trichostrongylus axei	—	3 870	3 870	25
Trichostrongylus pietersei	—	325	325	10
Trichostrongylus rugatus	—	40 085	40 085	28
Trichuris sp.	0	159	159	30
Cestodes		Scoleces	Total	
Moniezia expansa		48	48	13

De Vos (1982). The processed material was examined under a stereoscopic microscope and the arthropods collected, identified and counted.

Oestrid fly larvae were collected from the nasal passages and sinuses as described by Malan, Reinecke & Scialdo (1981).

RESULTS

Helminths

The total numbers of helminths recovered from the 48 adult goats examined on "Bucklands" are summarized in Table 1.

Twelve species of nematodes and 2 nematode genera were recovered, of these *Trichostrongylus rugatus* followed by *Skrjabinema* sp. were the most abundant. The most prevalent worms were *Teladorsagia circumcincta* followed by *Trichostrongylus rugatus*.

Excluding the *Skrjabinema* sp., the monthly mean total numbers of nematodes recovered are graphically presented in Fig. 1.

In the first year of the survey, the 6 months during which goats had the highest burdens were July, August and October 1985 to January 1986, in the second year these months were March and Septem-

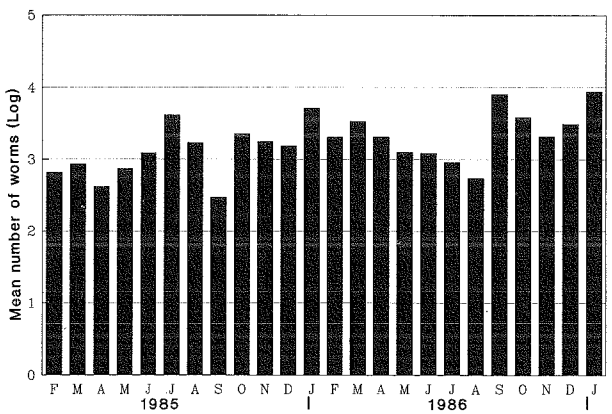

FIG. 1 The seasonal abundance of nematodes in adult Angora goats on the farm "Bucklands" in Valley Bushveld

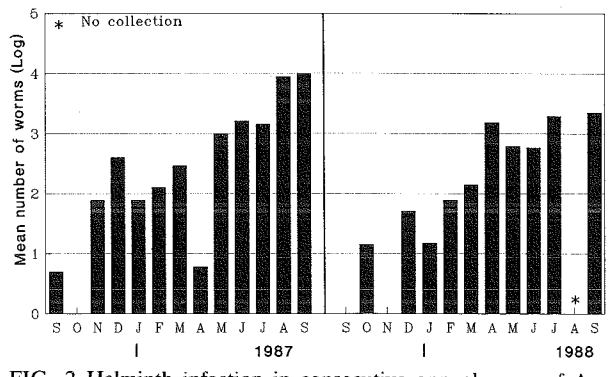

FIG. 2 Helminth infection in consecutive annual crops of Angora goat kids from 1 week to 12 months of age on the farm "Bucklands" in Valley Bushveld

TABLE 3 Ectoparasites recovered from 48 adult Angora goats on the farm "Bucklands" in Valley Bushveld

Ectoparasite species	Total No. of ectoparasites recovered					Number of animals infested
Ixodid ticks	Larvae	Nymphs	Males	Females	Total	
Amblyomma hebraeum	156	80	8	8	252	25
Amblyomma marmoreum	523	24	0	0	547	26
Boophilus decoloratus	22	0	0	6 (4)	28	5
Haemaphysalis leachi	2	0	0	0	2	1
Haemaphysalis silacea	1 253	299	38	12 (6)	1 602	43
Hyalomma marginatum rufipes	0	0	1	0	1	1
Ixodes pilosus	2	2	0	0	4	1
Rhipicephalus appendiculatus	1 710	248	20	40 (2)	2 018	40
Rhipicephalus evertsi evertsi	160	8	3	0	171	18
Rhipicephalus glabroscutatum	1 886	808	243	134 (16)	3 071	46
Rhipicephalus sp. (near *R. oculatus)*	0	0	6	2	8	3
Rhipicephalus simus	0	0	0	2	2	1
Lice	Nymphs		Adults		Total	
Damalinia limbata	63 619		68 092		131 711	48
Oestrid fly larvae	1st stage	2nd stage	3rd stage		Total	
Oestrus ovis	87	27	33		147	23

( ) = Number of maturing females, i.e. idiosoma of *B. decoloratus* > 4,0 mm; *H. silacea* > 5,0 mm; *R. appendiculatus* > 5,0 mm, and *R. glabroscutatum* > 4,5 mm in length. Females of the other tick species had not started maturing.

TABLE 4 Ectoparasites recovered from 50 Angora goat kids on the farm "Bucklands" in Valley Bushveld

Ectoparasite species	Total No. of ectoparasites recovered					Number of animals infested
Ixodid ticks	Larvae	Nymphs	Males	Females	Total	
Amblyomma hebraeum	32	49	2	0	83	20
Amblyomma marmoreum	92	34	0	0	126	24
Boophilus decoloratus	4	0	0	0	4	2
Haemaphysalis leachi	90	0	0	0	90	10
Haemaphysalis silacea	1 355	582	32	24 (14)	1 993	46
Ixodes pilosus	16	2	0	0	18	2
Rhipicephalus appendiculatus	2 154	1 051	20	40 (8)	3 265	42
Rhipicephalus evertsi evertsi	16	12	3	2	33	11
Rhipicephalus glabroscutatum	1 047	241	96	104 (16)	1 488	45
Rhipicephalus simus	0	0	2	6	8	3
Lice	Nymphs		Adults		Total	
Damalinia limbata	131 540		84 501		216 041	49
Oestrid fly larvae	1st stage	2nd stage	3rd stage		Total	
Oestrus ovis	75	12	10		97	18

( ) = Number of maturing females, i.e. idiosoma of *H. silacea* > 5,0 mm; *R. appendiculatus* > 5,0 mm, and *R. glabroscutatum* > 4,5 mm in length. Females of the other tick species had not started to mature

ber 1986 to January 1987. However, the differences in the magnitude of the worm burdens were not statistically significant (t test, P = 0,05).

The total numbers of helminths recovered from the 50 goat kids are summarized in Table 2.

Thirteen nematode species were recovered and *Skrjabinema* sp. followed by *Trichostrongylus rugatus* were the most abundant and *Skrjabinema* sp. and *Trichuris* sp. the most prevalent. Thirteen of the kids were infected with *Moniezia expansa.*

Excluding the *Skrjabinema* sp., the monthly nematode burdens of the kids are illustrated in Fig. 2.

No worms were recovered during October from the 1986 crop of kids and during September and November from the 1987 crop of kids. In both years infection increased erratically but steadily reaching the highst levels when the kids were 12 months old. The final worm burden (September 1987) was significantly higher (t test, P = 0,05) in the first crop of kids than in the second (September 1988).

Both kids of the 1986 crop examined during January 1987 were infected with *M. expansa*. The remaining kids of that crop were thereafter accidentally treated with a cestocide. Two kids each harboured 1 cestode later in the survey. All the kids examined of the next year's crop were infected with *M. expansa* from December 1987 to February 1988 as well as 1 each during March, April and July 1988.

Arthropods

The total numbers of ectoparasites recovered from the adult goats are summarized in Table 3.

The goats were infested with 12 species of ixodid ticks, of which *Rhipicephalus glabroscutatum* was the most abundant and prevalent. They were also all infested with *Damalinia limbata* and less than half with the larvae of *Oestrus ovis.*

The arthropod parasites recovered from the kids are summarized in Table 4.

The kids were infested with 10 ixodid tick species of which *Rhipicephalus appendiculatus* was the most abundant and *Haemaphysalis silacea* the most prevalent. With 1 exception they were all infested with *D. limbata* and 18 harboured the larvae of *O. ovis.*

Only *Amblyomma marmoreum, H. silacea, R. appendiculatus* and *R. glabroscutatum* exhibited

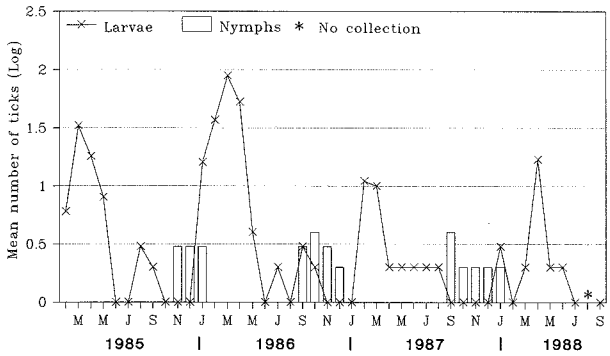

FIG 3 The seasonal abundance of *Amblyomma marmoreum* on Angora goats and kids on the farm "Bucklands" in Valley Bushveld

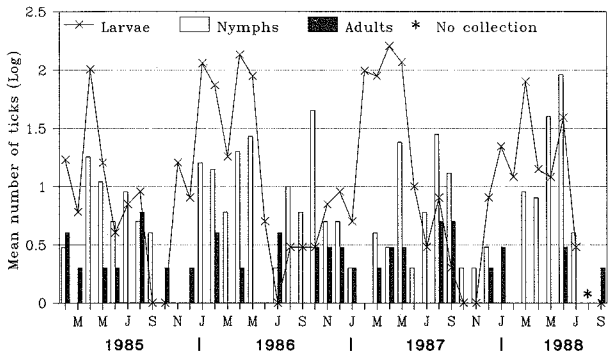

FIG 4 The seasonal abundance of *Haemaphysalis silacea* on Angora goats and kids on the farm "Bucklands" in Valley Bushveld

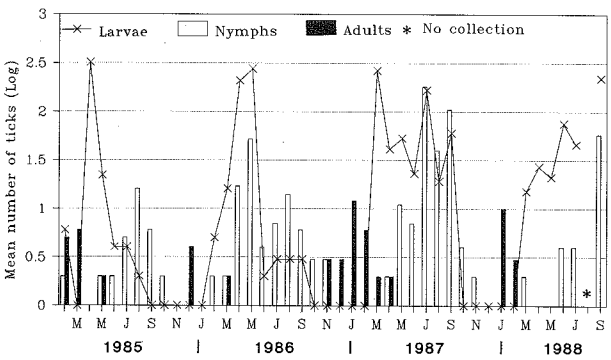

FIG 5 The seasonal abundance of *Rhipicephalus appendiculatus* on Angora goats and kids on the farm "Bucklands" in Valley Bushveld

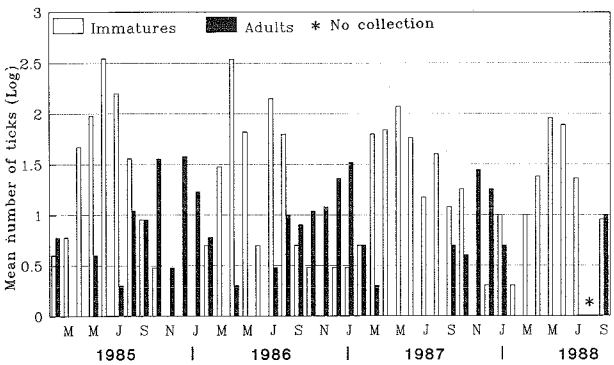

FIG 6 The seasonal abundance of *Rhipicephalus glabroscutatum* on Angora goats and kids on the farm "Bucklands" in Valley Bushveld

clear patterns of seasonal abundance on both the goats and the kids and these are illustrated in Fig. 3–6.

Comment: Slaughtering of adult goats and kids overlapped from September 1986 to January 1987. The tick burdens of the adult goats alone are illustrated in the figures from February 1985 to August 1986, those of the adults and kids combined from September 1986 to January 1987, and those of the kids alone from February 1987 until the end of the survey in September 1988.

The larvae of *A. marmoreum* were usually present in the largest numbers from February to April and the nymphs during the period September to January. The larvae of *H. silacea* were generally most abundant from January to June and the nymphs erratically from around March to September. *R. appendiculatus* larvae were present from about March to September and the nymphs from about April or May till September. The largest numbers of adults were present during January and February. The larvae and nymphs of the 2-host tick, *R. glabroscutatum* have been combined and were most abundant from February or March to August or September and the adults from about September to February.

DISCUSSION

Helminths

The nematode burdens are low considering that the adult goats were only occasionally treated with an anthelmintic while 1 crop of kids was treated twice and the other never. The reasons for this are probably three-fold. Firstly the climate of the Valley Bushveld is harsh, adversely affecting the survival of the free-living stages, secondly ground cover and hence protection for the free-living larvae in the form of grass is sparse, and thirdly Angora goats are mainly browsers and because of this they generally feed above ground level and thus do not ingest many infective larvae.

Boomker *et al.* (1989) recovered 8 nematode species and 2 nematode genera from adult Angora goats on the farm "Brakhill" in Valley Bushveld near Uitenhage in the eastern Cape Province. Excluding *Skrjabinema* sp. they recorded mean burdens of 595 worms. They also recovered 12 nematode species, 2 nematode genera and mean burdens of 1 170 worms from Boer goats on the same farm. The mean burden of 2 414 worms, excluding *Skrjabinema* sp., recovered from the adult goats in the present survey probably indicates a milder climate, greater ground cover and more grazing at "Bucklands". Nine species of nematodes and two nematode genera were common to the goats at the 2 localities.

Exluding *Cooperia pectinata, Cooperia punctata, Nematodirus helvetianus* and *Ostertagia ostertagi,* which are normally parasites of cattle, all the helminths harboured by the goats at "Bucklands" are definitive parasites of goats and sheep. Kudu examined on the farm at the same time were infected only with a race of *Cooperia rotundispiculum* (Boomker *et al.*, 1991), but no cross-infection to the goats apparently took place.

Seasonal abundance

At "Brakhill" Boomker *et al.* (1989) recorded increases in the abundance of helminths in goats from August or September to January or February. This

corresponds with the period September or October to January observed in the present survey. They suggested that these increases could be due to a rise in temperature coupled with rainfall during spring, causing the grass to sprout and the goats to graze, rather than browse, and hence ingest more infective larvae. Similar arguments could support the increase in infection in the adult goats at "Bucklands" during spring.

The kids were born during September of each year, but showed no real increase in infection until April or May of the following year. Their small worm burdens during the first few months of their lives, at a time when infective larvae were available, judging by the burdens of the older goats, could be due to the fact that the major portion of their diet consisted of milk. Fivaz *et al.* (1990), determined the worm burdens of Angora goat kids at approximately monthly intervals from birth to 5 months of age on irrigated Kikuyu grass pastures on the farm "Kranzdrift", which is located close to "Bucklands" in Valley Bushveld. These kids also failed to acquire significant infections before they were 3 months old.

The kids on "Bucklands" must, however, have been doing some grazing by December or January as they had ingested the intermediate host of *M. expansa.* It was only when they were 12 months old, in September of the following year, that they exhibited peak nematode burdens, thus confirming the availability of infection at this time. The acquisition of infection by the kids is not unlike that recorded for free-ranging impala lambs in the northern Transvaal (Horak, 1978). These animals, which are generally born during November and December, also harboured the largest nematode burdens at 12 months of age.

There was no evidence of seasonally arrested larval development in the kids or adult goats, a phenomenon also noted by Boomker *et al.* (1989). They ascribed this to the relatively mild winters experienced in the Valley Bushveld and hence no necessity for nematodes to overwinter in the host animal. The increases in the nematode burdens of the animals during spring were thus not a consequence of the maturation of arrested overwintering larvae.

Cooperia *spp.*

The presence of these worms in the goats was propably the result of cross-infection from cattle on the farm.

Haemonchus contortus

Very few worms were recovered from any of the goats or from young Dorper sheep examined at the same time (Horak, 1987a). The Valley Bushveld thus appears to be an unsuitable habitat for this nematode, a fact supported by the findings of Boomker *et al.* (1989). Fivaz *et al.* (1990), who examined Angora yearlings and kids on irrigated pastures on "Kranzdrift" close to "Bucklands", also recovered very few *H. contortus.*

Nematodirus *spp.*

The *N. helvetianus* infection probably resulted from cross-infection from cattle on the farm. *Nematodirus spathiger,* although widespread in South Africa, is particularly common along the coast of the Cape Province and the adjacent inland regions (Horak, 1981). It is resistant to adverse conditions because development to the infective stage takes place within the egg (Reinecke, 1983), hence its ability to survive in the Valley Bushveld. The burdens of the adult goats and kids did not appear to differ substantially although slightly more larvae were recovered in the older animals.

Oesophagostomum venulosum

The geographic distribution of this nematode is limited to the south-eastern, southern and south-western Cape Province (Horak, 1987a; Reinecke, Kirkpatrick, Swart, Kriel & Frank, 1987). The Valley Bushveld regions of the eastern Cape Province seem to be at the limits of its distributional range and hence the small number of worms recovered, as also recorded by Boomker *et al.* (1989).

Ostertagia *and* Teladorsagia *spp.*

The *O. ostertagi* infection probably resulted from cross-infection from cattle.

Teladorsagia circumcincta generally prefers a temperate climate with high rainfall (Levine, 1980; Reinecke, 1983). Its recovery as one of the major parasites of the adult goats in the present survey, conducted in a region with comparatively low rainfall and very high summer temperatures, is surprising. In the kids it can be considered a minor parasite indicating a difference in either the method or timing or age of infection between the 2 age groups of goats. On the irrigated pastures of "Kranzdrift", *Teladorsagia circumcincta* was a major parasite of both kids and yearling Angora goats and no *Teladorsagia trifurcata* were recovered (Fivaz *et al.* 1990).

On the farm "Brakhill" Boomker *et al.* (1989) recovered no *Teladorsagia trifurcata* from Angora goats while 25 % of Boer goats were infected. In the present study *Teladorsagia trifurcata* accounted for less than 1 % of the total adult *Teladorsagia* burden of the adult goats. The kids harboured no *Teladorsagia trifurcata.* If *Teladorsagia circumcincta* and *Teladorsagia trifurcata* conform to the concept of major and minor species, as described by Lichtenfels, Pilitt & Lancaster (1988), Angora goats appear to be particularly poor hosts of the minor species *Teladorsagia trifurcata.*

Skrjabinema *sp.*

No specific identification was made of this nematode, which may commonly be encountered in grazing antelope species and in goats as discussed by Boomker *et al.* (1989). It has been excluded from the determination of total worm burdens, as well as of seasonal abundance, because of its different type of life cycle and apparent non-pathogenicity (Reinecke, 1983).

Strongyloides papillosus

The majority of kids and adult goats were infected, differing markedly from the findings of Boomker *et al.* (1989) on "Brakhill" and Fivaz *et al.* (1990) on "Kranzdrift" where none of the goats were infected. The absence of infection in the kids until they reached 3 months of age in the present survey, seems to discount a milk-borne infection as described by Moncol & Grice (1974).

Trichostrongylus *spp.*

Trichostrongylus axei is a parasite of domestic livestock (Levine, 1980; Reinecke, 1983) that may compete with *H. contortus* or *Teladorsagia circumcincta* for space in the abomasa of sheep (Reinecke, 1977). This may have happened on the irrigated pastures of "Kranzdrift" where large numbers of *Teladorsagia circumcincta* were recovered but no

Trichostrongulus axei (Fivaz *et al.*, 1990). In the present survey moderate numbers of both the latter worms were present.

Trichostrongylus colubriformis appears to be a parasite more of sheep than of goats and seems to prefer more temperate climates than the Valley Bushveld (Horak, 1981).

Trichostrongylus pietersei was originally described from sheep and Angora goats in the Karoo (Le Roux, 1932), but it seems to prefer the milder climate of the coastal regions of the eastern and southern Cape Province (Rossiter, 1964; Muller, 1968). Small numbers only were encountered in the adult goats and kids on "Bucklands".

Trichostrongylus rugatus must be considered as one of the dominant species in goats and sheep in the eastern Karoo and eastern, southern and south-western Cape Province (Viljoen, 1964; Barrow, 1964; Rossiter; 1964; Horak, 1987a; Reinecke *et al.*, 1987; Boomker *et al.*, 1989). Its dominance may even be enhanced on irrigated pastures in the Valley Bushveld, where it and *Teladorsagia circumcincta* have caused the death of kids and yearling Angora goats (Fivaz *et al.*, 1990).

Trichuris *sp.*

No specific identification of the *Trichuris* sp. recovered was made. The fact that the majority of kids were infected and few of the adult goats, may indicate that older animals develop a degree of resistance.

Moniezia expansa

This was the only cestode recovered. It appeared during December or January when the kids were 3 or 4 months old and disappeared in May. The kids of the 1986 crop were unfortunately treated with a cestocide towards the end of January 1987, and but for the 2 kids examined in January and some much later in the year, no other kids of this crop were infected. This seemed to indicate that infection was acquired only in December or January and that the cestodes recovered from February to April in the kids examined during 1988 had actually survived from the December and January infections. The spontaneous disappearance of *Moniezia benedeni* with increasing age of the host has also been recorded in blue wildebeest calves (Horak, De Vos & Brown, 1983).

Arthropods

The total tick burdens of the goats were probably lower than could be expected because of the regular treatment of the other livestock on the farm with an acaricide, thus reducing the number of ticks questing for hosts from the ground or from the vegetation. Some species were more drastically affected than others and this will be dealt with later. Whereas the individual nematode species did not exhibit clear patterns of seasonal abundance, some of the ticks did.

While nematode burdens increased with the age of the kids, this did not occur with the ticks. The kids were born at a time of low tick infestation, as evidenced by the burdens of the adult goats. Thereafter their burdens fluctuated seasonally in the same manner as did those of the older animals and have been included on the same graphs.

Amblyomma hebraeum

This tick was the most severely affected by the acaricidal treatment applied to the other domestic livestock on the farm. Free-ranging kudu, scrub hares and helmeted guineafowls on the farm harboured total mean burdens of this tick of 19, less than 1 and 36 respectively. The same animal species on the adjacent Andries Vosloo Kudu Reserve, where no acaricidal treatment was applied, harboured 1 318, 53 and 464 ticks respectively (Horak & Knight, 1986). Not only were the numbers of parasitic ticks affected, but the numbers of free-living larvae on the vegetation were also drastically reduced on the farm compared with the reserve (Petney & Horak, 1987).

The small numbers of ticks recovered made it impossible to determine their seasonal abundance on the goats.

Amblyomma marmoreum

The adults of this tick prefer tortoises as hosts (Theiler, 1962; Norval, 1975), while the immature stages can be found on tortoises as well as many other animals (Dower, Petney & Horak, 1988; Horak, MacIvor, Petney & De Vos, 1987). Their presence on the goats is thus not unusual, and their seasonal abundance is similar to that described by Fivaz *et al.* (1990) and Horak, Williams & Van Schalkwyk (1991) on goats and sheep in the eastern Cape Province.

Boophilus decoloratus

This tick appears to be rare in the Valley Bushveld regions of the eastern Cape Province (Knight & Rechav, 1978; Rechav, 1982; Horak & Knight, 1986). The small numbers presently recovered confirm this.

Haemaphysalis leachi

The immature stages prefer rodents (Hussein & Mustafa, 1985) and the adults carnivores (Norval 1984; Horak, Jacot Guillarmod, Moolman & De Vos, 1987). The larvae recovered on the goats must be considered accidental infestations. The larger numbers on the kids are probably a reflection of the fact that they were kept closer to human habitation and were thus more likely to be exposed to dogs and the offspring of their ticks.

Haemaphysalis silacea

This tick is common in the Valley Bushveld regions (Howell, Walker & Nevill, 1978). It has a wide host range including goats, sheep, cattle, kudu and helmeted guineafowls.(Knight & Rechav, 1978; Rechav, 1982; Horak & Knight, 1986). The seasonal abundance of the immature stages on the goats was not unlike that on kudu from the same farm (Knight & Rechav, 1978).

Rhipicephalus appendiculatus

Horak, Williams & Van Schalkwyk (1991) have discussed the distributional boundaries of this tick in the eastern Cape Province. The farm "Bucklands" is situated fairly close to the south-western limit of its distribution, which lies approximately 50 km to the west.

Goats are better hosts of adult *R. appendiculatus* than are sheep (Horak & Knight, 1986), their longer ears probably affording better attachment sites. On both the adult goats and the kids, female ticks considerably outnumbered males, an unusual occurrence for this species (Kaiser, Sutherst & Bourne, 1982). The seasonal abundance on the goats is similar to that described for kudu and Angora goats on "Bucklands" (Knight & Rechav, 1978; Rechav, 1982).

Rhipicephalus glabroscutatum

The geographical distribution of this tick in the eastern Karoo and eastern Cape Province has been described by MacIvor (1985). Its original hosts were probably eland, kudu, bushbuck, mountain reedbuck and common duiker (MacIvor & Horak, 1987; Horak, Fourie, Novellie & Williams, 1991), but it now also attaches to the feet and lower limbs of goats, sheep and cattle (Horak & Knight, 1986). On goats the adults, with those of *A. hebraeum,* are a contributing cause to the development of lameness and foot abscesses (MacIvor & Horak, 1987).

The seasonal abundance of the immature and adult stages corresponds closely to that already described on several host species (MacIvor & Horak, 1987; Horak, Fourie, Novellie & Williams, 1991).

Rhipicephalus *sp. (near* R. oculatus)

This tick is fairly common in the Valley Bushveld regions of the eastern Cape Province, where in addition to Angora goats, adults may be found on sheep, cattle, kudu and scrub hares (Horak & Knight, 1986).

Other ixodid ticks

The small numbers of other species recovered are more a reflection of the geographic limits of distribution of these ticks rather than the suitability of Angora goats as hosts.

Damalinia limbata

This is the most commonly encountered biting louse of Angora goats in the eastern Karoo and the eastern Cape Province. In the present survey it was the most prevalent and abundant of all the parasites recovered. The kids were already infested by 1 week of age. Individual burdens fluctuated considerably and no clear pattern of seasonal abundance could be established.

Oestrus ovis

This fly is widespread in South Africa and close to 74 % of sheep and goats are infested with its larvae (Horak, 1977; Horak & Butt, 1977). Although the prevalence of infestation in the 2 hosts is the same, sheep harbour greater numbers of larvae than do goats (Horak 1977; Horak & Butt, 1977). In the present survey both sets of kids born in consecutive years became infested for the first time during December when they were 3 months old. Although a smaller proportion of kids (36 %) than adult goats (48 %) was infested the mean total burdens of infested kids and goats were reasonably similar (5,4 and 6,4 larvae respectively). Horak & Butt (1977) recovered a mean burden of 4,4 larvae from goats slaughtered at the Johannesburg Municipal Abattoir. The goats' habit of sneezing and snorting probably dislodges many larvae, thus accounting for their smaller burdens when compared with those of sheep. This may, however, also be due to better fly avoidance behaviour of the goats.

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Helminth and arthropod parasites of indigenous goats in the northern Transvaal

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ABSTRACT

BOOMKER, J., HORAK, I.G. & RAMSAY, K.A. 1994. Helminth and arthropod parasites of indigenous goats in the northern Transvaal. *Onderstepoort Journal of Veterinary Research*, 61:13–20

Helminth and arthropod parasites of 60 female indigenous goats of three age groups on a farm in the northern Transvaal were collected, identified and counted. Anoplocephalid tapeworms were present in the two younger groups of goats, while larvae of *Taenia hydatigena* were recovered from all three groups. Eight species and two genera of nematodes were found in the youngest goats, five species and three genera in the middle group and six species and two genera in the oldest goats. *Strongyloides papillosus* was the most numerous and most prevalent nematode in the youngest goats, while *Haemonchus contortus* was most numerous and most prevalent in both older groups.

Adult *H. contortus* was most abundant during the summer months, while *S. papillosus* occurred in the youngest goats during the cooler months (April to September). No pattern of seasonal abundance could be established for the other nematodes.

Only ixodid ticks were recovered and of the nine species present, the immature stages of *Amblyomma hebraeum* were most numerous and prevalent. *Boophilus decoloratus* was present from October to January and in August, and the adults of a *Rhipicephalus* sp. (near *R. pravus*) from January to March and during May. *Rhipicephalus simus* was present from October to January.

INTRODUCTION

Indigenous goats are widespread in Africa and play an important role in the culture and economies of particularly the indigent farming communities. These goats are usually not immunized against diseases and are seldom, if ever, treated against internal or external parasites. This has led to the natural selection of a small, hardy animal that supposedly has a high degree of resistance to parasites and diseases, and can exist with little or no veterinary intervention.

Surveys of the helminth and arthropod parasites of Angora and Boer goats have been done in the eastern Cape Province (Rechav 1982; Boomker, Horak & MacIvor 1989b; Fivaz, Horak & Williams 1990; Horak, Knight & Williams 1991c) and of ticks infesting Angora goats in the south-western Orange Free State (Fourie & Horak 1991). However, in South Africa, only the ticks of indigenous goats have been investigated and that in a survey in the north-western Transvaal (Rechav & De Jager 1991).

The purpose of the current investigation was to determine the seasonal abundance of helminths and arthropods parasitizing indigenous goats in the northern Transvaal.

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MATERIALS AND METHODS

The survey was conducted on the farm "Delftzyl" (24°35′–24°43′S, 29°14′–29°17′E; altitude approximately 850 m), situated near the village of Roedtan in the northern Transvaal. The farm extends over about 2 000 ha of predominantly Mixed Bushveld with small areas of Springbok Flats Turf Thornveld (Acocks 1988) and is divided into northern and southern sections of approximately equal size, separated by a road. Summers are warm to hot and winters are cool with occasional frost. Rain falls mainly during summer. Small numbers of indigenous cattle are present on the western part of the farm, while impalas, *(Aepyceros melampus)*, kudus (*Tragelaphus strepsiceros)*, common duikers (*Sylvicapra grimmia*), steenbok (*Raphicerus campestris)*, warthogs *(Phacochoerus aethiopicus)*, as well as black-backed jackals (*Canis mesomelas)*, and caracal (*Felis caracal)*, occur on both sections and on neighbouring farms.

"Delftzyl" is a government research farm where, in addition to the wild animals, only indigenous domesticated animals are kept and only the ruminants are allowed to roam freely. Both the grazing and browsing potential are good, and stock numbers are carefully maintained to prevent deterioration of the vegetation. In order to maintain the populations as naturally as possible, none of the domestic animals are treated against endo- or ectoparasites.

This survey was conducted on the eastern section of the farm, where, for the preceding three years, only goats and wild animals had been present. The goats were kraaled at night to limit predation by caracal and were returned to the pastures every morning.

A total of 60 female goats were selected according to age from a flock of about 300 animals. The animals selected remained with the flock until they were slaughtered. At the commencement of the survey during October 1990, 25 of these were 1–2 weeks old (age group 1), 12 were 12–13 months old (age group 2) and 23 were 24–25 months old (age group 3). Two goats of each age group were slaughtered each month from October 1990 to March 1991. During April 1991, three goats of age groups 1 and 3 were slaughtered, after which two goats of these age groups were slaughtered each month until August 1991. The last two goats of age group 1 were killed during September 1991.

The carcases were processed for helminth recovery as described by Boomker, Horak & De Vos (1989a). Representative samples, each consisting of one tenth of the ingesta of the abomasum, the small intestine and the large intestine, were made. These were examined with a stereoscopic microscope and all the worms removed and counted. The washings of the hearts, lungs and livers, as well as the digests of the respective parts of the intestinal tract were similarly examined *in toto*. All the worms were identified with the aid of a compound microscope with interference contrast lighting.

The skins were processed for ectoparasite recovery as described by Horak, Boomker, Spickett & De Vos (1992). All the material collected was examined under a stereoscopic microscope and the parasites were identified and counted.

RESULTS

The total monthly rainfall is graphically illustrated in Fig. 1. No rain was recorded from April to August 1991.

Helminths

The helminths recovered from the goats of each age group are listed in Table 1 and the seasonal abundance of the nematodes, excluding *Skrjabinema* spp., is graphically illustrated in Fig. 2 and 3.

Age group 1

Three goats were infected with adult *Moniezia expansa* and another three with *Avitellina* spp., and the larvae of *Taenia hydatigena* were present in six animals.

The most abundant and prevalent nematodes were *Strongyloides papillosus*, followed by *Haemonchus contortus*, *Oesophagostomum columbianum*, *Trichostrongylus* spp. and *Skrjabinema* spp. The remaining nematodes were present in less that 50% of the goats.

Total burdens tended to increase with the age of the goats. Those examined during October and November 1990, at approximately 1 and 2 months of age, harboured means of one and 61 adult nematodes, respectively, while those examined during

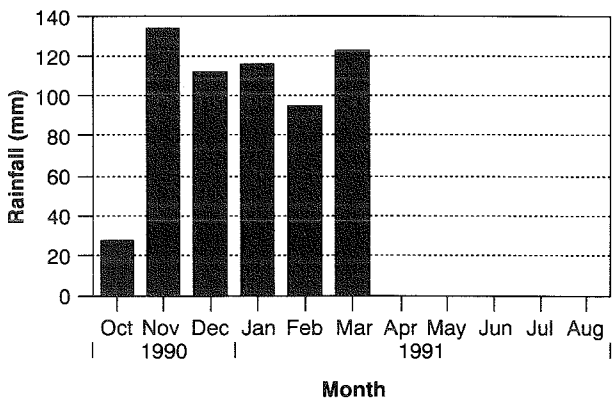

FIG. 1 Total monthly rainfall on the farm "Delftzyl" from October 1990 to August 1991. No rain fell from April to August

TABLE 1 The total helminth burdens of female indigenous goats on the farm "Delftzyl" in the northern Transvaal

Helminth species	Age group 1 (0–12 months) (25 goats)				Age group 2 (13–24 months) (12 goats)				Age group 3 (25–36 months) (23 goats)			
	Number of worms recovered			Percentage of animals infected	Number of worms recovered			Percentage of animals infected	Number of worms recovered			Percentage of animals infected
	Larvae	Adults	Total		Larvae	Adults	Total		Larvae	Adults	Total	
Cestodes												
Avitellina spp.	#	5	5	12	#	2	2	8	#	0	0	0
Moniezia benedeni	#	0	0	0	#	1	1	8	#	0	0	0
Moniezia expansa	#	6	6	12	#	0	0	0	#	0	0	0
Taenia hydatigena	6	#	6	24	10	#	10	58	13	#	13	35
Nematodes												
Cooperia hungi	–	10	10	4	–	0	0	0	–	0	0	0
Cooperia pectinata	–	30	30	12	–	0	0	0	–	0	0	0
Cooperia spp. females	–	0	0	0	–	10	10	8	–	0	0	0
Haemonchus contortus	1 231	3 284	4 515	84	1 545	2 998	4 543	100	2 365	4 302	6 667	96
Impalaia tuberculata	0	91	91	12	0	0	0	0	0	0	0	0
Oesophagostomum columbianum	79	710	789	56	58	231	289	83	22	555	577	65
Skrjabinema spp.	0	369	369	56	0	11	11	25	0	151	151	57
Strongyloides papillosus	0	7 354	7 354	88	2	524	526	75	2	467	469	70
Trichostrongylus colubriformis	–	190	190	44	–	0	0	0	–	55	55	22
Trichostrongylus deflexus	–	0	0	0	–	30	30	25	–	21	21	13
Trichostrongylus falculatus	–	36	36	28	–	1	1	8	–	10	10	4
Trichostrongylus spp. females	–	288	288	48	–	15	15	42	–	126	126	35
Trichuris spp.	0	196	196	44	0	70	70	33	0	312	312	44
Total nematode burden	1 310	12 558	13 868		1 605	3 890	5 495		2 389	5 999	8 388	
Mean nematode burden	52	502	554		134	324	458		104	261	365	

– Not applicable

Does not occur in ruminants

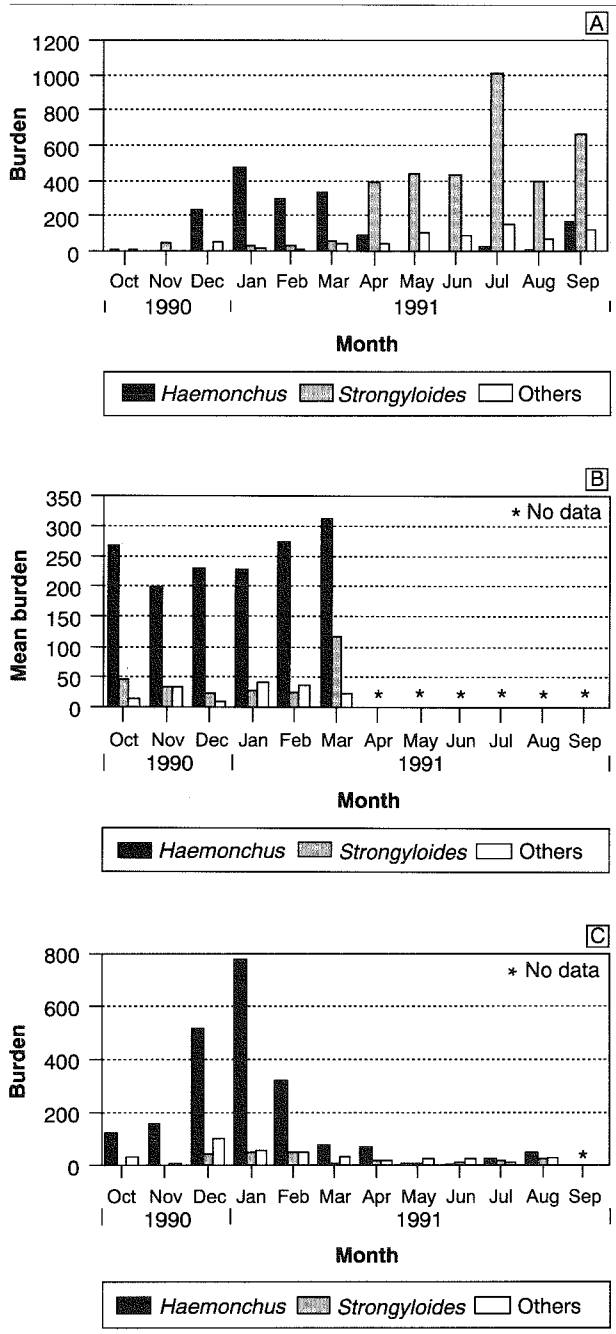

FIG. 2 The seasonal abundance of adult nematodes, excluding *Skrjabinema* spp., in (A) age group 1, (B) age group 2 and (C) age group 3 of indigenous goats on the farm "Delftzyl"

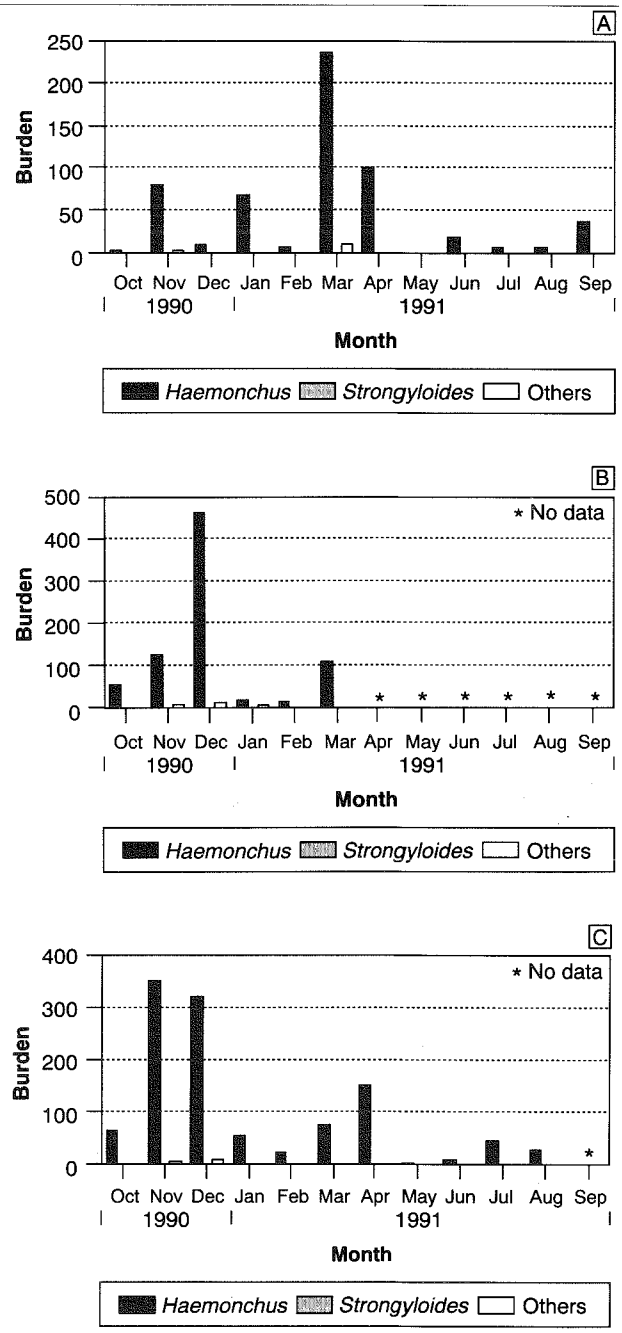

FIG. 3 The seasonal abundance of larval nematodes in (A) age group 1, (B) age group 2 and (C) age group 3 of indigenous goats on the farm "Delftzyl"

August and September 1991, at approximately 10 and 11 months of age, had mean burdens of 464 and 974 adult nematodes, respectively. The largest burden of 1 176 adult nematodes was recovered during July 1991 and consisted mainly of *S. papillosus*.

Adult *H. contortus* were present in peak numbers from December 1990 to March 1991 and 4th-stage larvae during March 1991.

S. papillosus infected 95,6 % of the kids and increased from a mean of 56 worms per animal during March to almost 400 during April 1991. Peak numbers were recorded during July 1991.

Although *Trichostrongylus* spp. were not recovered during the initial stages of the survey, they became more numerous from May 1991 onwards, and the largest burden of 131 worms was recovered from a goat examined during September 1991.

No *O. columbianum* were present from October to December 1990 nor during February 1991. A peak burden of 120 worms was recorded during July 1991, with between five and 60 worms being recovered during the other months. Fourth-stage larvae were present only in those goats examined during November 1990 and March 1991.

Few *Skrjabinema* spp. were recovered from the goats, the most being 145 from an animal examined during June 1991. These nematodes were more numerous during the cooler months.

Age group 2

One goat was infected with adult *Avitellina* spp. and another with *Moniezia benedeni*, and the larvae of *T. hydatigena* were present in seven animals.

All the goats were infected with *H. contortus*, which was the most numerous and the most prevalent nematode. *O. columbianum* was next most prevalent, followed by *S. papillosus*. *Trichostrongylus* spp. were present in 58 % of the goats and the remaining nematodes in less than 35 % of the animals.

Adult nematode burdens in this age group varied only slightly—from a mean of 318 during October 1991 to a mean of 468 during March 1991 (Fig. 2b). The largest burden in a single animal consisted of 506 nematodes, recovered during October 1990, and the smallest 50, from a goat examined during November 1990.

Adult *H. contortus* were present in fairly constant numbers from October 1990 to March 1991 (Fig. 2b). Fourth-stage larvae were present in peak numbers during December 1990.

Small numbers of *O. columbianum* were present each month and only two goats were not infected. Fourth-stage larvae were present during November and December 1990 and January 1991.

Age group 3

No adult tapeworms were recovered, but eight animals were infected with the larvae of *T. hydatigena*.

H. contortus was the most numerous and most prevalent nematode. *O. columbianum* was the next most numerous, followed by *S. papillosus*. Total burdens ranged from 1 099 in an animal examined during December 1990, to five in a goat examined during April 1991.

Adult *H. contortus* were present in peak numbers from December 1990 to February 1991, and 4th-stage larvae during November and December 1990.

Small numbers of *O. columbianum* were present each month except during August 1991, when none were found. Peak numbers were present during December 1990, when a mean of 70 worms per goat was recovered. Fourth-stage larvae were present only during November and December 1990.

Skrjabinema spp. were recovered only during the cooler months.

Trichostrongylus spp. were most numerous from December 1990 to February 1991, when all three species were present. Few worms were recovered, the most being 60 from goats slaughtered during February and August 1991. During the remaining months the goats were either uninfected or infected with only one species.

With the exception of February, May and June 1991, when none were recovered, *Trichuris* spp. were present in many of the goats, the largest burden being 62 worms. No pattern of seasonal abundance was evident.

Arthropods

Only ixodid ticks were recovered and the species and numbers present on the goats, irrespective of age group, are summarized in Table 2.

Small numbers of nine species were present. The immature stages of *Amblyomma hebraeum* were the most prevalent and the most abundant. The greatest number of adult ticks belonged to a *Rhipicephalus* sp. (near *R. pravus*).

Despite the small numbers, patterns of seasonal abundance were evident for some of the ticks. *Boophilus decoloratus* was present from October to January and in August, the *Rhipicephalus* sp. (near *R. pravus*) from January to March and during May, and *Rhipicephalus simus* from October to January.

DISCUSSION

Helminths

The inverse relationship between the ages of the goats, and both the numbers of tapeworms and the number of goats infected, follow the observations of Horak *et al.* (1991c) in Angora goats and is probably due to the development of immunity (Reinecke 1983).

The larvae of *T. hydatigena* appear to accumulate in the goats as they get older. The infected kids in age group 1 harboured one larva each, and the infected goats in age groups 2 and 3, 1,43 and 1,63 larvae, respectively. This could indicate that domestic dogs and jackals on the farm, both of which are known hosts of the adult tapeworms (Verster 1969), are heavily infected, and that the larvae survive for a long time in infected animals.

Cooperia pectinata were probably acquired from cattle (Reinecke 1983) and *Cooperia hungi* from im-

TABLE 2 Ixodid ticks recovered from 60 female indigenous goats on the farm "Delftzyl" in the northern Transvaal

Tick species	Total number of ticks recovered					Number of animals infested
	Larvae	Nymphs	Males	Females	Total	
Amblyomma hebraeum	200	12	0	0	212	15
Amblyomma marmoreum	26	0	0	0	26	8
Boophilus decoloratus	36	6	4	4	50	12
Haemaphysalis leachi	0	0	2	2	4	2
Hyalomma truncatum	0	0	2	2	4	2
Rhipicephalus appendiculatus	0	2	0	0	2	1
Rhipicephalus evertsi evertsi	80	2	0	0	82	9
Rhipicephalus sp. (near *R. pravus*)	0	0	14	10	24	9
Rhipicephalus simus	0	0	10	2	12	6
TOTAL	342	22	32	20	416	35

palas (Round 1968), and as very few were found, they should be regarded as accidental parasites.

H. contortus was the most prevalent and most numerous nematode in all the goats examined during this survey and followed the expected pattern of summer abundance recorded in sheep in the summer rainfall areas (Horak 1978a). The recovery of small numbers of adults and 4th-stage larvae during winter suggests that arrested development does not occur to any significant degree in the region in which the survey was conducted.

Impalaia tuberculata is primarily a parasite of antelope (Boomker 1990) but has previously been recovered from cattle running with impala in a nature reserve in the northern Transvaal (Horak 1978c). Its occurrence in only three kids in age group 1 indicates that it is an accidental parasite.

O. columbianum has become a fairly rare nematode in goats and sheep in South Africa because of regular anthelmintic treatment, especially with the benzimidazoles (Reinecke 1983). The high prevalence (>50% in all three age groups) reflects the absence of anthelmintic treatment.

Skrjabinema spp. have been recovered in large numbers from Angora and Boer goats in the eastern Cape Province (Boomker *et al.* 1989a; Horak *et al.* 1991c). These are reputedly non-pathogenic nematodes about which little is known (Reinecke 1983). Their presence in small numbers in this survey possibly reflects the unsuitability of the environment rather than the insusceptibility of the hosts.

Like the tapeworms, *S. papillosus* also appears to infect mainly younger ruminants (Reinecke 1983). It is generally more numerous during winter and should be regarded as a definitive parasite of indigenous goats.

Trichostrongylus deflexus is a parasite of a variety of antelope (Boomker 1990) and fills the niche in these hosts occupied by *Trichostrongylus colubriformis* in sheep. It was not recovered from age group 1, but occurred in almost equal numbers in age groups 2 and 3. On the other hand, *T. colubriformis* was present in larger numbers in age group 1 than in age group 3, and was not found in age group 2, probably because no goats of this group were examined during the cooler months. Although present country-wide, *Trichostrongylus falculatus* is found mainly in the more arid regions, where it infects a number of domestic and wild ruminants (Horak 1981).

The presence of the *Trichostrongylus* spp. in such small numbers implies that either the environment is unsuitable for the free-living stages or that indigenous goats are less susceptible to infection. Horak (1978a) also recovered only small numbers of *Trichostrongylus* spp. from sheep on dry-land pastures in the eastern Transvaal. He did, however, recover larger numbers from impalas on a nature reserve close to "Delftzyl" (Horak 1978b).

The increase in the total nematode burdens of the indigenous goat kids from 1–12 months of age is similar to that noted in Angora goat kids in the eastern Cape Province (Horak *et al.* 1991c) and impala lambs on a nature reserve close to the present study site (Horak 1978b). The low burdens in the very young kids probably result from a diet consisting mainly of milk and only small amounts of vegetation containing infective larvae.

Ixodid ticks

The immature stages of *A. hebraeum* infest a large number of large and small host species, including goats, while the adults prefer very large animals (Horak, MacIvor, Petney & De Vos 1987a). Rechav & De

Jager (1991) recovered fairly large numbers of adult ticks from indigenous goats in the north-western Transvaal, while Horak *et al.* (1991c) recovered a few from Angora goats in Valley Bushveld in the eastern Cape Province on a farm where regular tick control was practised.

Even though the larvae of *Amblyomma marmoreum* may also infest a large variety of large and small hosts (Horak *et al.* 1987a), all stages of development prefer the mountain tortoise (Dower, Petney & Horak 1988). Fairly large numbers of larvae have been recovered from Angora goats in Valley Bushveld (Horak *et al.* 1991c).

The preferred hosts of *B. decoloratus* are domestic cattle and kudus (Baker & Ducasse 1967; Horak *et al.* 1992). Goats and sheep can also be infested but do not appear to be very efficient hosts (Rechav & De Jager 1991; Horak, Williams & Van Schalkwyk 1991a). On sheep and kudus the largest numbers of this tick are present in early summer (Horak *et al.* 1991a, 1992), a finding confirmed in the present study.

The *Haemaphysalis leachi* recovered from the goats probably originated from the dogs or jackals on the farm. The immature stages of this tick have previously been recovered from Angora goats (Fivaz *et al.* 1990; Horak *et al.* 1991c).

The small numbers of *Hyalomma truncatum* are probably more a reflection of the unsuitability of the habitat than of the indigenous goat as a host. Larger numbers have been recovered from goats in a more favourable habitat in the south-western Orange Free State (Fourie & Horak 1991).

Rechav & De Jager (1991) and Horak *et al.* (1991c) have recovered both immature and adult *Rhipicephalus appendiculatus* from indigenous and Angora goats. The total of two nymphs on only a single goat in the present survey probably reflects the unsuitability of the particular habitat for this tick.

Adult *Rhipicephalus evertsi evertsi* have been recovered from indigenous goats in the north-western Transvaal (Rechav & De Jager 1991), but in the present survey only immature ticks were recovered. Zebras and eland are the preferred hosts of all stages of development of this tick (Horak, Fourie, Novellie & Williams 1991b), and sheep can harbour fairly large numbers of adults (Horak *et al.* 1991a).

All stages of development of the *Rhipicephalus* sp. (near *R. pravus*) have recently been recovered from scrub hares in the north-western and north-eastern Transvaal (Horak, Spickett, Braack & Penzhorn 1993), while goats seem to harbour only the adult stages. Angora goats are a preferred host of the adults of a closely related species, *Rhipicephalus punctatus*, in the south-western Orange Free State (Fourie & Horak 1991).

The preferred hosts for adult *Rhipicephalus simus* are monogastric animals such as zebras, carnivores and warthogs (Horak, De Vos & De Klerk 1984; Horak, Jacot Guillarmod, Moolman & De Vos, 1987b; Horak, Boomker, De Vos & Potgieter 1988), but cattle and sheep can also be infested (Horak 1982; Horak *et al.* 1991a). The early to mid-summer abundance on the goats in the present study is earlier than that observed on most other host species on which the ticks are most numerous in late summer.

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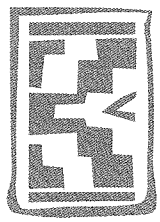

Parasites of domestic and wild animals in South Africa. XXXIX. Helminth and arthropod parasites of Angora goats in the southern Karoo

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ABSTRACT

HORAK, I.G., MACIVOR, K.M. DE F. & GREEFF, C.J. 2001. Parasites of domestic and wild animals in South Africa. XXXIX. Helminth and arthropod parasites of Angora goats in the southern Karoo. *Onderstepoort Journal of Veterinary Research*, 68:27–35

Parasites were collected from 160 Angora goats and kids on the Jansenville Experimental Farm, Eastern Cape Province. Six nematodes were identified to species level and three to generic level. *Nematodirus spathiger* was the most numerous of the economically important nematodes recovered. It was always present, and fourth stage larvae were collected from untreated goats from August to March, while animals used as tracers also picked up most infection from August to March. Kids born on the farm during October acquired their first nematode infections between 2 and 3 months of age and the intensity of infection increased erratically thereafter to reach a plateau once the kids were 14 months of age. Eight of the nine kids between 3 and 5 months of age and examined between January and March were infected with *Moniezia expansa*.

Five ixodid tick species were collected from the goats of which *Rhipicephalus glabroscutatum* was the most numerous and prevalent. Its immature stages were present mainly from March to September and adults from July to January. The goats also harboured the biting louse *Damalinia limbata* and the sucking louse *Linognathus africanus*. The greatest intensity of infestation with *L. africanus* occurred on the kids during the first few months of their lives. The larvae of the nasal bot fly, *Oestrus ovis* were present in kids at 1 month of age, and infestation took place mainly from spring to late summer.

Keywords: Angora goats, biting and sucking lice, cestodes, ixodid ticks, Karoo, nasal bot fly larvae, nematodes

INTRODUCTION

A number of surveys on the seasonal intensity of parasitic infections of goats have been conducted in South Africa. These involved goats (breed not stated) farmed at four altitudes in KwaZulu-Natal (Baker & Ducasse 1968); Angora and Boer goats in the Eastern Cape Province (Rechav 1982; MacIvor & Horak 1984; Horak 1987; Boomker, Horak & MacIvor 1989; Horak, Knight & Williams 1991b); Angora goats on irrigated grass pasture in the Eastern Cape Province (Fivaz, Horak & Williams 1990); Angora goats in False Upper Karoo vegetation in the south-western Free State (Fourie & Horak 1991); and indigenous goats in Sour Bushveld or in Mixed Bushveld in the Northern Province (Rechav & De Jager 1991; Boomker, Horak & Ramsay 1994).

A survey on the prevalence of *Oestrus ovis* infestation in goats slaughtered at the Johannesburg Municipal abattoir has also been conducted (Horak & Butt 1977).

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These surveys demonstrated that goats browsing natural scrub vegetation had lighter nematode burdens than those grazing irrigated kikuyu grass (*Pennisetum clandestinum*) pasture (Boomker *et al.* 1989; Fivaz *et al.* 1990; Horak *et al.* 1991b). They also confirmed the link between the seasonal intensity of infestation with adult *Amblyomma hebraeum* and adult *Rhipicephalus glabroscutatum* and the prevalence of foot abscess in goats (MacIvor & Horak 1987). In addition, the seasonal intensity of infestation with adult *Ixodes rubicundus* and adult *Rhipicephalus warburtoni* (then referred to as a tick of the *Rhipicephalus pravus* group) determined in these surveys, corresponded to the occurrence of paralysis caused by these ticks (Fourie, Horak & Marais 1988; Fourie & Horak 1991; Fourie, Horak & Van Zyl 1992). The surveys also indicated that goats are particularly prone to infestation with the biting louse *Damalinia limbata* (MacIvor & Horak 1984; Horak *et al.* 1991b). It was apparent from the abattoir survey on goats and one conducted on sheep that these animals are probably equally susceptible to infestation with the larvae of the nasal bot fly *O. ovis*, but that goats harbour fewer larvae than sheep (Horak 1977; Horak & Butt 1977).

Although goats are farmed extensively in the Karoo, no surveys on the parasites of these animals in this region have been published. The object of the present survey was an attempt to rectify this shortcoming to some extent by determining not only the species composition of the parasitic macro-fauna of Angora goats in the Noorsveld vegetation region of the south-eastern Great Karoo, but also the acquisition of infection by kids from 1 week of age until the age of 23 months, as well as the seasonal acquisition and intensity of infection in older goats.

MATERIALS AND METHODS

The Jansenville Experimental Farm (32°55'S, 24°41'E) is 2 128 ha in extent and is situated 2 km north-east of Jansenville in the Eastern Cape Province. The vegetation in this region is classified as Noorsveld and is dominated by *Euphorbia coerulescens* colloquially known as noors (Acocks 1988). At the time of the survey there were 916 Angora goats on the farm.

Sets of three untreated Angora goat wethers born during October 1984 were slaughtered at monthly intervals from the age of 10 months until they reached 24 months of age. Sets of three similarly aged wethers (hereafter referred to as tracers) were treated in consecutive months with the anthelmintic Ivomec (Ivermectin: Merial) approximately 1 month prior to slaughter and were slaughtered at the same time as the untreated wethers. Both sets of goats ran with a flock of goats of the same age, and were not treated with pesticides for the control of ticks and lice.

In addition, sets of three untreated kids of mixed sex born during October 1985 were slaughtered at monthly intervals from 1 week of age until they were 23 months old. These kids ran with their dams in the ewe flock until weaning and thereafter with a flock of goats of their own age.

The right lung, liver, abomasum, small intestine and large intestine of each goat were processed for helminth recovery as described by Boomker *et al.* (1989). This included digesting the mucosa of the abomasum and the small and large intestines. Two aliquots, each representing 1/50th of the volume of the ingesta of the latter three organs separately, were made. These aliquots, and the material resulting from the digests and from the processed lung and liver, were examined under a stereoscopic microscope and the female worms identified to generic level and counted. All immature worms were identified and counted under a standard light microscope, while the males were first cleared in lactophenol and then identified and counted under the same microscope. The remainders of the abomasal and small and large intestinal ingesta were decanted into a large, flat-bottomed plastic tray and examined macroscopically for adult nematodes belonging to the larger species, and for cestode scolices and strobila.

The skins of the goats were processed for the recovery of ticks and lice as described by Horak, Boomker, Spickett & De Vos (1992). The processed material was examined under a stereoscopic microscope and the ticks and lice present were collected, identified and counted. Oestrid fly larvae were collected from the nasal passages and sinuses as described by Malan, Reinecke & Scialdo (1981). Unfortunately, the data on the numbers of individual goats infested with the larvae of *O. ovis* and detailing the stages of development of the larvae were mislaid, but that on the total numbers of larvae recovered from each set of three goats were not.

RESULTS AND DISCUSSION

Helminths

The species and genera of helminths recovered from the three groups of goats are summarized in Table 1.

Six nematodes were identified to species level and three to generic level. A single cestode species was also recovered. The intensity of infection with *Nematodirus spathiger* followed by those of *Trichostrongylus rugatus* and *Trichostrongylus pietersei* were the highest for the economically important nematodes recovered, but the total numbers of the former worms were nevertheless always low. Angora goats spend more time browsing than grazing (Aucamp 1979) and hence are less likely to acquire third stage infective

TABLE 1 Helminths collected from three groups of Angora goats in the southern Karoo, Eastern Cape Province

Helminth species	Total numbers of helminths recovered and goats infected					
	Tracers (n = 43)	No. infected	Untreated goats (n = 45)	No. infected	Kids (n = 72)	No. infected
Nematodes						
Haemonchus contortus (MM)	0	0	2	2	0	0
Nematodirus spathiger (4th)	1 425	14	2 860	23	1 200	17
Nematodirus spathiger (Ad)	1 411	20	15 290	44	8 131	49
Skrjabinema sp. (4th, Ad)	73 540	43	81 850	44	5 500	25
Teladorsagia sp. (4th)	0	0	1	1	0	0
Teladorsagia sp. (F)	0	0	0	0	1	1
Trichostrongylus axei (MM)	0	0	25	1	9	3
Trichostrongylus falculatus (MM)	0	0	175	6	0	0
Trichostrongylus pietersei (MM)	0	0	741	15	25	1
Trichostrongylus rugatus (MM)	75	2	926	12	175	5
Trichostrongylus spp. (FF)	125	5	1 468	23	504	22
Trichuris sp. (Ad)	46	18	111	33	131	31
Cestodes						
Moniezia expansa (Scolices)	1	1	1	1	61	9

N = Number of animals examined
4th = Fourth stage larvae
Ad = Adults
MM = Males
FF = Females

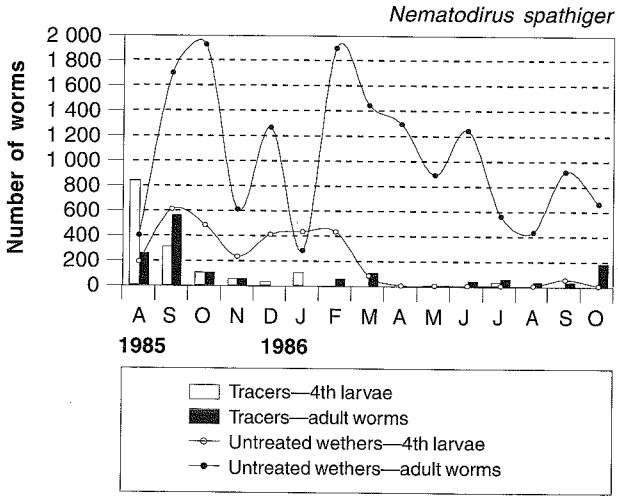

FIG. 1 The seasonal intensity of infection with *Nematodirus spathiger* in Angora goats in the southern Karoo, Eastern Cape Province

larvae from the grass in their diet than are animals that graze. This is particularly so in the Noorsveld region around Jansenville where noors, shrubs and small trees dominate (Acocks 1988).

Only two *Haemonchus contortus* and two worms belonging to a *Teladorsagia* sp. were recovered. Both these nematodes are important parasites of goats. The first has been recovered in substantial numbers from indigenous goats in Mixed Bushveld in the Northern Province, South Africa and in Maputo and Gaza Provinces, southern Mozambique (Boomker *et al.* 1994; Atanásio 2000). The second, with *Trichostrongylus rugatus*, was responsible for several mortalities in Angora goat kids on irrigated kikuyu grass pastures near Grahamstown, Eastern Cape Province (Fivaz *et al.* 1990). The near absence of these nematodes at Jansenville can be ascribed to the arid climate, with an average annual rainfall of 250 mm, poor ground cover and very high summer temperatures.

Nematodirus spathiger

The seasonal intensity of infection with *N. spathiger* in the wethers and its monthly acquisition by the tracer goats are graphically illustrated in Fig. 1.

Nematodirus spathiger was always present with total burdens for the sets of three untreated wethers fluctuating between 425 and 2 375 worms. Fourth stage larvae were recovered from these wethers from August 1985 to March 1986 and again from two goats in September 1986. The tracer goats picked up infection from the pastures from August 1985 to March 1986, matching the months in which fourth stage larvae were present in the untreated wethers. The tracers acquired no infection during April and May 1986, but then picked up small numbers of worms from June till October 1986.

Nematodirus spathiger is widespread in South Africa, but is particularly prevalent in the south and south-western regions of the country, in the adjacent inland regions and in the Karoo (Viljoen 1964; 1969; Muller 1968; Horak 1981; Boomker & Horak 1992; Boomker, Horak, Watermeyer & Booyse 2000). The eggs and third stage larvae, which develop inside the eggs, are resistant to heat and to desiccation (Viljoen 1969). In the Karoo these eggs accumulate wherever there are faecal concentrations and the larvae hatch whenever rain falls. This results in large numbers of infective larvae within a small area in which there may also be a flush of green vegetation, hence resulting in infection (Reinecke 1983). Judging by the presence of fourth stage larvae in the tracers and the untreated wethers, infection is available on the pastures at the time kids are born and during their first few months of life. However, the very young kids only became lightly infected, acquiring their major infection with this nematode once they were approximately a year old.

Skrjabinema sp.

Large numbers have been recovered from goats and from grysbok (*Raphicerus melanotis*) in Valley Bushveld and considerably fewer from goats in Mixed Bushveld (Boomker *et al.* 1989; 1994; Horak *et al.* 1991b). Little is known about these reputedly non-pathogenic worms (Reinecke 1983). No explanation can be given as to why the intensity and prevalence of infection in the kids born at Jansenville in 1985 were significantly lower than those in the tracers and untreated wethers born in 1984 (Table 1).

Trichostrongylus spp.

Trichostrongylus falculatus is a parasite of wild ruminants in South Africa (Horak 1981; Horak, Meltzer & De Vos 1982; Boomker *et al.* 2000), but is frequently encountered in domestic small stock (Viljoen 1964; Muller 1968; Boomker *et al.* 1989; 1994). *Trichostrongylus pietersei* was originally described from Angora goats and sheep in the Karoo (Le Roux 1932), but appears to be more common in the southern coastal regions of the country (Rossiter 1964; Muller 1968). *Trichostrongylus rugatus* is the dominant *Trichostrongylus* species in goats in the Valley Bushveld (Boomker *et al.* 1989; Horak *et al.* 1991b), including those grazing irrigated kikuyu grass pastures within this region (Fivaz *et al.* 1990). In addition, it is an important parasite of sheep in the coastal and inland areas of the Eastern Cape Province (Barrow 1964; Rossiter 1964).

The few *Trichostrongylus* spp. worms recovered in the present survey are probably a reflection of the prevailing arid climate in the Jansenville region. The combined totals of all the *Trichostrongylus* spp. in the untreated wethers and those acquired monthly by the tracer goats were too small to determine meaningful patterns of seasonal intensity of infection.

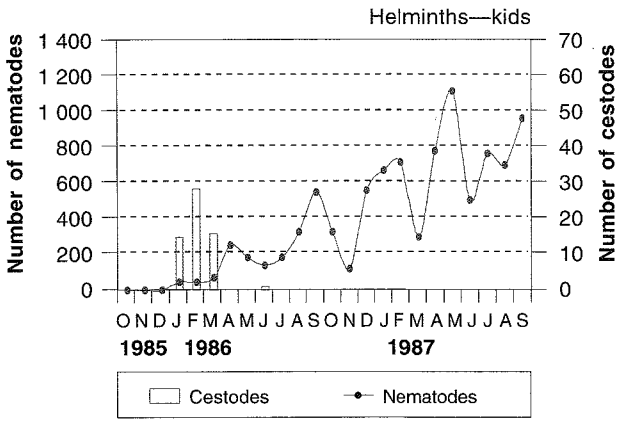

FIG. 2 The acquisition of helminth infection by Angora goat kids from 1 week to 23 months of age in the southern Karoo, Eastern Cape Province

The acquisition of helminth infection and increase in burdens (excluding *Skrjabinema* sp.) in the kids from 1 week to 23 months of age are graphically illustrated in Fig. 2.

The kids acquired their first nematode infections between 2 and 3 months of age (December 1985 to January 1986) and the intensity of infection increased erratically as the kids grew older, reaching a plateau generally varying between 600 and 1 200 worms once the kids had reached 14 months of age in December 1986.

Moniezia expansa

Eight of the nine kids examined between the ages of 3 and 5 months (January to March 1986) were infected with *M. expansa* (Fig. 2). Only one other kid was infected with this cestode. The virtual absence of cestodes in kids older than 6 months indicates an age resistance to infection in Angora goats. A similar observation has been made in Angora goat kids in Valley Bushveld and in indigenous goat kids in Mixed Bushveld in the Northern Province (Horak *et al.* 1991b; Boomker *et al.* 1994). The presence of *M. expansa* in kids practically only from January to March implies that its life cycle in Angora goats at Jansenville takes a year to complete, with infection surviving during the intervening months in oribatid mite intermediate hosts. The pattern of infection in the goats differs from that recorded in young tracer sheep on irrigated pastures on the Gauteng Province highveld where infection was acquired throughout the year with peaks during the early and the late summer months (Horak & Louw 1977).

Arthropods

The total numbers of arthropods collected from all 160 goats examined are summarized in Table 2.

TABLE 2 Arthropod parasites collected from 160 Angora goats and kids in the southern Karoo, Eastern Cape Province

Arthropod species	Total numbers of arthropods collected					Number of goats and kids infested
Ixodid ticks	Larvae	Nymphs	Males	Females	Total	
Amblyomma marmoreum	66	0	0	0	66	5
Hyalomma truncatum	0	0	12	9	21	5
Rhipicephalus evertsi evertsi	297	310	8	13	628	33
Rhipicephalus exophthalmos	0	0	111	86	197	36
Rhipicephalus glabroscutatum	1 780	492	412	168	2 852	94
Lice	Nymphs		Adults			
Damalinia limbata	712 865		436 387		1 149 252	159
Linognathus africanus	60 892		60 787		121 679	81
Oestrid fly larvae	Larvae					
Oestrus ovis	1 190				1 190	Unknown

Five ixodid tick species were collected from the goats of which *Rhipicephalus glabroscutatum* was the most abundant and prevalent. These ticks are all adapted to hot, arid environments (Theiler 1950; Howell, Walker & Nevill 1978; MacIvor 1985; Walker & Olwage 1987; Walker, Keirans & Horak 2000). The goats were also infested with the biting louse *Damalinia limbata* and the sucking louse *Linognathus africanus* as well as the larvae of the nasal bot fly *Oestrus ovis*.

Amblyomma marmoreum

The adults of this tick prefer tortoises as hosts, and while the immature stages can also be found on these animals, the larvae particularly parazitize various mammals and birds (Theiler 1962; Norval 1975; Horak, MacIvor, Petney & De Vos 1987; Dower, Petney & Horak 1988). The collection of larvae in the present survey during March, May and August falls within the period February to August or September recorded on goats in Valley Bushveld approximately 200 km to the east of the survey locality (Horak *et al.* 1991b), and observed on leopard tortoises (*Geocheolone pardalis*) in the Eastern Cape Province by Norval (1975).

Hyalomma truncatum

Only 21 adult ticks were collected and these were present during November 1985 and October and November 1986. The adults of this tick prefer large ruminants or equids as hosts, but will attach to smaller animals (Norval 1982; Walker 1991). The early summer intensity of infestation noted at Jansenville has also been recorded on Cape mountain zebras (*Equus zebra zebra*) and eland (*Taurotragus oryx*) near Cradock, approximately 130 km to the north-east of the survey farm (Horak, Fourie, Novellie & Williams 1991a).

Rhipicephalus evertsi evertsi

The preferred hosts of all stages of development of this two-host tick are domestic and wild equids and ruminants, on which the adults attach under the tail and the immature stages in the ear canals (Walker *et al.* 2000). With the exception of Cape mountain zebras, Burchell's zebras (*Equus burchelli*) and eland (Horak *et al.* 1991a), adults are seldom collected in large numbers.

Rhipicephalus exophthalmos

This tick is present in the drier southern and western regions of South Africa and also in Namibia (Keirans, Walker, Horak & Heyne 1993; Walker *et al.* 2000). It has been collected from Angora goats in Valley Bushveld [as *Rhipicephalus* sp. (near *R. oculatus*)], approximately 200 km to the south-east of the study site, but only three of 98 animals examined there were infested (Horak *et al.* 1991b). Its hosts are domestic and wild ruminants and scrub hares (Keirans *et al.* 1993; Walker *et al.* 2000). Ticks were present on cattle in the Valley Bushveld site chiefly from spring to late summer (Horak 1999) compared to a peak in the intensity of infestation during spring on the goats in the present survey.

Rhipicephalus glabroscutatum

The seasonal intensity of infestation with *R. glabroscutatum* derived from the tick burdens of all the goats examined between August 1985 and October 1986 is graphically illustrated in Fig. 3.

The immature stages of this two-host tick were present mainly from March to September and the adults from July to January.

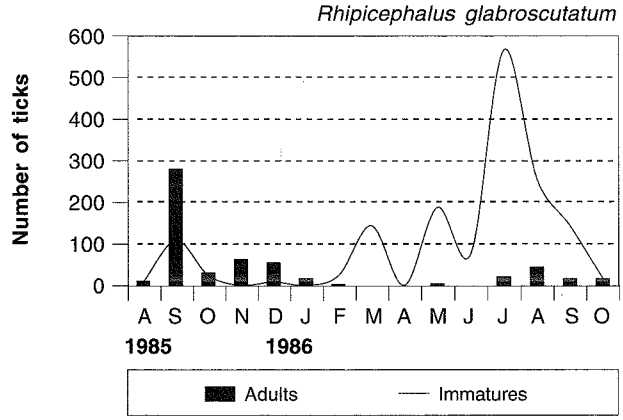

FIG. 3 The seasonal intensity of infestation with *Rhipicephalus glabroscutatum* on Angora goats in the southern Karoo, Eastern Cape Province

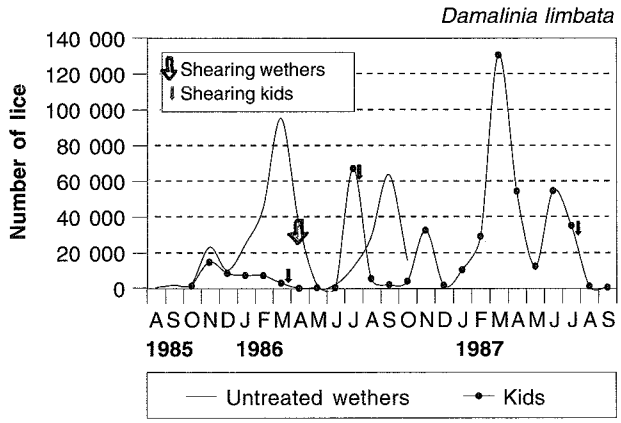

FIG. 4 The intensity of infestation with the biting louse *Damalinia limbata* on Angora goats in the southern Karoo, Eastern Cape Province

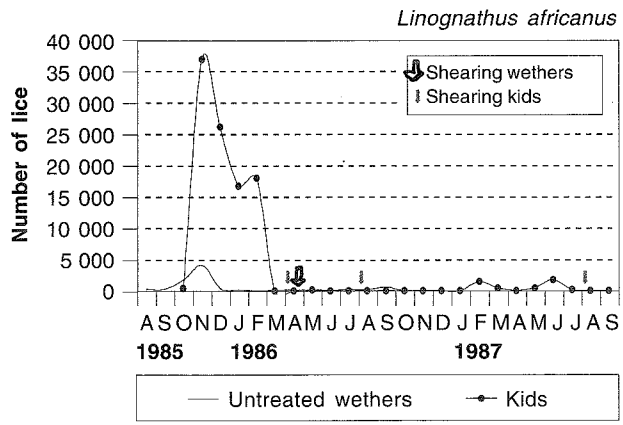

FIG. 5 The intensity of infestation with the sucking louse *Linognathus africanus* on Angora goats in the southern Karoo, Eastern Cape Province

Rhipicephalus glabroscutatum is found only in South Africa, where it occurs in the more arid south-eastern summer rainfall regions and in the southern and south-western winter rainfall regions (MacIvor 1985; Walker *et al.* 2000). The preferred hosts of all stages of development are domestic and wild ruminants to which the vast majority of ticks attach around the feet and the lower legs (Walker *et al.* 2000). The seasonal intensity of infestation recorded in the present study is similar to that on Angora goats, cattle and greater kudus in Valley Bushveld (Horak *et al.* 1991b, 1992; Horak 1999), and confirms the single annual life cycle of the tick. The presence of adult ticks is significantly associated with the occurrence of foot abscess in goats (MacIvor & Horak 1987).

Damalinia limbata

The intensity of infestation of this louse on the untreated wethers and on the kids is graphically illustrated in Fig. 4.

This is the most prevalent biting louse of Angora goats in the Eastern Cape Province and very large burdens can be present. Kids were already infested with *D. limbata* at 1 week of age. In previous surveys kids were also infested within a few days of birth and burdens increased rapidly thereafter (Fivaz *et al.* 1990; Horak *et al.* 1991b). In the present survey, the intensity of infestation was adversely affected by shearing and remained low for 1–3 months thereafter and then rapidly increased in all groups of goats signifying a short life cycle and prolific reproduction. Murray (1968) noted that at shearing lice are removed with the shorn fleece of sheep, and that on newly-shorn animals the biting louse *Damalinia ovis* and its eggs can be killed by a rise in skin temperature caused by solar radiation, thus accounting for a further reduction in louse burdens.

Linognathus africanus

The intensity of infestation with this louse on the untreated wethers and on the kids is graphically illustrated in Fig. 5.

Lignognathus africanus was present on the kids during the first few months of their lives and again just before they became 1 and 2 years old, respectively.

This louse was not collected in any of the previous surveys conducted on Angora goats in the Eastern Cape Province. It is, however, considered by goat farmers to be a pathogenic infestation of both heavily pregnant ewes as well as their new-born kids. If the time of its occurrence on the untreated wethers in the present survey can be equated to that on the dams of the kids in the survey it is apparent that older goats harbour infestation at precisely the time that the kids are born. The new-born kids then serve as an ideal vehicle to harbour and propagate infestation.

The kids were already infested with small numbers of *L. africanus* at 1 week of age, and these increased dramatically in the following 3 weeks to reach a mean intensity of infestation exceeding 12 000 lice by the time they were 1 month old. This increase probably originated from two sources, firstly further transfer of infestation from the ewes and secondly rapid multiplication on the highly susceptible kids. The virtual disappearance of the louse once the goats had reached 5 months of age is related to shearing, seasonality and probably resistance to infestation as the goats grew older. Its reappearance on the wethers in late winter and spring would correspond to increases on goat ewes during the periparturient period. This increase is possibly related to the stress suffered by most animals, and particularly heavily pregnant ewes, after winter.

Oestrus ovis

The seasonal intensity of infestation with the larvae of *O. ovis* in the three groups of goats is graphically illustrated in Fig. 6.

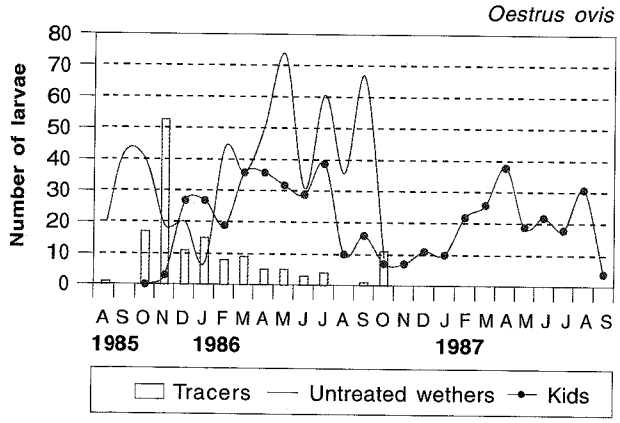

FIG. 6 The seasonal intensity of infestation with the larvae of *Oestrus* ovis in the nasal passages of Angora goats in the southern Karoo, Eastern Cape Province

Larvae were always present in the untreated goats. No larvae were recovered from the tracer goats in September 1985 and August 1986, while the largest numbers were collected from October 1985 to January 1986 and again in October 1986. Infestation was already present in the kids at 1 month of age in November 1985.

Kids born during September in Valley Bushveld were first infested with the larvae of *O. ovis* during December (Horak *et al.* 1991b), whereas kids born during October in Valley Bushveld, but maintained on irrigated kikuyu grass pastures, were infested for the first time during February (Fivaz *et al.* 1990). The seasonal pattern in the intensity of infestation in the kids, untreated wethers and the tracer goats in the present study indicates that new infestation generally took place during spring, from September onwards, probably as a result of the synchronous hatching of flies from pupae accumulated during the late winter months (Horak 1977). The intensity of infestation then peaked from late summer to late winter because of the successive generations of flies that developed. These flies were probably only present until late summer. As a result very few larvae were deposited in the nostrils of the tracer goats during the autumn and winter months and larvae over-wintered in the nasal passages of untreated goats. A similar pattern of infestation has been recorded in sheep in Gauteng Province, South Africa (Horak 1977).

Control

Contrary to the general practice of treating Angora goat kids within the survey region with anthelmintics five or six times before they reach 6 months of age, a single treatment against cestodes during late January or in February and against nematodes when the kids reach a year of age in October would seem to be adequate for the control of helminths. The control of lameness in goats caused by the adults of *R. glabroscutatum* attaching to the feet between the claws, and of foot abscess, the prevalence of which has been statistically correlated with the presence of this tick (MacIvor & Horak 1987), can be accomplished by applying acaricide in a foot dip from August to October. If at all practicable, biting and sucking lice can be controlled by treating ewes shortly before parturition. A second treatment 2 weeks later should kill lice that had hatched from eggs unaffected by the first treatment and should also delay the build up of infestation. If this is not feasible because of the possibility of abortion when handling heavily pregnant animals, the kids should be treated during their first month of life followed by a second treatment 2 weeks later. The ewes can then be treated at the same time as the kids. Thereafter, two treatments 2 weeks apart after each shearing should assist in keeping infestation in control. Treatment administered during October or November for the control of *O. ovis* larvae will interrupt the life cycle of this fly before it becomes well established during summer.

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Sympatric cattle and goats

The single publication I refer to in this section comes from the recently completed dissertation of one of my masters degree students, and because I identified and counted several of the ticks and had considerable input in compiling the manuscript, I feel justified in including it here. One of the reasons for its inclusion is that the results demonstrate that goats are good hosts of some tick species that are normally associated with cattle and excellent hosts of others (Nyangiwe & Horak 2007). A second reason for its inclusion is that the survey on which it is based was conducted in the eastern region of the Eastern Cape Province, a region in which the indigenous blue tick *Rhipicephalus* (*Boophilus*) *decoloratus* used to abound, but has now largely been displaced by the introduced Asiatic blue tick *Rhipicephalus* (*Boophilus*) *microplus*. The latter tick is purported to be a tick of cattle, but several goats examined by Nyangiwe & Horak (2007) were infested, indicating a possible change in its host preference in South Africa.

Nyangiwe, N. & Horak, I.G. 2007. Goats as alternative hosts of cattle ticks. *Onderstepoort Journal of Veterinary Research*, 74: 1-7.

Onderstepoort Journal of Veterinary Research, 74:1–7 (2007)

Goats as alternative hosts of cattle ticks

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ABSTRACT

NYANGIWE, N. & HORAK, I.G. 2007. Goats as alternative hosts of cattle ticks. *Onderstepoort Journal of Veterinary Research*, 74:1–7

The objective of this study was to compare the presence on goats and cattle of adult ticks that usually infest cattle. To this end ticks collected from sets of five goats were compared with those collected from sets of five cattle at 72 communal dip-tanks in the eastern region of the Eastern Cape Province. *Amblyomma hebraeum* was present on goats at 25 and on cattle at 39 dip-tanks, and a total of 61 goats and 138 cattle were infested. Adult *Rhipicephalus* (*Boophilus*) *microplus* was present on goats at 48 and on cattle at 69 dip-tanks, and a total of 113 goats and 242 cattle were infested. The lengths of 84 of 148 female *R.* (*Boophilus*) *microplus* collected from the goats exceeded 5 mm or more, indicating that they could successfully engorge on these animals. The differences between the proportions of dip-tanks at which *A. hebraeum* or *R.* (*Boophilus*) *microplus* was present on goats and cattle and also between the proportions of goats and cattle that were infested were significant (Chi-square test, $P < 0.01$). Adult *Rhipicephalus appendiculatus* was present on goats at 70 and on cattle at 67 dip-tanks, and a total of 296 goats and 271 cattle were infested. The proportion of dip-tanks at which cattle were infested did not differ significantly from the proportion of tanks at which goats were infested (Fischer's exact probability test, $P = 0.44$), but the proportion of infested cattle was significantly lower than the proportion of infested goats (Chi-square test, $P < 0.05$). Adult *Rhipicephalus evertsi evertsi* was present on goats and cattle at all 72 sampling localities, and a total of 334 goats and 316 cattle were infested. The proportion of infested cattle was significantly lower than the proportion of infested goats (Chi-square test, $P < 0.05$). These results underscore the necessity of including goats in any tick control programme designed for cattle at the same locality.

Keywords: Adult ixodid ticks, alternative hosts, *Amblyomma hebraeum*, cattle, Eastern Cape Province, goats, *Rhipicephalus* (*Boophilus*) *microplus*, *Rhipicephalus appendiculatus*, *Rhipicephalus evertsi evertsi*

IINTRODUCTION

Four tick species are of major economic importance as vectors of diseases that affect domestic cattle in southern Africa. These are *Amblyomma hebraeum*, the vector of *Ehrlichia* (*Cowdria*) *ruminantium*, the cause of heartwater in cattle, sheep, goats and certain wild ruminant species (Allsopp, Bezuidenhout & Prozesky2004), *Rhipicephalus*(*Boophilus*) *decoloratus*, the vector of *Babesia bigemina*, the cause of babesiosis or African redwater in cattle (De Vos, De Waal & Jackson 2004), *Rhipicephalus* (*Boophilus*) *microplus*, an introduced tick, which is responsible for the transmission of both *B. bigemina* and *Babesia bovis*, the latter the cause of Asiatic redwater in cattle (De Vos *et al.* 2004), and *Rhipicephalus appendiculatus*, the vector of *Theileria parva*, the cause of

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theileriosis in cattle (Lawrence, Perry & Williamson 2004a, b). A fifth tick, *Rhipicephalus evertsi evertsi*, which is a vector of *Babesia caballi* and *Theileria equi*, the cause of piroplasmosis in horses (De Waal & Van Heerden 2004), has a preference for horses in all its stages of development, but is also a common parasite of cattle, goats and sheep (Norval 1981; Walker, Keirans & Horak 2000).

Several surveys have been conducted on the ticks that infest cattle and goats in South Africa. Some of these have focused only on cattle (Baker & Ducasse 1967; Londt, Horak & De Villiers 1978; Schröder 1980) and others only on goats (Rechav & De Jager 1991; Boomker, Horak & Ramsay 1994; MacIvor & Horak 2003), while a third group have included both cattle and goats at the same locality and same time (Baker & Ducasse 1968; Rechav 1982; Horak, Knight & Williams 1991; Horak 1999; Bryson, Tice, Horak, Stewart & Du Plessis 2002a, b), or in tandem (Fourie & Horak 1990, 1991; Fourie, Kok & Heyne 1996).

There are no tick species that infest either of these hosts to the exclusion of the other, but whereas goats are often the hosts of large numbers of immature ticks and fewer adults (Baker & Ducasse 1968; Bryson *et al.* 2002a; MacIvor & Horak 2003), cattle may harbour large numbers of both adult and immature ticks (Baker & Ducasse 1967; Horak 1982, 1999; Rechav 1982; Bryson *et al.* 2002b). There may, however, also be considerable proportional differences in the species composition of adult ticks on goats and cattle on the same farm (Fourie *et al.* 1996). After examining goats at five localities at which cattle were also present, Baker & Ducasse (1968) came to the conclusion that goats played an important role in maintaining tick infestations on stock farms in KwaZulu-Natal Province, and that they should be included in tick control programmes applied to cattle.

The opportunity to compare the species composition of ticks on goats and cattle examined in numerically equal small groups at the same time at several localities arose during a survey on the geographic distribution of ticks in the eastern region of the Eastern Cape Province, South Africa. The objective of the present communication is to highlight the role of goats as hosts of adult ticks of species that usually infest and transmit diseases to cattle.

MATERIALS AND METHODS

Within the five municipal districts that constitute the eastern region of the Eastern Cape Province, there are 1 057 communal dip-tanks at each of which there are 200 or more cattle registered, and 75 of these dip-tanks were selected for survey purposes. At each dip-tank five healthy adult goats, preferably with visible tick infestations, and five healthy, but preferably visibly tick-infested, year-old cattle were examined. Adult ticks were collected from the ears, bodies, bellies, feet, tails and peri-anal regions of these animals on the single occasion that each dip-tank was visited. The ticks were stored in 70% ethyl alcohol in labelled vials for later identification and quantification under a stereoscopic microscope.

The length of the idiosoma of engorging female *R.* (*Boophilus*) *microplus* collected from the goats was measured and the number of maturing (also referred to as standard) females determined. The idiosomal length of a standard *R.* (*Boophilus*) *microplus* female is 4.5–8.0 mm in length and is an indication that she will fully engorge and detach within the next 24 h (Wharton & Utech 1970). The same procedure was not followed with the ticks collected from cattle because living engorging and engorged female *R.* (*Boophilus*) *microplus* were required for acaricide resistance tests. We have chosen to use the name *R.* (*Boophilus*) *microplus* as proposed by Murrell & Barker (2003) after Murrell, Campbell & Barker (2000) and Beati & Keirans (2001) had shown that the genus *Rhipicephalus* is paraphyletic with respect to the genus *Boophilus*. Many people, however, prefer to retain *Boophilus* as a generic name.

The collections of ticks from each goat or bovine were not intended to be exhaustive and consequently the numbers of ticks recovered from these animals cannot be compared. However, the presence or absence of particular tick species on the two host species as well as at the various dip-tanks can be compared. A Chi-square test was used to compare the proportion of dip-tanks at which goats were positive for each of the four tick species with the proportion of dip tanks at which cattle were positive for the same species.

It was possible to sample five goats and five cattle at 72 of the 75 selected dip-tanks and consequently the presence or absence of ticks on 360 goats could be compared with that on the same number of cattle. A Chi-square test was used to compare the proportion of positive goats to the proportion of positive cattle for each of the tick species, and Wilcoxon's signed rank test for matched pairs was used to compare the difference between the number of infested goats and the number of infested cattle at each dip-tank.

For comparative purposes the numbers of ticks collected from goats and cattle during previous surveys conducted at various localities in South Africa have been summarized and presented in tabular format.

RESULTS

Amblyomma hebraeum was present on goats at 25 and on cattle at 39 dip-tanks, and a total of 61 goats and 138 cattle were infested (Fig. 1). The proportion of dip-tanks at which goats were infested differed from the proportion of tanks at which infested cattle were present (Chi-square test, $P < 0.05$). The proportion of cattle infested with *A. hebraeum* was higher than the proportion of goats (Chi-square test, $P < 0.01$), and the median of the difference between the number of infested cattle and infested goats was greater than zero ($P < 0.01$).

Rhipicephalus (*Boophilus*) *microplus* was present on goats at 48 and on cattle at 69 dip-tanks, and a total of 113 goats and 242 cattle were infested (Fig. 1). The proportion of dip-tanks at which goats were infested differed from the proportion of tanks at which infested cattle were present (Chi-square test, $P <$

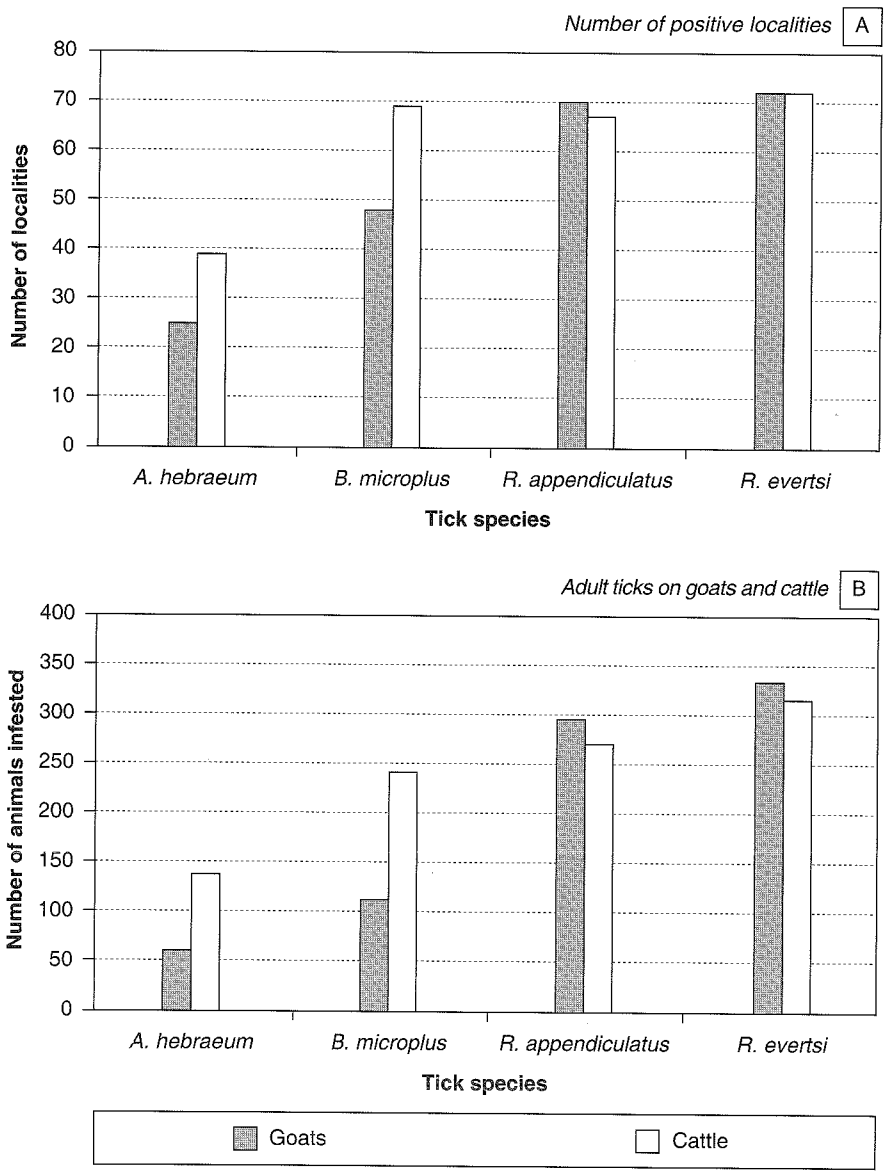

FIG. 1 The numbers of (A) dip-tanks at which *Amblyomma hebraeum*, *Rhipicephalus* (*Boophilus*) *microplus*, *Rhipicephalus appendiculatus* and *Rhipicephalus evertsi evertsi* were present on goats and cattle, and the total numbers of (B) goats and cattle on which these ticks were present at 72 dip-tanks in the eastern region of the Eastern Cape Province, South Africa

TABLE 1 Numbers of ticks collected in previous surveys from goats and cattle examined at the same localities in various provinces of South Africa

Province and Tick species	Total No. of adult ticks (total No. of collections)	
	Goats	Cattle
KwaZulu-Natal Province[1]	**Untreated**	**Untreated**
Amblyomma hebraeum	26 (10)	312 (20)
Rhipicephalus (Boophilus) microplus	266 (all stages) (9)	32 692 (all stages) (18)
Rhipicephalus appendiculatus	179 (39)	782 (70)
Rhipicephalus evertsi evertsi	184 (48)	662 (88)
Eastern Cape Province[2]	**Untreated, but ran with a treated herd**	**Untreated in previous 5 weeks**
Amblyomma hebraeum	16 (48)	1 092 (46)
Rhipicephalus appendiculatus	60 (48)	1 244 (46)
Rhipicephalus evertsi evertsi	3 (48)	74 (46)
North West Province[3]	**Untreated**	**Untreated in previous 7 days**
Amblyomma hebraeum	90 (123)	3 461 (141)
Rhipicephalus appendiculatus	38 (123)	1 387 (141)
Rhipicephalus evertsi evertsi	226 (123)	836 (141)
Mpumalanga Province[3]	**Untreated**	**Untreated in previous 7 days**
Amblyomma hebraeum	6 (30)	72 (36)
Rhipicephalus appendiculatus	32 (30)	38 (36)
Rhipicephalus evertsi evertsi	404 (30)	37 (36)
Free State Province[4]	**Untreated**	**Untreated**
Hyalomma marginatum rufipes	41 (750)	2 598 (397)
Hyalomma truncatum	72 (750)	270 (397)
Ixodes rubicundus	2 052 (750)	4 565 (397)
Rhipicephalus evertsi evertsi	3 (750)	197 (397)
Rhipicephalus warburtoni	3 782 (750)	562 (397)

[1] Baker & Ducasse (1968)
[2] Horak *et al.* (1991) and Horak (1999)
[3] Bryson *et al.* (2002a, b)
[4] Fourie & Horak (1990, 1991) and Fourie *et al.* (1996)

0.01). The proportion of infested cattle was higher than the proportion of infested goats (Chi-square test, $P < 0.01$), and the median of the difference between the number of infested cattle and infested goats was greater than zero ($P < 0.01$). One hundred and forty-eight female *R. (Boophilus) microplus* that had been collected from the goats were measured and 84 of these were 5 mm or more in length, implying that they would probably engorge and detach within the next 24 h.

Rhipicephalus appendiculatus was present on goats at 70 and on cattle at 67 dip-tanks, and a total of 296 goats and 271 cattle were infested. The proportion of dip-tanks at which goats were infested did not differ from the proportion of tanks at which cattle were infested (Fischer's exact probability test, $P = 0.44$). However, the proportion of cattle infested was lower than the proportion of goats (Chi-square test, $P < 0.05$), and the median of the difference between the number of infested cattle and infested goats was equal to zero ($P = 0.1$).

Rhipicephalus evertsi evertsi was present on goats and cattle at all 72 dip-tanks, and a total of 334 goats and 316 cattle were infested (Fig. 1). The proportion of infested cattle was lower than the proportion of infested goats (Chi-square test, $P < 0.05$), and the median of the difference between the number of infested cattle and of infested goats was less than zero ($P < 0.05$).

With the exception of Free State Province, in which certain species of ticks collected from goats and cattle differed considerably from those on goats and cattle examined in other provinces, the same three or four major species were collected at most localities (Table 1). Apart from *R. evertsi evertsi* on goats in Mpumalanga Province, and *Rhipicephalus warburtoni* on goats in Free State Province, cattle ex-

amined at the same localities as goats invariably harboured more adult ticks than did goats that were infested with the same species.

DISCUSSION

Horak, MacIvor, Petney & De Vos (1987) concluded that the larger the host species the greater the likelihood that it would harbour large numbers of adult *A. hebraeum*, and this was confirmed by the present findings. In ten collections made over a period of a year from a goat in Thornveld in KwaZulu-Natal, Baker & Ducasse (1967) recovered a total of 26 adult *A. hebraeum*. The total number collected from two calves sampled at the same times as the goat at the same locality, where no stock had been dipped in an acaricide for the previous 6 years, was 312 adult ticks (Table 1). Horak, Knight & Williams (1991) collected a total of 16 adult ticks from 48 adult Angora goats that were slaughtered in pairs at monthly intervals on a farm in Valley Bushveld in the Eastern Cape Province. Forty-six young cattle that were also slaughtered in pairs at monthly intervals at the same locality as the goats, were infested with a total of 1 092 adult *A. hebraeum*. Goats can, however, harbour larger numbers of adult ticks of this species and Rechav & De Jager (1991) recovered approximately 1 160 adult ticks in 220 collections made from goats over a period of 22 months in Limpopo Province. MacIvor & Horak (2003) collected totals of 387 and 214 adult ticks from 24 Angora and 24 of Boer goats respectively, that were each slaughtered in pairs at monthly intervals on a farm in Valley Bushveld in the Eastern Cape Province.

Rhipicephalus (*Boophilus*) *microplus* uses cattle as hosts and is usually only found on other animals provided infested cattle are present at the same locality. Baker & Ducasse (1967) recovered a total of 266 ticks in all stages of development in nine consecutive collections from a goat, while the total yield of nine collections from two calves at the same locality was 32 692 ticks (Table 1). Mason & Norval (1980) recorded 81 collections of *R.* (*Boophilus*) *microplus* from cattle and a single collection each from a goat and a horse during the National Tick Survey conducted in Zimbabwe. Horak, Sheppey, Knight & Beuthin (1986) recovered *R.* (*Boophilus*) *microplus* from a grey rhebok, *Pelea capreolus*, grazing with cattle outside the Bontebok National Park near Swellendam in the Western Cape Province, South Africa, but not one of 59 of these antelopes examined inside the park, where no cattle are permitted, was infested (Horak *et al.* 1986; Horak & Boomker 1998).

The recovery of *R.* (*Boophilus*) *microplus* from goats at so many localities in the present study can be ascribed to the high prevalence of infestation on cattle at the same dip-tanks (Fig. 1), and to the fact that questing *R.* (*Boophilus*) *microplus* larvae were collected from the vegetation at 62 of the 72 survey sites (Nyangiwe & Horak, unpublished data 2006). A more significant finding, however, is the large proportion of female ticks 5 mm or more in length collected from the goats. This is a good indication that the ticks were successfully completing their life cycles on the goats and could perhaps even do so in the absence of infested cattle to replenish their infestations. If this is so, a further adaptation to several wildlife species, particularly bushbuck, *Tragelaphus scriptus* and greater kudus, *Tragelaphus strepsiceros*, that share much of their habitat with goats in the Eastern Cape Province, and are excellent hosts of the closely related *R.* (*Boophilus*) *decoloratus* (Horak, Potgieter, Walker, De Vos & Boomker 1983; Horak, Boomker, Spickett & De Vos 1992), may be imminent.

Minimum temperature requirements for *R.* (*Boophilus*) *microplus* in Africa are approximately 4 °C lower than those required by the same species in South America, and in contrast to ticks in the latter region, African *R.* (*Boophilus*) *microplus* can withstand periods of low rainfall during the winter months (Estrada-Peña, Bouattour, Camicas, Guglielmone, Horak, Jongejan, Latif, Pegram & Walker 2006). Moreover, crossbreeding experiments between South African and Australian *R.* (*Boophilus*) *microplus* resulted in hybrid sterility (Spickett & Malan 1978), indicating additional mutations in South African *R.* (*Boophilus*) *microplus*. An adaptation by this tick to a new host species may thus not be an unrealistic expectation.

Domestic cattle and large herbivores such as greater kudus and male nyalas, *Tragelaphus angasii*, are hosts favoured by *R. appendiculatus* (Baker & Ducasse 1967; Horak 1982; Horak *et al.* 1992; Horak, Boomker & Flamand 1995). Horak *et al.* (1991) collected a total of only 60 adult ticks from 48 adult Angora goats, while 46 young cattle on the same farm harboured a total of 1 244 adult *R. appendiculatus* (Table 1). Twenty-five greater kudus examined on the farm and on an adjacent nature reserve harboured a total of 604 adult ticks (Horak *et al.* 1992). Although the actual numbers of ticks collected from goats and from cattle in the present study cannot be compared, 25 more goats at three more localities than cattle were infested with adult ticks.

Rhipicephalus evertsi evertsi has the most widespread distribution of all ticks belonging to the genus *Rhipicephalus* in Africa, and also has one of the largest host ranges (Walker *et al.* 2000). The preferred hosts of all its parasitic life stages are domestic and wild equids, but large numbers may infest cattle, goats and sheep (Norval 1981; Walker *et al.* 2000). Baker & Ducasse (1968) collected more adult ticks from untreated cattle than from goats at five localities in KwaZulu-Natal Province, but the converse was true for goats in Mpumalanga Province (Bryson *et al.* 2002a; Table 1). In the present study ticks were collected from both goats and cattle at all 72 survey localities, but a total of 334 goats compared to 316 cattle were infested with adult ticks (Fig. 1).

CONCLUSIONS

The results of this study indicate that goats are good hosts of most of the economically important ticks that infest cattle, and that *R.* (*Boophilus*) *microplus*, which has previously been considered a cattle tick, may be in the process of adapting to goats. In the light of these findings it is imperative to include goats in any tick control programme applied to sympatric cattle.

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Dogs

The survey on dogs that had been diagnosed with *Babesia canis* infection at the Faculty of Veterinary Science, Onderstepoort, revealed that, even though the ticks that were responsible for the transmission of the organism may have detached from the dogs before any clinical signs were apparent, 304 of the 395 affected dogs examined were infested with *Haemaphysalis leachi* (now known as *Haemaphysalis elliptica*) (Horak 1995). Although this may be considered circumstantial evidence, it nevertheless appears to support the belief that *H. elliptica* is the principal vector of *B. canis* in South Africa. The other surveys indicated that where dogs were kept in an urban or township environment, and were either caged or chained, they were likely to be infested with *Rhipicephalus sanguineus* (Bryson, Horak, Höhn & Louw 2000; Neves, Afonso & Horak 2004), of which all stages of development use dogs as hosts. Dogs in suburban or rural environments on the other hand were more likely to be infested with *H. elliptica* (*H. leachi*) and *Rhipicephalus simus* (Horak, Emslie & Spickett 2001b; Horak & Matthee 2003; Neves *et al*. 2004; Nyangiwe, Horak & Bryson 2006), of which the immature stages use rodents as hosts.

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IXODID TICKS COLLECTED AT THE FACULTY OF VETERINARY SCIENCE, ONDERSTEPOORT, FROM DOGS DIAGNOSED WITH *BABESIA CANIS* INFECTION

I G HORAK*

ABSTRACT

In an attempt to identify the vectors of *Babesia canis*, ticks were collected over a period of 3 years from a total of 395 dogs diagnosed as infected with this protozoan parasite at the Veterinary Faculty, Onderstepoort. *Haemaphysalis leachi* was the only tick species recovered from 164 of these dogs, and it occurred in mixed infestation on a further 140 of the dogs. *Rhipicephalus sanguineus* was collected in pure infestation from 59 dogs with a further 87 harbouring mixed infestations. Sixteen dogs harboured only *Rhipicephalus simus* and 58 others carried this tick in mixed infestations. Because the incubation period of *B. canis* is thought to be longer than the time most ixodid ticks spend on their hosts, no conclusion can be made on the vector status of any of the tick species. However, the majority of dogs diagnosed with clinical canine babesiosis at Onderstepoort were concurrently infested with *H. leachi*.

Key words: Dogs, ixodid ticks, *Babesia canis* infection, canine babesiosis

Horak I.G. **Ixodid ticks collected at the Faculty of Veterinary Science, Onderstepoort, from dogs diagnosed with *Babesia canis* infection.** *Journal of the South African Veterinary Association* (1995) 66 No. 3, 170-171(En) Department of Veterinary Tropical Diseases, Faculty of Veterinary Science, University of Pretoria, 0110 Onderstepoort, Republic of South Africa.

Babesia canis is the most common tick-borne protozoal infection of dogs in South Africa. The chief vector in this country is reported to be *Haemaphysalis leachi*, while *Rhipicephalus sanguineus* may apparently also play a role[3]. It has recently been demonstrated that there are vector-specific strains of *B. canis*[5], and a strain has been isolated from an infected dog at Onderstepoort which could be transmitted by *H. leachi* but not by *R. sanguineus*[4]. It was not possible to demonstrate that the latter tick transmitted *B. canis* at Onderstepoort[4].

Many dogs with clinical *B. canis* infections are presented for treatment at the Veterinary Academic Hospital, Faculty of Veterinary Science, University of Pretoria, Onderstepoort. Ticks were collected in 70% ethyl alcohol by veterinary students at the Outpatients Clinic of this faculty from dogs in which *B. canis* was identified in blood smears. Ticks were also collected at necropsy from dogs which had similarly been diagnosed as infected with *B. canis*. All the ticks were later identified under a stereoscopic microscope and counted. The survey lasted from June 1991 to May 1994 and ticks were collected from 395 dogs (Table 1).

Ten tick species were collected from the 395 *B. canis* infected dogs. The most abundant and prevalent species was *H. leachi*, followed by *R. sanguineus* and *Rhipicephalus simus*. The largest numbers of adult *H. leachi*, *R. sanguineus* and *R. simus* recovered from individual dogs comprised 242, 47 and 15 ticks respectively.

Several aspects of this survey can be criticised. Firstly, the incubation period of *B. canis* infection is thought to vary between 10 and 21 days[1], while most female ticks only remain attached for approximately 7 to 10 days, with the males generally persisting for longer periods[3]. Consequently, the ticks collected from the infected dogs were not necessarily those responsible for transmission of the *Babesia*. Secondly, only ticks from the anterior half of each dog were collected and not all the ticks present on this half were necessarily collected. Thirdly, ticks were not collected from every dog infected with *B. canis*. Finally, it would appear that ticks were collected from a smaller proportion of infected dogs during the summer recess months of December and January than during other months. Despite these shortcomings, it is apparent that, at the time of diagnosis of *B. canis* infection, most dogs seen at the Faculty of Veterinary Science, Onderstepoort were concurrently infested with *H. leachi*.

Combining the present findings with those of a 3-year survey conducted on healthy dogs on a small-holding near Grahamstown, a total of 16 ixodid tick species was recovered from the dogs in the 2 surveys[2]. Dogs should, however, be considered as preferred hosts of only 4 of these, namely *H. leachi*, *Ixodes pilosus*, *R. sanguineus* and *R. simus*. The remainder are probably

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Table 1: **Ticks collected from 395 dogs diagnosed with *Babesia canis* infection at the Faculty of Veterinary Science, Onderstepoort**

Ixodid tick species	Numbers of ticks collected					No. of dogs infested	No. of dogs with single species infestations
	Larvae	Nymphs	Males	Females	Total		
Amblyomma hebraeum	7	13	7	2	29	9	1
Amblyomma marmoreum	0	1	0	0	1	1	0
Boophilus decoloratus	0	3	6	34	43	12	5
Haemaphysalis leachi	24	101	1184	843	2152	304	164
Haemaphysalis spinulosa	0	0	1	1	2	1	0
Hyalomma truncatum	0	0	12	11	23	6	0
Rhipicephalus appendiculatus	0	8	0	0	8	4	1
Rhipicephalus evertsi evertsi	2	10	4	1	17	9	1
Rhipicephalus sanguineus	21	130	525	408	1084	146	59
Rhipicephalus simus	0	0	131	64	195	74	16

accidental infestations reflecting tick abundance in the immediate environment in which the dogs were kept rather than host preference.

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Article — Artikel

Ectoparasites of dogs belonging to people in resource-poor communities in North West Province, South Africa

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ABSTRACT

A total of 344 dogs belonging to people in resource-poor communities in North West Province, South Africa, was examined for ectoparasites, and all visible arthropods were collected from the left side of each dog. By doubling these numbers it was estimated that the dogs harboured 14 724 ixodid ticks, belonging to 6 species, 1028 fleas, belonging to 2 species, and 26 lice. *Haemaphysalis leachi* accounted for 420 and *Rhipicephalus sanguineus* for 14 226 of the ticks. Pure infestations of *H. leachi* were present on 14 dogs and of *R. sanguineus* on 172 dogs. Small numbers of *Amblyomma hebraeum, R. appendiculatus, R. evertsi evertsi* and *R. simus* were also collected. The predominance of *R. sanguineus* accounts for the high prevalence of canine ehrlichiosis (*Ehrlichia canis*) within the survey region, compared to canine babesiosis (*Babesia canis*), which is transmitted by *H. leachi,* and is a much rarer disease.

Key words: dogs, ectoparasites, *Haemaphysalis leachi,* resource-poor communities, *Rhipicephalus sanguineus.*

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INTRODUCTION

Surveys carried out in various countries around the world have shown that *Rhipicephalus sanguineus* is an extremely widespread and common tick species on domestic dogs in southern Africa[1,8,11–13,18,22,24,27,28,32]. Tick surveys indicated that *Haemaphysalis leachi, R. sanguineus* and *R. simus* are the most prevalent species on domestic dogs[3,9,19,20,24,30]. This prevalence differs markedly between studies[3,8,9,24,27]. Dogs belonging to more affluent communities where sophisticated veterinary services are available to clients, tend to have a higher prevalence of *H. leachi*[3,9,10]. On the other hand, dogs from rural townships appear to have a higher prevalence of *R. sanguineus*[2,24,26].

It is almost a century since it was first demonstrated that the yellow dog tick, *H. leachi,* could transmit *Babesia canis* to dogs[15]. It can transmit the disease, known as canine babesiosis, both transstadially and transovarially[15,29]. In South Africa, *H. leachi* is the major vector of this disease, and appears to transmit a particularly virulent strain[14,32]. Although *R. sanguineus* transmits *B. canis* in other parts of the world[29,32], recent research in South Africa suggests that it may be unable to do so in this country[14]. Thus, although *R. sanguineus* is frequently collected from dogs suffering from canine babesiosis[9,14], it seems that it is not an important vector of this disease in South Africa. Serological and cross-immunity studies have revealed differences between the various strains of *B. canis* in South Africa, North Africa and in Europe[14,32], which possibly accounts for the different transmission profiles.

Rhipicephalus sanguineus is the only efficient tick vector of *Ehrlichia canis,* the aetiological agent of canine ehrlichiosis, a common tick-borne disease of dogs world-wide[4], and transmission takes place transstadially but not transovarially[5]. In southern Africa, canine ehrlichiosis is usually diagnosed on typical clinical signs and the identification of the specific morulae in the monocytes of stained blood smears[16,17]. Serological surveys carried out in Zimbabwe have indicated that *E. canis* is widespread in domestic dogs in that country[17]. It is also prevalent in dogs in Bloemfontein and its surrounding districts, Free State, South Africa[23]. *E. canis* may persist in the blood of infected dogs for more than 2 years, and appears to be present in the blood of chronically infected dogs[5], which then act as reservoirs for the infection.

An outreach programme has been conducted by the Veterinary Faculty of the Medical University of South Africa (MEDUNSA) at the Maboloka Outreach Clinic, North West Province, South Africa, for the past decade. The present surveys were conducted as components of 3 projects evaluating the health status of a population of dogs belonging to resource-poor communities in this region, and the dog owners were clients of this clinic or of the Veterinary Faculty itself. These projects also sought ways to elicit community participation in tick control[7].

Results emanating from this programme indicated that the dog population had an unusually high mortality rate, with a high prevalence of malnutrition, external and internal parasites, canine ehrlichiosis, distemper and genital tumours[24–27]. Various parameters pertaining to the dog population in the Maboloka area were compared with those of a healthy population of dogs in South Africa[25,26]. The Maboloka dogs were found to be markedly anaemic, and had very high serum gammaglobulin levels[26]. It was postulated that these abnormalities were due to large burdens of external and internal parasites coupled with malnutrition[26].

One of the objectives of this work was to compare the species composition of the tick population parasitising dogs in resource-poor communities in the North West Province of South Africa with those found in other surveys. Another was to ascertain whether the tick species present could be associated with specific tick-borne diseases.

MATERIALS AND METHODS

Three hundred and forty-four randomly selected dogs, all owned by clients of the Animal Hospital at the Faculty of Veterinary Science at MEDUNSA (25° 40′S, 27°56′E), or of the Outreach Clinic at Maboloka (25°26′S, 27°51′E), North West Province, were sampled for ectoparasites. The collections formed part of 3 separate projects. The 1st group of dogs formed

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part of a project conducted during March/April 1989 evaluating the health status of dogs belonging to clients of the Animal Hospital. The owners of these dogs belonged mainly to the urban community of Garankuwa (25°40'S, 27°56'E) that virtually surrounds the University. The dogs were selected using tables of random numbers in a statistical package (IBM PC Version 3.0 1984). Only dogs older than 3 months or heavier than 2.5 kg were considered. Only 1 dog was sampled if there was more than 1 in a household.

The 2nd group formed part of a project conducted during March/April 1990 to evaluate changes in the health status of dogs at the Maboloka Outreach Clinic. The selection of dogs was random, with the Maboloka area divided into 4 quadrants with 25 dogs sampled in each quadrant. The 3rd group was also examined during 1990 at Maboloka, and consisted of dogs from 3 localities designated A, B and C. Fifty dogs from each of these localities were sampled only for ticks. The objective of this was to evaluate various methods of community participation in tick control, and to compare dogs at the 3 localities by cluster sampling.

Ectoparasites were collected from the dogs using a modification of a previously published method[8,24,27]. The anatomical areas of the dog sampled for parasites are illustrated in Fig. 1.

The sites sampled were the left eyelid and a 10-mm area around the eye (area 1); the left ear base, external and internal pinna and ear canal (area 2); left neck and shoulder (area 3); left front and back feet, carpus/tarsus distally (area 4); left dorsal tail root (50 × 50 mm) (area 5) and left ventral belly/groin (20 × 100 mm) (area 6). Collections were only made from the left side of the dog and the numbers of parasites collected doubled to approximate the total burden. All visible ectoparasites were removed by forceps, and the subsamples from each dog were pooled and stored in 70 % ethanol for later identification.

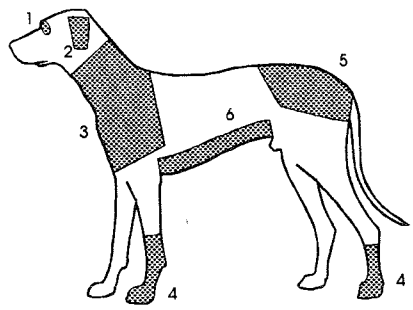

Fig. 1: **Anatomical areas of dog sampled for ectoparasites, only left side sampled.**

RESULTS

The ticks collected from the dogs are listed in Tables 1, 2, 3. The dominant tick species collected in the 3 surveys were *H. leachi* and *R. sanguineus*, with the latter tick outnumbering the former in all instances (Table 1). The total numbers of *R. sanguineus* collected from dogs examined at the Animal Hospital (Group 1) and the percentage of dogs infested with this tick were markedly lower than for the dogs at the Maboloka Outreach Clinic (Groups 2 and 3). With the exception of the larger burdens and greater number of dogs infested with *H. leachi* at locality C, Group 3, the tick burdens of the dogs in Groups 2 and 3 were similar. In all, 6 ixodid tick species were recovered from the dogs. Pure infestations of 4 species were present on 188 dogs and mixed infestations on 60 dogs, while 96 animals harboured no ticks (Tables 2, 3).

The other ectoparasites collected from the dogs in Groups 1 and 2 are summarised in Table 4. Two flea species, a louse species and the larvae of a calliphorid fly were recovered from the dogs. The number of fleas collected and the number of dogs infested at Maboloka (Group 2) considerably exceeded the number collected and the number of dogs infested at the Animal Hospital (Group 1). Most fleas on the dogs at the Animal Hospital belonged to a subspecies of the cat flea *Ctenocephalides felis strongylus*, while most at Maboloka were poultry fleas, *Echidnophaga gallinacea*. The prevalence of *C. felis strongylus* was higher than that of *E. gallinacea* at both localities.

DISCUSSION

Many surveys of ixodid ticks have been conducted in southern Africa, but only a few have involved dogs. A veterinary practitioner found the most common tick on dogs in Harare, Zimbabwe, to be *H. leachi* (51 %), followed by *R. sanguineus* (31 %) and *R. simus* (9.5 %). *Boophilus decoloratus, R. appendiculatus, R. evertsi evertsi* and *R. pravus* were also present, indicating that the dogs must have had contact with domestic ruminants[3].

In Eastern Cape Province, South Africa, *H. leachi* comprised 71.4 % and *R. simus* 15.7 % of the total number of ticks collected once or more each week from 4 domestic dogs over 3 years[10]. *R. sanguineus*

Table 1: **Major ixodid tick species collected from dogs during 3 surveys conducted in North West Province, South Africa.**

Group	No. of dogs	*Haemaphysalis leachi*				*Rhipicephalus sanguineus*				
		Nymphs	Males	Females	No. infested	Larvae	Nymphs	Males	Females	No. infested
1 (Medunsa)	94	0	20	16	7	4	94	194	118	32
2 (Maboloka)	100	4	2	4	4	206	1444	1366	602	75
3 (Maboloka) A	50	0	58	4	8	364	1478	1090	646	45
B	50	0	24	14	7	96	1468	1622	800	37
C	50	0	116	158	29	112	456	2138	1250	39

Table 2: **Ixodid ticks collected from 344 dogs during 3 surveys in North West Province, South Africa.**

Species	Total number collected						No. infested
	Larvae	Nymphs	Males	Females	Total	Relative % abundance	
A. hebraeum	20	6	2	0	28	0.19	11
H. leachi	0	4	220	196	420	2.85	55
R. appendiculatus	10	0	0	2	12	0.08	4
R. evertsi evertsi	2	0	0	0	2	0.01	1
R. sanguineus	782	3618	6410	3416	14226	96.62	228
R. simus	0	0	20	16	36	0.25	11

Table 3: **The prevalence of tick infestation on 344 dogs in North West Province, South Africa.**

Tick species	Number of dogs harbouring:		
	pure infestations	mixed infestations	no ticks
Amblyomma hebraeum	1		
Haemaphysalis leachi	14		
		60	96
Rhipicephalus sanguineus	172		
Rhipicephalus simus	1		

Table 4: **Arthropods collected from dogs during 2 surveys conducted in North West Province, South Africa.**

Group	No. of dogs	Number of arthropods collected and number of dogs infested (*n*)			
		Ctenocephalides felis strongylus Adult	*Echidnophaga gallinacea* Adult	*Heterodoxus spiniger* Adults/nymphs	*Cordylobia anthropophaga* Larvae
1 (Medunsa)	94	64 (21)	12 (3)	10 (2)	2 (1)
2 (Maboloka)	100	230 (41)	714 (30)	16 (4)	0

was not found on these dogs. In a study at the Veterinary Faculty, University of Pretoria, Onderstepoort, 77.0 % of 395 dogs diagnosed with *B. canis* infection were infested with *H. leachi*, and 37.0 % and 18.7 % with *R. sanguineus* and *R. simus* respectively[9]. The dogs in both these surveys, like those in the Zimbabwe survey, belonged to owners from more affluent communities than those in the current survey. In contrast to the results of earlier surveys conducted in the same region as the current survey and in which no *H. leachi* was recovered[24,27], small numbers were collected during this study. Canine babesiosis is not common at Maboloka[24,27], and this is probably directly related to the low prevalence *H. leachi* on dogs in this region.

H. leachi is present in the eastern half and southern regions of South Africa and throughout Zimbabwe, even in those lowveld and other arid areas where the average annual rainfall might seem too low for the tick's survival[19]. In South Africa and Zimbabwe the preferred hosts of adult *H. leachi* are all members of the family Canidae (including jackals), hyaenas, the large cats, and viverrids, while the larvae and nymphs prefer murid rodents[10,19]. It has been suggested that the distribution of *H. leachi* is affected more by the abundance of rodent hosts for the immature stages than by climate[19]. Dogs belonging to wealthy owners with large suburban gardens and probably getting regular exercise outside the garden confines, and dogs in semi-rural or rural environments are both likely to come into contact with ticks nurtured on rodents and thus tend to have a high prevalence of *H. leachi* infestations. In 2 surveys currently being conducted by I.G.H., *H. leachi* is one of the dominant species on dogs belonging to members of rural communities in northeastern KwaZulu-Natal, as well as on farm dogs in southeastern North West Province, South Africa. *R. sanguineus* has not been collected from any of the dogs in these surveys.

Various surveys conducted world-wide indicate that *R. sanguineus* is a common parasite of dogs and that its distribution may be expanding. In 1946 it was listed from 26 states in the United States of America; it has now been recorded from all 50 states[34]. It has also spread to regions of Argentina where it was not previously present[6]. In Queensland, Australia, it was the most prevalent tick on 112 sheep dogs examined[1], and in a survey of stray dogs in the Rabat region of Morocco, it was found on 68 % of the dogs[22]. Of 105 stray dogs examined at the Central Veterinary Laboratory in Kabul, Afghanistan, nearly 30 % had ticks, and 10 of these were infested with *R. sanguineus*[13]. In Oklahoma and Arkansas, USA, 870 domestic dogs were examined and a total of 74 865 ticks collected, of which 62 % were *R. sanguineus*[12]. The last survey also indicated that *R. sanguineus* was more frequently present on the head, neck and back of the dogs, as well as being present between the toes[12]. Thirty percent of 820 dogs examined by Nigerian veterinarians at various clinics had ticks, and 160 were infested with *R. sanguineus*[31].

A survey conducted in Porto Alegre City, Brazil, indicated that 93.2 % of the 450 dogs examined were infested with *R. sanguineus* and that it was by far the most abundant species[28]. In addition, a total of 31 out of 32 farm dogs examined in municipalities in Rio de Janeiro were infested with this tick[33]. Recent work in Israel has demonstrated that *R. sanguineus* is common on dogs there[18]. The large number of *R. sanguineus* collected in the present survey is in agreement with the findings of previous workers in this region, who also found it to be the predominant tick species[24,27].

Many of the earlier records of *R. sanguineus*, from hosts other than domestic dogs, probably refer to *R. turanicus*, a tick with which it is easily confused[34]. Because all stages of development of *R. sanguineus* make virtually exclusive use of dogs as hosts[34], animals that are confined in kennels, houses or small gardens, or are chained, are more likely to be infected with this tick[9]. Forty-two percent of the dogs at Maboloka were either chained or kept in cages[24,27], providing ideal conditions for the tick to flourish[12]. The smaller proportion of dogs infested and the lower burdens of *R. sanguineus* on the dogs surveyed at the Animal Hospital of MEDUNSA compared with those at the Maboloka clinic, probably reflect the more affluent urban environment from which the owners of the former dogs come as opposed to that of the latter. The large population of *R. sanguineus* on the dogs at the Outreach Clinic is clearly one of the most important reasons for the high prevalence of canine ehrlichiosis in animals served by this facility[24,27].

Another characteristic of our survey was the almost total absence of *R. simus*. As mentioned earlier, this species accounted for 9.5 %, of the ticks collected from dogs in Harare, Zimbabwe, and 15.7 % and 18.7 % from dogs in the Eastern Cape Province and at the Veterinary Faculty, Onderstepoort, South Africa, respectively[3,9,10]. It is also one of the dominant species on dogs currently being surveyed by I.G.H. in northeastern KwaZulu-Natal and on farm dogs in

southeastern North West Province, South Africa. *R. simus* is widespread in the moister regions of southern Africa and the adults prefer domestic dogs, large wild carnivores, suids, equids and domestic cattle as hosts[34]. The immature stages prefer murid rodents[20,34]. In Zimbabwe it has been noted that *R. simus* rarely occurs in communal grazing areas because of overgrazing[20]. Similar conditions existed at Maboloka, where many of the dogs were restrained in a very arid environment, especially during winter. This was probably not conducive to vegetation cover, or the survival of rodent hosts.

The presence of *Amblyomma hebraeum, R. appendiculatus* and *R. evertsi evertsi* on the dogs probably reflects contact with other domestic livestock kept by the owners and confined close to the dogs at night.

Surveys for arthropods on dogs have been conducted world-wide. Moroccan researchers recorded 18 species of parasites on stray dogs, but considered only the fleas and ticks to be of economic importance[22]. Ninety-five percent of the dogs harboured ctenocephalid fleas, with *C. canis* constituting 75 % of the flea population and *C. felis* the remaining 25 %[22]. No lice were found on the dogs. A survey performed on 112 sheep dogs in Queensland, Australia, found that 13 % of dogs had fleas, of which 78 % were *C. felis* and 21 % *E. gallinacea*[1]. In Afghanistan, 105 stray dogs were examined for parasites. More than ⅓ were infested with fleas, and 3 species, namely *C. canis, Pulex irritans* and *Ceratophyllus fasciatus,* were recovered[13]. No lice were collected.

A number of surveys on the prevalence of insect species on dogs have been described in sub-Saharan Africa. In Nigeria 820 dogs were examined at 4 veterinary clinics; 26 % of these animals were infested with *C. canis* and 28 % with the louse *Trichodectes canis*[31]. Both *C. canis* and *C. felis* were present on kennelled dogs near Onderstepoort, South Africa, with the latter species predominating[8].

An extensive cross-sectional study of dogs at Maboloka, conducted by staff of the Veterinary Faculty at MEDUNSA, revealed that *E. gallinacea* (70 %) was the predominant flea, with *C. canis* (2 %) and *C. felis* (28 %) also present in a representative sample of 299 fleas[24,27]. Four dogs were infested with *Heterodoxus spiniger* and 1 with *Trichodectes canis.* The larvae of *Cordylobia anthropophaga* were also present[24,27].

The close association between the dogs and the free-ranging chickens of their owners probably accounts for their heavy burdens of *E. gallinacea.* The large numbers of *E. gallinacea* recovered, despite its lower prevalence than that of *C. felis strongylus,* reflects its tendency to stick fast in clumps, thus making it easier to see and collect. The smaller number of fleas and lower prevalence of infestation at the Animal Hospital compared to the Outreach Clinic, is probably related to the more affluent urban environment of their owners. Only 1 louse species (*Heterodoxus spiniger*) was recovered in the present survey, and then only in small numbers, and from only 6 of 194 dogs.

Myiasis, caused by the larvae of *Cordylobia anthropophaga,* is common in the survey region[24,27], and some dogs examined at the Clinic have had more than 50 larvae embedded in their skins. The very low prevalence of *C. anthrophaga* in this survey was possibly due to the difficulty in detecting larvae in the skin of dogs that are not visibly affected, particularly if these larvae are in the 1st instar. Another factor that may have played a role is that *C. anthropophaga* is seasonal in its occurrence and is especially prevalent in midsummer, whereas these surveys were conducted in late summer.

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Parasites of domestic and wild animals in South Africa. XL. Ticks on dogs belonging to people in rural communities and carnivore ticks on the vegetation

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ABSTRACT

HORAK, I.G., EMSLIE, F.R. & SPICKETT, A.M. 2001. Parasites of domestic and wild animals in South Africa. XL. Ticks on dogs belonging to people in rural communities and carnivore ticks on the vegetation. *Onderstepoort Journal of Veterinary Research*, 68:135–141

Ixodid ticks were collected at weekly intervals from February 1999 to April 2000 from domestic dogs belonging to people in rural communities in north-eastern KwaZulu-Natal. Seven ticks were identified to species level and adult *Haemaphysalis leachi* followed by immature *Amblyomma hebraeum* and adult *Rhipicephalus simus* were the most prevalent. Infestation with adult *H. leachi* was most intense during February and March 1999 and from January to April 2000, and least intense during October 1999. Infestation with adult *R. simus* was most intense during February and March 1999 and least during July and September of the same year.

For 12 consecutive years, from August 1988 to July 2000, free-living ticks were collected at monthly intervals from the vegetation of two landscape zones in the Kruger National Park. Most adult *H. leachi* were collected in the one zone from March to June, and no ticks were collected in October, whereas, with the exception of March, most were collected in the other zone during the period January to June, and only one tick was collected in October. Most adult *R. simus* were collected during February and March at both localities and only a single tick was collected in September. Adult *Rhipicephalus turanicus* was present only in the one zone and was collected only from January to June.

Keywords: Domestic dogs, free-living ticks, *Haemaphysalis leachi,* ixodid ticks, *Rhipicephalus simus, Rhipicephalus turanicus,* rural communities, seasonal intensity of infestation

INTRODUCTION

Several surveys on ticks infesting domestic dogs in southern Africa have been conducted (Goldsmid 1963; Horak 1982; 1995; Rautenbach 1986; Horak, Jacot Guillarmod, Moolman & De Vos 1987b; Bryson, Horak, Höhn & Louw 2000), and the distribution and host spectrum of some of these ticks described (Theiler 1962; Norval & Mason 1981; Norval 1984; Walker, Keirans & Horak 2000). *Haemaphysalis leachi*, *Rhipicephalus sanguineus* and *Rhipicephalus simus* were the most prevalent species in the surveys, but their proportional intensity of infestation differed markedly in the various studies. Dogs belonging to more affluent owners tend to have a higher prevalence of *H. leachi* and *R.simus* (Goldsmid 1963; Horak *et al.* 1987b; Horak 1995). On the other hand, dogs belonging to less affluent owners, who often live in urban or peri-urban townships, have a higher prevalence of *R. sanguineus* (Bryson *et al.* 2000). Both *H. leachi* and *R. simus* utilize rodents as hosts for their immature stages (Norval & Mason 1981; Rechav 1982; Norval 1984), while the immature stages of *R. sanguineus*, like the adults, feed virtually only on domestic dogs (Walker *et al.* 2000).

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Along with other ticks, the adults of several species that parasitize both domestic dogs and wild carnivores have been collected by drag-sampling vegetation in the Kruger National Park (KNP) with flannel strips (Spickett, Horak, Van Niekerk & Braack 1992; Horak, Spickett & Braack 2000).

In this paper we discuss the tick species collected from domestic dogs belonging to people living in a rural environment in north-eastern KwaZulu-Natal, and compare their seasonal intensities of infestation with that of ticks collected from vegetation in the KNP, in which both large and small wild carnivore species abound.

MATERIALS AND METHODS

The State Veterinary District of Jozini in north-eastern KwaZulu-Natal includes the region east of the Lebombo Mountains down to the Indian Ocean and comprises the Magisterial Districts of Ingwavuma and Ubombo. This area, much of which is less than 80 m above sea level, is known as Maputaland. The soil is sandy and the vegetation in part of the region is classified as Coastal Forest and Thornveld, and in the remainder as Lowveld (Acocks 1988).

At weekly intervals from February 1999 to April 2000 Animal Health Technicians, reporting to the State Veterinarian, Jozini and residing at various localities within the Maputaland region (Fig. 1), collected ticks from their own dogs or from the dogs of their neighbours. These ticks were placed in bottles containing 70% alcohol and a label added. The ticks in the weekly collections were identified and counted and the monthly totals for each locality calculated. Seasonal intensity of infestation was determined from the mean monthly intensity of infestation for all the localities.

Using flannel strips, free-living ticks were collected at monthly intervals for a period of 12 consecutive years from August 1988 to July 2000, by drag-sampling the vegetation alongside the Nhlowa road approximately 15 km north of the Crocodile Bridge rest camp (25°22'S, 31°54'E; Alt. 217 m) in the south-east of the KNP, Mpumalanga Province (Fig. 1). The vegetation of this region is classified as Lowveld (Acocks 1988) and the landscape zone described as *Sclero-*

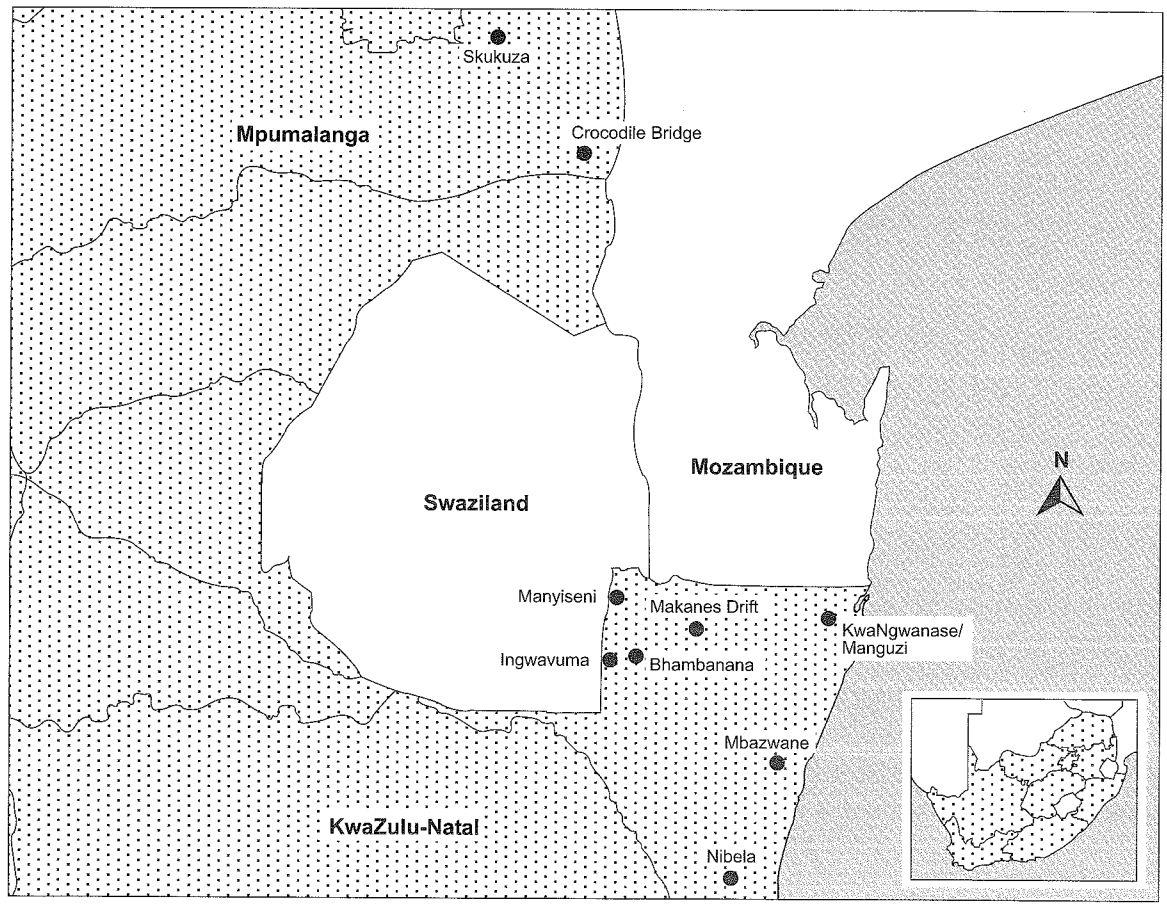

FIG. 1 Localities at which ticks were collected from dogs in north-eastern KwaZulu-Natal and from vegetation in the Kruger National Park

carya caffra/Acacia nigrescens Savanna (Gertenbach 1983). The vegetation next to a firebreak alongside the Nwaswitshaka River, approximately 5 km south-west of the Skukuza rest camp (24°58'S, 31°36'E; Alt. 262 m) in the south-west of the park (Fig. 1), was sampled in a similar fashion. The vegetation of this landscape zone is described as Thickets of the Sabie and Crocodile Rivers (Gertenbach 1983) and is also classified as Lowveld (Acocks 1988). Although a large number of tick species were collected from the vegetation, only the adults of those ticks that prefer carnivores as hosts, namely *H. leachi*, *R. simus* and *Rhipicephalus turanicus* were considered for the purpose of this study. The seasonal abundance of a particular species on the vegetation was determined by adding the numbers of ticks of that species collected in the same month of each year over the 12-year collection period.

Because of rain or impassable roads no collections were made along the Nhlowa Road during only one month in the entire 12-year survey period, and dur-

TABLE 1 Ixodid ticks collected from domestic dogs belonging to owners in rural communities in north-eastern KwaZulu-Natal

Tick species	Number of ticks collected					No. of collections
	Larvae	Nymphs	Males	Females	Total	(total = 388)
Amblyomma hebraeum	27	1 218	25	17	1 287	217
Haemaphysalis leachi	0	4	77	573	654	232
Haemaphysalis zumpti	0	0	0	4	4	4
Rhipicephalus appendiculatus	0	4	8	24	36	62
Rhipicephalus simus	0	1	181	226	408	107
Rhipicephalus tricuspis	0	0	0	14	14	4
Rhipicephalus turanicus	0	0	1	9	10	9
Rhipicephalus sp.	0	0	3	2	5	5

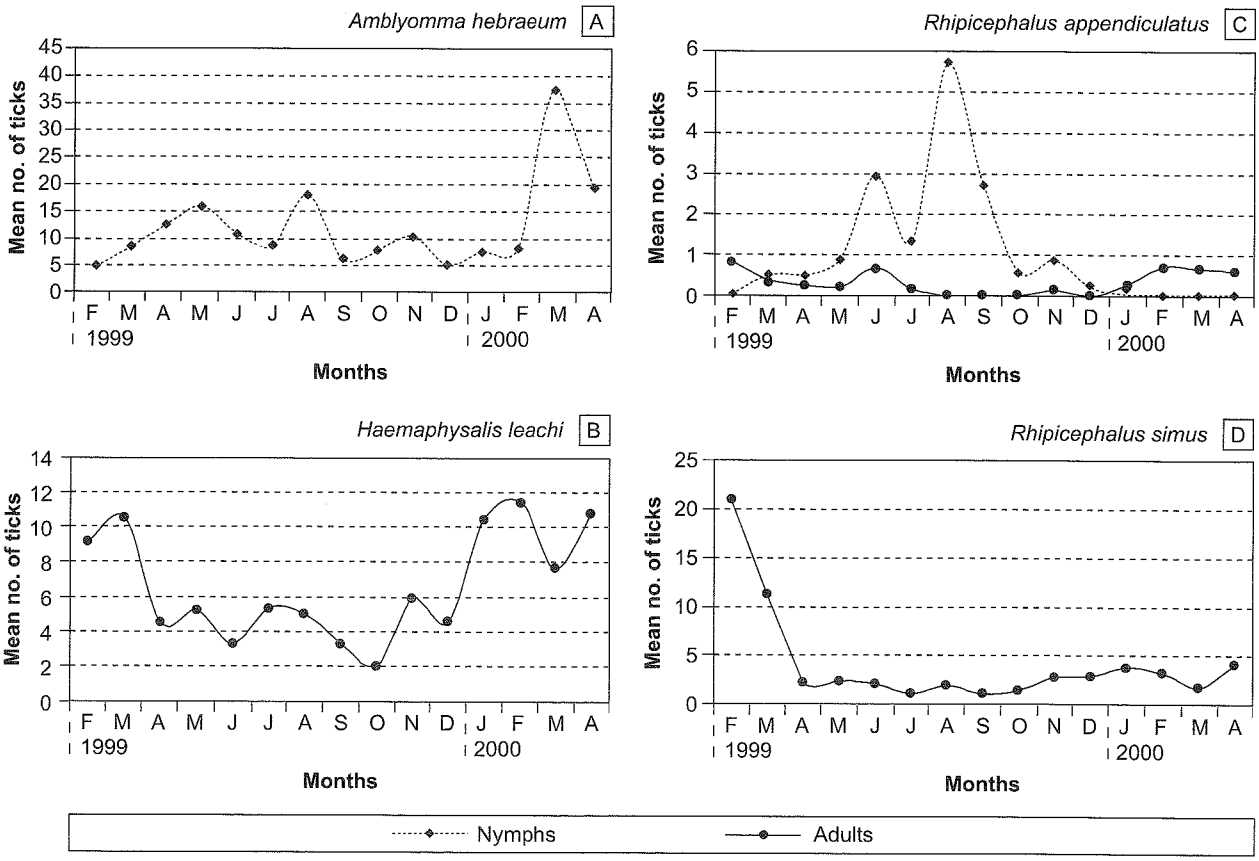

FIG. 2 The seasonal intensity of infestation of (A) *Amblyomma hebraeum* nymphs, (B) *Haemaphysalis leachi* adults, (C) *Rhipicephalus appendiculatus* nymphs and adults, and (D) *Rhipicephalus simus* adults on domestic dogs in north-eastern KwaZulu-Natal

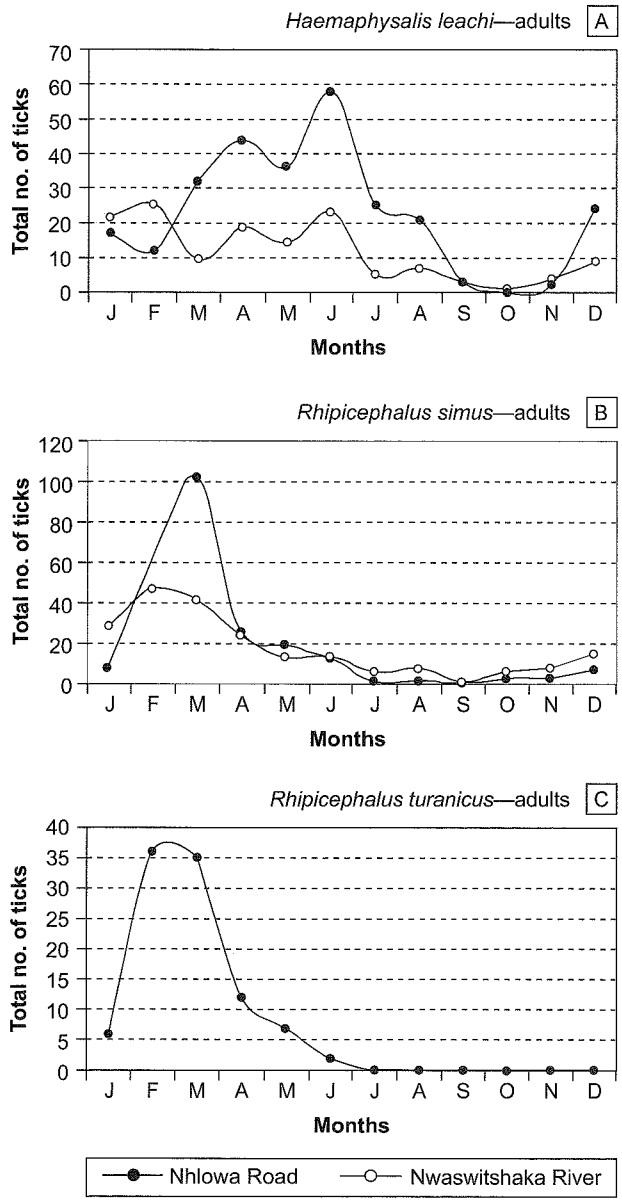

FIG. 3 The seasonality of adult (A) *Haemaphysalis leachi*, (B) *Rhipicephalus simus*, and (C) *Rhipicephalus turanicus* on vegetation in the southern Kruger National Park

ing 10 months alongside the Nwaswitshaka River. The graphs illustrating the seasonality of ticks on the vegetation have been adjusted to compensate for the missing data.

RESULTS

The species composition of the ticks collected from dogs in north-eastern KwaZulu-Natal is summarized in Table 1, and the seasonal intensity of infestation with *Amblyomma hebraeum, H. leachi, Rhipicephalus appendiculatus* and *R. simus* are graphically illustrated in Fig. 2.

Seven ixodid tick species were identified to species level, and infestation with the nymphs of *A. hebraeum* was most intense. No seasonal pattern of infestation was evident for this tick. *Haemaphysalis leachi* was the most prevalent tick and infestation was most intense during February and March 1999 and January to April 2000. Few were collected during October 1999. Albeit present in very small numbers, infestation with the nymphs of *R. appendiculatus* was most intense from June to September 1999, and the adults in February 1999 and from February to April 2000. Infestation with *R. simus* was most intense during February and March 1999, and least during July and September 1999.

The total numbers of free-living adult *H. leachi, R. simus* and *R. turanicus* collected in each calendar month from vegetation in the KNP are graphically illustrated in Fig. 3.

With the exception of a single tick each, *H. leachi* was never collected from the vegetation during the month of October and *R. simus* during the month of September at either of the localities in the KNP. The largest numbers of *H. leachi* were present alongside the Nhlowa road in the south-east of the park from March to June, and alongside the Nwaswitshaka River firebreak in the south-west during the period January to June. Most *Rhipicephalus simus* were collected from the vegetation at both localities during February and March. *Rhipicephalus turanicus* was collected only in the south-east of the park, and only from January to June with most present during February and March.

DISCUSSION

The most prevalent ticks on dogs in a survey conducted in Harare, Zimbabwe were *H. leachi, R. sanguineus* and *R. simus* (Goldsmid 1963). These dogs were also infested with small numbers of the cattle ticks *Boophilus decoloratus, R. appendiculatus* and *Rhipicephalus evertsi evertsi*. Infestation with *H. leachi*, an *Ixodes* sp. (near *I. pilosus*) and *R. simus* was the most intense on dogs on small-holdings near Grahamstown in the Eastern Cape Province, South Africa (Horak *et al.* 1987b). No *R. sanguineus* was found on these dogs, but they harboured small numbers of the cattle ticks *A. hebraeum, Haemaphysalis silacea* and *R. appendiculatus*. At the Faculty of Veterinary Science, University of Pretoria, Onderstepoort, the majority of 395 dogs diagnosed with *B. canis* infection were infested with *H. leachi*, and considerably fewer with *R. sanguineus* and *R. simus* (Horak 1995). Some of these dogs also had small burdens of *A. hebraeum, B. decoloratus, Hyalomma truncatum, R. appendiculatus* and *R. evertsi evertsi*.

Infestation with *R. sanguineus* was the most prevalent and intense on dogs at the Faculty of Veterinary Science of the Medical University of Southern Africa

and at an outreach clinic run by that Faculty in North West Province (Rautenbach, Boomker & De Villiers 1991; Bryson *et al.* 2000). The dogs in these surveys belonged to owners from less affluent communities than those in the Zimbabwe, Eastern Cape and Onderstepoort surveys, and a large percentage of the dogs were either chained or caged (Rautenbach *et al.* 1991). This provided ideal breeding conditions for all stages of development of *R. sanguineus.*

Amblyomma hebraeum

The adults of this tick prefer large herbivores including domestic cattle as hosts and the immature stages may be collected from a variety of large and small animals (Theiler 1962; Norval 1983; Horak, MacIvor, Petney & De Vos 1987a). Many larvae and fewer nymphs have been collected from wild carnivores, and domestic dogs are also frequently infested, but usually only with small numbers of ticks (Horak *et al.* 1987b; Horak 1995; Bryson *et al.* 2000; Horak, Braack, Fourie & Walker 2000). The large number of ticks collected from the dogs in north-eastern KwaZulu-Natal is a reflection both of the suitability of the habitat for this species, and of the proximity between the dogs and their owners' cattle.

Haemaphysalis leachi

This tick is present in the moister eastern half and southern regions of South Africa (Howell, Walker & Nevill 1978). It has, however, been suggested that the distribution of *H. leachi* is affected more by the presence of rodent hosts for the immature stages than by climate (Norval 1984). The rural environment of the dogs in the present survey was ideal for them to have come into contact with adult ticks that had fed on rodents during their immature stages, hence the high prevalence of infestation. The preferred hosts of adult *H. leachi* are all larger members of the order Carnivora, including domestic dogs, jackals and the large cats, while the larvae and nymphs prefer murid rodents, but will also feed on canids (Theiler 1962; Norval 1984; Horak *et al.* 1987b; 2000). Rather strangely, however, only two of eight hunting dogs (*Lycaon pictus*) and one of ten spotted hyaenas (*Crocuta crocuta*), examined in surveys conducted on wild carnivores in South Africa, were infested with adult *H. leachi* and then only with between one and five ticks each (Horak *et al.* 1987b; 2000).

On dogs on small-holdings near Grahamstown, in the south-east of South Africa, the seasonal intensity of infestation with adult *H. leachi* followed nearly the same pattern for three consecutive years (Horak *et al.* 1987b). Most ticks were present from May or June to February, with the smallest numbers collected during March or April. In the present surveys in the north-east of the country in KwaZulu-Natal and in the KNP, most ticks were collected between January and March or April from dogs and from January to June from vegetation respectively. The lowest numbers were collected from dogs and vegetation during October. The reasons for these contrasting patterns in the seasonal intensity of infestation between the northern and southern study sites could be due to differences in climate, day-length and the seasonal abundance of rodents around the homesteads of the dog owners or in the veld.

Rhipicephalus appendiculatus

Although *R. appendiculatus* prefers ruminants as hosts in all its stages of development (Walker *et al.* 2000), large numbers have been collected from wild carnivores and some from domestic dogs (Goldsmid 1963; Norval, Walker & Colborne 1982; Horak *et al.* 1987b; 2000; Horak 1995; Bryson *et al.* 2000). The presence of nymphs on dogs in north-eastern KwaZulu-Natal from March to December and the majority of adults during the period February to April is not unlike that on nyalas (*Tragelaphus angasii*) in nature reserves to the south of the study region (Horak, Boomker & Flamand 1995), or on the vegetation alongside the Nhlowa road in the KNP (Spickett *et al.* 1992).

Rhipicephalus simus

Rhipicephalus simus is widespread in the moister regions of southern Africa and its adults prefer domestic dogs, large wild carnivores, suids, equids and domestic cattle as hosts (Norval & Mason 1981; Walker *et al.* 2000; Horak *et al.* 2000). The immature stages feed on murid rodents (Norval & Mason 1981; Rechav 1982; Walker *et al.* 2000). This species comprised between 9 % and 18 % of the ticks collected from dogs in Harare, Zimbabwe, and from dogs on small-holdings near Grahamstown in the Eastern Cape Province and at Onderstepoort, South Africa (Goldsmid 1963; Horak *et al.* 1987b; Horak 1995).

In the Eastern Cape Province infestation with adult *R. simus* was most intense on dogs from August to April or May, and least intense during June and July (Horak *et al.* 1987b). Most *R. simus* were collected from dogs in north-eastern KwaZulu-Natal and the vegetation in the KNP during February and March, and the smallest numbers from July to October in the present surveys. The seasonal intensity of infestation on dogs in KwaZulu-Natal and on the vegetation in the KNP is similar to that on warthogs (*Phacochoerus africanus*) examined close to the current drag-sampling localities in the KNP during 1980 and 1981 (Horak, Boomker, De Vos & Potgieter 1988).

The reason for the low numbers of ticks on dogs in KwaZulu-Natal from February to April in the second year of the survey must probably be sought elsewhere than in a paucity of hosts for the immature stages. *Rhipicephalus simus* and *H. leachi* make use

of the same rodent species as hosts for these stages (Norval & Mason 1981; Norval 1984), and often even the same animal (Braack, Horak, Jordaan, Segerman & Louw 1996), and there was no similar decline in the numbers of *H. leachi* on the dogs in the second year of the study.

Rhipicephalus tricuspis

This tick has been collected from the smaller wild canids, for which it seems to have a preference, and from domestic dogs (Walker *et al.* 2000). *Rhipicephalus tricuspis* has not previously been reported in KwaZulu-Natal, but has been found in southern Mozambique north of the region in which the present survey on dogs was conducted (Walker *et al.* 2000). Although the tick's preferred habitat is various types of dry woodland, the soil structure in many of the regions in which it has been recorded is sandy. Another of its preferred hosts is spring hares (*Pedetes capensis*), and these animals require compacted sandy soil to make their burrows (Skinner & Smithers 1990). Spring hares do not occur in north-eastern KwaZulu-Natal, but the sandy nature of the soil within the survey region apparently contributes towards its suitability as a habitat for *R. tricuspis.*

Rhipicephalus turanicus

The identity of this tick has long been confused with that of *R. sanguineus*. However, its status as a valid separate species has been confirmed and the preference of its adults for cattle, sheep, domestic dogs, wild carnivores and hares established (Pegram, Clifford, Walker & Keirans 1987; Walker *et al.* 2000). In north-eastern KwaZulu-Natal adult *R. turanicus* was present on scrub hares (*Lepus saxatilis*) throughout the year with the highest prevalence of infestation from January to July (Horak, Spickett, Braack, Penzhorn, Bagnall & Uys 1995). Small numbers have also been collected from wild carnivores in the KNP (Horak *et al.* 2000). In the present surveys ten ticks were collected from the dogs in KwaZulu-Natal (Table 1), and 95 from the vegetation along the Nhlowa road in the KNP. The presence of adult *R. turanicus* in the south-east of the KNP only from January to June suggests that a single life cycle is completed annually at this locality.

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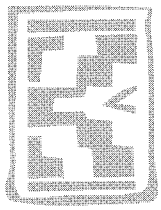

Parasites of domestic and wild animals in South Africa. XLIII. Ixodid ticks of domestic dogs and cats in the Western Cape Province

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ABSTRACT

HORAK, I.G. & MATTHEE, SONJA. 2003. Parasites of domestic and wild animals in South Africa. XLIII. Ixodid ticks of domestic dogs and cats in the Western Cape Province. *Onderstepoort Journal of Veterinary Research*, 70:187–195

Ticks were collected at monthly intervals for 16 consecutive months from individual dogs by their owners in or close to the town of Stellenbosch, Western Cape Province. They were also collected for 27 consecutive months from dogs presented for a variety of reasons at three veterinary clinics in Stellenbosch, and from dogs upon admission to an animal welfare shelter. At one of the veterinary clinics ticks were also collected from cats.

Dog owners collected six ixodid species from their pets and the most numerous of these were *Haemaphysalis leachi* and *Rhipicephalus gertrudae*. Twelve ixodid tick species and the argasid tick, *Otobius megnini* were collected from dogs at veterinary clinics and the animal shelter, and *H. leachi*, *R. gertrudae* and *Rhipicephalus sanguineus* were the most numerous. A total of nine dogs were infested with the Karoo paralysis tick, *Ixodes rubicundus*. No clear pattern of seasonality was evident for *H. leachi*, which was present throughout the year. The largest numbers of adult *R. gertrudae* were generally present from August to October, while adult *R. sanguineus* were collected during October 2000, February and March 2001, from January to April 2002 and during October 2002. Five ixodid tick species, of which *H. leachi* was the most numerous and prevalent, were collected from cats.

Keywords: Cats, dogs, *Haemaphysalis leachi*, ixodid ticks, *Rhipicephalus gertrudae*, *Rhipicephalus sanguineus*, seasonality, Stellenbosch, Western Cape Province

INTRODUCTION

During the past 20 years 50 943 ixodid ticks, belonging to 22 species in six genera have been counted on domestic dogs in five surveys conducted in South Africa (Horak, Jacot Guillarmod, Moolman & De Vos 1987b; Horak 1995; Bryson, Horak, Höhn & Louw 2000; Horak, Emslie & Spickett 2001; Jacobs, Fourie, Kok & Horak 2001). Three tick species were predominant in these surveys, namely *Haemaphysalis leachi*, *Rhipicephalus sanguineus* and *Rhipicephalus simus*, and 10 662, 35 460 and 1 989 individuals of the three species, respectively, were counted.

Haemaphysalis leachi is widely distributed in Africa and its adults infest both domestic and wild carnivores and felids (Walker 1991; Horak, Braack, Fourie & Walker 2000). *Rhipicephalus sanguineus* has probably the most widespread global distribution of any ixodid tick and nearly exclusively uses domestic dogs as hosts for both its immature and adult stages of development (Walker, Keirans & Horak 2000). Although it is widespread in South Africa, its

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distribution is patchy in that it is confined to localities within urban, suburban, peri-urban and rural areas where there are both domestic dogs and human dwellings and associated man-made structures, to which its free-living stages are adapted. *Rhipicephalus simus* is widely distributed in southern Africa and its adults prefer domestic and wild carnivores, felids, suids and equids and also domestic cattle as hosts (Walker *et al.* 2000). However, in the western regions of the Western Cape, Northern Cape and Free State Provinces of South Africa it appears to be partially or wholly replaced by *Rhipicephalus gertrudae* (Walker *et al.* 2000), of which the adults prefer cattle, sheep, equids, wild carnivores and primates, including humans, as hosts (Brain & Bohrmann 1992; Walker *et al.* 2000; Horak, Fourie, Heyne, Walker & Needham 2002).

Infestation with any tick has a nuisance value, but *H. leachi* also transmits *Babesia canis* to dogs (Lewis, Penzhorn, Lopez-Rebollar & De Waal 1996), *R. sanguineus* transmits *Ehrlichia canis* (Groves, Dennis, Amyx & Huxsoll 1975) and, in countries other than South Africa, also *Babesia canis* (Liebisch & Gillani 1979). It can also transmit *Rickettsia conori*, the causative organism of tick-bite fever in humans (Neitz, Alexander & Mason 1941), and hence its control from both veterinary and medical perspectives is important. Heavy infestations with *R. gertrudae* have been recorded as a major contributing factor towards the deaths of young baboons, *Papio ursinus* in an arid environment in Namibia (Brain & Bohrmann 1992).

Four of the five above-mentioned surveys were done in the provinces of Gauteng, North West, north-eastern KwaZulu-Natal and central Free State, all summer rainfall regions (Horak 1995; Bryson *et al.* 2000; Horak *et al.* 2001; Jacobs *et al.* 2001), while the fifth was conducted in a non-seasonal rainfall region in the Eastern Cape Province (Horak *et al.* 1987b). No survey of the ticks infesting dogs in the Western Cape Province, a winter rainfall region, has been conducted and the present study was undertaken to fill this gap in our knowledge.

The checklist of the ticks of Africa, south of the Sahara, compiled by Theiler (1962), does not indicate from which countries records for cats originate. Besides this list there appears to be only one published report of ticks infesting domestic cats in South Africa, and it pertains to ticks on cats in the Kruger National Park that have become feral (Horak *et al.* 2000). The current survey adds to our knowledge in this field.

MATERIALS AND METHODS

The survey region comprised the town of Stellenbosch (33°55' S, 18°50' E) and its immediate environs in the Western Cape Province, and two groups of dogs were examined. In one ticks were collected from individual dogs by their owners, and in the other they were collected from dogs presented at three veterinary clinics, or upon admission to an animal welfare shelter.

Once a month from September 2000 to December 2001 the dog owners manually de-ticked their dogs and placed the ticks from each dog in separate labelled vials containing 70% alcohol. Two of these dogs were de-ticked by one of us (S.M.), and the sites of attachment recorded. The veterinarians, or their assistants, manually de-ticked dogs presented at their practices from October 2000 to December 2002, and the ticks for each month were pooled for each practice. Two of the veterinarians had collected ticks prior to the commencement of the survey, and these ticks have been included in the total counts, but not in the monthly seasonal occurrence counts. One of the veterinarians also collected ticks from cats. Ticks were collected from dogs upon their admission to the animal welfare shelter from October 2000 to December 2002, and the ticks for each month were pooled. Ticks were also collected each month from December 2001 to June 2002 and from October to December 2002 from dogs upon admission to an animal welfare shelter in the nearby town of Franschhoek (33°50' S, 19°07' E), Western Cape Province.

RESULTS

The species and numbers of ticks collected from individual dogs by their owners are summarized in Table 1. Ticks belonging to six ixodid species were collected. The most numerous of these were *H. leachi* and *R. gertrudae*, and their sites of attachment are summarized in Table 2 and their seasonality is graphically illustrated in Fig. 1. More than 50% of adult *H. leachi* and *R. gertrudae* attached to the head, ears, neck and shoulders of the dogs. *Haemaphysalis leachi* was present throughout the year with the largest numbers collected during September 2000 and June 2001 and the smallest numbers during November 2000 and March 2001. Most *R. gertrudae* were collected during September and October 2000 and August and September 2001. With the exception of April when only one was collected, none were present from February to June 2001.

The total numbers of ticks collected from dogs at veterinary clinics and the animal shelter at Stellenbosch are summarized in Table 3. Twelve ixodid tick species and the argasid tick, *Otobius megnini* were collected from these dogs, and the seasonal occurrence of *H. leachi*, *R. gertrudae* and *R. san-*

TABLE 1 Ticks collected from dogs belonging to individual owners at Stellenbosch, Western Cape Province

Tick species	Number of ticks					No. of collections (98)
	Larvae	Nymphs	Males	Females	Total	
Haemaphysalis aciculifer	0	0	0	1	1	1
Haemaphysalis leachi	0	3	410	826	1 239	96
Haemaphysalis zumpti	0	0	1	0	1	1
Ixodes pilosus group	0	0	0	3	3	3
Ixodes rubicundus	0	0	4	29	33	3
Rhipicephalus gertrudae	0	0	115	127	242	26

TABLE 2 Attachment sites of adult *Haemaphysalis leachi* and *Rhipicephalus gertrudae* on dogs at Stellenbosch, Western Cape Province

Tick species (No. collected)	Body region					Rump and perineum
	Head	Ears	Neck and shoulders	Lower legs, feet	Abdomen	
Haemaphysalis leachi (112)	12.5	9.8	37.5	6.2	30.4	3.6
Rhipicephalus gertrudae (19)	10.6	10.5	31.6	10.5	36.8	0

TABLE 3 Ticks collected from dogs at veterinary clinics and at an animal shelter at Stellenbosch, Western Cape Province

Tick species	Number of ticks					No. of collections (108)
	Larvae	Nymphs	Males	Females	Total	
Amblyomma marmoreum	0	9	0	0	9	2
Boophilus decoloratus	0	0	0	1	1	1
Haemaphysalis aciculifer	0	0	1	2	3	3
Haemaphysalis leachi	23	25	1 560	4 566	6 174	107
Haemaphysalis spinulosa	0	0	1	1	2	1
Hyalomma truncatum	0	0	0	1	1	1
Ixodes pilosus group	0	9	7	41	57	29
Ixodes rubicundus	0	0	0	7	7	6
Rhipicephalus gertrudae	0	0	188	249	437	54
Rhipicephalus lounsburyi	0	0	0	3	3	2
Rhipicephalus nitens	8	0	0	0	8	2
Rhipicephalus sanguineus	1	5	98	115	219	12
Otobius megnini	0	3	0	0	3	3

TABLE 4 Ticks collected from dogs at an animal shelter at Franschhoek, Western Cape Province

Tick species	No. of ticks					No. of collections (10)
	Larvae	Nymphs	Males	Females	Total	
Haemaphysalis leachi	0	1	506	449	956	10
Rhipicephalus gertrudae	0	0	9	17	26	3
Rhipicephalus nitens	0	0	0	1	1	1
Rhipicephalus sanguineus	1	4	83	56	144	2

TABLE 5 Ticks collected from cats at a veterinary clinic at Stellenbosch, Western Cape Province

Tick species	Number of ticks					No. of collections (20)
	Larvae	Nymphs	Males	Females	Total	
Amblyomma marmoreum	0	2	0	0	2	1
Haemaphysalis leachi	0	1	70	65	136	20
Haemaphysalis spinulosa	0	0	0	1	1	1
Ixodes pilosus group	0	17	2	4	23	7
Rhipicephalus gertrudae	0	0	3	2	5	2

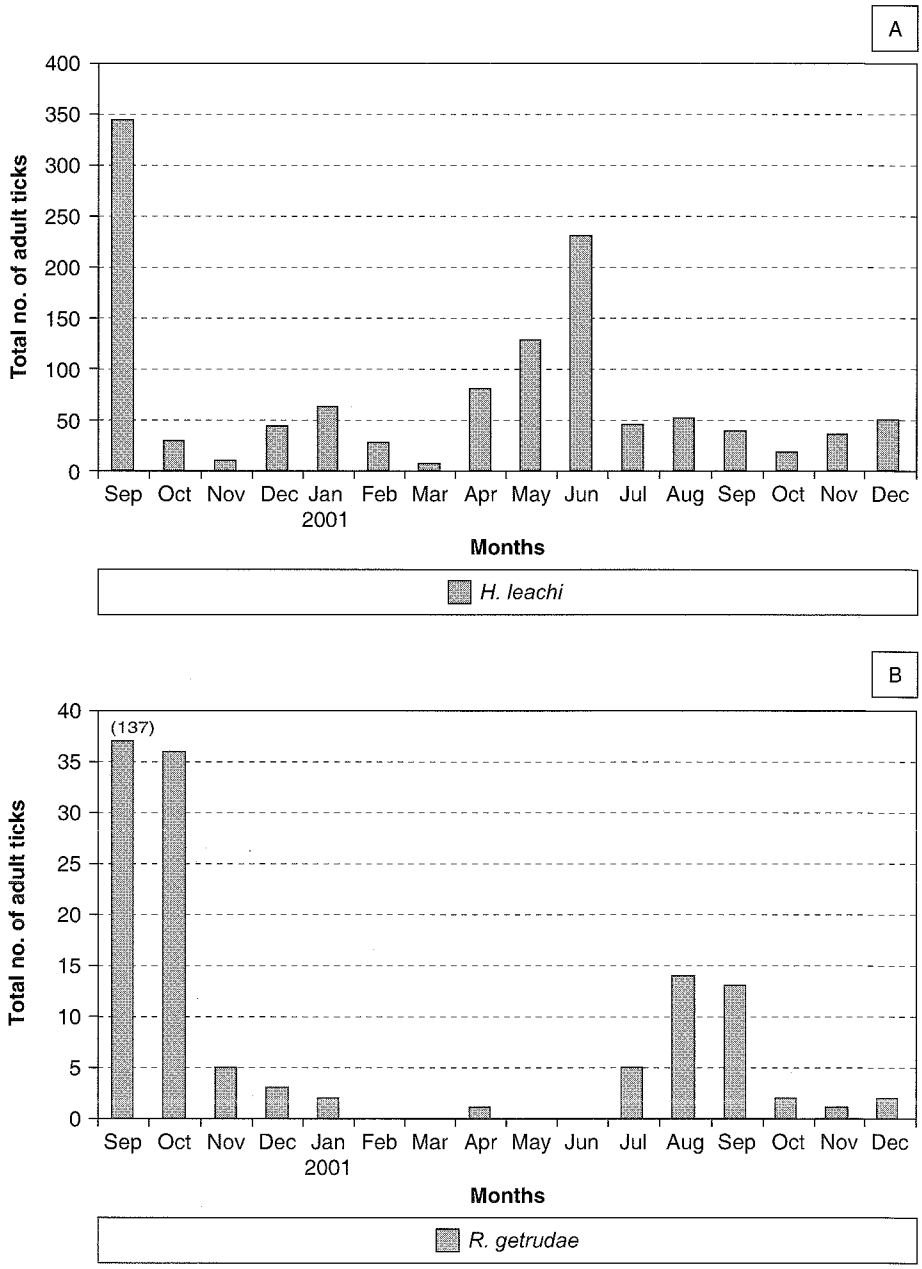

FIG. 1 The seasonal occurrence of adult (A) *Haemaphysalis leachi* and (B) *Rhipicephalus gertrudae* on dogs belonging to individual owners at Stellenbosch, Western Cape Province

guineus are graphically illustrated in Fig. 2. Most *H. leachi* were collected during August 2001 and from May to September 2002. *Rhipicephalus gertrudae* was most numerous in October 2000, September, October and December 2001, and August to October 2002. No ticks of this species were collected during March to May and July 2001 and during June and July 2002. *Rhipicephalus sanguineus* was present during October 2000, February and March 2001, and from January to April and during October 2002.

Four ixodid tick species were recovered from dogs at the animal shelter at Franschhoek, the most numerous of these being *H. leachi* and *R. sanguineus*, while a single female *R. nitens* was also collected (Table 4). *Haemaphysalis leachi* was collected during every month that collections were made, whereas *R. sanguineus* was present only during March and April 2002.

Five ixodid tick species were collected from cats at a veterinary clinic in Stellenbosch, and of these *H.*

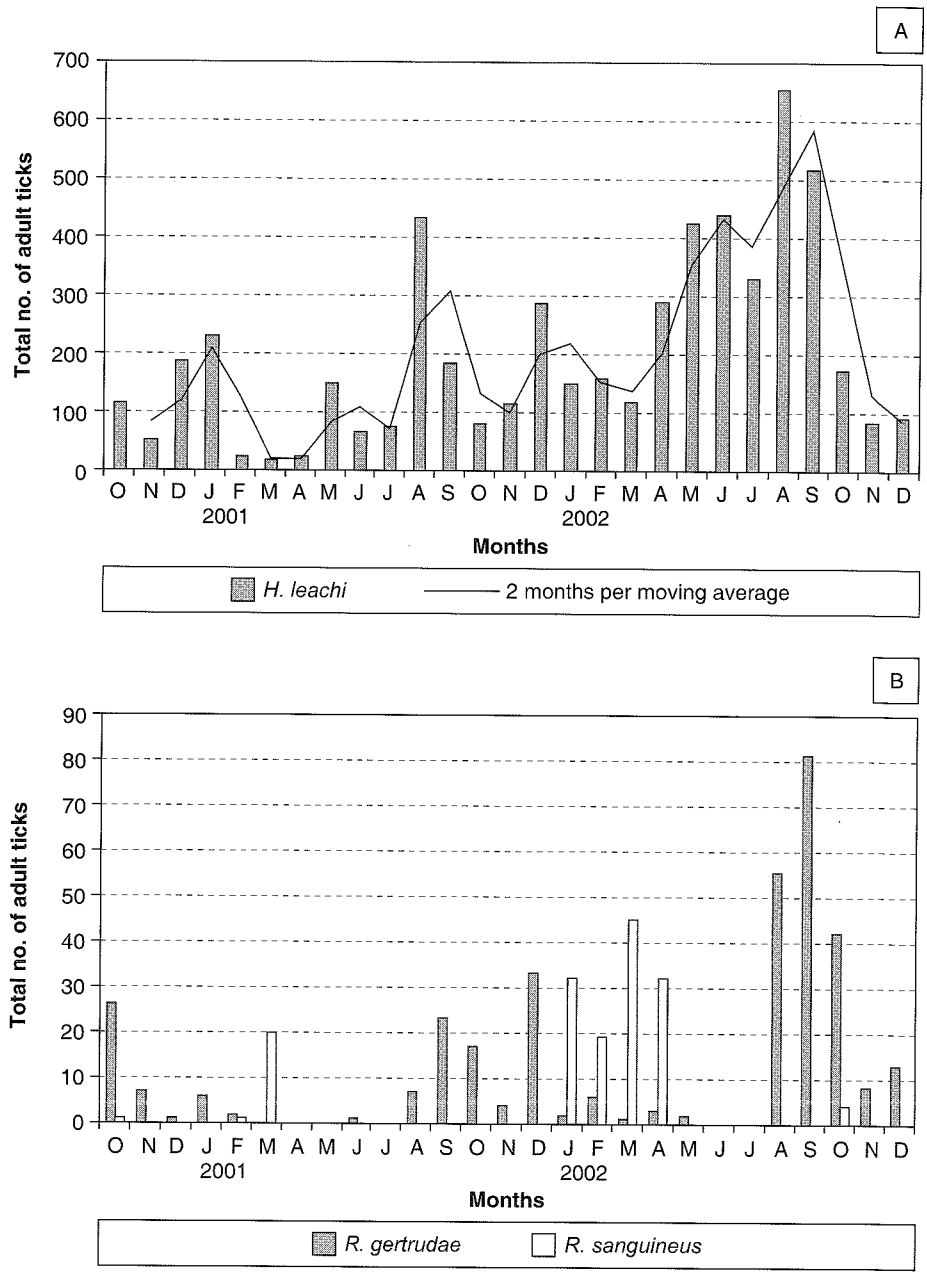

FIG. 2 The seasonal occurrence of (A) adult *Haemaphysalis leachi* (including 2-month moving average), and (B) adult *Rhipicephalus gertrudae* and *Rhipicephalus sanguineus* on dogs at veterinary clinics and an animal welfare shelter at Stellenbosch, Western Cape Province

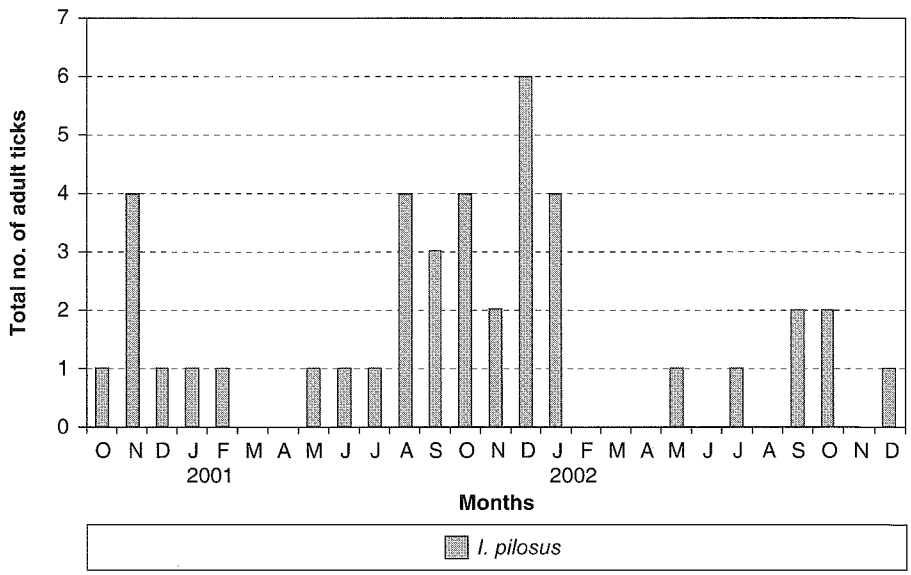

FIG. 3 The seasonal occurrence of adult *Ixodes pilosus* group ticks on dogs belonging to individual owners and at an animal welfare shelter, and on dogs and cats at veterinary clinics at Stellenbosch, Western Cape Province

leachi and ticks of the *Ixodes pilosus* group were the most numerous (Table 5).

The combined seasonal occurrence of adult ticks of the *I. pilosus* group on both dogs and cats at the various survey localities in Stellenbosch is graphically illustrated in Fig. 3. With the exception of March and April 2001 and 2002, when none were recovered, adult ticks of this group were present in every month of the year either during 2001 or 2002.

DISCUSSION

The major differences between this survey and those conducted on dogs elsewhere in South Africa were the frequency with which *Ixodes rubicundus* and *R. gertrudae* were recovered, and the apparently restricted seasonal occurrence of *R. sanguineus*.

All the parasitic stages of development of *Amblyomma marmoreum*, the South African tortoise tick, prefer the latter animals as hosts (Norval 1975). However, the frequency with which the immature stages, and particularly larvae, are recovered from domestic and wild carnivores implies that they are both widespread and catholic in their host preference (Horak *et al.* 1987b; 2000). The presence of nymphs on a dog at a veterinary clinic and another at the animal shelter at Stellenbosch during November 2000 not only confirms the presence of questing immature stages at this time of year but also their rather non-selective host preference. The collection of *Boophilus decoloratus* from dogs is not unusual (Goldsmid 1963; Horak 1995; Jacobs *et al.* 2001), and indicates that the infested animals had been in localities in which domestic cattle or horses, the preferred hosts of this tick, were kept (Mason & Norval 1980).

Although *Haemaphysalis aciculifer* is fairly widespread in South Africa, it is seldom present in large numbers (Walker 1991). It infests a variety of hosts and has been collected from wild carnivores (Norval 1985). One of the largest infestations recorded on the latter animals consisted of 15 adults collected from a honey badger, *Mellivora capensis* in the Kruger National Park (Horak *et al.* 2000). Its immature stages have been collected from ground-nesting birds in the Western Cape Province (Horak & Boomker 1998), thus establishing its presence here and accounting for the adults in four collections from dogs.

Adult *H. leachi* prefer the larger wild canids and felids as well as domestic dogs as hosts (Norval 1984; Horak *et al.* 1987b; 2000), but have also been collected from feral domestic cats (Horak *et al.* 2000). In the central Free State most adult *H. leachi* were collected from the neck, back and legs of dogs (Jacobs *et al.* 2001). Although the attachment sites of only 112 adult ticks of this species were determined in the present survey, most of these were collected from the head, neck and shoulders of the dogs. This tick is widespread throughout the

warmer eastern regions of the country (Howell, Walker & Nevill 1978), and it would appear that Stellenbosch and its environs in the Western Cape Province is an imminently suitable habitat. Adult *H. leachi* is most numerous on dogs in the Eastern Cape Province from May or June to February (Horak *et al.* 1987b), in the central Free State from September to November (Jacobs *et al.* 2001), and in north-eastern KwaZulu-Natal from January or February to March or April (Horak *et al.* 2001), but no clear pattern of seasonality emerged in the present survey. However, most ticks appeared to be present during the cooler months of the year from May to September. The year-round presence of *H. leachi* on dogs at Stellenbosch implies that canine babesiosis can be expected during any season.

The southern regions of the Western Cape Province do not seem to be an ideal habitat for *Hyalomma truncatum* (Howell *et al.* 1978), and few ticks of this species are encountered here (Horak & Boomker 1998). Although adult *H. truncatum* feed on a variety of domestic ungulates (Norval 1982), they sometimes also infest dogs (Norval 1982; Horak 1995; Jacobs *et al.* 2001), on which penetrating necrotic lesions may occur at their sites of attachment (Burr 1983). The single tick collected in the current survey is probably a rare accidental infestation of a dog in this region.

Ticks of the *Ixodes pilosus* group have been collected from domestic dogs and several wild carnivore species and appear to have a preference for felids (Horak *et al.* 1987b; 2000). Consequently the recovery of ticks of this group from both dogs and cats in the present survey is to be expected, particularly as the Stellenbosch region lies within the distribution range of these ticks (Howell *et al.* 1978). Most of the ticks collected from cats were nymphs, and the greater proportional density of ticks of this species on these animals than on dogs confirms its preference for felids. Although few ticks were collected from animals at any of the survey sites, and hence an accurate evaluation cannot be made, peaks in activity from late winter and spring to midsummer are evident. In the coastal region of the Eastern Cape Province most *I. pilosus* group adults were present on caracals, *Caracal caracal* from November to May (Horak *et al.* 1987b), whereas most adults were present on antelopes and scrub hares, *Lepus saxatilis* in the Bontebok National Park outside Swellendam in the Western Cape Province from October to December (Horak, Sheppey, Knight & Beuthin 1986), somewhat similar to the present findings.

It has been suggested that the caracal is a preferred host of adult *I. rubicundus* (Horak, Moolman & Fourie 1987a). The subsequent collection of this tick from a black-backed jackal, *Canis mesomelas*, an African wild cat, *Felis lybica*, and a caracal in the Northern Cape Province (Horak *et al.* 2000), as well as from a domestic dog in the central region of the Free State Province (Jacobs *et al.* 2001), denotes that several carnivore species may be suitable hosts for adult ticks of this species. The recovery in the present survey of ticks from nine dogs, of which one harboured ten and another 18, confirms this observation.

Prior to this study there were only 11 records of *R. gertrudae* infesting domestic dogs and none from cats (Walker *et al.* 2000; Jacobs *et al.* 2001), now there are at least 94 records for dogs and two for cats. Its immature stages, like those of *R. simus*, prefer murid rodents as hosts. Thus *R. gertrudae* not only occupies the potential geographic distribution of *R. simus* in the Western Cape Province, but also utilizes some of the latter tick's preferred hosts (Walker *et al.* 2000). However, whereas *R. simus* is a spring to late summer tick on dogs in the Eastern Cape Province and a summer to late summer tick on these animals in north-eastern South Africa (Horak *et al.* 1987b; 2001), *R. gertrudae* is primarily a spring tick on dogs in the Western Cape Province (Fig. 1 and 2), and an autumn to spring tick on sheep in this province and in the Northern Cape Province (Horak & Fourie 1992).

Rhipicephalus lounsburyi is a small tick that attaches around and between the hooves of sheep and wild antelopes in north-eastern Eastern Cape Province and southern and western Western Cape Province (Horak *et al.* 1986; Walker 1990), and its presence on dogs must be considered accidental. The distribution of *Rhipicephalus nitens* is confined to the fynbos regions of the Western and Eastern Cape Provinces (Walker *et al.* 2000), and all stages of development prefer sheep, wild antelopes and scrub hares as hosts (Horak, Williams & Van Schalkwyk 1991; Horak & Boomker 1998). The collection of an adult tick from a dog at Franschhoek during December 2001, and larvae from a dog at Stellenbosch during June 2002 and from another during July reflect accidental infestations during months when adults or larvae are particularly numerous on antelopes and scrub hares in the Western Cape Province (Horak *et al.* 1986). Adults have previously been collected from dogs on small-holdings near Grahamstown in the Eastern Cape Province (Horak *et al.* 1987b).

In northern Gauteng Province adult *R. sanguineus* are most numerous on dogs from December to May with a secondary peak during September (Horak 1982), while in central Free State Province they are most numerous from January to April (Jacobs *et al.* 2001). Although adult ticks were present throughout the year at both localities, numbers were generally low during June and July (mid-winter). The adult ticks collected at Stellenbosch during October 2000 and 2002 possibly stem from recently-moulted over-wintered nymphs, while those collected during the period January to April at Stellenbosch and Franschhoek probably represent the next generation adult progeny of spring-moulted ticks. This corresponds somewhat to the situation in northern Gauteng, but suggests that only two life cycles per year are completed at Stellenbosch, and not three as at the former locality (Horak 1982). Because of the chronic nature of canine ehrlichiosis, dogs suffering from it may present several months after detachment of the vector adult *R. sanguineus* ticks.

The larvae and various nymph stages of the argasid tick *O. megnini* may be found in the external ear canals of cattle that are kraaled at night, and of calves that are reared in stone or brick-walled pens (Howell *et al.* 1978; Fourie & Horak 1990). They have also been collected from the ear canals of sheep, goats, horses, dogs, cats and humans (Howell *et al.* 1978; Naude, Heyne, Van Der Merwe & Benic 2001; Huchzermeyer 2002). The source of the ticks on dogs in the present survey is likely to have been premises in which infested cattle or horses had been housed.

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Ixodid ticks on dogs in southern Mozambique

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ABSTRACT

NEVES, L., AFONSO, SONIA & HORAK, I.G. 2004. Ixodid ticks on dogs in southern Mozambique. *Onderstepoort Journal of Veterinary Research*, 71:279–283

The objective of this study was to determine the species and distribution of ticks infesting domestic dogs in southern Mozambique. To this end 89 collections were taken from dogs and the geographic coordinates of the localities at which they were made noted. Fifty-eight of these collections were from animals in the city of Maputo and 16 from animals at rural settlements close to Maputo. A further 15 collections were made from dogs in rural environments north of Maputo. Ten ixodid tick species, of which one was only identified to genus level, were recovered. *Rhipicephalus sanguineus* was the most numerous of the ten species, and its prevalence and intensity of infestation were significantly higher on city dogs than on rural dogs ($P < 0.01$), whereas the converse was true for *Haemaphysalis leachi* ($P < 0.01$). Including the city of Maputo, the exact localities at which nine tick species were collected, were recorded

Keywords: Dogs, ixodid ticks, Maputo, Mozambique

INTRODUCTION

In her publication on the ticks of domestic stock in Mozambique (then known as Portuguese East Africa) Theiler (1943) listed 13 species of ixodid ticks and mentioned that 11 of these could infest dogs. However, specimens of only three of these species, namely *Haemaphysalis leachi*, *Rhipicephalus appendiculatus* and *Rhipicephalus simus* appeared to actually come from dogs in Mozambique, while the rest were probably extrapolations from South African data. Some years later Dias (1960, 1993) listed the ticks infesting domestic and wild animals in Mozambique, and recorded 12 species on dogs. Nevertheless, he expressed doubts concerning the validity of some of these species, and two of them, namely *Haemaphysalis humerosoides* and *Rhipicephalus reichnowi* are now considered synonyms of *H. leachi* and *Rhipicephalus planus*, respectively (Camicas, Hervy, Adam & Morel 1998; Walker, Keirans & Horak 2000).

In north-eastern KwaZulu-Natal Province, South Africa, a region adjoining the southern border of Mozambique, Horak, Emslie & Spickett (2001) recovered seven species of ixodid ticks from dogs belonging to persons in rural communities. Adult *H. leachi* followed by immature *Amblyomma hebraeum* and adult *R. simus* were the most numerous of these. In the Kruger National Park, South Africa, to the west of southern Mozambique, Horak, Braack, Fourie & Walker (2000) recorded 15 ixodid tick species on 13 species of wild carnivores. *Haemaphysalis leachi* and *R. simus* were amongst the most numerous of the adult ticks collected from these animals. Elsewhere in South Africa Bryson, Horak, Höhn & Louw (2000) collected ticks from

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dogs belonging to people in resource-limited communities in North West Province. Many of these dogs were either caged or chained within the confines of their owners' properties and *Rhipicephalus sanguineus* was the most numerous of the six species present. Jacobs, Fourie, Kok & Horak (2001) collected ticks from dogs in households in affluent and in resource-limited communities in and around the city of Bloemfontein, Free State Province, South Africa, and recorded significantly more *R. sanguineus* on dogs in the latter than in the former localities.

The South African surveys indicated that caged or chained dogs, or dogs owned by urban householders are more likely to be infested with *R. sanguineus* than those on larger properties, whereas those kept under more extensive conditions on small-holdings or farms, are liable to be infested with *H. leachi* and *R. simus*. Although the latter two species are also common on wild carnivores, no *R. sanguineus* have been collected from these animals (Horak *et al.* 2000). This survey was initiated to determine the species spectrum of ticks infesting domestic dogs in and around the city of Maputo as well as further afield in Mozambique, and whether there were differences in the species composition of the tick burdens of dogs in the city compared to those of dogs at rural settlements. In addition the geographic coordinates of each locality at which ticks were collected were recorded.

MATERIALS AND METHODS

Ticks were collected from 58 dogs in households in eight suburbs of the city of Maputo, and 16 collections were taken from dogs that were allowed to roam freely at three rural settlements around Maputo. Amongst the latter are six collections made at different times from the same dog at Goba, but listed separately. Five collections were also taken from dogs allowed to range freely at Sabié a rural settlement north-west of Maputo, and ten from dogs in provinces north of Maputo Province. Amongst the latter are four collections made from the same dog at Luala, Zambezia Province and a single collection made from this dog when it and its owners moved to Praia de Xai-Xai, Gaza Province.

All visible ticks were collected from each dog and placed in separate labelled vials containing 70 % ethyl alcohol, thereafter the body surface of the dog was palpated and all ticks detected in this manner were collected and placed in the same vials as the visual collections. The ticks were initially sorted, identified and counted under a stereoscopic microscope at the Veterinary Faculty, University Eduardo Mondlane, in Maputo and their identities confirmed at the Faculty of Veterinary Science, University of Pretoria, South Africa.

RESULTS AND DISCUSSION

The geographic coordinates of the collection localities and the tick species collected at each locality are summarized in Table 1. Seven species were collected from the dog at Goba and five species each from dogs in the city of Maputo and at the Boane rural settlement.

The species and total numbers of ticks collected from dogs at all localities combined are summarized in Table 2, and the numbers of *H. leachi* and *R. sanguineus* collected either from city or from dogs at rural settlements in southern Maputo Province are compared in Table 3.

Ten tick species, of which one was only identified to genus level, were collected from the dogs. Four (6.9 %) of the 58 dogs examined in the city of Maputo were infested with *H. leachi* and 55 (94.8 %) with *R. sanguineus*. In the rural settlements around Maputo 15 (93.8 %) of the 16 collections contained *H. leachi* and three (18.8 %) *R. sanguineus*. The intraspecific and the interspecific prevalence of both tick species at the two localities differed significantly ($P < 0.01$) (Fisher's Exact test). In addition, the intensity of infestation of *H. leachi* on dogs at rural settlements around the city of Maputo was significantly greater than that on dogs within the city, while the converse was true for *R. sanguineus* ($P < 0.01$) (Wilcoxon Rank sum test). Furthermore, the intensity of infestation of *R. sanguineus* on city dogs was significantly higher than that of *H. leachi* on the same group of dogs, whereas the converse was true for dogs in rural settlements ($P < 0.01$).

Amblyomma spp.

An *A. hebraeum* larva was collected from a single dog at Malhangalene in the city of Maputo, and larvae and/or nymphs of this tick were collected from dogs at the rural settlements of Goba and Sabié as well as at Save in Manica Province. A larva and the nymphs of an *Amblyomma* sp. were present on dogs at Malhangalene and at the rural settlement of Chiango. The immature stages of *A. hebraeum* and *Amblyomma marmoreum* and probably other species of *Amblyomma* readily infest domestic dogs that are allowed to roam freely and also wild carni-

TABLE 1 Localities in Mozambique at which ticks were collected from dogs

Locality	Coordinates	Tick species
City of Maputo		
Dalo Ferroviario Laulane Luis Cabral Malhangalene Militin Polana Caniço Polana Cimento	25°53'12" S, 32°36'14" E 25°55'37" S, 32°36'24" E 25°54'20" S, 32°35'64" E 25°55'53" S, 32°32'50" E 25°57'33" S, 32°34'56" E 25°57'29" S, 32°35'26" E 25°56'10" S, 32°36'29" E 25°57'57" S, 32°35'15" E	*A. hebraeum*, *Amblyomma* sp., *H. leachi*, *R. sanguineus*, *R. simus*
Rural settlements around the city of Maputo		
Boane Chiango Goba	26°04'18" S, 32°20'20" E 25°54'33" S, 32°39'36" E 26°03'59" S, 32°10'25" E	*H. leachi*, *H. spinulosa*, *R. sanguineus*, *R. simus*, *R. turanicus* *Amblyomma* sp., *H. leachi* *A. hebraeum*, *H. leachi*, *H. spinulosa*, *R.* (*Boophilus*) *microplus*, *R. pravus* group, *R. simus*, *R. turanicus*
Maputo Province		
Sabié	25°16'22" S, 32°14'24" E	*A. hebraeum*, *H. leachi*
Gaza Province		
Praia de Xai-Xai	25°06'33" S, 33°34'48" E	*H. leachi*
Manica Province		
Matthews' home Save	20°10'08" S, 33°13'15" E 21°16'55" S, 33°19'14" E	*H. leachi*, *H. spinulosa*, *R. simus* *A. hebraeum*
Zambezia Province		
Luala	17°44'11" S, 36°15'26" E	*H. leachi*, *H. spinulosa*, *R. sanguineus*, *R. tricuspis*

TABLE 2 Ticks in 89 collections from dogs in Mozambique

Tick species	Total number of ticks collected					No. of collections
	Larvae	Nymphs	Males	Females	Total	
Amblyomma hebraeum	11	22	0	0	33	7
Amblyomma sp.	1	4	0	0	5	3
Haemaphysalis leachi	0	31	115	111	257	29
Haemaphysalis spinulosa	0	0	3	6	9	4
Rhipi. (*Boophilus*) *microplus*	0	0	0	1	1	1
Rhipicephalus pravus group	0	0	0	1	1	1
Rhipicephalus sanguineus	0	68	799	617	1 484	62
Rhipicephalus simus	0	0	47	36	83	19
Rhipicephalus tricuspis	0	0	0	3	3	1
Rhipicephalus turanicus	0	0	9	13	22	4

vores (Horak, Jacot Guillarmod, Moolman & De Vos 1987; Horak *et al.* 2000, 2001). However, the presence of an *A. hebraeum* larva and the immature stages of an *Amblyomma* sp. on dogs in the suburb of Malhangalene is difficult to explain because in Africa the adults of most species of this genus feed on cattle, or other large herbivorous animals (Petney, Horak & Rechav 1987), that are unlikely to be found in a city suburb. However, Malhangalene differed in other respects from the other suburbs of

TABLE 3 *Haemaphysalis leachi* and *Rhipicephalus sanguineus* on dogs in the city of Maputo and in surrounding rural settlements

Species and number of ticks collected							
Haemaphysalis leachi			Positive collections	*Rhipicephalus sanguineus*			Positive collections
Nymphs	Adults	Total		Nymphs	Adults	Total	
Maputo city							
0	6	6[A]	4/58[C]	54	1 391	1 445[B]	55/58[D]
Rural settlements around Maputo							
30	137	167[A]	15/16[C]	0	5	5[B]	3/16[D]

Items in the same column with the same superscript differ significantly ($P < 0.01$)

Maputo in that the dogs there were also infested with adult *R. simus*, a tick usually encountered on dogs in rural areas (Horak *et al.* 1987, 2001).

Haemaphysalis spp.

Dogs in three suburbs of the city of Maputo and also at rural settlements in Maputo and other provinces were infested with *H. leachi*, and dogs at Boane, Goba, the Matthews' homestead and at Luala with *Haemaphysalis spinulosa*. Adult *H. leachi* are parasites of dogs, jackals (*Canis* spp.) and the large wild cats such as cheetahs, *Acinonyx jubatus*, lions, *Panthera leo*, leopards, *Panthera pardus* as well as African civets, *Civettictis civetta* (Norval 1984; Horak *et al.* 1987, 2000, 2001). Although the immature stages may use dogs as hosts (Horak *et al.* 1987), they prefer burrow-dwelling rodents (Norval 1984). The life cycle is sustained by the rodent/carnivore host complex (Norval 1984; Horak *et al.* 2000), and this could account for the high prevalence of *H. leachi* on dogs in the rural areas and their scarcity in the city.

Rhipicephalus (Boophilus) microplus

This tick is a parasite of cattle and its occurrence on other hosts is probably dependent on the presence of cattle as maintenance hosts. In KwaZulu-Natal 266 *R. (B.) microplus* were collected from a goat compared to an average burden of 16 346 on two calves examined at the same time at the same dip-tank area (Baker & Ducasse 1968). Its presence on a dog in the rural environment of Goba can probably be ascribed to the fact that this animal was used to muster a herd of goats at a locality in which there was also cattle.

Rhipicephalus spp.

All developmental stages of *R. sanguineus* prefer domestic dogs as hosts to the virtual exclusion of all other animals (Walker *et al.* 2000), and its life cycle is adapted to man-made structures such as human dwellings and dog kennels (Howell, Walker & Nevill 1978). Consequently it is particularly prevalent in cities or townships where dogs are chained, caged or confined to the properties of their owners (Bryson *et al.* 2000), as is the case in the city of Maputo. It was also present on three of the nine dogs examined at the rural settlement of Boane. The presence of *R. sanguineus* on dogs in the seaboard city of Maputo is to our knowledge the first time that it has been recorded close to an ocean in southern Africa.

This observation, taken in conjunction with those of various surveys conducted inland, implies that provided dogs are kept confined to small properties, or are chained or kennelled, the possibility exists that they can sustain populations of *R. sanguineus* at any locality within the region. The dog examined on four occasions at Luala, Zambezia Province was infested both with *R. sanguineus* and *H. leachi*. This dog lived in the home of its owners, where it was likely to have acquired infestation with the former tick, but also accompanied them into rural areas, where it probably acquired infestation with the latter.

The single *R. pravus*-group tick was taken from a dog at Goba, a host species on which, and a region in which ticks of this group have previously been recorded (Walker *et al.* 2000). Its immature stages feed on elephant shrews, *Elephantulus* spp., and all stages of development feed on scrub hares, *Lepus saxatilis*. It is particularly prevalent on the latter ani-

mals in the northern regions of the Kruger National Park, South Africa to the west of southern Mozambique (Horak, Spickett, Braack, Penzhorn, Bagnall & Uys 1995).

The immature stages of the remaining three species of *Rhipicephalus* feed on rodents, hence the prevalence of their adults on dogs at rural settlements where rodents are likely to occur. However, nine of the 12 dogs examined at Malhangalene, Maputo city were infested with adult *R. simus*, indicating an abundance of rodent hosts for its immature stages. Malhangalene straddles the transition between an urban suburb and a shantytown and the probability of a large rodent population in the latter locality cannot be excluded. *Rhipicephalus simus* was also present on dogs in the rural settlements of Boane and Goba as well as at the Matthews homestead in Manica Province.

One collection from the dog at Luala contained three female *R. tricuspis*, a tick that has previously been recorded on a dog in Mozambique (Dias 1993). Its preferred hosts appear to be steenbok, *Rhaphicerus campestris*, spring hares, *Pedetes capensis* and hares, *Lepus* spp. (Walker *et al.* 2000).

Rhipicephalus turanicus was present on a dog at Boane and on the dog at Goba. Although there appear to be only three locality records for *R. turanicus* in Mozambique (Walker *et al.* 2000), it has been collected from dogs and scrub hares in north-eastern KwaZulu-Natal, to the south, and from wild carnivores and from the vegetation in the Kruger National Park, to the west (Horak *et al.* 1995, 2000, 2001). The four collections from dogs in this survey are from localities that lie between these regions.

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Onderstepoort Journal of Veterinary Research, 73:305–309 (2006)

RESEARCH COMMUNICATION

Ixodid ticks on dogs in the eastern region of the Eastern Cape Province, South Africa

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ABSTRACT

NYANGIWE, N., HORAK, I.G. & BRYSON, N.R. 2006. Ixodid ticks on dogs in the eastern region of the Eastern Cape Province, South Africa. *Onderstepoort Journal of Veterinary Research*, 73:305–309

The objective of this study was to determine the species composition and geographic distribution of ixodid ticks infesting domestic dogs in the eastern region of the Eastern Cape Province. Seventy-two communal cattle dip-tanks within this region were randomly selected as survey localities and their geographic coordinates recorded. In addition to ticks that were collected from five cattle and five goats at each of the dip-tanks, ticks were also collected from five dogs whenever possible. No dogs were available at 19 dip-tanks and no ticks were collected from dogs at 13 dip-tanks, while ticks were collected from 132 of 200 dogs at 40 dip-tanks. Eight ixodid tick species were collected from these dogs, and *Haemaphysalis leachi* followed by *Rhipicephalus appendiculatus* and *Rhipicephalus simus* were present on dogs at the largest number of dip-tanks. Seven dogs were simultaneously infested with three tick species and one with four species. The geographic distributions of *Amblyomma hebraeum*, *H. leachi*, *R. appendiculatus* and *R. simus* recovered from the dogs lay within the ranges previously reported for these ticks.

Keywords: *Amblyomma hebraeum*, dogs, Eastern Cape Province, geographic distribution, *Haemaphysalis leachi*, ixodid ticks, *Rhipicephalus appendiculatus*, *Rhipicephalus simus*, species composition

Six surveys on the ticks that infest dogs have been conducted in South Africa and a total of 23 ixodid and one argasid tick species have been recovered from these animals (Horak, Jacot Guillarmod, Moolman & De Vos 1987b; Horak 1995; Bryson, Horak, Höhn & Louw 2000; Horak, Emslie & Spickett 2001; Jacobs, Fourie, Kok & Horak 2001; Horak & Matthee 2003). Furthermore, the seasonal occurrence of five species, namely *Haemaphysalis leachi*, ticks of the *Ixodes pilosus* group, *Rhipicephalus gertrudae*, *Rhipicephalus sanguineus* and *Rhipicephalus simus* has been determined on dogs or wild carnivores (Horak 1982; Horak *et al.* 1987b; 2001; Jacobs *et al.* 2001; Horak & Matthee 2003). With the exception of *R. sanguineus*, the geographic distributions of the above-mentioned ticks have been mapped (Howell, Walker & Nevill 1978; Walker, Keirans & Horak 2000). These five tick species, plus *Ixodes rubicundus*, all regularly use dogs as hosts. All developmental stages of ticks of the *I. pilosus* group and *R. sanguineus* use dogs, whereas the immature stages

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of the remaining four species infest rodents or elephant shrews, and the adults dogs or other animals (Norval & Mason 1981; Norval 1984; Horak *et al.* 1987b; Fourie, Horak & Van den Heever 1992; Jacobs *et al.* 2001).

During a more comprehensive survey on the ticks infesting domestic animals in the eastern region of the Eastern Cape Province dogs were also examined. This region has a seaboard of approximately 250 km and rises from the Indian Ocean to a height of approximately 2000 m above sea level. The vegetation along the coast is described as Coastal Forest and Thornveld, adjacent to this in the west lies a strip of vegetation described as Eastern Province Thornveld and in the east a strip described as Ngongoni Veld. With the exception of ribbons of Valley Bushveld along the rivers, the inland vegetation, including that in the mountainous north, is described as Highland Sourveld (Acocks 1988).

Ninety out of a total of 1057 communal cattle dip-tanks in this region were selected by means of a table of random numbers, and 72 of these were eventually allocated to the survey. In addition to the ticks that were collected from five cattle and five goats at each of the dip-tanks, ticks were collected from five dogs whenever possible. To minimize stress to the dogs as well as injuries to the researchers the ticks were collected from the dogs by their owners. The ticks were stored in 70% ethyl alcohol in labelled vials for later identification and counting and, together with the geographic coordinates of the dip-tanks at which they were collected, constitute the principal components of this communication.

No dogs were available at 19 of the dip-tanks and no ticks were collected from 65 dogs examined at 13 dip-tanks. Two hundred dogs were examined at the remaining 40 dip-tanks and 132 of these animals were infested. A total of eight ixodid tick species was collected and *H. leachi*, followed by *Rhipicephalus appendiculatus* and *R. simus* were present on dogs at the largest number of dip-tanks (Table 1). Three of the eight tick species, namely *Amblyomma hebraeum*, *R. appendiculatus* and *Rhipicephalus evertsi evertsi* are ticks of cattle and their presence on dogs reflects the abundance of the former animals as well as the ticks that infest them in the region. The remaining five species are ticks that usually or frequently infest dogs or wild carnivores (Norval & Mason 1981; Norval 1984; Horak *et al.* 1987b; Jacobs *et al.* 2001). Two of these, namely ticks of the *I. pilosus* group and *R. simus*, also infest cattle (Howell *et al.* 1978; Walker *et al.* 2000). Twenty-eight of the dogs were simultaneously infested with two species of ticks, seven with three and one with four species.

The small number of ticks collected and the low percentage of dogs infested is rather surprising as it is unlikely that any of them had been treated with an acaricide. The difficulty in controlling a suspicious, frightened rural dog while trying to collect ticks from it might have contributed to this result.

Although adult *A. hebraeum* prefer large herbivorous animals (Norval 1983; Horak, MacIvor, Petney & De Vos 1987a), its immature stages, and more particularly larvae, infest a large variety of hosts including large and small herbivores, carnivores and birds (Norval 1983; Horak *et al.* 1987a; Horak, Braack, Fourie & Walker 2000). In all surveys conducted on domestic dogs in those regions of South Africa in which *A. hebraeum* is present it has always been collected from these animals (Horak *et al.* 1987b; 2001; Horak 1995; Bryson *et al.* 2000) (Fig. 1A).

Haemaphysalis leachi was not only present on dogs at 90% of the 40 dip-tanks at which ticks were collected, but was collected from 70.4% of tick-infested dogs (Table 1). It is a common tick on rural, free-running domestic dogs and on the larger wild felids (Horak *et al.* 1987b; 2000; 2001). Its immature stages infest murid rodents (Norval 1984), and have been collected from these animals in the north-east, south-east, south-west and central regions of South Africa (Horak, Sheppey, Knight & Beuthin 1986; Fourie *et al.* 1992; Braack, Horak, Jordaan, Segerman & Louw 1996; Petney, Horak, Howell & Meyer 2004; Horak, Fourie & Braack 2005).

The geographic distribution of *H. leachi* in South Africa has been mapped by Howell *et al.* (1978), and appears to be patchy and discontinuous particularly in the western regions. Norval (1984), however, believed that this tick was likely to be present at localities wherever the tick-rodent-carnivore relationship was satisfactory. The sites at which it was collected in the present survey (Fig. 1B), all fall within its distribution range as mapped by Howell *et al.* (1978). With the exception of the southern coastal regions of the Western Cape Province, *H. leachi* would appear to be the most numerous adult tick on dogs in coastal and adjacent inland regions from southern Mozambique in the north-east to the western regions of the Western Cape Province in the south-west (Horak *et al.* 1987b; 2001; Horak & Matthee 2003; Neves, Afonso & Horak 2004) (Fig. 1B).

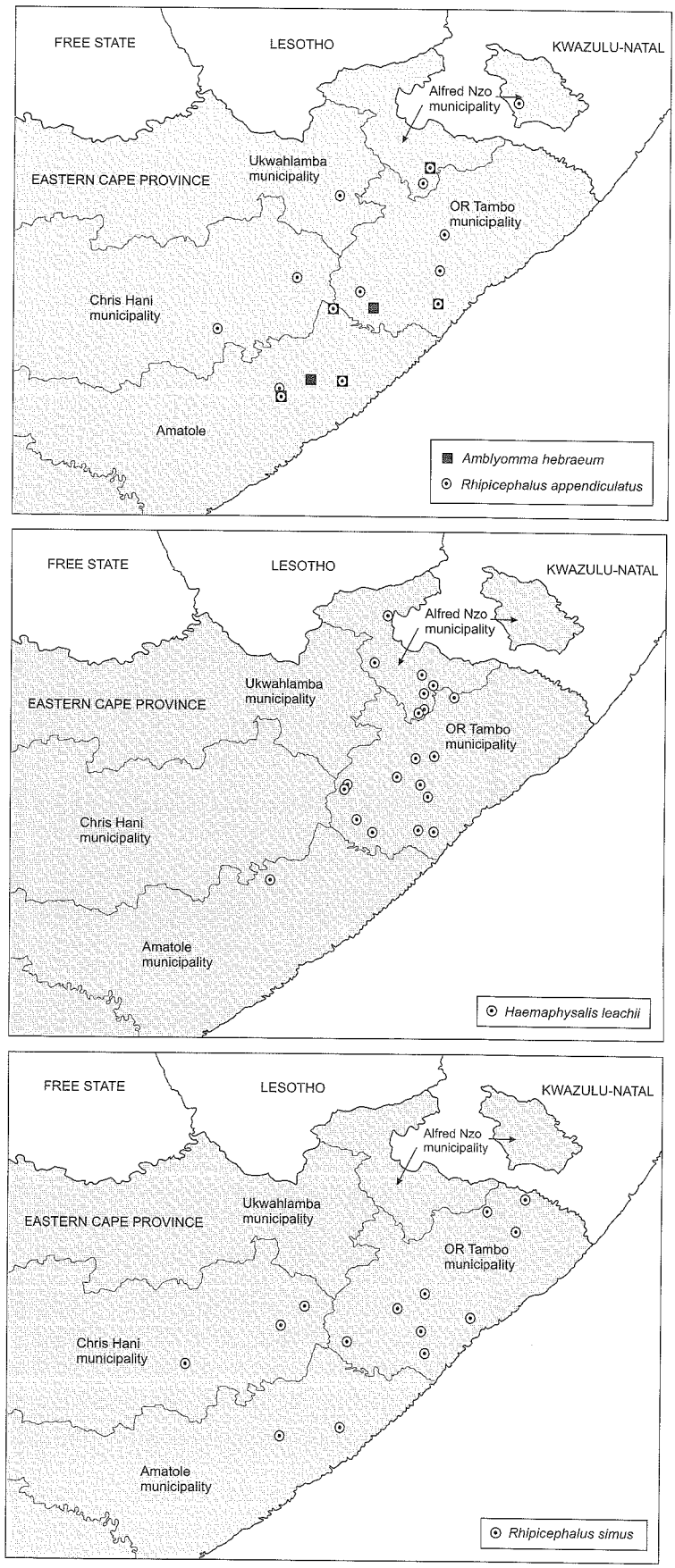

FIG. 1 Localities at which (A) *Amblyomma hebraeum* and *Rhipicephalus appendiculatus*, (B) *Haemaphysalis leachi*, and (C) *Rhipicephalus simus* were present on dogs in the eastern region of the Eastern Cape Province, South Africa

TABLE 1 Ticks collected from 200 dogs (of which 132 were infested) at 40 localities in the eastern region of the Eastern Cape Province, South Africa

Tick species	No. of localities	No. of dogs infested	Stage of development	No. of ticks
Amblyomma hebraeum	7	19	Larvae Nymphs Males Females	16 34 5 1
Haemaphysalis leachi	36	93	Males Females	25 168
Haemaphysalis spinulosa	1	1	Males	1
Ixodes pilosus group	2	2	Females	2
Rhipicephalus appendiculatus	14	19	Nymphs Males Females	4 12 13
Rhipicephalus evertsi evertsi	2	2	Males	2
Rhipicephalus sanguineus	2	7	Nymphs Males Females	3 10 12
Rhipicephalus simus	14	29	Males Females	23 31

All stages of development of *I. pilosus* group ticks have been collected from dogs and caracals, *Caracal caracal*, in the central coastal and adjacent inland regions of the Eastern Cape Province (Horak *et al.* 1987b). Its presence on two dogs in the more eastern regions of this province is thus not unexpected.

Although *R. appendiculatus* is essentially a tick of cattle and large wild bovids (Walker *et al.* 2000), it is not infrequently encountered in all its developmental stages on dogs and on wild carnivores (Horak *et al.* 1987b; 2000; 2001, Bryson *et al.* 2000). Its recovery from cattle or from the vegetation at all 72 dip-tanks at which cattle were examined is proof of the tick's abundance in this region and it is consequently not unusual that several dogs were infested. The dip-tanks at which *R. appendiculatus* was recovered from dogs all lie within the previously plotted distribution range of this tick (Howell *et al.* 1978; Walker *et al.* 2000) (Fig. 1A).

All stages of development of *R. sanguineus* infest dogs (Walker *et al.* 2000), and its life cycle is adapted to man-made structures such as human dwellings, dog kennels or cages (Howell *et al.* 1978; Horak 1982). It is particularly prevalent on dogs in townships or cities where the animals are confined to the properties of their owners (Bryson *et al.* 2000; Neves *et al.* 2004). Its presence on dogs at two of the dip-tanks implies that these animals were probably chained, kennelled or caged at the homesteads of their owners at night.

Adult *R. simus* infests monogastric animals such as zebras, *Equus* spp., warthogs *Phacochoerus africanus*, and domestic and wild carnivores and also cattle (Walker *et al.* 2000). Because its immature stages infest murid rodents (Norval & Mason 1981; Braack *et al.* 1996; Walker *et al.* 2000), it is more common on free-running dogs in rural environments or on large suburban properties, where rodents are likely to be plentiful, than on city dogs (Horak *et al.* 1987b; 2001). Its preference for dogs rather than for cattle in the present study is evident in that it was collected from 29 dogs at 14 of the 53 dip-tanks at which dogs were examined, compared to none from cattle at the 72 dip-tanks at which the latter animals were examined.

Rhipicephalus simus is present on dogs from southern Mozambique in the north-east to at least as far as Grahamstown, Eastern Cape Province in the south-east (Horak *et al.* 1987b; 2001; Neves *et al.* 2004). Although it appeared to be more common on dogs at lower altitudes (Fig. 1C), the localities at

which it was collected from dogs in the present study fall within its distribution range as mapped by Walker *et al.* (2000). In south-western Western Cape Province and in central Free State Province it is replaced on dogs and other animals by the closely-related *Rhipicephalus gertrudae* (Jacobs *et al.* 2001; Horak & Matthee 2003).

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CHAPTER 7

TICKS OF WILDLIFE

My involvement in the field of parasites of wildlife commenced in 1971 with a study in North-West Province on the efficacy of a parasiticide against the larvae of a nasal botfly, *Gedoelstia hässleri*, that infest blesbok, *Damaliscus pygargus phillipsi*. After this I was approached to conduct surveys on the parasites of blesbok in the Percy Fyfe and Rietvlei Nature reserves, followed by impalas, *Aepyceros melampus*, in the Nylsvley Nature Reserve. These were followed by numerous surveys in the Kruger National Park and in various other National parks as well as in provincial and privately owned nature reserves and on wildlife farms.

The publications that follow record the results of studies commenced in 1980 and published from late 1988 onwards. Publications that appeared prior to this date were included in one or the other of two of my earlier theses. With the exception of the studies by Fourie, Vrahimis, Horak, Terblanche & Kok (1991), Zieger, Horak, Cauldwell & Uys (1998b), Fourie, Horak, Kok & Van Zyl (2002), Petney, Horak, Howell & Meyer (2004), Horak, McKay, Heyne & Spickett (2006a), Horak, McKay, Henen, Heyne, Hofmeyr & De Villiers (2006d), Horak, Golezardy & Uys (2007), during which I identified some, or the majority of ticks, and MacIvor & Horak (2003) and Uys & Horak (2005), in which K. MacIvor and A. Uys identified all the ticks, I was responsible for the identification of all the ticks in the publications that relate to ticks of wildlife.

Ruminants

With the possible exception of small mammals, most of my wildlife studies have been devoted to the parasites of wild ruminants. Thus the tick burdens of gemsbok, *Oryx gazella*, in Free State Province (Fourie *et al*. 1991), greater kudus, *Tragelaphus strepsiceros* in the Kruger National Park and in the Eastern Cape Province (Horak, Boomker, Spickett & De Vos 1992b; Petney & Horak 1997), nyalas, *Tragelaphus angasii*, in north-eastern KwaZulu-Natal (Horak, Boomker & Flamand 1995c), impalas, *Aepyceros melampus*, in the Kruger National Park (Horak, De Vos & Braack 1995a; Horak, Fourie & Van Zyl 1995d; Horak, Gallivan, Braack, Boomker & De Vos 2003), and African buffaloes, *Syncerus caffer*, eland, *Taurotragus oryx*, and giraffes, *Giraffa camelopardalis*, at various localities, have been determined (Horak, Golezardy & Uys 2006c; Horak *et al.* 2007).

These surveys revealed that the larger the host species the greater the number of adult ticks it was likely to harbour (Gallivan & Horak 1997; Horak *et al*. 2007). They also showed that male animals, probably partly because of their greater size, usually harbour more adult ticks than do females of the same species (Horak *et al*. 1992b; 1995c). Furthermore they indicated that for their comparatively small size impalas carry inordinately large tick burdens (Horak *et al*. 2003), and that provided African buffaloes are challenged with *Rhipicephalus* (*Boophilus*) *decoloratus* when they are young, they become resistant to infestation with this tick at about one year of age (Horak *et al*. 2006c).

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Ecto- and endoparasites of introduced gemsbok in the Orange Free State

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The gemsbok, *Oryx gazella*, is an introduced species in the Orange Free State. Two antelope were shot each month in the Willem Pretorius Nature Reserve from February 1987 to January 1988 in order to determine their parasitic burdens. Although none of the gemsbok harboured large burdens, nine ixodid tick species, two louse species, 17 nematode species and a cestode species were recovered. *Margaropus winthemi*, which was mainly present from July to September, was the most abundant tick, followed by *Rhipicephalus evertsi evertsi*, which showed no clear pattern of seasonal abundance. Young antelope harboured significantly greater numbers of the sucking louse *Linognathus oryx* than did older animals. *Trichostrongylus falculatus* was the most numerous nematode, followed by *Cooperia fuelleborni*. No pattern of seasonal abundance was evident for any of the helminths.

Die gemsbok *Oryx gazella* is 'n uitheemse spesie in die Oranje-Vrystaat. Twee gemsbokke is op 'n maandelikse basis in die Willem Pretoriuswildtuin vanaf Februarie 1987 tot Januarie 1988 versamel ten einde hul parasietladings te bepaal. Alhoewel geen individu besondere hoë ladings gehad het nie is nege verskillende skildbosluisspesies, twee luisspesies, 17 rondewurmspesies en 'n lintwurmspesie herwin. *Margaropus winthemi*, wat hoofsaaklik vanaf Julie tot September op die bokke voorgekom het, was die volopste, gevolg deur *Rhipicephalus evertsi evertsi*, wat geen duidelike seisoenale voorkoms getoon het nie. Jong bokke het betekenisvol meer bloedsuiende luise *Linognathus oryx* vergeleke met ouer bokke gehuisves. *Trichostrongylus falculatus* gevolg deur *Cooperia fuelleborni* was die volopste rondewurms. Geen patroon van seisoenale voorkoms is deur enige van die helminte getoon nie.

Keywords: Ecto- and endoparasites, *Oryx gazella*, antelope, introduced species

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Introduction

The natural distribution of gemsbok, *Oryx gazella* was confined to the more arid regions of southern Africa, principally in the central north-western and northern Cape, as well as in Botswana and Namibia (Du Plessis 1969). This antelope has, however, been introduced into many regions of southern Africa and it is now widely distributed (Terblanché 1988; Fourie & Vrahimis 1989). It failed to thrive in several regions into which it had been introduced and parasites may play a role in this (Horak, Potgieter, Walker, De Vos & Boomker 1983a; Fourie & Vrahimis 1989).

According to available empirical evidence on parasite-induced mortality, the probability of a host dying within a given time can be related to its parasitic burden (Anderson 1979). Where it is suspected that parasites may be the cause of host mortality, quantification of parasitic burdens should be a basic prerequisite. This paper describes the quantitative and qualitative aspects of the parasite populations associated with introduced gemsbok in the Willem Pretorius Nature Reserve. An attempt was made to elucidate the reasons for the slow population growth of gemsbok within this reserve. No previous work on the parasite loads of any of the mammal species within this reserve has been published.

Materials and Methods

Study area

The Willem Pretorius Nature Reserve (28° 16′ – 28° 21′S; 27° 07′ – 27° 23′E, altitude 1 375–1 510 m) is located approximately 30 km north-east of the town Winburg in the Orange Free State, Republic of South Africa. In area the reserve comprises 12 091 ha, of which the Allemanskraal Dam, when full, covers 2 742 ha.

The climate is characterized by dry, cold winters and generally warm to hot summers. Frost occurs from mid-May to mid-October with 100–150 frost days per year (Bourquin 1973). The mean annual rainfall is 520,8 mm of which 75% occurs between October and April (Bourquin 1973).

The reserve lies in Transitional *Cymbopogon–Themeda* veld (Acocks 1975), and can be divided into four basic vegetation types (Müller 1986). These are:

(i) Tree and shrub community of the hilly areas (10,0% of area);
(ii) Grassland community of the hilly areas (11,3% of area);
(iii) Grassland community of the plains (67,1% of area);
(iv) Thornveld (11,6%).

Information on the variety of game species, abundance, as well as whether introduced or naturally occurring, is summarized in Table 1.

Survey animals

Two gemsbok were shot monthly from February 1987 to January 1988 for the collection of external and internal parasites. An attempt was made on each occasion to shoot at

Table 1 Large animals present in the Willem Pretorius Nature Reserve during 1988

Species	Number	Status
Black wildebeest (*Connochaetes gnou*)	474	Reintroduced
Eland (*Taurotragus oryx*)	104	Reintroduced
White rhinoceros (*Ceratotherium simum*)	16	Reintroduced?
Blesbok (*Damaliscus dorcas phillipsi*)	762	Reintroduced
Red hartebeest (*Alcelaphus buselaphus caama*)	161	Reintroduced
Springbok (*Antidorcas marsupialis*)	943	Reintroduced
Burchell's zebra (*Equus burchelli*)	118	Reintroduced
Gemsbok (*Oryx gazella*)	135	Introduced
Mountain reedbuck (*Redunca fulvorufula*)	200	Present at all times
Ostrich (*Struthio camelus*)	210	Reintroduced
Impala (*Aepyceros melampus*)	152	Introduced
Buffalo (*Syncerus caffer*)	160	Reintroduced?
Kudu (*Tragelaphus strepsiceros*)	28	Reintroduced
Giraffe (*Giraffa camelopardalis*)	45	Introduced

Reintroduced? = Status uncertain

random one juvenile (horns < 300 mm and coat colour brown or with adult colouring) or sub-adult (adult colouring with horn length and body size approximately three quarters of that of adults), as well as one adult. Twenty-four gemsbok (11 calves, 2 sub-adults and 11 adults) were examined. All were shot in the neck to prevent damage to the brain or to the heart and lungs, which were required for parasite recovery.

The carcasses were transported to a laboratory as soon as possible after death to prevent the loss of external parasites. On arrival the carcasses were weighed to the nearest kilogram.

Parasite recovery

At the laboratory the animals were skinned and eviscerated. The skins were processed for ectoparasite recovery as described by Horak, Meltzer & De Vos (1982) and the nasal passages and sinus cavities for the recovery of oestrid larvae as described by Malan, Reinecke & Krecek (1981).

The ticks, lice and oestrid larvae recovered were counted and identified under a stereoscopic microscope. The lungs and gastro-intestinal tracts were processed for helminth recovery and the worms were counted as described by Horak, De Vos & Brown (1983b).

Parasite densities (*n*/kg) were determined by dividing the total number of ecto- and endoparasites recovered from each animal by the live mass of the animal.

Kidney fat index

The physiological condition of the animals was determined by using the kidney fat index (Smith 1970):

$$\text{Kidney fat index} = \frac{\text{Weight of perinephric fat}}{\text{Kidney weight}} \times 100$$

Correlations between kidney fat index and parasite densities were performed.

Data analysis

The comparisons of means and variances were conducted using *t*-tests on transformed data (Petney, Van Ark & Spickett 1990).

Results

Ectoparasites

Nine ixodid tick species and two louse species were recovered (Table 2). *Margaropus winthemi* was the most abundant tick and the only one for which a clear pattern of seasonal abundance could be determined. The largest numbers were present from July to September. *Rhipicephalus evertsi evertsi* was the second most abundant and although it occurred throughout the year, the largest numbers of immatures were present from February to May and from Decem-

Table 2 The total numbers of ectoparasites recovered from 24 gemsbok in the Willem Pretorius Nature Reserve

Ectoparasite	Number recovered					Number of animals infested
	Larvae	Nymphs	Males	Females	Total	
Ticks						
Amblyomma marmoreum	457	11	0	0	468	14
Hyalomma marginatum rufipes	0	0	50	20	70	11
Hyalomma truncatum	0	0	23	3	26	6
Ixodes rubicundus	0	0	1	2	3	3
Margaropus winthemi	2128	3912	7249	2797	16086	16
Rhipicephalus evertsi evertsi	3737	806	283	161	4987	24
Rhipicephalus follis	0	0	12	27	39	4
Rhipicephalus gertrudae	0	0	50	13	63	7
Rhipicephalus punctatus	0	0	35	5	40	6
Lice			Nymphs	Adults	Total	
Damalinia sp.			0	9	9	7
Linognathus oryx			382	3499	3881	22

ber to January while adults were present during March, September and November.

The larvae of *Amblyomma marmoreum* were most abundant from February to April. *Hyalomma marginatum rufipes* was erratically present throughout the year whereas *Hyalomma truncatum* was recovered only from July to January 1988. Adults of *Rhipicephalus follis* and *Rhipicephalus gertrudae* were erratically present in small numbers from September to December.

Significantly more sucking lice *Linognathus oryx* were recovered from the calves and sub-adults than from adult gemsbok ($t = 2,97$; $df = 22$; $p < 0,05$).

Helminths

The numbers and species of helminths recovered are presented in Table 3. Although the numbers of helminths recovered were not particularly large, 17 nematode species, one cestode and the larvae of another cestode were recovered. *Trichostrongylus falculatus* was the most abundant followed by *Cooperia fuelleborni*. No clear pattern of seasonal abundance was evident for any of the helminth species.

Parasite densities and condition

The parasite densities of the gemsbok belonging to the various age categories are presented in Table 4. No seasonal trends in these densities were discernible. A comparison between the parasite densities of calves and sub-adults (grouped together) and those of adults showed no significant differences ($t = 1,40$; $df = 22$ and $p > 0,1$).

Only one kidney fat index rating in excess of 50 was recorded (Table 4). The lowest kidney fat index ratings were recorded during July to November when most values were below 25.

There was no significant correlation between parasite density and kidney fat index.

Table 3 The total numbers of helminths recovered from 24 gemsbok in the Willem Pretorius Nature Reserve

Helminths	Number recovered			Number of animals infected
	4th stage	Adults	Total	
Nematodes				
Agriostomum equidentatum	0	2	2	1
Cooperia/Paracooperia spp.	30	–	30	1
Cooperia fuelleborni	–	8914	8914	13
Cooperia hungi	–	60	60	1
Cooperia neitzi	–	150	150	2
Cooperia yoshidae	–	3864	3864	14
Dictyocaulus sp.	0	3	3	2
Haemonchus spp.	125	–	125	4
Haemonchus bedfordi	–	23	23	2
Haemonchus contortus	–	943	943	15
Haemonchus mitchelli	–	25	25	1
Impalaia tuberculata	60	2502	2562	9
Longistrongylus sabie	0	221	221	7
Oesophagostomum sp.	30	31	61	3
Paracooperia serrata	–	91	91	3
Strongyloides sp.	0	145	145	4
Trichostrongylus axei	0	255	255	7
Trichostrongylus falculatus	0	18485	18485	16
Trichuris sp.	0	187	187	12
Cestodes	Larvae	Scolices	Total	
Moniezia sp.	*	25	25	5
Taenia hydatigena	4	*	4	2

* = Not recovered in ruminants

Table 4 The parasite densities and kidney fat indices of 24 gemsbok in the Willem Pretorius Nature Reserve

Date	Age category	Sex	Parasite density *	Kidney fat index
February 1987	Calf	M	13,69	26,2
	Adult	M	20,73	36,5
March	Calf	F	7,44	26,5
	Adult	F	13,54	85,6
April	Calf	M	10,68	12,1
	Adult	M	14,39	20,2
May	Calf	M	21,69	47,9
	Adult	M	16,44	39,1
June	Calf	F	4,04	23,0
	Adult	M	51,44	44,7
July	Sub-adult	M	35,35	15,2
	Adult	M	35,30	7,6
August	Calf	M	18,72	12,0
	Adult	F	22,88	25,9
September	Calf	F	3,95	15,4
	Adult	M	34,88	16,8
October	Calf	F	32,05	18,8
	Calf	M	5,52	26,9
November	Sub-adult	M	31,98	16,6
	Adult	M	12,52	9,9
December	Calf	F	8,26	19,7
	Adult	F	2,32	25,4
January 1988	Calf	F	7,35	24,6
	Adult	M	36,05	24,3

* Parasite density = Total number of ecto- and endoparasites recovered/kg host live mass

Climate

Total monthly rainfall exceeded 50 mm during February, September, November and December. The lowest mean minimum temperatures were recorded from June to August and the highest maxima from February to April and October to January.

Discussion

Although no individual gemsbok was particularly heavily infested with large numbers of parasites, a wide variety of species was recovered.

Ixodid ticks

Amblyomma marmoreum

Tortoises are the preferred hosts of the adults of this tick but the immature stages can be found on reptiles, birds and

mammals (Petney, Horak & Rechav 1987). Their presence on the gemsbok is thus not unexpected. The period of maximum larval and nymphal abundance on the antelope corresponds to that observed by Norval (1975) in the eastern Cape Province.

Hyalomma spp.

As was the case with sheep and cattle on the farm 'Preezfontein' in the south-western Orange Free State (Fourie, Horak & Marais 1988b; Fourie & Horak 1990), *H. marginatum rufipes* was more abundant than *H. truncatum* on the gemsbok. Peak abundance on the domestic stock on the farm occurred between November and February or April but ticks were erratically present in small numbers on the gemsbok almost throughout the year.

Although only small numbers of *H. truncatum* were present, it was recovered from at least one gemsbok during each month from October to January. The largest numbers of this tick were present on the cattle on 'Preezfontein' during September and from November to January (Fourie & Horak 1990).

Margaropus winthemi

This is a one-host tick reaching peak numbers during the winter months (Howell, Walker & Nevill 1983; Horak, Knight & De Vos 1986). One of its original hosts was probably the Cape mountain zebra *Equus zebra zebra* but it has adapted to various large wild hosts as well as horses and cattle (Howell *et al.* 1978).

Burdens exceeding 30 000 ticks per animal have been recovered from Cape mountain zebras in the Mountain Zebra National Park during July (Horak *et al.* 1986). In the present survey the largest individual burdens were recorded on gemsbok during July, August and September, but these never exceeded 5 000 ticks.

Ixodes rubicundus

This tick can cause paralysis and subsequent mortality amongst domestic stock and wild ruminants, including gemsbok (Howell *et al.* 1983; Fourie & Vrahimis 1989). Burdens of between 0,26 and 2,12 female ticks/kg host mass have been recorded on paralysed gemsbok (Fourie & Vrahimis 1989). The recovery of only three ticks from the gemsbok examined during the present investigation probably indicates that the study region represents a marginal distribution area for the tick.

Rhipicephalus spp.

Rhipicephalus evertsi evertsi was the second most abundant tick collected. It prefers equids as hosts (Norval 1981; Horak *et al.* 1986), but has also been recovered from a large variety of other ungulates (Theiler 1962).

Adult female ticks of this species can cause paralysis, particularly amongst sheep lambs (Gothe & Bezuidenhout 1986). Odd cases of paralysis in adult sheep and calves have also been reported (Stampa 1959).

Rhipicephalus follis, although never present in very large numbers, has a fairly widespread distribution in South Africa. It occurred from December to April on bushbuck *Tragelaphus scriptus* in the Weza State Forest, Natal (Horak, Keep, Spickett & Boomker 1989).

In Namibia, Biggs & Langenhoven (1984) found that adult ticks of the *Rhipicephalus capensis* group, in which *R. gertrudae* predominated, were present on cattle in substantial numbers from November to March. This is two months later than in the present survey.

Rhipicephalus punctatus, then referred to as *Rhipicephalus* sp. (near *Rhipicephalus pravus*), has recently been incriminated as a cause of paralysis in Angora goats (Fourie, Horak & Marais 1988a). This tick exhibited a major peak of abundance on sheep on the farm 'Preezfontein' during February and a minor peak during August (Fourie *et al.* 1988b). On cattle on the same farm it was present during January and April, and from September to November (Fourie & Horak 1990). With the exception of the two females recovered during May, the seasonal abundance of this tick on the gemsbok was reasonably similar to that found on the cattle on 'Preezfontein'. We do not know whether larger numbers of this tick than presently recovered could cause paralysis of gemsbok or not.

Lice

Few gemsbok were infested with *Damalinia* sp., and those that were, harboured only one or two lice. Since these lice feed mainly on skin debris (Nelson, Keirans, Bell & Clifford 1975) it is unlikely that they would have a detrimental effect, unless they occurred in very large numbers.

The significantly larger burdens of the blood-sucking louse *L. oryx* on the young gemsbok, when compared with those of the adult animals, are similar to results obtained for sucking lice on rock dassies *Procavia capensis* (Fourie, Horak & Visser 1987). A possible reason for this disparity in burdens may be that the physical nature of the juvenile skin favours the feeding of these lice.

Helminths

Nematodes

With a single exception, namely the sub-adult animal examined during November, young gemsbok harboured fewer nematodes than did adult animals (Table 2). These differences were significant. The reasons for these differences could be two-fold. First, several of the calves examined were still suckling and were therefore not exposed to the same extent to infective nematode larvae as were the older animals. Second, except for four months, rainfall was low and hence veld contamination was probably also low. This is confirmed by the small numbers of fourth stage larvae recovered from the antelope, indicating that little infection had been acquired from the grazing. The higher burdens in the adult animals were probably the result of the survival of earlier infections and the gradual acquisition of new infections. Infections in all age groups were very low and would probably not have any deleterious effects.

Most of the nematodes recovered probably originally emanated from other host species, both from within and outside the reserve but may also be parasites of gemsbok. Thus *Haemonchus contortus* and *Trichostrongylus axei* are primarily parasites of sheep; *Cooperia hungi, Longistrongylus sabie* and *Impalaia tuberculata* parasites of impala; *Cooperia yoshidai* of blesbok (Horak 1981); *Agriostomum*

equidentatum and *Paracooperia serrata* of springbok (Horak *et al.* 1982); *Haemonchus bedfordi* of blue wildebeest and black wildebeest (Horak *et al.* 1983b) and *Cooperia neitzi* of kudu (Boomker, Horak & De Vos 1989). *Trichostrongylus falculatus* prefers a fairly dry habitat (Horak 1981) and this would overlap the habitat preferences of gemsbok resulting in a stable host-parasite relationship. The same possibly also applies to *Cooperia fuelleborni*.

Cestodes

Two gemsbok harboured *Cysticercus tenuicollis*, the larval stage of *Taenia hydatigena*. These cysts had probably been acquired from jackals, which are one of the host species of the adult worms (Reinecke 1983), from within the reserve.

Moniezia sp. was recovered only from the calves (Table 2). This is similar to the observations made on blue wildebeest *Connochaetes taurinus*, the adult animals becoming resistant to infection (Horak *et al.* 1983b).

General

This study was initiated as part of an investigation to determine the reasons for the low population growth of gemsbok in the reserve, but no evidence that parasites are responsible could be found. As no data are available on the parasite burdens of other animals in the reserve, no comparisons on the relative levels of parasite infection can be made. Nevertheless, the gemsbok were infected with a large variety of tick and nematode species, many of which do not occur in the natural habitat of the antelope (Howell *et al.* 1983; Horak 1981). Although the parasite burdens were never very high, the potential always exists that under more favourable conditions, large burdens with concurrent detrimental effects could develop. In addition, because of the numerous parasite species harboured by the gemsbok, they could always serve as a source or reservoir of infection.

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PARASITES OF DOMESTIC AND WILD ANIMALS IN SOUTH AFRICA. XXX. ECTOPARASITES OF KUDUS IN THE EASTERN TRANSVAAL LOWVELD AND THE EASTERN CAPE PROVINCE

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ABSTRACT

HORAK, I. G., BOOMKER, J., SPICKETT, A. M. & DE VOS, V., 1992. Parasites of domestic and wild animals in South Africa. XXX. Ectoparasites of kudus in the eastern Transvaal Lowveld and the eastern Cape Province. *Onderstepoort Journal of Veterinary Research*, 59, 259–273 (1992)

Sets of four kudus were shot and examined for arthropod parasites at approximately monthly intervals from April 1981 to March 1983 in the southern part of the Kruger National Park, eastern Transvaal Lowveld. These animals harboured 10 ixodid tick species of which *Boophilus decoloratus* followed by *Amblyomma hebraeum* were the most abundant. The seasonal abundances of these ticks and of *Amblyomma marmoreum, Rhipicephalus appendiculatus, Rhipicephalus evertsi evertsi* and *Rhipicephalus zambeziensis* were determined. The kudus were also infested with 3 lice and 1 louse fly species, as well as the nymphs of a pentastomid.

Sixteen kudus were shot in the Andries Vosloo Kudu Reserve, eastern Cape Province and 9 on an adjacent farm. These animals were infested with 12 tick species. *A. hebraeum* followed by *Rhipicephalus glabroscutatum* were the most abundant on kudus in the reserve and *R. glabroscutatum* followed by *Haemaphysalis silacea* on the animals on the farm. The seasonal abundances of *A. hebraeum,A. marmoreum, H. silacea, R. appendiculatus, R. glabroscutatum* and a *Rhipicephalus* sp. (near *R. oculatus*) were determined on the kudus in the reserve. The kudus were also infested with 3 lice and 1 louse fly species. Two kudus examined in the Addo Elephant National Park were infested with 6 tick, 1 louse and 1 louse fly species.

INTRODUCTION

A number of surveys on the abundance of ectoparasites on a variety of host species have already been conducted in the eastern Transvaal Lowveld and the eastern Cape Province. Blue wildebeest, Burchell's zebras, warthogs and helmeted guineafowls have been examined in the Kruger National Park, eastern Transvaal Lowveld (Horak, De Vos & Brown, 1983; Horak, De Vos & De Klerk, 1984; Horak, Boomker, De Vos & Potgieter, 1988; Horak, Spickett, Braack & Williams, 1991). While kudus, cattle, Dorper sheep, Angora goats, scrub hares and helmeted guineafowls have been examined in the Andries Vosloo Kudu Reserve and/or on the adjacent farm "Bucklands", eastern Cape Province (Knight & Rechav, 1978; Rechav, 1982; Horak, Williams & Van Schalkwyk, 1991; Horak, Spickett, Braack & Williams, 1991; Horak, Knight & Williams, 1991; Horak & Fourie, 1991).

Several studies on the ixodid tick burdens of kudus, *Tragelaphus strepsiceros,* have been published. Knight & Rechav (1978) examined 25 animals from the farms "Bucklands" and "Ulster" and Horak, Potgieter, Walker, De Vos & Boomker (1983) 4 animals in the Kruger National Park and 5 from the Andries Vosloo Kudu Reserve. Horak & Knight (1986) and Petney & Horak (1987) also compared the burdens of some of the animals from the Andries Vosloo Kudu Reserve, included in the present paper, with those of kudus on the adjacent farm "Bucklands". These surveys all indicate that kudus are good hosts of several tick species and may become heavily infested, a fact also commented on by Lightfoot & Norval (1981) in Zimbabwe.

Kudus are large antelope that are widely distributed in southern and East Africa. They prefer light forest or dense bush (Ansell, 1971) and generally avoid open country (Dorst & Dandelot, 1972; Rautenbach, 1982). They usually live in small groups comprising adult cows and their offspring. Calves remain hidden for approximately the first 3 months of life and then join the cow groups (Novellie, 1983). Male animals leave the group when about 2 years old, while females stay with the group until fully mature (Novellie, 1983). Adult bulls form bachelor groups that join the cows during the breeding season (Novellie, 1983).

The present paper describes surveys on the abundance of ectoparasites of kudus shot in the Kruger National Park, eastern Transvaal Lowveld, in the Andries Vosloo Kudu Reserve and on the adjacent farm "Bucklands", and in the Addo Elephant National Park, eastern Cape Province. The kudus in these surveys were also examined for internal parasites and this has been reported elsewhere (Boomker, Horak & De Vos, 1989; Boomker, Horak & Knight, 1991).

MATERIALS AND METHODS

Parasite recovery

After the animals had been shot they were transported to the laboratories at Skukuza in the Kruger National Park or Grahamstown in the eastern Cape Province. There the carcass of each animal was skinned and half the skin of the head, half the skin of the body and upper legs, the whole skin of the tail as well as 1 lower front leg and 1 lower back leg with skin attached were placed separately in plastic bags. A tick-detaching agent[1] was added

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TABLE 1 Arthropod parasites of 95 kudus in the Kruger National Park

Arthropod species	Total number recovered					No. of kudus infested
Ixodid ticks	Larvae	Nymphs	Males	Females	Total	
Amblyomma hebraeum	67 216	9 801	659	291(9)	77 967	95
Amblyomma marmoreum	465	0	0	0	465	18
Boophilus decoloratus	161 815	107 711	35 959	18 140(360)	323 625	95
Haemaphysalis leachi/spinulosa	1	0	0	0	1	1
Hyalomma truncatum	0	0	30	6	36	16
Ixodes sp.	2	1	0	0	3	2
Rhipicephalus appendiculatus	11 915	3 208	3 062	1 721(31)	19 906	88
Rhipicephalus evertsi evertsi	9 015	940	167	63(2)	10 185	92
Rhipicephalus simus	0	0	6	9	15	5
Rhipicephalus zambeziensis	14 365	2 062	963	485(7)	17 875	91
Lice	Nymphs		Adults		Total	
Damalinia sp.	4 336		2 375		6 711	73
Haematopinus taurotragi	470		413		883	23
Linognathus taurotragus	4 782		2 781		7 563	43
Louse flies	Adults				Total	
Lipoptena paradoxa	4 616				4 616	94
Pentastomids	Nymphs				Total	
Linguatula nuttalli	667				667	60

( ) = Number of maturing females i.e. idiosoma of *A. hebraeum* >9,5 mm; *B. decoloratus* >4,0 mm; *R. appendiculatus* >5,0 mm; *R. evertsi evertsi* >6,0 mm; *R. zambeziensis* >5,0 mm. Females of the other tick species had not started to mature

to the skins in the bags which were tightly secured and stored overnight. The following morning the skins were thoroughly scrubbed with brushes with steel bristles and washed. The tick-detaching agent remaining in the plastic bags and the material obtained from scrubbing and washing the skins were sieved on sieves with 0,15 mm apertures. The residues in the sieves were collected, preserved in 10 % formalin and stored.

Pentastomid nymphs were recovered from the hearts, livers and lungs of the kudus, which had all been processed for helminth recovery (Boomker *et al.*, 1989).

Parasite counts

Representative samples of the material collected were examined under a stereoscopic microscope, and the parasites identified and counted. The remainder of the material was examined macroscopically for the presence of adult ticks and louse flies. These and the pentastomid nymphs recovered from the hearts, livers and lungs were counted and identified under a stereoscopic microscope. The data on the louse flies will be reported separately.

Surveys at Particular Localities

Kruger National Park (KNP)

Study site

This has been described in some detail by Boomker *et al.* (1989). In summary, it is located in the southern part of the park between latitude 25° 06′–25° 21′ S and longitude 31° 27′–31° 36′ E. The vegetation is classified as Lowveld (Acocks, 1988). The days are warm to hot in summer and mild in winter and frost occurs occasionally. Rainfall varies from 600–700 mm per annum and usually falls in summer.

Survey animals

Each month from April 1981 to March 1983, 4 kudus were shot in the study area. At each occasion an attempt was made to obtain 1 adult male, 1 adult female, 1 young or sub-adult male and 1 calf of either sex. The animals were aged according to Simpson (1971). For statistical reasons they have been grouped according to age into calves (0–12 months old), juveniles (13–24 months old), young adults (25–48 months old) and prime or old adults (49 months and older). A total of 96 kudus were shot, but only 95 were examined for ectoparasites as the material collected from 1 had not been adequately preserved.

Arthropod burdens

The total numbers of arthropod parasites recovered from the kudus shot in the survey area are summarized in Table 1.

The animals were infested with 10 ixodid tick species. *Boophilus decoloratus* and *A. hebraeum* were the most abundant and all kudus were infested. They were also infested with 3 lice and 1 louse fly species.

Seasonal abundance

The seasonal abundances of *A. hebraeum, Amblyomma marmoreum, B. decolaratus, Rhipicephalus appendiculatus, Rhipicephalus evertsi evertsi* and *Rhipicephalus zambeziensis* on the kudus are graphically illustrated in Fig. 1.

A. hebraeum exhibited no clear pattern of seasonal abundance, while the larvae of *A. marmoreum* were consistently present from March to July 1982 and during February and March 1983. Peak burdens of *B. decoloratus* were recorded in September and October 1981, and November and December

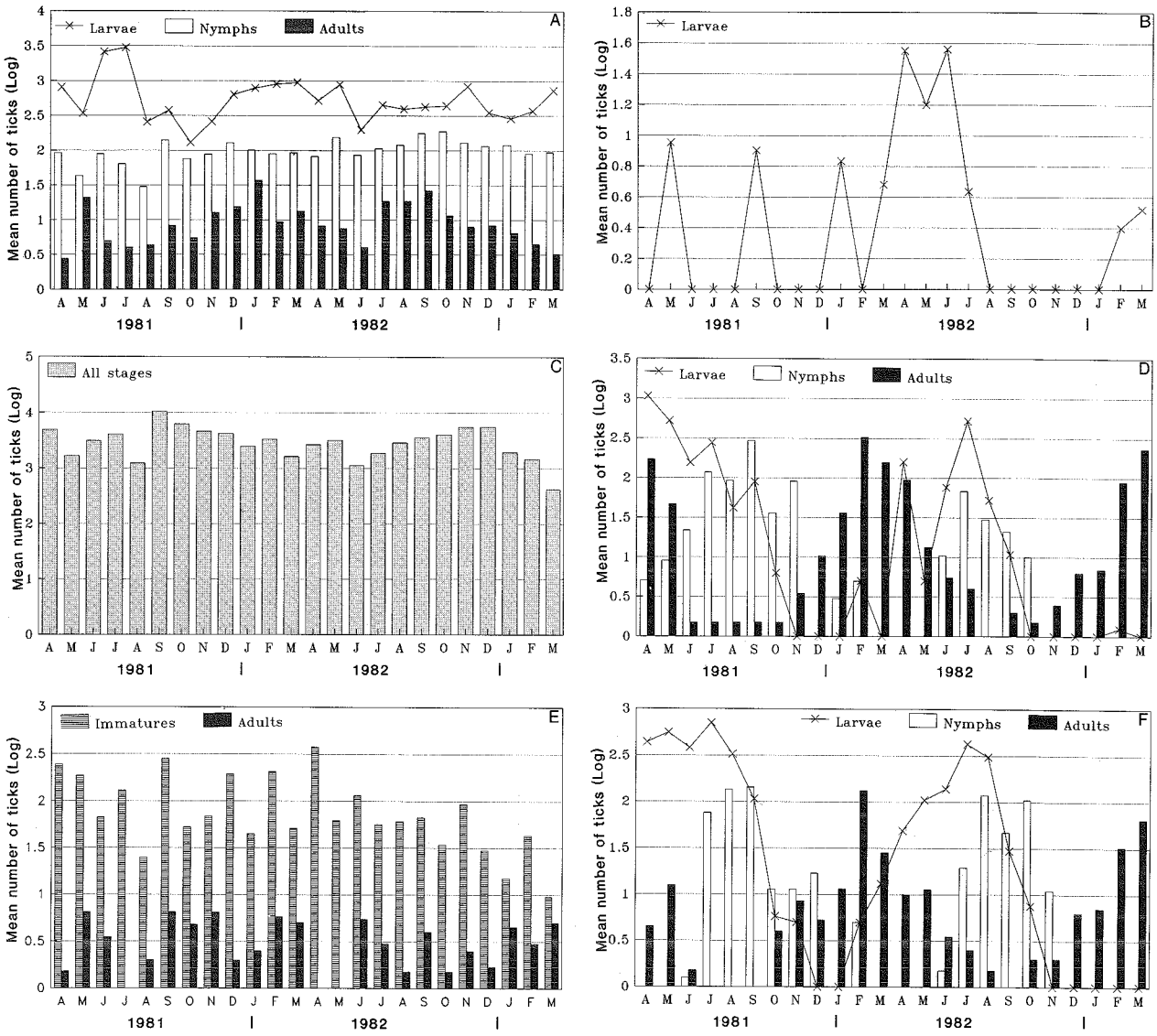

FIG. 1 The seasonal abundance of
A. *Amblyomma hebraeum*, B. *Amblyomma marmoreum*, C. *Boophilus decoloratus*, D. *Rhipicephalus appendiculatus*, E. *Rhipicephalus evertsi evertsi* and F. *Rhipicephalus zambeziensis* on kudus in the Kruger National Park

1982. The larvae of *R. appendiculatus* reached the largest numbers from April to July, the nymphs from July to September or November, and the adults during February to April. No clear pattern of seasonal abudance was evident for *R. evertsi evertsi*. Large numbers of larvae of *R. zambeziensis* were present from April to September, nymphs from July to September or October and adults during February and March.

Host sex-preferences

The host sex-preferences of *A. hebraeum* and *B. decoloratus* are summarized in Table 2.

Adult male kudus harboured significantly more nymphs, males and females of *A. hebraeum,* and more males and females of *B. decoloratus* than adult female animals. No such differences were noted for the other tick species or between adult animals and calves of 6 months or less of age.

Andries Vosloo Kudu Reserve (AVKR) and the farm "Bucklands"

Study site

The reserve (6 497 ha in extent) and the farm (5 480 ha), share an 11 km common boundary, and are situated in the eastern Cape Province around 33° 07 ′ S and 26° 40′ E with altitudes ranging from 335–538 m. The vegetation is classified as Valley Bushveld (Acocks, 1988). Rainfall is non-seasonal and the long-term mean annual total is 484 mm of which slightly more than 300 mm falls from October to March.

At the time of the survey the reserve contained approximately 450 kudus, 54 hartebeest, 140 eland and 100 buffaloes, and the farm approximately 300 kudus, 300 Dorper sheep, 4 000 Angora goats and 185 cattle. The domestic stock were regularly treated with an acaricide. Both properties harboured

TABLE 2 A comparison of the burdens of *Amblyomma hebraeum* and *Boophilus decoloratus* of 15 adult male and 15 adult female kudus shot in pairs during the same months and in the same locality, using a Wilcoxon matched-pairs signed-ranks test

Tick species	Developmental stage	Mean number of ticks recovered from adult kudus		Wilcoxon T value	Significance P =
		Male kudus	Female kudus		
Abmlyomma hebraeum	Nymphs	144,7	103,2	20,0	0,050
	Males	22,1	2,8	0,0	0,001
	Females	11,1	0,5	0,0	0,001
Boophilus decoloratus	Males	503,7	338,2	24,0	0,050
	Females	302,3	154,2	15,0	0,050

TABLE 3 Arthropod parasites of 16 kudus in the Andries Vosloo Kudu Reserve

Arthropod species	Total number recovered					No. of kudus infested
Ixodid ticks	Larvae	Nymphs	Males	Females	Total	
Amblyomma hebraeum	32 009	3 568	464	252(22)	36 293	16
Amblyomma marmoreum	2 112	0	0	0	2 112	11
Boophilus decoloratus	8	36	34	20	98	5
Haemaphysalis silacea	10 003	2 309	1 410	415(66)	14 137	16
Hyalomma marginatum rufipes	0	0	3	0	3	1
Hyalomma truncatum	0	0	2	0	2	1
Ixodes pilosus	0	14	2	12	28	4
Rhipicephalus appendiculatus	4 391	775	334	180(24)	5 680	16
Rhipicephalus evertsi evertsi	296	145	18	10	469	16
Rhipicephalus glabroscutatum	13 596	7 269	1 043	544(20)	22 452	16
Rhipicephalus sp. (near *R. oculatus*)	0	0	104	41(14)	145	13
Rhipicephalus simus	0	0	2	4	6	2
Lice	Nymphs		Adults		Total	
Haematopinus taurotragi	486		92		578	4
Linognathus taurotragus	1 895		784		2 679	16
Louse flies	Adults				Total	
Lipoptena paradoxa	108				108	13

( ) = Number of maturing females i.e. idiosoma of *A. hebraeum* >9,5 mm; *H. silacea* >5,0 mm; *R. appendiculatus* >5,0 mm; *R. glabroscutatum* >4,0 mm; *Rhipicephalus* sp. (near *R. oculatus*) >5,0 mm in length. Females of the other tick species had not started to mature

large numbers of small antelope, scrub hares and helmeted guineafowls.

Survey animals

Each month, from February 1985 to January 1986, and every 3 months thereafter, commencing March 1986 until December 1986, a single adult male kudu was shot on the reserve. With the exeption of June 1985 when 2 kudus were shot, 1 adult male kudu was shot on "Bucklands" every 3 months from March 1985 until December 1986. In this way 16 kudus on the reserve and 9 kudus on the farm where shot and examined.

Arthropod burdens

The total numbers of arthropod parasites recovered from kudus on the reserve and on the farm are summarized in Tables 3 and 4 respectively.

The kudus on the reserve were infested with 12 ixodid tick species of which *A. hebraeum* followed by *Rhipicephalus glabroscutatum* were the most abundant. The animals on the farm were infested with 9 tick species of which *R. glabroscutatum* followed by *Haemaphysalis silacea* were the most abundant. The kudus were infested with 3 lice and 1 louse fly species.

Seasonal abundance

The seasonal abundances of *A. hebraeum, A. marmoreum, H. silacea, R. appendiculatus, R. evertsi evertsi, R. glabroscutatum* and a *Rhipicephalus* sp. (near *R. oculatus*) on only those kudus which were shot from February 1985 to January 1986 in the reserve, are graphically represented in Fig. 2.

The largest numbers of larvae of *A. hebraeum* were present from March to May and during July 1985, nymphs during March, November and December and adults during December. Peak numbers of larvae of *A. marmoreum* were present during February, April and May 1985. The larvae of *H. silacea* reached peak numbers from February to August and during December 1985 and January 1986, the nymphs from May to August 1985 and the adults during August and October 1985. The larvae of *R. appendiculatus* reached the largest numbers from March to June, the nymphs from June to October and the adults from February to April 1985 and during January 1986. The immature stages of *R. evertsi evertsi* were at their lowest from August to November. Large numbers of immature *R. glabroscutatum,* a 2-host tick, were present from March to

TABLE 4 Arthropod parasites of 9 kudus on the farm "Bucklands", eastern Cape Province

Arthropod species	Total number recovered					No. of kudus infested
Ixodid ticks	Larvae	Nymphs	Males	Females	Total	
Amblyomma hebraeum	157	24	14	4	199	7
Amblyomma marmoreum	54	2	0	0	56	5
Boophilus decoloratus	43	34	21	4	102	3
Haemaphysalis silacea	1 994	783	410	112(16)	3 299	9
Hyalomma marginatum rufipes	0	0	2	0	2	1
Rhipicephalus appendiculatus	1 638	796	70	20	2 524	9
Rhipicephalus evertsi evertsi	92	130	20	1	243	8
Rhipicephalus glabroscutatum	11 460	5 980	580	236(16)	18 256	9
Rhipicephalus sp. (near *R. oculatus*)	0	0	30	13	43	6
Lice	Nymphs		Adults		Total	
Damalinia sp.	16		0		16	1
Haematopinus taurotragi	30		22		52	1
Linognathus taurotragus	1 344		525		1 869	9
Louse flies	Adults				Total	
Lipoptena paradoxa	68				68	7

( ) = Number of maturing females, i.e. idiosoma of *H. silacea* >5,0 mm; *R. glabroscutatum* >4,0 mm in length. Females of the other tick species had not started to mature

TABLE 5 The mean numbers of ticks recovered from kudus examined during the same months in the Andries Vosloo Kudu Reserve and on the farm "Bucklands"

Ixodid tick species	Mean numbers of ticks recovered					
	Kudus in Kudu Reserve			Kudus on "Bucklands"		
	Larvae	Nymphs	Adults	Larvae	Nymphs	Adults
Amblyomma hebraeum	3 188	325	66	17	3	2
Amblyomma marmoreum	119	0	0	6	0,2	0
Boophilus decoloratus	0	0	3	5	4	3
Haemaphysalis silacea	505	81	70	222	87	58
Hyalomma marginatum rufipes	0	0	0	0	0	0,2
Hyalomma truncatum	0	0	0,3	0	0	0
Ixodes pilosus	0	0	0,3	0	0	0
Rhipicephalus appendiculatus	489	63	20	182	88	10
Rhipicephalus evertsi evertsi	21	11	1	10	14	2
Rhipicephalus glabroscutatum	873	376	113	1 273	664	91
Rhipicephalus sp. (near *R. oculatus*)	0	0	8	0	0	5
Rhipicephalus simus	0	0	0,5	0	0	0

August and adults during February and from September to December 1985. The adults of the *Rhipicephalus* sp. (near *R. oculatus*) were present in all months except May and June.

The 9 kudus shot at 3-monthly intervals (2 during June 1985) on the farm "Bucklands" could be paired with 8 animals shot during the same months in the adjacent AVKR. The burdens of these animals are compared in Table 5.

With the exeption of the larvae, nymphs and males of *A. behraeum,* for which the differences were significant, such differences between the farm and the reserve were not evident for any of the other tick species.

Addo Elephant National Park

Study site

The park is located in the eastern Cape Province at 33 ° 30 ′ S; 25 ° 45′ E and the vegetation is described as Valley Bushveld (Acocks, 1988).

Survey animals

Two adult male kudus were shot in this reserve during April 1985.

Arthropod burdens

The kudus were infested with 6 ixodid tick species, 1 louse and 1 louse fly species (Table 6).

More than 90 % of the tick population on the kudus consisted of *A. hebraeum.*

DISCUSSION

General observations

Utech, Seifert & Wharton (1978) and Sutherst, Wharton, Cook, Sutherland & Bourne (1979) found that the calves of domestic cattle carried fewer *Boophilus microplus* than their dams. Although the kudu calves were not necessarily the offspring of the kudu females shot during the same months in the Kruger National Park, comparisons of the calves' tick burdens with those of the females were nevertheless made. It was possible to pair 16 calves aged

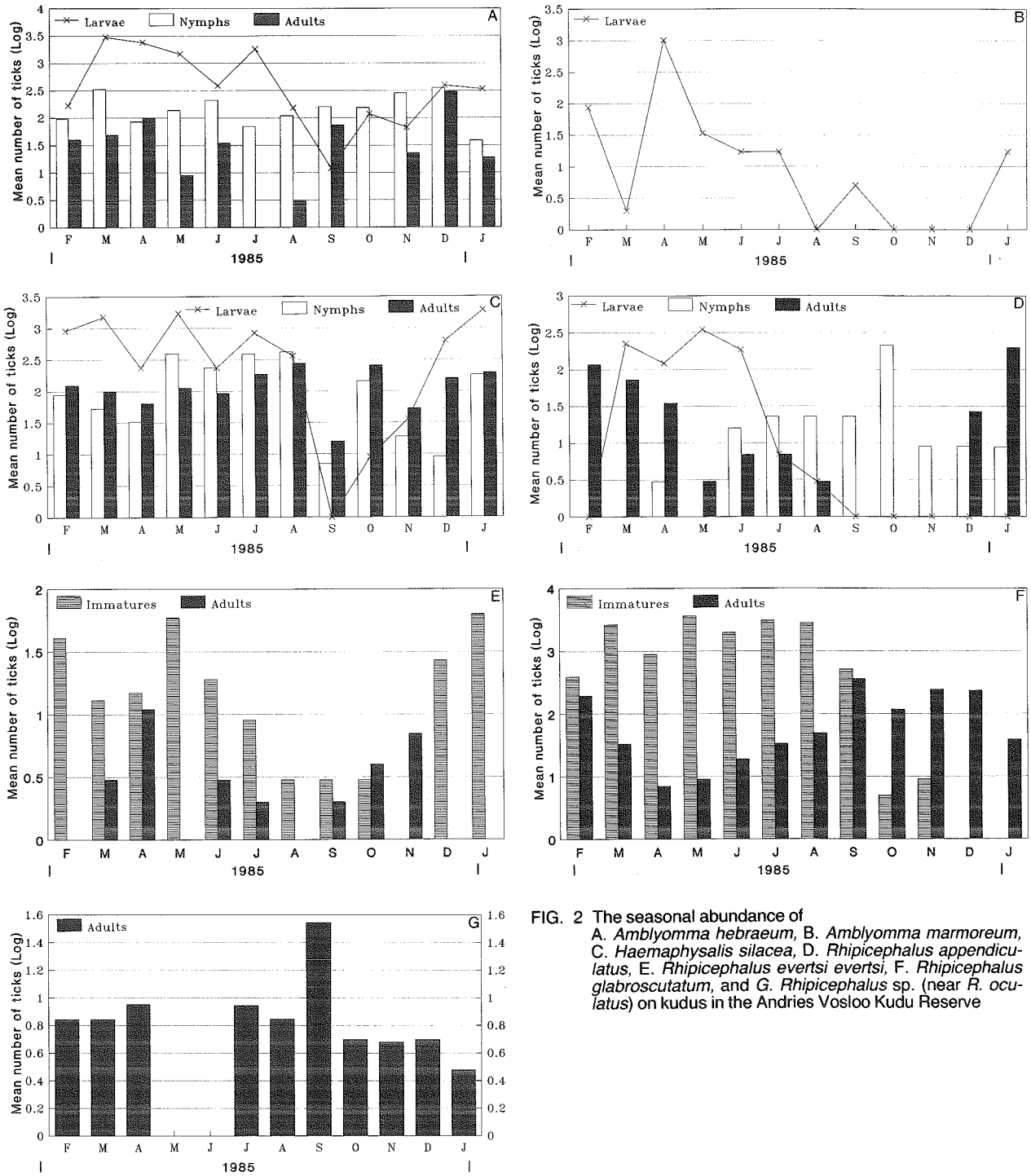

FIG. 2 The seasonal abundance of A. *Amblyomma hebraeum*, B. *Amblyomma marmoreum*, C. *Haemaphysalis silacea*, D. *Rhipicephalus appendiculatus*, E. *Rhipicephalus evertsi evertsi*, F. *Rhipicephalus glabroscutatum*, and G. *Rhipicephalus* sp. (near *R. oculatus*) on kudus in the Andries Vosloo Kudu Reserve

6 months or less with 16 adult females shot during the same months. No significant differences between the tick burdens of the calves and those of the cows were recorded. In fact, if one considers the size of the young calves compared with that of the cows, it would seem as if they are more prone to infestation than the cows.

Seifert (1971) recorded considerably more *B. microplus* on bulls than on domestic cows. He suggested that this strongly implies an influence of sex hormones on resistance. Our findings in the KNP show that adult male kudus carry significantly more nymphs (P=0,05), and males and females (P=0,001) of *A. hebraeum* and males and females (P=0,05) of *B. decoloratus* than do adult female animals. No such differences were recorded for any of the other tick species.

Horak, MacIvor, Petney & De Vos (1987) have suggested that the larger the host animal species the more likely it is to carry greater numbers of adult

TABLE 6 Arthropod parasites of 2 kudus in the Addo Elephant National Park

Arthropod species	Total number recovered					No. of kudus infested
Ixodid ticks	Larvae	Nymphs	Males	Females	Total	
Amblyomma hebraeum	14 957	1 165	30	10	16 162	2
Amblyomma marmoreum	17	0	0	0	17	2
Haemaphysalis silacea	985	125	119	44(4)	1 273	2
Hyalomma truncatum	0	0	1	0	1	1
Rhipicephalus evertsi evertsi	213	138	7	3	361	2
Rhipicephalus glabroscutatum	2	32	0	0	34	1
Lice	Nymphs		Adults		Total	
Linognathus taurotragus	22		6		28	1
Louse flies	Adults				Total	
Lipoptena paradoxa	11				11	2

( ) = Number of maturing females, i.e. idiosoma of *H. silacea* >5,0 mm in length. Females of the other tick species had not started to mature

A. hebraeum. The larger size of male kudus when compared to females may thus partially be responsible for the greater number of adult *A. hebraeum* carried by the former animals.

Kudus are good hosts of the immature stages of a large number of tick species (Horak & Knight, 1986; Tables 1 and 3). They are also good hosts of the adults of some species, such as *B. decoloratus, H. silacea, R. appendiculatus, R. glabroscutatum, R. zambeziensis* and a *Rhipicephalus* sp. (near *R. oculatus*). In addition adult male kudus must be considered good hosts of adult *A. hebraeum*.

Acaricidal treatment of the domestic livestock on "Bucklands" significantly affected the burdens only of *A. hebraeum* of kudus on the farm. This was probably due to the fact that cattle on the farm, which would have been good hosts for the adults of *A. hebraeum* as well as the other species, and the sheep and goats, which, with the exception of *R. glabroscutatum*, are generally poor hosts of the adults of most species, were all regularly treated with an acaricide and hence were poor hosts of all species. Thus, only the kudus, which, with the possible exception of the males, are not good hosts of adult *A. hebraeum*, but are good hosts of the adults of the other tick species, would have been largely responsible for maintaining the population of *A. hebraeum* on the farm. Petney & Horak (1987) state that the kudus clearly maintain a small but seemingly stable population of *A. hebraeum* on "Bucklands".

The eland and buffaloes on the reserve are very good hosts of adult *A. hebraeum* and individual animals may harbour more than 1 000 adult ticks (Horak, MacIvor, Petney & De Vos, 1987). They are also good hosts of the adults of the other tick species. These animals would largely be responsible for the large total burdens of *A. hebraeum* on the kudus on the reserve and they and the kudus themselves for the total burdens of the other tick species on the kudus.

The role kudus may play as reservoir hosts of ticks infesting cattle in mixed cattle and game ranching operations will depend on the population density of the former animals. As kudus are browsers (Owen-Smith, 1979; Novellie, 1983) their densities will be dependent upon the amount and quality of available browse. Thus in the Valley Bushveld of the eastern Cape Province where browse, particularly the spekboom *(Portulacaria afra)* is abundant, kudu density can be considerably higher than in the north-eastern Transvaal. Conventional stock fences do not serve as a barrier to kudus and consequently they could also disseminate ticks over considerable distances and several farms.

Both the tick reservoir status of kudus and their mobility could be advantageous to the stock farmer in that they could serve as a source of infected ticks on a cattle farm. This would help maintain immunity to diseases such as babesiosis *(Babesia bigemina)* and heartwater *(Cowdria ruminantium)* in cattle otherwise kept relatively tick-free by regular acaricidal treatment.

Amblyomma hebraeum

The 28 adult male kudus examined in the KNP harboured a mean of 1 003 larvae, 131 nymphs, 16 males and 8 females of this tick compared with 2 001, 223, 29 and 16, respectively, for the 16 males examined in the AVKR. The latter burdens were almost exactly double the former for each life stage as well as for the total. The larval:nymphal:adult ratio was virtually identical for male kudus on the 2 reserves being approximately 44:5:1.

This tick was introduced into the eastern Cape Province during the 1830's, probably on cattle from Zululand (Theiler, 1975; Provost & Bezuidenhout, 1987). The large numbers recovered from the kudus in this region confirm that it has become well established there. The fact that the kudus in the AVKR harboured nearly twice the burdens of those in the KNP does not, however, imply that the former habitat is more favourable than the latter; it is more a reflection of stocking density. The KNP is close to 2 M ha in extent and contains approximately 15 000 kudus, 400 eland, 30 000 buffaloes and 8 000 giraffes (all good hosts of adult *A. hebraeum*) resulting in an approximate stocking density of 1 of these animals per 37 ha. In the Kudu Reserve the approximate

stocking density for kudus, eland and buffaloes combined is 1 animal per 9,4 ha.

The immature stages of *A. hebraeum* have a wide host range (Theiler, 1962; Norval, 1974a). They utilize not only the same hosts as the adults, but a variety of small domestic and wild ruminants as well as scrub hares and helmeted guineafowls (Horak, MacIvor, Petney & De Vos, 1987). The higher stocking density in the AVKR is also reflected in the tick burdens of those hosts that harbour only immature stages; scrub hares had mean burdens of 46 larvae and 15 nymphs (Horak & Fourie, 1991) compared with 11 larvae and 11 nymphs on scrub hares in the KNP (Horak, Spickett & Braack, unpublished data). Helmeted guineafowls in the AVKR harboured 568 larvae and 26 nymphs, and those in the KNP 185 and 17 (Horak, Spickett, Braack & Williams, 1991). The hares, kudus and guineafowls in the AVKR were all examined at the same time, whereas in the KNP the hares and guineafowls were examined several years after the kudus.

If the number of immature ticks carried by female kudus and the smaller antelope as well as those harboured by scrub hares and guineafowls are taken into account the ratio of parasitic larvae and nymphs to adults will shift even further in favour of the immature stages.

The largest burden of adult ticks harboured by a single kudu was 72 males and 58 females recovered from a male shot in the KNP during January 1982 and 185 males and 119 females from a male shot in the AVKR during December 1985. The tick burdens of the 2 kudus examined in the Addo Elephant National Park indicate that burdens of *A. hebraeum* could possibly be even higher on kudus in this reserve than in either of the other reserves.

Despite only 1 animal being examined each month in the AVKR, larvae appeared to be more abundant during late summer and winter, nymphs during early summer and again in late summer and adults from early to late summer. This pattern of seasonal abundance corresponds to that observed by Knight & Rechav (1978) on kudus and by Rechav (1982) on cattle examined in the same locality, and is probably regulated by climate. In the KNP, where temperatures are higher than those in the eastern Cape Province, no clear pattern of seasonal abundance was evident and the tick's life cycle appeared to continue uninterrupted throughout the year.

Amblyomma marmoreum

Tortoises are the preferred hosts for all parasitic stages of this tick (Theiler, 1962; Norval, 1975b; Dower, Petney & Horak, 1988). Helmeted guineafowls, scrub hares, caracal, kudus, eland and cattle are all good hosts of the larvae if the numbers recovered and percentage of hosts infested are taken into account (Horak, MacIvor, Petney & De Vos, 1987; Horak & Fourie, 1991). With the possible exception of guineafowls, none of these animals are good hosts of the nymphs.

The large total number of larvae recovered from the kudus in the AVKR compared with those on "Bucklands" and in the KNP is due to 2 animals. One of these harboured 1 008 and the other 865 larvae.

The period of peak larval abundance (January to July) on kudus in the AVKR was longer than that on animals in the KNP (April to June). The seasonal abundance of larvae on helmeted guineafowls in the AVKR was similar to that on the kudus at the same locality, while that on guineafowls in the KNP extended from February or March to July or August (Horak, Spickett, Braack & Williams, 1991). The only nymphs recovered were from a kudu examined on "Bucklands" during December 1986.

Boophilus decoloratus

This was by far the most abundant tick on the kudus in the KNP, a finding also applicable to blue wildebeest and Burchell's zebras examined in this park (Horak, De Vos & Brown, 1983; Horak *et al.*, 1984). Drag-sampling of 32 of the 35 vegetation zones in the KNP during March 1988 indicated that *A. hebraeum* was the dominant species (Spickett, Horak, Braack & Van Ark, 1991), but this may well have been due to the month in which the samples were collected. Monthly drag-sampling of 2 vegetation zones near the study site over a period of 3 years, from 1988 to 1991, indicated that *R. zambeziensis* followed by *B. decoloratus* were most abundant in the zone north of the study site and *A. hebraeum* followed by *R. appendiculatus* and then *B. decoloratus* in the zone east of the study site (Horak, Spickett & Braack, unpublished data). Although it is possible that *B. decoloratus* was the dominant tick on the vegetation within the study area this seems unlikely in the light of the drag-sampling data from the 2 zones.

Two possible reasons for the large numbers of *B. decoloratus* on the kudus are, firstly that this is a 1-host tick, spending approximately 21 days on an animal in order to complete its parasitic life cycle (Londt & Spickett, 1976). Thus *B. decoloratus* recovered at slaughter represent ticks acquired during the previous 3 weeks compared with the multi-host tick species in which each stage, with the possible exception of males, spends approximately only 7 days on the host. Secondly the loss between the developmental stages, which do not each have to seek a new host in the case of a 1-host tick, is considerably less than that encountered with multi-host ticks. Furthermore kudus must be accepted as one of the preferred hosts of *B. decoloratus*. In the present study they harboured mean total burdens of 3 407 ticks of this species compared with 548 on blue wildebeest and 1 827 on Burchell's zebras examined in the KNP during earlier studies (Horak, De Vos & Brown, 1983; Horak *et al.*, 1984).

The overall ratio of larvae to nymphs to adults is 3,0:2,0:1,0 and this implies a good translation to adulthood without too much loss during the developmental stages and further confirms that kudus are one of the preferred hosts of *B. decoloratus*. On blue wildebeest and Burchell's zebras examined in the KNP during earlier studies these ratios were 8,9:1,7:1,0 and 3,0:1,1:1,0 respectively, indicating that wildebeest are poor hosts and zebras good hosts (Horak, De Vos & Brown, 1983; Horak *et al.*, 1984).

The ratios of males to females on the 3 host species were 1,98:1,00; 1,35:1,00 and 2,07:1,00 for the kudus, wildebeest and zebras, respectively. The most logical explanations for this disparity seem to be firstly, that because of the larger size of the females they are more easily rubbed or groomed off by the host and secondly, that the males remain attached for longer than the females. This differs markedly from the findings of Davey & Cooksey (1988) for *B. microplus* and *Boophilus annulatus* on artificially infested cattle. They recovered fewer males than females and recorded ratios of 1,00:1,36 and 1,00:1,35 males to females for the 2 tick species. They ascribed these differences to a selective mortality of males at some point in their development resulting in more females reaching the adult stage.

If one accepts that the kudus in the KNP acquired infestation on a daily basis and that female *B. decoloratus* spend 6 days on the animals, of which the last day is spent engorging before detaching (Londt & Spickett, 1976), then approximately 1/6 of all females should be engorging. This would imply that there should have been a total of 3 023 engorging females compared with the 360 actually recovered. This small number could be due to acquired resistance in the kudus as noted in the case of *Bos indicus* cross breeds of cattle and *B. microplus* (Sutherst, Maywald, Bourne, Sutherland & Stegeman, 1988). In cattle this resistance is only fully evident at approximately 2 years of age, but was already effective in the kudu calves. The small number could also be due to the fact that the kudus were usually shot after 08:00 h whereas many of the engorged females may have detached earlier.

It is probable that red-billed oxpeckers, which are commonly found on kudus in the KNP, also played a role in reducing the numbers of engorging female *B. decoloratus*. This tick is one of the preferred foods of these birds (Bezuidenhout & Stutterheim, 1980). Blue wildebeest and Burchell's zebras examined in the KNP also harboured small numbers of engorging female *B. decoloratus* compared to the total burdens of ticks of this species (Horak, De Vos & Brown, 1983; Horak *et al.*, 1984).

The peaks of abundance recorded for *B. decoloratus* on the kudus during September and October 1981 and November and December 1982 correspond to the peaks recorded during October 1978 on blue wildebeest and September 1979 and 1980 and December 1980 on Burchell's zebras in the KNP. These peaks, which occurred in spring or early summer, could be due to synchronous hatching of large numbers of larvae from eggs that had overwintered (Robertson, 1981; Spickett & Heyne, 1990). The spring rise could also possibly be coupled to a decrease in host resistance resulting from poor nutrition during the preceding winter and early spring months (Sutherst *et al.*, 1979).

Baker & Ducasse (1967) recovered peak numbers of *B. decoloratus* from calves in Natal from November to June. With the exception of 1 year when large numbers of ticks were present during November and December, Robertson (1981) recovered most *B. decoloratus* from cattle on a coastal property in the eastern Cape Province from February to June during a 4 year survey. Spickett, De Klerk, Enslin & Scholtz (1989) recorded peaks in the activity of *B. decoloratus* on cattle in the south-eastern Transvaal during February, July, October and December. In Natal Baker, Ducasse, Sutherst & Maywald (1989) recorded peak activity on cattle during spring and autumn. Rechav & Kostrzewski (1991) found peaks of activity in March/April, July, September/October, and December/January on cattle in the northern Transvaal. Horak, Williams & Van Schalkwyk (1991) recovered most *B. decoloratus* from Merino sheep during July and November in the eastern Orange Free State and in the eastern Cape Province. It would thus appear that in South Africa *B. decoloratus* may be encountered in peak numbers during any or all seasons. Nevertheless, spring and late summer seem to be the most preferred times.

The inland Valley Bushveld regions of the eastern Cape Province are not a suitable habitat for the free-living stages of *B. decoloratus*. Very few were recovered from the kudus in the AVKR and on "Bucklands" and none on the kudus from the Addo Park. Knight & Rechav (1978) also recovered only a few *B. decoloratus* from the kudus they examined on "Bucklands" and its environs.

In the KNP 21,3 % of all *B. decoloratus* were attached to the lower legs and feet of the kudus, 13,9 % to the heads and ears, 63,4 % to the necks, bodies and upper legs and 1,4 % to the tails. Only 10,9 % of the population of female ticks was attached to the legs and lower feet compared with 24,9 % of the males, indicating a selective loss of the larger female life stage from this attachment site.

Furthermore only 4,4 % of all engorging females were recovered from the lower legs and feet while 81,1 % and 6,1 % were recovered from the necks, bodies and upper legs and from the tails, respectively. This indicates that the lower legs and feet were particularly unfavourable for the completion of the female life cycle whereas the tails seemed to afford most protection for these large ticks. On Burchell's zebras examined in the park at an earlier occasion 8,0 % of *B. decoloratus* were attached to the lower legs and feet, 8,9 % to the heads and ears and 83,1 % to the necks, bodies, upper, legs and tails (Horak *et al.*, 1984).

Haemaphysalis silacea

According to Howell, Walker & Nevill (1978) this tick is found in well-wooded ravines and river valleys in the eastern Cape Province and in Natal. Hence its presence on kudus in the Valley Bushveld vegetation of the AVKR, "Bucklands" and Addo Elephant National Park. It has a wide host range including kudus, eland, sheep, goats, cattle and helmeted guineafowls (Knight & Rechav, 1978; Horak, Potgieter, Walker, De Vos & Boomker, 1983; Horak & Knight, 1986).

In the present survey 27,8 % of all males and 59,5 % of all females were found attached on the tails of the kudus in the AVKR. In addition 84,8 % of all the engorging female ticks were recovered from the tails. This need not necessarily imply that the tail

is a preferred site of attachment for female ticks of this species, but rather that the long hair on the tail affords greater protection against grooming for this larger life stage and particularly for those that are engorging.

As only 1 kudu was examined at each occasion the pattern of seasonal abundance on these animals is not reliable. It would, however, appear as if the life cycle continues throughout the year. Combining the findings of this study with those of Norval (1975a), Knight & Rechav (1978), Rechav (1982) and Horak, Williams & Van Schalkwyk (1991), larvae are most numerous from summer to early winter, nymphs from autumn to spring and adults in spring and in late summer.

***Hyalomma* spp.**

The distribution of *Hyalomma marginatum rufipes* includes the Valley Bushveld regions of the eastern Cape Province, while that of *Hyalomma truncatum* includes the latter region as well as the KNP (Howell *et al.*, 1978). Scrub hares are the preferred hosts of the immature stages of both these ticks (Horak & MacIvor, 1987; Rechav, Zeederberg & Zeller, 1987; Horak & Fourie, 1991). Using the number of ticks recovered from scrub hares as criterion the Valley Bushveld is not a good habitat for the 2 *Hyalomma* spp. (Horak & MacIvor, 1987; Horak & Fourie, 1991), whereas the KNP is a good habitat for *H. truncatum* (Horak, Spickett & Braack, unpublished data). The small number of adult ticks recovered from the kudus in the KNP is therefore evidence that these animals are not good hosts of this tick. The preferred hosts of the adults are eland and zebras and probably giraffes (Rechav *et al.*, 1987; Horak, Fourie, Novellie & Williams, 1991). The small numbers of the 2 *Hyalomma* spp. on the kudus in the eastern Cape Province are a reflection both of the unsuitability of the habitat and the host species.

Adult *H. truncatum* were generally recovered from the kudus in the KNP during any month from January to July. In the AVKR and on "Bucklands" *Hyalomma* spp. were recovered in March, April and during June.

Ixodes pilosus

In the Cape Province this tick is generally confined to the Sourveld coastal regions (Howell *et al.*, 1978). Its presence on the animals in the AVKR probably reflects its most northern distribution at this particular point. The preponderance of parasitic females over males is typical for this species (Norval, 1974b; Horak, Sheppey, Knight & Beuthin, 1986), in which mating probably takes place off the host.

Rhipicephalus appendiculatus

The KNP, AVKR and "Bucklands" all lie within the geographic distribution of this tick as described by Howell *et al.* (1978). The Addo Elephant National Park is situated to the west of the southern limits of this distribution and no *R. appendiculatus* were recovered from the kudus examined in this park.

The adults appear to prefer large bovids such as cattle, eland and buffaloes but kudus, sable antelopes and impala are also good hosts (Norval, Walker & Colborne, 1982; Horak, Potgieter, Walker, De Vos & Boomker, 1983). The immature stages can also be recovered in large numbers from these hosts, but may be encountered in similar large numbers on Burchell's zebras and on a variety of smaller animals such as sheep, goats, small antelope and scrub hares (Norval *et al.*, 1982; Horak *et al.*, 1984; Horak & Knight, 1986).

The taxonomic differences between *R. appendiculatus* and *R. zambeziensis* have only fairly recently been described (Walker, Norval & Corwin, 1981). We have always been able to distinguish between the nymphs of the 2 species and did so for each of the separate skin regions examined. The larvae and adults, however, were only differentiated once the ticks for each kudu had been pooled and hence no preferred sites of attachment for these stages can be identified. In the KNP 21,8 % of nymphs of *R. appendiculatus* were recovered from the lower legs and feet, 53,1 % from the heads and ears and 25,1 % from the necks, upper legs, bodies and tails of the kudus. These figures were 27,4 %, 50,1 % and 22,5 % respectively for the animals in the AVKR. Baker & Ducasse (1967) recovered 58,0 % of nymphs from the heads and ears of live-sampled cattle in Natal and 16,6 % from their legs and feet. In Uganda Kaiser, Sutherst & Bourne (1982) recovered 24 % of nymphs from the head and ears of live-sampled cattle and 20 % from around the hooves.

The overall ratio of larvae to nymphs to adults of 2,49:0,67:1,00 on kudus in the KNP and 8,54:1,51:1,00 in the AVKR compared with the 16:4:1 we consider closer to the normal population distribution for a 3-host tick, can have various explanations. Firstly, the recovery of the immature stages by the scrubbing method employed may not be as effective as for the larger adults. Secondly, smaller antelope species and scrub hares may carry substantial numbers of immatures with few or no adults (Horak, 1982; Boomker, Du Plessis & Boomker, 1983; Horak & Knight, 1986). Large numbers of *Rhipicephalus* spp. nymphs and probably also larvae, may selectively be removed by oxpeckers (Bezuidenhout & Stutterheim, 1980). Baker & Ducasse (1967) recorded ratios of 4,10 larvae to 2,87 nymphs to 1,00 adults on live-sampled cattle in Natal.

The ratio of males to females of 1,78:1,00 on kudus in the KNP and 1,86:1,00 in the AVKR compares favourably with that of 1,84:1,00 and 1,88:1,00 recorded by Londt, Horak & De Villiers (1979) and Horak (1982) on cattle in the northern Transvaal and of 1,99:1,00 found by Kaiser *et al.* (1982) on cattle in Uganda. The latter authors recorded a ratio of 1,84:1,00 only 7 days after the hosts had been picked clean of ticks and suggested that further experiments to explain this phenomenon were necessary. Bezuidenhout & Stutterheim (1980) found that oxpeckers consume nearly twice as many female *Rhipicephalus* spp. as they do males.

If one assumes that female *R. appendiculatus* spend approximately 7 days on their hosts

(Minshull, 1982), that these hosts are constantly exposed to infestation during periods of peak seasonal abundance of the ticks, and that the female ticks engorge during the last 24 h of their attachment, then approximately 1/7 (14,3 %) of the female ticks should be maturing. On the kudus in the KNP only 1,8 % were maturing, whereas this figure was 13,3 % for the animals in the AVKR. Minshull (1982) found that most engorged females of *R. appendiculatus* detached from artificially infested cattle between 06:00 and 08:00 h. As most of the kudus in the KNP were shot after 08:00 h many engorged female ticks could already have detached. The same argument does not apply to the animals in the AVKR, which were also shot after 08:00 h and yet harboured a large proportion of maturing females. Oxpeckers, which as mentioned previously, prefer female *Rhipicephalus* spp. ticks to males, may also be responsible for the small number of maturing ticks in the KNP. These birds were not present in the AVKR.

The seasonal abundance of the adults and nymphs in the 2 reserves was reasonably similar. In the AVKR increased numbers of larvae were recovered 1 month earlier than in the KNP, whereas peak larval activity extended for 1 month longer in the latter reserve. In general terms larvae were active from late summer to winter or spring, nymphs from winter to spring and adults from mid-summer to autumn. This pattern of abundance corresponds to that observed on cattle in Natal by Baker & Ducasse (1967), in the northern Transvaal by Horak (1982) and in the eastern Cape Province by Rechav (1982).

Short & Norval (1981) state that the pattern of seasonal abundance is chiefly dependent on the activity period of the adults and that this is regulated by the combined influences of humidity, temperature and daylength. Unfortunately too few animals were examined in each of the reserves to determine accurately the periods of activity of the adults. If, however, tick counts from cattle slaughtered at monthly intervals over a 2 year period on "Bucklands" at the same time as the kudus in the AVKR (Horak, unpublished data), are added to the latter data it would appear as if peak adult activity extends from December to February in this region of the eastern Cape Province. This corresponds exactly with that recorded by Rechav (1981) in this area. Taking the mean values for the 2 year study in the KNP into account peak adult activity occurred from February to May in this park.

Rhipicephalus evertsi evertsi

Although this tick has a very widespread distribution in South Africa (Howell *et al.*, 1978), it never occurs in very large numbers except on zebras and eland (Horak *et al.*, 1984; Horak, Fourie, Novellie & Williams, 1991). If the burdens of the kudus in the KNP are compared with those of Burchell's zebras examined a few years previously in the same park (Horak *et al.*, 1984) it is obvious that kudus are not a preferred host of *R. evertsi evertsi*. The mean burdens of the zebras comprised 606 larvae, 259 nymphs and 76 adults compared with 95 larvae, 10 nymphs and 2 adults on the kudus. In addition, it would appear as if kudus do not, or cannot, harbour many nymphs of this 2-host tick, of which the immature stages occur in the ear canal. This could affect the successful translation of larvae to nymphs when many larvae are present. In the KNP mean burdens of 95 larvae translated into only 10 nymphs compared with mean burdens of 16 larvae on kudus in the AVKR and "Bucklands" combined, translating into 11 nymphs. The largest number of nymphs recovered from a kudu was 72, compared with 626 from an eland and 1 944 from a zebra (Horak, unpublished data).

Combining the total numbers of adult *R. evertsi evertsi* recovered from all the kudus examined in the present surveys, the ratio of males to females is 2,75:1,00. The marked preponderence of males is probably because more males than females may be recovered from animals even within 1 week of them having been picked clean of ticks, and that males may remain on the host for longer than females and thus their numbers accumulate (Kaiser *et al.*, 1982).

No clear pattern of seasonal abundance was evident. The fact that both adults and immatures may be present throughout the year indicates that more than 1 life cycle can be completed annually and that development is continuous in the regions in which the present surveys were conducted. This corresponds to the observations made by Matson & Norval (1977) on cattle in Zimbabwe, Horak, Williams & Van Schalkwyk (1991) on sheep in the Orange Free State and in the eastern Cape Province, Horak *et al.* (1984) and Horak, Fourie, Novellie & Williams (1991) on Burchell's zebras in the KNP as well as on Cape mountain zebras and eland in the Karoo respectively.

Rhipicephalus glabroscutatum

The geographic distribution of this tick has been described by MacIvor (1985). It is largely confined to the eastern Cape Province where it inhabits non-coastal areas of low rainfall characterized by Karoo and Karoid vegetation, with isolated pockets extending into the western Cape Province. Its original hosts were probably the antelope inhabiting these regions and more particularly eland, kudus, mountain reedbuck and common duikers (MacIvor, 1985; Horak & Knight, 1986; MacIvor & Horak, 1987; Horak, Fourie, Novellie & Williams, 1991) and probably also bushbuck. Scrub hares may harbour the immature stages only (Horak & Knight, 1986; Horak & Fourie, 1991). With the introduction of domestic stock into these regions *R. glabroscutatum* now also infests goats, sheep and cattle (MacIvor & Horak, 1984, 1987; MacIvor, 1985; Horak & Knight, 1986; Horak, Williams & Van Schalkwyk, 1991).

According to MacIvor (1985) the preferred site of attachment is the legs and feet. In the present survey 83,9 % of all immature ticks and 95,7 % of all adults were recovered from the lower legs and feet of the kudus in the AVKR and on "Bucklands". MacIvor & Horak (1987) state that while goats may frequently harbour large numbers of adult ticks between their hooves none where found between the hooves of the antelope they examined on one of the farms on which they worked. They suggested

that this difference might be due to the structure of the hooves with the concave axial corium of the goat hoof resulting in a space in the interdigital region which could be exploited by ticks, while the straight axial corium of the antelopes' hooves limited this space.

The seasonal abundance of *R. glabroscutatum* on a variety of host species has been determined in the eastern Cape Province (Knight & Rechav, 1978; MacIvor & Horak, 1984, 1987; Horak, Williams & Van Schalkwyk, 1991; Horak, Knight & Williams, 1991; Horak & Fourie, 1991), the Karoo (Horak, Fourie, Novellie & Williams, 1991) and the south-western Cape Province (Horak, Sheppey, Knight & Beuthin, 1986). In all these regions the greatest numbers of immature ticks were recovered from March to August and of adults from September to January or February. It is probable that only 1 generation is completed annually (MacIvor, 1985).

***Rhipicephalus* sp. (near *R. oculatus*)**

The taxonomic problems that exist between this tick and *Rhipicephalus oculatus* have been discussed by Walker (1991). Its geographic distribution has also been briefly addressed by Walker (1991). It is fairly common in certain Valley Bushveld regions of the eastern Cape Province, where the adults may be found on scrub hares, kudus, cattle, sheep and goats (Horak & Knight, 1986).

In the present study 10,6 % of the ticks were recovered from the heads and ears of the kudus, 80,8 % from the necks, bodies and upper legs, and equal proportions from the lower legs plus feet and from the tails. May and June appear to be the only months in which no adult ticks are present. This pattern of seasonal abundance was confirmed on scrub hares, sheep, goats and cattle examined in the AVKR or on "Bucklands" at the same time as the kudus (Horak, unpublished data).

Rhipicephalus simus

Although this tick has a widespread distribution, mainly in the eastern regions of South Africa (Howell *et al.*, 1978), it is seldom encountered in large numbers. The preferred hosts of the adults are large monogastric animals such as zebras, warthogs, large wild carnivores and dogs, but they also occur on cattle (Howell *et al.*, 1978; Horak *et al.*, 1984; Horak, Jacot Guillarmod, Moolman & De Vos, 1987; Horak *et al.*, 1988).

In the KNP a total of 15 adults were recovered from the 95 kudus examined, while 33 Burchell's zebras, 7 large carnivores and 51 warthogs examined in the park harboured totals of 381, 669 and 560 adults respectively (Horak *et al.*, 1984; Horak Jacot Guillarmod, Moolman & De Vos, 1987; Horak *et al.*, 1988). The 25 kudus shot in the AVKR and on "Bucklands" harboured a total of only 6 adults while 46 cattle examined on "Bucklands" at the same time harboured 48 adults (Horak, unpublished data). It is thus obvious that kudus are not good hosts of adult *R. simus*. The immature stages prefer rodents (Norval & Mason, 1981).

Twelve of the 15 ticks recovered from the kudus in the KNP and all 6 ticks from the kudus in the AVKR were collected from the lower legs and feet of the animals. Too few ticks were present to determine any pattern of seasonal abundance.

Rhipicephalus zambeziensis

This tick has only fairly recently been described and its morphology compared with that of *R. appendiculatus* (Walker *et al.*, 1981). Its ecology and that of *R. appendiculatus,* with particular emphasis on Zimbabwe, have also been described (Norval *et al.*, 1982). In South Africa *R. zambeziensis* has to date only been found in the Transvaal and more particularly on farms in the west of the province as well as in the northern and southern regions of the KNP in the east of the province (Norval *et al.*, 1982). This distribution falls entirely within that of *R. appendiculatus* as illustrated by Howell *et al.* (1978). However, more recent data from the KNP indicate that there are areas of overlap as well as regions in which one or the other tick occurs almost exclusively (Horak, Spickett & Braack, unpublished data). The study site from which the kudus in the KNP were collected lies within such a region of overlap. To the east and west of this site there are zones within the KNP in which *R. appei diculatus* occurs almost exclusively and to the north a zone in which *R. zambeziensis* occurs virtually exclusively (Horak, Spickett & Braack, unpublished data).

Although large carnivores, warthogs, bushpigs and equids can be infested, the preferred hosts of *R. zambeziensis* seem to be impala, bushbuck, nyalas, kudus, eland and probably cattle and buffaloes (Norval *et al.*, 1982; Walker, 1991). In the present study 91 of the 95 kudus were infested. Two of the 4 kudus that were not infested were examined during November and 1 during December, both months of generally low abundance for all stages of development (Fig. 1). The total numbers of *R. appendiculatus* and *R. zambeziensis* recovered from the kudus suggest that the zone in which they were examined is equally favourable for both tick species.

As mentioned earlier for *R. appendiculatus*, we can unfortunately also only give the preferred sites of attachment for the nymphal stage of *R. zambeziensis.* Of these 81,4 % were attached to the lower legs and feet, 9,2 % to the head and ears, 8,6 % to the neck, body and upper legs and 0,8 % to the tail. Thus the nymphs of *R. appendiculatus* prefer the heads and ears and those of *R. zambeziensis* the lower legs and feet of kudus.

The ratio of larvae to nymphs to adults of 9,92:1,42:1,00 indicates that the kudus are good hosts of larvae, while many nymphs possibly fed on other host species. The total numbers of larvae of *R. appendiculatus* and *R. zambeziensis* recovered from the kudus were reasonably similar but fewer nymphs and adults of *R. zambeziensis* were recovered. This suggests that kudus may be less favoured as hosts of these stages than for those of *R. appendiculatus.*

The ratio of male to female *R. zambeziensis* of 1,99:1,00 is comparable to that of *R. appendiculatus* on the same animals. As in the case of the latter tick, few maturing females were recovered.

According to Norval *et al.* (1982) the seasonal abundances of these 2 ticks are similar in Zimbabwe. The present results confirm this finding and the periods of seasonal activity are almost identical; larvae exhibiting peak abundance in autumn and winter, nymphs during winter and spring and adults in late summer.

Lice

Damalinia sp. have not previously been recovered from kudus, while *Haematopinus taurotragi* and *Linognathus taurotragus,* which were both originally described from eland, have (Ledger, 1980). The lice infestations were always light and no pattern of seasonal abundance or host age-preference or host sex-preference could be determined.

Flies

The majority of kudus at each survey locality were infested with the louse fly *Lipoptena paradoxa.* The seasonal abundance of this fly on the kudus and other aspects of its biology will be reported separately.

Pentastomid nymphs

In earlier surveys Horak, De Vos & Brown (1983) and Horak *et al.* (1988) recovered the nymphs of *Linguatula nuttalli* from 12 (21,8 %) of 55 blue wildebeest and 18 (35,3 %) of 51 warthogs examined in the KNP. Kudus would appear to be more susceptible to infection as 60 (63,2 %) of the 95 animals examined in the park were infected. Lions are the final host of this parasite.

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Arthropod burdens of impalas in the Skukuza region during two droughts in the Kruger National Park

I.G. HORAK, V. DE VOS and L.E.O. BRAACK

Horak, I.G., V. de Vos and L.E.O. Braack. 1995. Arthropod burdens of impalas in the Skukuza region during two droughts in the Kruger National Park. *Koedoe* 38(1): 65-71. Pretoria. ISSN 0075-6458.

Ixodid ticks and lice were collected at monthly intervals from March 1980 to February 1981 from impalas of all ages and both sexes in Landscape Zone 4 (Thickets of the Sabie and Crocodile Rivers) in the south-west of the Kruger National Park. Similar collections were made from adult animals *in extremis* in the same landscape zone during October and November of the drought of 1982 as well as from 15 to 22-month-old male impalas examined at monthly intervals from March to October of the drought of 1992.

The louse burdens of the adult animals examined during the 1982 drought were significantly greater than those of adult animals examined during the same months of 1980, a year of normal rainfall. The tick burdens were also larger, but not significantly so. The tick and louse burdens of the young impalas examined during the drought of 1992 were significantly smaller than those of animals of the same age examined during 1980.

Key words: ixodid ticks, lice, impalas, drought.

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Introduction

During the past 14 years, the southern regions of the Kruger National Park have experienced two severe droughts. The first, during 1982/83, resulted in numerous deaths of animals, particularly impalas and warthogs. Deaths were less obvious in the second drought during 1991/92.

The ixodid tick and louse burdens of impalas in the Skukuza region of the park were monitored during these droughts and the results are presented here.

Materials and Methods

Study Site

All the impalas were collected within a 20 km radius of Skukuza in the thickets of the Sabie and Crocodile rivers landscape zone [Landscape Zone 4 of Gertenbach (1983)].

1980/81:
Each month from March 1980 to February 1981 an impala lamb, a 15 to 26-month-old ram born in November/December 1979, an adult male and an adult female were shot and examined for ectoparasites.

1982/83
A large number of impalas died in October and November 1982 during the drought of 1982/83. Three adult males and seven adult females, judged

to be terminally affected, were shot in these months and examined for ectoparasites.

1992/93
Each month from March 1992 to April 1993 three young impala rams aged from 15 to 28 months, and born in November/December 1990, were shot and examined for ectoparasites.

Ectoparasite recovery

Ixodid ticks and lice were recovered from the impalas, identified and counted as described by Horak *et al.* (1992).

Selection of data

The ectoparasite burdens of four adult animals (two rams and two ewes) examined during October and November 1980 were compared with those of the ten adult animals (three rams and seven ewes) shot *in extremis* during October and November 1982. The ectoparasite burdens of eight 15 to 22-month-old rams examined singly from March to October 1980 were compared with those of 24 similarly aged animals examined in sets of three from March to October 1992. (Six animals had been examined in March 1992 but using tables of random numbers the ectoparasite burdens of only three of these were used for comparative purposes. This was done to avoid bias as only three animals were examined in each of the other months).

Statistical procedures

The ectoparasite burdens of the three groups of impalas were compared by means of the Mann-Witney *U*-test for non-parametrically distributed data.

Rainfall

Rainfall was measured at a weather station at Skukuza.

Game counts

The numbers of impalas in the Nwaswitshaka region, in which most of the impalas were examined, were estimated annually by aerial census.

Free-living ticks

In an unrelated survey free-living ticks were collected in the Nwaswitshaka region by monthly drag-sampling of the vegetation from August 1988 until July 1994 (Spickett *et al.* 1995).

Results

The mean total tick and louse burdens of the various groups of impalas examined are summarised in Table 1.

The total tick burdens of the four adult animals (two males, two females) examined in October and November 1980, prior to the droughts, were smaller than those of the ten animals (three males, seven females) examined in October and November 1982 during the drought. The differences were, however, not statistically significant. Similar observations were made for the louse burdens, but here the differences were statistically significant ($P \geq 0{,}05$).

The total tick and louse burdens of the eight young male impalas examined in 1980 prior to the droughts were significantly larger than those of the 24 similarly aged animals examined during the 1992 drought ($P \geq 0{,}05$).

Total annual rainfall (July to June) at Skukuza from 1979/80 to 1992/93 is graphically illustrated in Fig. 1A. Figure 1B illustrates the numbers of impalas estimated to be present in the Nwaswitshaka region during the annual game census.

The two years preceding the 1982/83 drought had better than average and average rainfall respectively, while the two years preceding the 1991/92 drought were characterised by less than average rainfall. In fact, the year immediately preceding the latter drought had the second lowest rainfall of the previous 12 years.

With three exceptions, the numbers of impalas along the Nwaswitshaka River fluctuated between approximately 3 000 and 6 000. These three exceptions occurred during 1987, 1990 and 1992 when the numbers

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Table 1
The mean total tick and louse burdens of impalas examined around Skukuza in normal and drought years

Period	Rainfall	No. of impalas	Sex	Age	Mean total numbers (range) of ticks and lice collected			
					Ticks	Significance	Lice	Significance
Oct-Nov 1980	Normal	4	Mixed	Adult	4 734 (2 654 - 5 713)		304 (8 - 920)	
Oct-Nov 1982	Drought	10	Mixed	Adult	7 461 (2 144 - 14 727)	$P \geq 0,35$	2 667 (323 - 7 666)	$P \geq 0,02$
Mar-Oct 1980	Normal	8	Male	15-22 mon	8 696 (2 526 - 16 831)		2 689 (192 - 17 872)	
Mar-Oct 1992	Drought	24	Male	15-22 mon	678 (152 - 2 176)	$P \geq 0,001$	461 (22 - 5 872)	$P \geq 0,02$

declined to approximately 2 800, 2 400 and 1 000 respectively.

The total numbers of free-living ticks as well as the numbers of larvae of *Amblyomma hebraeum*, *Boophilus decoloratus* and *Rhipicephalus zambeziensis* collected from the vegetation annually are graphically illustrated in Fig. 2A-D.

The total numbers of ticks as well as the numbers of *A. hebraeum* larvae declined on the vegetation from 1989/90 onwards. The total numbers of *B. decoloratus* larvae declined from 1988/89, with a particularly large reduction being evident in 1992/93. The lowest numbers of *R. zambeziensis* larvae were collected from the vegetation during 1992/93.

Discussion

The differences in the tick burdens of the impalas during the two droughts can probably be ascribed to differences in the rainfall in the years preceding the droughts. The rainfall in the two years preceding the 1982/83 drought was above average and average respectively, and it can be assumed that this ensured that there was a mat of decaying vegetation under the standing grass from which the ticks were collected. This mat supplied an ideal habitat for the survival of the ticks, even in the drought year, hence their high numbers.

The rainfall in the two years preceding the 1991/92 drought was below average in 1989/90 and well below average in 1990/91. This, coupled with a fire in part of the study area during September 1990, not only led to severe depletion of the standing grass, but also to the virtual disappearance of the mat of dead and decaying material under the grass. (The cloth tails by means of which the ticks were collected from the vegetation were frequently dragged over bare soil during 1991 and 1992).

With the disappearance of the mat the microhabitat, in which the female ticks laid eggs, the eggs developed and hatched, and the newly hatched larvae could shelter, no longer existed. In addition the sparseness of the standing grass meant that there was less vegetation from which the larval ticks could quest for a passing host animal. Compounding the reduction in tick numbers was the fact that few impalas remained in the Nwaswitshaka area (Fig. 1B) and thus fewer engorged female ticks detached and laid eggs there. All these factors led to a reduction of tick numbers on the vegetation (Fig. 2), which was in turn reflected in the small numbers of ticks collected from the impalas examined during 1992 (Table 1).

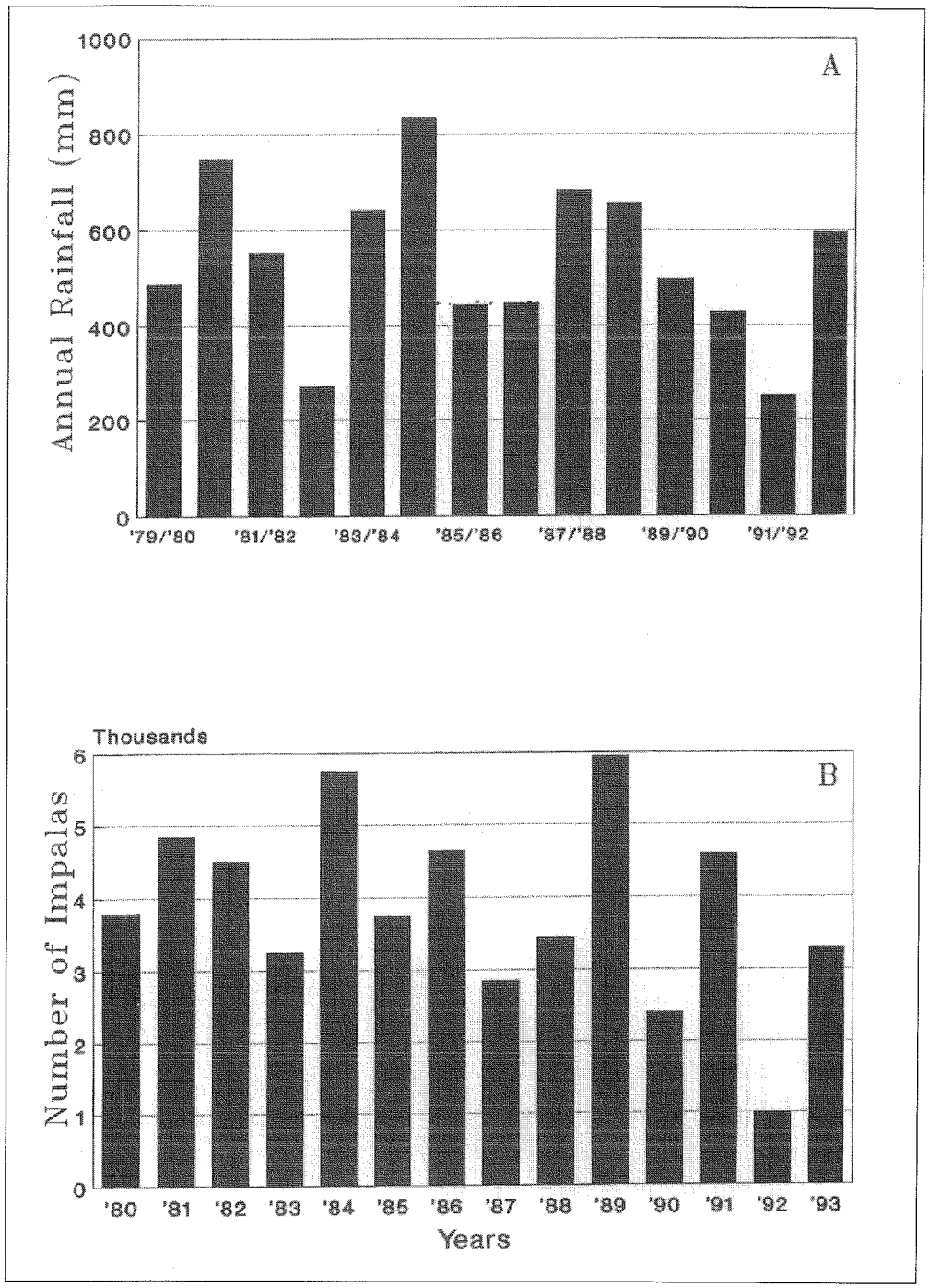

Fig. 1. (A) Annual rainfall at Skukuza 1979/80–1992/93. (B) Annual counts of impalas in the Nwaswitshaka census block, 1980-1993.

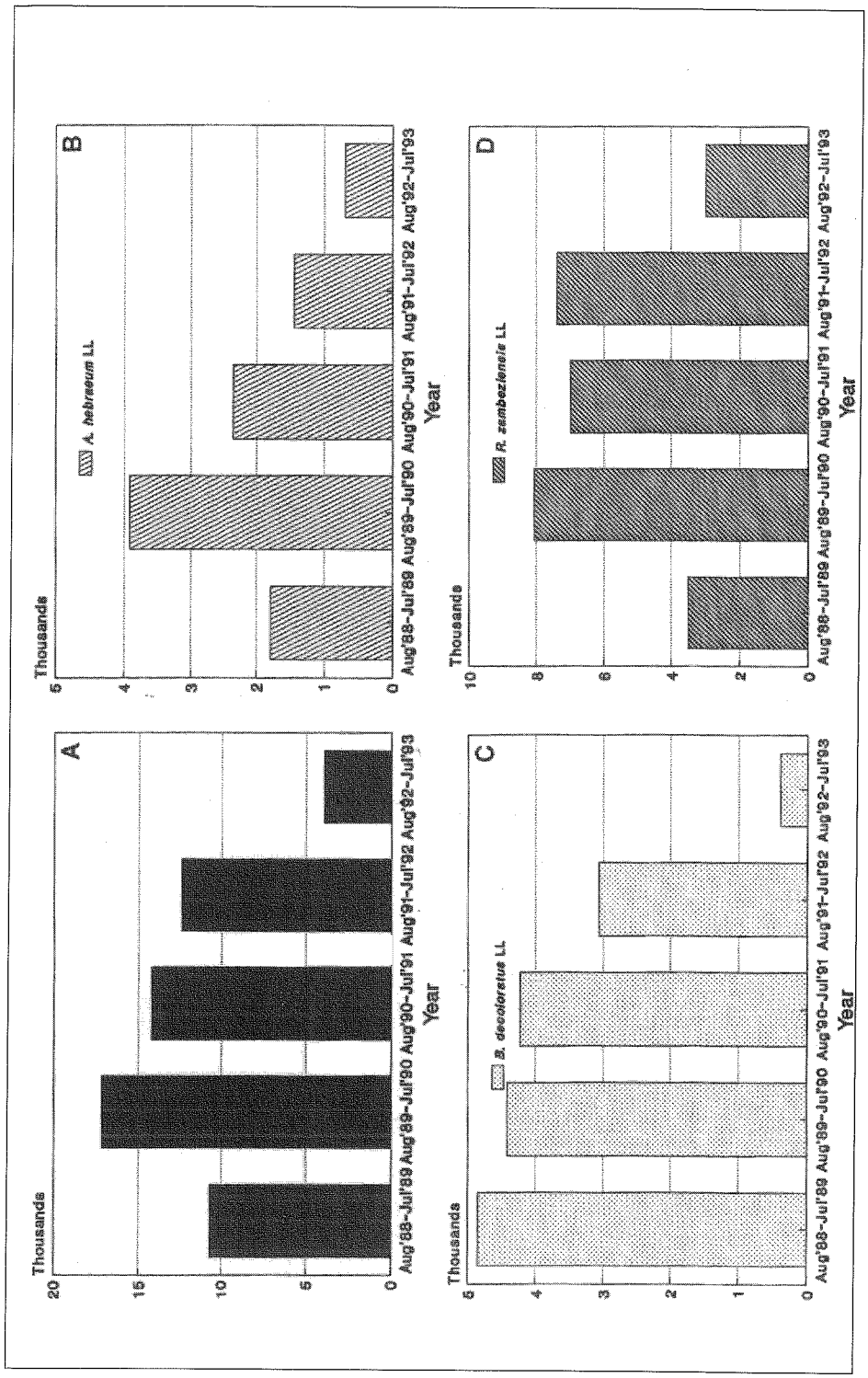

Fig. 2. Total numbers of ticks collected annually by monthly drag-sampling of the vegetation along the Nwaswitshaka River, 1988/89 - 1992/93. (A) All stages of all ticks. (B) Larvae of *Amblyomma hebraeum*. (C) Larvae of *Boophilus decoloratus*. (D) Larvae of *Rhipicephalus zambeziensis*.

Despite the fact that the numbers of larvae of *A. hebraeum* as well as those of *R. zambeziensis* may exceed those of *B. decoloratus* on the vegetation (Spickett *et al.* 1995), *B. decoloratus* is by far the most abundant tick on ruminants and zebras in the park (Horak *et al.* 1983a, 1983b, 1983c; 1984; 1992). This apparent anomaly can be explained by the fact that *B. decoloratus* is a one-host tick, with its three parasitic developmental stages present consecutively on the same host for a period of approximately three weeks (Howell *et al.* 1978). It also completes more than one life cycle per annum. The other ticks are three-host species probably completing only one life cycle per annum, with each of their three parasitic developmental stages spending approximately only one week on the host. In addition their immature stages may infest hares or birds, while *B. decoloratus* is confined to ruminants or zebras.

Although *B. decoloratus* is present in the park throughout the year it has a definite peak in abundance on the vegetation and on hosts during September to November (Spickett *et al.* 1992; Horak *et al.* 1983b, 1984, 1992). Burdens exceeding 10 000 ticks have been recorded on kudus in the park during these months (Horak *et al.* 1992). It is also precisely at this time of year that impalas in the park suffer the greatest degree of nutritional stress as graze and browse are both scarce and dry after the normally dry winters. Hence the large numbers of larvae on the vegetation during these months infest particularly susceptible hosts resulting in very large tick burdens. These large burdens would then exacerbate the effects of drought on already stressed animals. The ten adult animals examined in the drought during October and November 1982 had a mean total burden of 7 461 ticks (Table 1). Their mean burden of *B. decoloratus* comprised 6 381 ticks, with a range of 1 624 to 12 995.

Young impalas (15 to 22 months of age) appear to be more susceptible to tick infestation than older animals. The mean total burden of the eight young animals examined from March to October of 1980 (a year of normal rainfall) exceeded that of the adult animals examined *in extremis* at the peak of the *B. decoloratus* season in the drought of 1982 (Table 1). Yet the 24, 15 to 22-month-old impalas, examined during the drought of 1992, harboured a mean burden less than 10% of that of the young impalas examined in 1980. This is further evidence of the marked effect that the prolonged dry period, culminating in the drought of 1991/92, had on the tick population.

It would appear as if susceptibility to ticks and susceptibility to lice are concomitant phenomena. The adult impalas examined during the drought had high tick and louse burdens, as did the young male impalas examined before the drought (Table 1).

Acknowledgements

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Onderstepoort Journal of Veterinary Research, 62:171–179 (1995)

Parasites of domestic and wild animals in South Africa. XXXIV. Arthropod parasites of nyalas in north-eastern KwaZulu-Natal

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ABSTRACT

HORAK, I.G., BOOMKER, J. & FLAMAND, J.R.B. 1995. Parasites of domestic and wild animals in South Africa. XXXIV. Arthropod parasites of nyalas in north-eastern KwaZulu-Natal. *Onderstepoort Journal of Veterinary Research*, 62:171–179

Seventy-three nyalas (*Tragelaphus angasii*) in the Umfolozi, Mkuzi and Ndumu Game Reserves in north-eastern KwaZulu-Natal were examined for arthropod parasites during 1983 and 1984. In addition, six animals were examined during 1994. Ten ixodid tick species, two louse species and a louse fly species were recovered. The nyalas were good hosts of all stages of development of *Boophilus decoloratus, Rhipicephalus appendiculatus* and *Rhipicephalus muehlensi* and the immature stages of *Amblyomma hebraeum* and *Rhipicephalus maculatus*.

Adult male animals harboured more adult ticks, biting lice and louse flies than did adult females.

B. decoloratus was generally most abundant from October to May. The larvae of *R. appendiculatus* peaked from April to October, nymphs from July to October and adults, on adult male nyalas, from February to May. Larvae of *R. maculatus* were most abundant from May to July and nymphs from June to October. The immature stages of *A. hebraeum* and all stages of *R. muehlensi* were present throughout the year.

Keywords: Arthropod parasites, nyalas, north-eastern KwaZulu-Natal, *Tragelaphus angasii*

INTRODUCTION

Several surveys of ixodid ticks infesting domestic and wild animals in KwaZulu-Natal, have already been conducted. Baker & Ducasse (1967) and Baker, Ducasse, Sutherst & Maywald (1989) examined cattle, and Baker & Ducasse (1968), goats. Buffaloes *(Syncerus caffer)*, nyalas *(Tragelaphus angasii)*, common reedbuck *(Redunca arundinum)*, impalas *(Aepyceros melampus)*, bushbuck *(Tragelaphus scriptus)*, common duikers *(Sylvicapra grimmia)*, red duikers *(Cephalophus natalensis)*, bushpigs *(Potamochoerus larvatus)* and scrub hares *(Lepus saxatilis)* were examined by Horak, Potgieter, Walker, De Vos & Boomker (1983), Horak, Keep, Flamand & Boomker (1988), Horak, Keep, Spickett & Boomker (1989), Horak, Boomker & Flamand (1991a) and Horak, Spickett, Braack, Penzhorn, Bagnall & Uys (1995). Baker & Keep (1970) published a checklist of ticks infesting the larger wild animals in KwaZulu-Natal game reserves, while Keep (1971) produced such a list specifically for nyalas.

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Nyalas in the north-eastern KwaZulu-Natal game reserves had to be culled during the late 1970s and early 1980s because their numbers exceeded the carrying capacity of the land. Culling or relocation has subsequently continued at irregular intervals. In conjunction with this activity, parasites were collected from some of the culled animals and Boomker, Horak & Flamand (1991) reported on the helminths recovered. They also summarized the available data on the morphometrics, feeding and behaviour of nyalas and briefly described the physiography of the Umfolozi, Mkuzi and Ndumu Game Reserves.

According to Smithers (1983), male nyalas are considerably taller and heavier than females. Adult males are horned and slatey-grey to dark brown in colour with a few white, vertical stripes on the body. They have a dorsal crest of long hair from the back of the head to the base of the tail and a heavy fringe of long hair on the under-parts of the neck and along the middle line of the chest and belly. Females are hornless, bright chestnut in colour and have up to 18 white, vertical stripes on their bodies. Nyalas are predominantly browsers and have a restricted habitat in that they are usually found in thickets in dry savanna woodland or riverine woodland (Smithers 1983).

The present paper records the ectoparasite burdens of nyalas culled in the Umfolozi, Mkuzi and Ndumu Game Reserves in north-eastern KwaZulu-Natal.

MATERIALS AND METHODS

Study areas and animals

Umfolozi

The Umfolozi Game Reserve (28°12′–28°21′S; 31°42′–31°59′E) comprises about 47753 ha of hilly country, 130–600 m above sea level. Two vegetation types are recognized, namely Zululand Thornveld along the slopes and crests of the hills and Lowveld in the valleys (Acocks 1988). Both browse and grazing are plentiful. Annual rainfall is 500–750 mm and falls mainly in summer. Summers are hot and winters cool to mild, and frost seldom occurs.

An attempt was made to obtain one adult male, one adult female and one juvenile nyala of either sex at monthly intervals from March 1983 to April 1984, but neither the population sample nor the monthly collection was always possible. Forty nyalas were examined, of which 14 were adult males, 15 adult females, four juvenile males and seven juvenile females. No animals were examined during September or November 1983.

Mkuzi

The Mkuzi Game Reserve, which is approximately 25091 ha in extent, is situated in the so-called Maputaland (27°33′–27°46′S; 32°07′–32°19′E; altitude 130–300 m), and extends from the eastern foothills of the Lebombo mountain range, eastwards into the Makatini flats. The vegetation of the higher areas is classified as Lowveld, while that at lower altitudes consists of the Zululand Palm Veld subdivision of Coastal Forest and Thornveld (Acocks 1988). Rain falls mostly in summer with a variation of 500–750 mm. Summers are hot and often humid and winters are mild. Frost seldom occurs.

Nineteen nyalas were shot from March 1983 to May 1984. Of these, six were adult males, five adult females, five juvenile males and three juvenile females. In addition to these animals three adult male and three adult female nyalas were examined during March 1994.

Ndumu

The Ndumu Game Reserve (26°50′–26°56′S; 32°09′–32°21′E; altitude 30–100 m) comprises approximately 11000 ha. It is situated in the extreme north of KwaZulu-Natal and shares a common boundary in the north with southern Mozambique. Ndumu falls within the Lowveld subtype of Tropical Bush and Savannah (Acocks 1988). Rainfall varies from 500 to 750 mm per annum and falls mostly in summer. Summers are hot and humid and winters are mild; frost does not occur.

Fourteen nyalas, five adult males, three adult and one old female, one juvenile male and four juvenile females, were shot in this reserve from April 1983 to May 1984.

Collection and counting of parasites

The arthropod parasites of the nyalas were collected, identified and counted as described by Horak, Boomker, Spickett & De Vos (1992) for kudus. The numbers of engorging female ticks were determined only on the six animals examined in Mkuzi during March 1994.

RESULTS

Umfolozi

The ectoparasites collected from animals examined in the Umfolozi Game Reserve are summarized in Table 1.

The nyalas were infested with ten ixodid tick species of which *Rhipicephalus muehlensi*, followed by *Rhipicephalus appendiculatus*, were the most abundant. Every animal was infested with these ticks and with *Boophilus decoloratus*. The nyalas also harboured two louse species and a louse fly.

The seasonal abundances of these ticks and of the immature stages of *Rhipicephalus maculatus* are graphically illustrated in Fig. 1.

The largest numbers of *B. decoloratus* were collected during April and May 1983 and from October 1983 to February 1984. Larvae of *R. appendiculatus* were most abundant from April to October, nymphs from July to October and adults on adult male nyalas during the months of February to May. Larvae of *R. maculatus* were most abundant from May to July and nymphs, from June to October. No clear pattern of seasonal abundance was evident for *R. muehlensi.*

Comment: Observations on the seasonal abundances of all stages of development of *B. decoloratus* and of *R. muehlensi* and the immature stages of *R. appendiculatus* and *R. maculatus* are compromised by the fact that no nyalas were examined during September and November 1983.

Mkuzi

The arthropod burdens of animals examined in this reserve during 1983/1984 and during 1994 are summarized in Tables 2 and 3, respectively.

Eight ixodid tick species were recovered from the first set of nyalas and seven from the second set. Animals examined during the months of October to March generally harboured substantial numbers of *B. decoloratus*, while those examined during May, June and July had very small burdens. The seasonal abundances of *R. appendiculatus* and *R. maculatus* appeared to be similar to those recorded on the nyalas examined in the Umfolozi Game Reserve. *R. muehlensi*, which comprised more than 75% of the

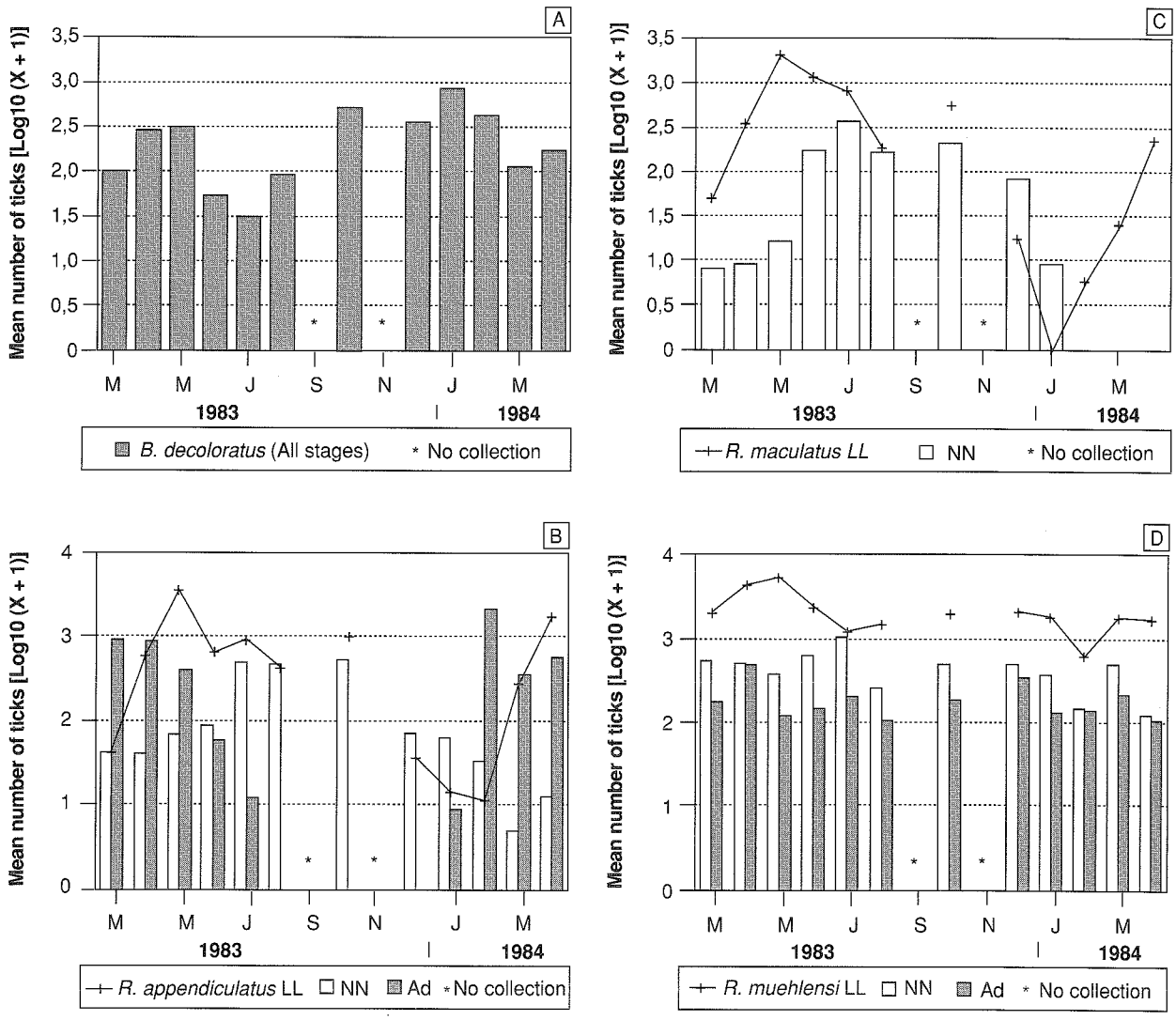

FIG. 1 The seasonal abundance of A. *Boophilus decoloratus*
B. *Rhipicephalus appendiculatus*, (adults only on male animals)
C. *Rhipicephalus maculatus*
D. *Rhipicephalus muehlensi* on nyalas in the Umfolozi Game Reserve

ticks collected from both groups of animals, was present in large numbers throughout the survey.

Most of the nyalas were infested with *Linognathus angasi* and all, with *Lipoptena paradoxa.*

Ndumu

The numbers of arthropods collected from nyalas in this reserve are summarized in Table 4.

The animals were infested with eight ixodid tick species, two species of louse and a louse fly species. *R. muehlensi* was the most abundant and prevalent tick, while considerably fewer *R. appendiculatus* than *R. maculatus* were recovered. The approximately 4-month intervals at which animals were examined, precluded determination of seasonal abundance.

Host sex preference

Twenty-one adult male and 21 adult female nyalas were shot in pairs at the same times and at the same localities during the 1983/1984 survey period. In addition, three adult male and three adult female animals were shot in the Mkuzi Game Reserve on 9–10 March 1994. The parasite burdens of the male and female nyalas were compared by means of the Mann-Whitney *U*-test for non-parametrically distributed data. The mean burdens of the major parasites on these 48 animals are summarized in Table 5.

Adult male nyalas harboured significantly more ($P \leq 0,05$) nymphs of *Amblyomma hebraeum,* males and females of *B. decoloratus, R. appendiculatus* and *R. muehlensi,* males of *R. maculatus,* nymphs and adults of the *Damalinia* sp. and adults of *L. paradoxa* than did adult female nyalas.

Locality preferences

The mean parasite burdens of nyalas examined in each of the reserves during 1983 and 1984 are summarized in Table 6.

Umfolozi was a good habitat for *A. hebraeum*, the only habitat in which *Haemaphysalis silacea* was present, and the only habitat of the three which was more suitable for *R. appendiculatus* than for *R. maculatus.* Mkuzi was a good habitat for *A. hebraeum, B. decoloratus, R. maculatus* and *R. muehlensi.* With the exceptions of *R. muehlensi,* for which it appeared to be the best of the three habitats, and of *R. maculatus*, Ndumu was the least favourable habitat for nearly all tick species. It must, however, be remembered that the animals were not examined in each of the reserves at the same times.

DISCUSSION

Hunters in KwaZulu-Natal often comment on the large numbers of ticks encountered on nyalas. The present findings confirm this observation, particularly as trophy hunters invariably shoot adult male animals and the head and cape (skin of the neck) of the animal are regarded as the trophy. *R. appendiculatus* and *R. muehlensi* prefer the ears, heads and upper necks of male nyalas as attachment sites and are

TABLE 1 Arthropod parasites of 40 nyalas examined in the Umfolozi Game Reserve during 1983/1984

Arthropod species	Total numbers recovered					No. of nyalas infested
Ixodid ticks	Larvae	Nymphs	Males	Females	Total	
Amblyomma hebraeum	16 296	3 030	66	22	19 414	39
Amblyomma spp.	56	0	0	0	56	1
Boophilus decoloratus	4 611	3 225	1 526	1 063	10 425	40
Haemaphysalis aciculifer	0	0	0	2	2	1
Haemaphysalis silacea	571	152	47	60	830	16
Ixodes sp. (near *I. pilosus*)	598	8	14	16	636	11
Rhipicephalus appendiculatus	32 343	7 352	3 160	2 580	45 435	40
Rhipicephalus evertsi evertsi	644	0	10	4	658	15
Rhipicephalus maculatus	20 674	4 183	6	64	24 927	35
Rhipicephalus muehlensi	92 024	19 724	4 662	2 940	119 350	40
Lice	Nymphs		Adults		Total	
Damalinia sp.	2 134		1 269		3 403	13
Linognathus angasi	5 132		2 792		7 924	36
Louse flies	Males		Females		Total	
Lipoptena paradoxa	1 032		1 304		2 360[a]	38

[a] Including pieces of flies whose sex could not be determined

consequently present on those parts of the animal which will ultimately become the trophy. In addition, adults of the latter tick are present throughout the year so that large numbers of ticks are always present on and around the heads of nyalas.

Horak *et al.* (1992) noted that adult male kudus carried significantly more nymphal and adult *A. hebraeum* and adult *B. decoloratus* than did adult females. A similar finding for *L. paradoxa* on kudus was reported by Visagie, Horak & Boomker (1992). These authors postulated that body size, grooming or hormonal influences could be responsible for these differences. If it is assumed that adult male and female nyalas utilize the same habitat, the reasons for the lower tick, louse and louse fly burdens on the females justify further investigation.

Amblyomma spp.

Horak, MacIvor, Petney & De Vos (1987) observed that the larger the host species the greater the likeli-

TABLE 2 Arthropod parasites of 19 nyalas examined in the Mkuzi Game Reserve during 1983/1984

Arthropod species	Total numbers recovered					No. of nyalas infested
Ixodid ticks	Larvae	Nymphs	Males	Females	Total	
Amblyomma hebraeum	7 169	916	28	4	8 117	19
Amblyomma spp.	1 271	0	0	0	1 271	7
Boophilus decoloratus	6 882	1 966	492	214	9 554	18
Ixodes sp. (near *I. pilosus*)	32	0	0	0	32	1
Rhipicephalus appendiculatus	4 650	348	775	645	6 418	18
Rhipicephalus evertsi evertsi	112	8	2	0	122	4
Rhipicephalus maculatus	12 499	1 488	56	58	14 101	19
Rhipicephalus muehlensi	105 491	17 856	7 409	5 238	135 994	19
Lice	Nymphs		Adults		Total	
Damalinia sp.	112		104		216	4
Linognathus angasi	1 492		562		2 054	17
Louse flies	Males		Females		Total	
Lipoptena paradoxa	354		414		798[a]	19

[a] Including pieces of flies whose sex could not be determined

TABLE 3 Arthropod parasites of six nyalas examined in the Mkuzi Game Reserve during March 1994

Arthropod species	Total numbers recovered					No. of nyalas infested
Ixodid ticks	Larvae	Nymphs	Males	Females	Total	
Amblyomma hebraeum	2 620	274	24	4	2 922	6
Amblyomma spp.	81	0	0	0	81	2
Boophilus decoloratus	1 785	375	160	146 (16)	2 466	6
Rhipicephalus appendiculatus	8	0	975	535 (22)	1 518	6
Rhipicephalus evertsi evertsi	48	0	11	2	61	5
Rhipicephalus maculatus	220	19	14	14	267	6
Rhipicephalus muehlensi	30 880	4 351	3 235	2 092 (190)	40 558	6
Lice	Nymphs		Adults		Total	
Damalinia sp.	222		55		277	3
Linognathus angasi	639		232		871	6
Louse flies	Males		Females		Total	
Lipoptena paradoxa	295		403		704[a]	6

( ) = Number of engorging female ticks, i.e. idiosoma of *B. decoloratus* and *R. muehlensi* > 4,0 mm and *R. appendiculatus* > 5,0 mm in length

[a] = Including pieces of six flies whose sex could not be determined

TABLE 4 Arthropod parasites of 14 nyalas examined in the Ndumu Game Reserve during 1983/1984

Arthropod species	Total numbers recovered					No. of nyalas infested
Ixodid ticks	Larvae	Nymphs	Males	Females	Total	
Amblyomma hebraeum	224	190	0	0	414	9
Amblyomma spp.	48	0	0	0	48	2
Boophilus decoloratus	388	164	66	36	654	10
Ixodes sp. (near *I. pilosus)*	48	32	2	0	82	3
Rhipicephalus appendiculatus	2 888	196	234	176	3 494	12
Rhipicephalus evertsi evertsi	32	0	0	0	32	1
Rhipicephalus maculatus	10 000	734	86	56	10 876	13
Rhipicephalus muehlensi	93 764	17 724	6 370	4 176	122 034	14
Lice	Nymphs		Adults		Total	
Damalinia sp.	24		48		72	2
Linognathus angasi	1 968		616		2 584	12
Louse flies	Males		Females		Total	
Lipoptena paradoxa	368		452		822[a]	12

[a] Including pieces of two flies whose sex could not be determined

hood that it would harbour large numbers of adult *A. hebraeum*. From a subsequent study it would appear as if kudus lie on the border between the really large and the smaller wild-host species (Horak *et al.* 1992). Male kudus may harbour fairly substantial numbers of adult *A. hebraeum,* while females seldom carry more than two or three ticks. Although both the Umfolozi and Mkuzi Game Reserves are located in habitats favourable for *A. hebraeum*, not all animals were infested with adults, and the largest burden of adult *A. hebraeum* comprised only 22 ticks, which incidently were recovered from an adult female nyala. This indicates that nyalas fall within the group of smaller host species, i.e. they are good hosts of the immature stages but not of adult *A. hebraeum.*

The absence of a pattern of seasonal abundance can be ascribed to the year-round warm climate of the reserves, similar to that encountered in the Kruger National Park, where all stages of *A. hebraeum* were present on kudus throughout the year (Horak *et al.* 1992).

Both *Amblyomma marmoreum* and *Amblyomma nuttalli,* whose adults prefer to feed on tortoises, are present in KwaZulu-Natal (Walker 1991). We are unable to differentiate between the immature stages of these ticks and have therefore allocated specimens resembling them, merely to *Amblyomma* spp. Most of these ticks were collected from nyalas in the Mkuzi Game Reserve and were present mainly during March.

Boophilus decoloratus

Substantial numbers of this tick have been recorded on cattle at lower altitudes in southern KwaZulu-Natal (Baker & Ducasse 1967; Baker *et al.* 1989). Although Baker & Keep (1970) list it as occurring on numerous wild animals, including nyalas, in this province, quantitative studies by Horak *et al.* (1983, 1988, 1989, 1991a) indicate that it is present only in small numbers on wild animals in those regions where the latter authors conducted their studies. In the present survey, however, nyalas in the Mkuzi Game Reserve harboured fairly large numbers of *B. decoloratus.* The overall ratio of larvae to nymphs to adults of 3,7:1,5:1,0, calculated from all the nyalas examined, is not unlike that found on kudus in the Eastern Transvaal (3,0:2,0:1,0) and implies a good translation of larvae and nymphs to adulthood (Horak *et al.* 1992). With the exception of two localities at which tick numbers increased in spring, Baker *et al.* (1989) recorded the largest burdens of *B. decoloratus* on cattle from mid to late summer or autumn. In this survey, the largest burdens were present on nyalas examined in months falling within the period October to May (spring to autumn).

Haemaphysalis spp.

Baker & Keep (1970) recorded *H. aciculifer* on common duikers, common reedbuck and bushbuck in the Umfolozi/Hluhluwe Game Reserve complex, and Horak *et al.* (1989) collected this tick from common duikers and bushbuck in the Weza State Forest, southern KwaZulu-Natal. Although *H. aciculifer* is widely distributed, it is never encountered in very large numbers (Walker 1991). It was collected from only one nyala in this study.

H. silacea has been recorded on animals in the Umfolozi/Hluhluwe Game Reserve complex and in the

TABLE 5 A comparison of the parasite burdens of 24 male and 24 female nyalas examined at the same localities in north-eastern KwaZulu-Natal at the same times

Developmental stage	Male nyalas		Female nyalas		Significance $P \leq 0,05$
	Mean burden (range)	No. of nyalas infested	Mean burden (range)	No. of nyalas infested	
Ixodid ticks					
Amblyomma hebraeum					
Larvae	503,5 (0–1 866)	21	282,3 (0–1 135)	21	–
Nymphs	114,0 (0–368)	21	41,5 (0–160)	20	0,020
Males	2,7 (0–10)	14	1,9 (0–20)	7	–
Females	0,8 (0–4)	8	0,5 (0–10)	2	–
Boophilus decoloratus					
Larvae	186,6 (0–1 157)	19	124,2 (0–464)	21	–
Nymphs	106,3 (0–596)	17	57,1 (0–256)	18	–
Males	61,4 (0–504)	20	18,9 (0–128)	14	0,030
Females	43,3 (0–344)	22	9,7 (0–76)	15	0,005
Rhipicephalus appendiculatus					
Larvae	517,3 (0–3 746)	18	605,5 (0–5 421)	17	–
Nymphs	144,1 (0–912)	14	88,3 (0–560)	15	–
Males	194,2 (0–1 232)	17	4,9 (0–30)	10	0,002
Females	150,4 (0–1 030)	16	2,5 (0–20)	10	0,005
Rhipicephalus maculatus					
Larvae	419,3 (0–3 276)	20	480,2 (0–1 929)	18	–
Nymphs	92,5 (0–448)	17	82,7 (0–448)	18	–
Males	3,8 (0–42)	10	0,0 (0)	0	0,010
Females	6,4 (0–44)	8	0,7 (0–16)	1	–
Rhipicephalus muehlensi					
Larvae	3 561,8 (448–12 564)	24	3 833,2 (762–8 875)	24	–
Nymphs	625,9 (28–3 712)	24	662,2 (0–2 046)	23	–
Males	389,3 (78–1 239)	24	174,2 (14–555)	24	0,002
Females	256,4 (36–1 152)	24	117,5 (10–351)	24	0,010
Lice					
Damalinia sp.					
Total	159,8 (0–2 044)	17	2,0 (0–32)	2	0,001
Linognathus angasi					
Total	156,2 (0–1 056)	22	248,7 (0–3 504)	20	–
Louse flies					
Lipoptena paradoxa					
Adults	114,0 (28–340)	24	37,6 (0–220)	23	0,001

TABLE 6 The mean total arthropod parasite burdens of nyalas examined in the Umfolozi, Mkuzi and Ndumu Game Reserves during 1983/1984

Arthropod species	Mean total burdens per species		
	Umfolozi (40)	Mkuzi (19)	Ndumu (14)
Ixodid ticks			
Amblyomma hebraeum	485	427	30
Amblyomma spp.	1	67	3
Boophilus decoloratus	261	503	47
Haemaphysalis silacea	21	0	0
Ixodes sp. (near *I. pilosus*)	16	2	6
Rhipicephalus appendiculatus	1 136	338	250
Rhipicephalus evertsi evertsi	16	6	2
Rhipicephalus maculatus	623	742	777
Rhipicephalus muehlensi	2 984	7 158	8 717
Lice			
Damalinia sp.	85	11	5
Linognathus angasi	198	108	185
Louse flies			
Lipoptena paradoxa	59	42	59

( ) = Number of animals examined in each reserve

Mkuzi Game Reserve by Baker & Keep (1970), but we collected it only in the Umfolozi Game Reserve. The preferred habitat of this tick is localized areas of Valley Bushveld in the Eastern Cape Province (Walker 1991), where large numbers have been recorded on kudus (Horak *et al.* 1992).

Ixodes pilosus complex

McKay (1994) believes that there are three separate species in this complex. Although *I. pilosus* sensu stricto does occur in KwaZulu-Natal (McKay 1994), the nyalas in the present study harboured adult ticks which he describes as "thick haired *pilosus*".

Rhipicephalus spp.

The adults of *R. appendiculatus* prefer large bovids such as cattle, eland and buffaloes, but kudus, sable antelope and impalas are also good hosts (Norval, Walker & Colborne 1982; Horak *et al.* 1983, 1992). Adult male, but not female, nyalas can now be added to this list. Six male animals each harboured more than 600 adult ticks and one of them, 2262 ticks.

Baker & Ducasse (1967) recovered 69,3% of adult *R. appendiculatus* from the ear pinnae of cattle and 80,0% from the pinnae and the remainder of the cattle's heads. The three male nyalas examined in the Mkuzi Game Reserve during 1994 harboured a total of 1461 adult *R. appendiculatus* of which 520 (35,6%) attached on their heads and ears. This distribution pattern could be the result of competition with the numerous adult *R. muehlensi* which were also present. The male nyalas harboured a total of 3428 of these, of which 2316 (67,6%) were attached to their heads and ears. The three female nyalas examined at the same time, harboured a total of 49 adult *R. appendiculatus* and 1899 adult *R. muehlensi*, of which 57,1% and 91,0%, respectively, were attached to their heads and ears.

The period of peak abundance of *R. appendiculatus* on the male nyalas (February to May) is the same as that recorded on kudus in north-eastern Eastern Transvaal (Horak *et al.* 1992).

R. evertsi evertsi has a very widespread distribution in South Africa (Howell, Walker & Nevill 1978) but, except on zebras and eland, the adults never occur in very large numbers (Horak, Fourie, Novellie & Williams 1991b). Nyalas, like kudus, appear to be poor hosts of this tick (Horak *et al.* 1992). Not only were few adults collected, but very few larvae of this two-host tick developed into nymphs.

Within the South African borders, *R. maculatus* is present in the coastal regions of KwaZulu-Natal (Walker 1991). The adults prefer large animals with thick skins, such as elephants, black and white rhinoceroses, buffaloes, bushpigs and warthogs (Baker & Keep 1970; Horak *et al.* 1983, 1991a). Excluding elephants, the immature stages are also found on these hosts as well as on various duiker species, reedbuck, impalas, and particularly on nyalas, also on scrub hares (Baker & Keep 1970; Horak *et al.* 1983, 1988, 1991a, 1995). The seasonal abundances of the immature stages are similar to those of *R. appendiculatus*.

Nyalas, and probably also bushbuck, must be regarded as the preferred hosts of all developmental stages of *R. muehlensi* (Horak *et al.* 1983, 1988; this study). This tick, like *R. maculatus*, is present in South Africa only in the coastal regions of northern KwaZulu-Natal (Walker 1991). Large numbers of nymphs, and probably also larvae (which at the time were lumped with other larvae and identified as *Rhipicephalus* spp.), have been recovered from red duikers and numerous larvae from scrub hares (Horak *et al.* 1991a, 1995). Nyalas, bushbuck and red duikers are all browsers and are found in habitats containing thickets, various types of woodland or forests, while scrub hares prefer savanna woodland and scrub (Smithers 1983).This implies that *R. muehlensi* also prefers these habitat types.

The large totals of these ticks recovered from nyalas, reflect the year-round abundance of all developmental stages of *R. muehlensi.* As discussed earlier, competition with adult *R. appendiculatus* may affect the proportion of adult *R. muehlensi* attaching to the heads and ears of nyalas.

Lice

With few exceptions, louse burdens were low, and adult male animals harboured significantly more *Damalinia* sp. than did adult females. No pattern of seasonal abundance was evident for either of the louse species.

Louse flies

The biology of *L. paradoxa*, with particular reference to kudus, was discussed by Visagie *et al.* (1992). The preferred hosts of this fly are all browsing antelopes, namely common duikers, bushbuck, nyalas and kudus. Adult male kudus and nyalas harbour significantly more of these flies than do adult female animals (Visagie *et al.* 1992; Table 5). Visagie *et al.* (1992) collected 3594 flies whose sex could be determined, from common duikers, bushbuck and kudus. Of these flies 2243 (62,4%) were females. In the present study 4622 *L. paradoxa* whose sex could be determined were collected, and 2573 (55,7%) of these were females.

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Arthropod parasites of impalas in the Kruger National Park with particular reference to ticks

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Adult male and female impalas *Aepyceros melampus* were examined for ectoparasites at monthly intervals for a period of 17 and 15 months, respectively, at Skukuza and north of Malelane in the southern Kruger National Park, Mpumalanga, South Africa. A total of 34 male and 31 female impalas were examined and *Boophilus decoloratus* was the most abundant and prevalent ixodid tick collected. In addition to this tick of which both the mean immature and adult burdens were large, the impalas also harboured large numbers of immature and few adult ticks of other species. Comparisons were also made between male and female animals and between the two localities for the six major tick species and four louse species collected. Male animals from north of Malelane harboured significantly more ($p<0.05$) adult *Rhipicephalus appendiculatus* than did females from the same locality, which in turn harboured significantly more *Damalinia aepycerus* than the males. There were no differences in the tick and lice burdens between male and female impalas examined around Skukuza. Significantly more ($p<0.05$) *Amblyomma hebraeum* immatures, *Amblyomma marmoreum* larvae, *Damalinia elongata* nymphs and adults and *D. aepycerus* nymphs, and significantly fewer ($p<0.05$) *Rhipicephalus evertsi evertsi* immatures and *R. appendiculatus* nymphs were collected from impalas around Skukuza than from those examined north of Malelane. In addition the life stage compositions of populations of various ixodid tick species were compared on impalas, kudus, nyalas and cattle from several localities. With few exceptions the cattle harboured greater percentages of adult *A. hebraeum, R. appendiculatus* and *R. evertsi evertsi* than did the antelopes, which conversely harboured greater percentages of immature ticks.

Keywords: arthropod parasites, impala, lice, ticks

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Introduction

Wild artiodactyls not only serve as hosts for a variety of ticks of veterinary importance (Horak 1982; Horak, Potgieter, Walker, De Vos & Boomker 1983) but they may also suffer mortality owing to tick infestations (Ferrar & Kerr 1971; Lightfoot & Norval 1981; Melton 1987). Mortality frequently occurs amongst animals introduced into new areas (Fourie & Vrahimis 1989) or animals under nutritional stress (Lightfoot & Norval 1981; Melton 1987). This is often evident in small wildlife parks where a high host density can lead to excessive tick burdens resulting in high mortalities (Ferrar & Kerr 1971).

Game ranching in combination with livestock farming is a common practice in South Africa. On these mixed farms the judicious selection of the wild animal species that are to be kept with the domestic stock is important. Cattle for instance carry a larger proportion of adult ticks than impalas *Aepyceros melampus*, which, however, are efficient hosts for the immature stages of a number of tick species (Horak 1982). Thus when cattle and impalas occur sympatrically the latter will make an important contribution to the adult ticks on the cattle.

The distribution of ticks is affected by a number of factors such as vegetation, habitat and climate (Theiler 1966). Wild animals with a wide geographic distribution range may therefore be infested with different tick species in different regions of their distribution. In order to determine the host status of wild artiodactyls for ticks, sampling should consequently be done in various habitats within the distribution range of the host species. The specific objective of the present study was to determine the species diversity and numbers of ectoparasites infesting impalas in a Lowveld Veld Type habitat of the Kruger National Park, Mpumalanga.

Material and Methods

At monthly intervals from January 1980 until May 1981 adult male impalas from north (25–30 km) of Malelane and from around Skukuza were shot and examined for ectoparasites. Impala near Malelane were sampled in mixed bushwillow woodlands, and those near Skukuza in Sabie Crocodile thorn thickets. Female animals at each of these localities were examined from March 1980 to May 1981. Ectoparasites were collected, identified and counted as described by Horak, Boomker, Spickett & De Vos (1992).

A total of 32 (17 male and 15 female) and 33 (17 male and 16 female) impalas were examined from the northern Malelane region and from around Skukuza, respectively. The tick burdens of the adult male and female impalas examined from the two localities were compared using two-tailed paired t tests on log (count + 1) transformed data.

Table 1 Mean arthropod parasite burdens of 65 impalas in the Kruger National Park. Numbers of animals infested are given in parentheses

Ixodid ticks	Larvae	Nymphs	Males	Females	Total number recovered
Amblyomma hebraeum	554.4(65)	101.4(65)	0.9(26)	0.2(6)	42691
Amblyomma marmoreum	15.7(16)	–	–	–	1020
Boophilus decoloratus	1476.0(65)	718.5(65)	290.5(65)	137.9(65)	170482
Rhipicephalus appendiculatus	118.0(37)	60.1(30)	9.4(33)	5.6(30)	12556
Rhipicephalus evertsi evertsi	288.9(63)	50.8(51)	1.9(45)	0.7(27)	22246
Rhipicephalus zambeziensis	225.2(34)	73.1(26)	12.9(36)	6.4(36)	20646

Lice	Nymphs	Adults	Total number recovered
Damalinia aepycerus	55.8(34)	23.2(26)	5136
Damalinia elongata	116.9(25)	64.9(24)	11816
Linognathus aepycerus	44.9(30)	25.8(29)	4596
Linognathus nevelli	19.8(12)	12.9(15)	2124

Results

The mean numbers of arthropod parasites collected from the impalas are summarized in Table 1. Six ixodid tick species, of which *Boophilus decoloratus* was the most prevalent, parasitized the impalas. Except for *Amblyomma marmoreum*, of which only the larvae were collected, all developmental stages of the other ticks were present on the impalas. With the exception of *B. decoloratus* the mean number of adult ticks was less than 20 per animal. Both biting and sucking lice (*Damalinia* spp. and *Linognathus* spp.) occurred on the impalas (Table 1.). Mean lice burdens were, however, relatively low and less than half the animals were infested.

The mean tick and lice burdens of impalas from north of Malelane and from Skukuza are summarized in Table 2. Significantly more immature *Amblyomma hebraeum* and *A. marmoreum* were present on impalas sampled at Skukuza than on those from the Malelane region. Conversely significantly more *Rhipicephalus appendiculatus* nymphs and *Rhipicephalus evertsi evertsi* larvae and nymphs were collected from impalas from the Malelane region. Except for *Damalinia aepycerus* adults, significantly more biting lice were collected from impalas at Skukuza than from the Malelane region (Table 2).

In general the tick and lice burdens on male and female impalas did not differ significantly. However, male impalas from the Malelane region harboured significantly more adult *R. appendiculatus* (both sexes) than did females. Female impalas, in turn, harboured more *D. aepycerus* adults than males. At Skukuza no difference in the tick and lice burdens was evident between sexes.

Discussion

Seventeen ixodid tick species indigenous to South Africa, of which nine include both immature and adult stages, have been collected from impalas (Theiler 1962; Horak 1982; this study). Some of these ticks, namely *A. hebraeum, B. decoloratus, R. appendiculatus* and *R. evertsi evertsi* are of veterinary importance since they can either transmit pathogens or cause tick toxicoses in domestic stock (Howell, Walker & Nevill 1983). The ticks collected from impalas in a Mixed Bushveld region in the Nylsvley Nature Reserve (Horak 1982) differed slightly from those collected from impalas in this study. *Ixodes cavipalpus* and *Hyalomma marginatum rufipes* were not collected from impalas from the Malelane region or from Skukuza. Since few ticks of these species parasitized the impalas at Nylsvley these can be considered incidental infes-

Table 2 Mean numbers of ticks and lice collected from impalas north of Malelane and around Skukuza in the Kruger National Park and statistical comparison of the values

	Larvae			Nymphs			Males			Females		
Ixodid ticks	$\bar{X}(1)$	$\bar{X}(2)$	p	$\bar{X}(1)$	$\bar{X}(2)$	p	$\bar{X}(1)$	$\bar{X}(2)$	p	$\bar{X}(1)$	$\bar{X}(2)$	p
Amblyomma hebraeum	426.0	678.9	S	67.8	133.9	S	0.5	1.2	N	0.1	0.2	N
Amblyomma marmoreum	3.3	27.7	S									
Boophilus decoloratus	1893.0	1071.5	N	885.4	556.6	N	370.3	213.1	N	168.3	108.4	N
Rhipicephalus appendiculatus	170.6	66.8	N	92.8	28.5	S	4.8	13.9	N	3.7	7.5	N
Rhipicephalus evertsi evertsi	483.0	100.6	S	75.8	26.5	S	1.8	2.0	N	0.8	0.6	N
Rhipicephalus zambeziensis	111.3	335.6	N	28.5	116.4	N	4.8	20.8	N	2.5	10.3	N

	Nymphs			Adults		
Lice	$\bar{X}(1)$	$\bar{X}(2)$	p	$\bar{X}(1)$	$\bar{X}(2)$	p
Damalinia aepycerus	14.5	95.8	S	12.6	33.5	N
Damalinia elongata	8.6	221.8	S	7.9	120.2	S
Linognathus aepycerus	23.8	65.2	N	17.5	33.9	N
Linognathus nevelli	1.5	37.5	N	4.3	21.3	N

(1) = Malelane, (2) = Skukuza, S = significant ($p < 0.05$), N = not significant

tations. Impalas from the Malelane region and Skukuza were, however, infested with *Rhipicephalus zambeziensis*, a tick which was not present on animals examined in the Nylsvley Nature Reserve. At the latter locality *R. evertsi evertsi* followed by *R. appendiculatus* were the dominant tick species (Horak 1982). In this study *B. decoloratus* followed by *A. hebraeum* were the dominant species.

There were no differences in the species diversities of arthropod parasites infesting impalas in the Malelane and Skukuza areas. However, significant differences in tick numbers (mainly *A. hebraeum* and *R. evertsi evertsi*) were recorded between impalas in the two areas. These differences are possibly due to the fact that the population densities of buffalo and zebra, which serve as good hosts for the adults of *A. hebraeum* and *R. evertsi evertsi*, respectively, differ between the two regions. The virtual absence of differences in tick burdens between the sexes is significant. This is possibly related to the high degree of reciprocal allogrooming (Mooring & Hart 1992) and selfgrooming which reportedly have a tick-removal function (Hart, Hart, Mooring & Olubayo 1992), as well as the foraging of oxpeckers on the impalas (Hart, Hart & Mooring 1990).

Impalas may carry large burdens of immature ticks. A dead impala ram has been found with about 50 000 *R. appendiculatus* larvae and nymphs (Lightfoot & Norval 1981). Impalas under nutritional stress can also become heavily infested with ticks (Lightfoot & Norval 1981). It has been suggested that compared to cattle, impalas carry fewer adult ticks (Macleod, Colbo, Madbouly & Mwanaumo 1977; Horak 1982). The percentage composition of larvae, nymphs and adults in specific tick populations on cattle, impalas, nyalas and kudus is summarized in Table 3. For *A. hebraeum* the values for impalas, nyalas and kudus are remarkably similar. On these hosts adult ticks constituted only 1 or 2% of the population. Values for adults of up to 49% have been recorded on cattle (Table 3). With the exception of nyalas in the Mkuzi Game

Table 3 The life stage composition of ixodid tick populations on various antelope species and on cattle

Tick species	Larvae(%)	Nymphs(%)	Adults(%)	Host	Locality	Reference
Amblyomma hebraeum	90	9	1	impalas	Nylsvley	Horak 1982
	84	15	1	impalas	KNP	This study
	88	10	2	kudus	AVKR	Horak et al. 1992
	86	13	1	kudus	KNP	Horak et al. 1992
	84	15	1	nyalas	UGR	Horak et al. 1995
	88	11	1	nyalas	MGR	Horak et al. 1995
	33	18	49	cattle	Nylsvley	Horak 1982
	66	9	25	cattle	Bucklands*	Horak & Knight 1986
Boophilus decoloratus	56	27	17	impalas	KNP	This study
	50	33	17	kudus	KNP	Horak et al. 1992
	44	30	26	nyalas	UGR	Horak et al. 1995
	72	21	7	nyalas	MGR	Horak et al. 1995
Rhipicephalus appendiculatus	67	28	5	impalas	Nylsvley	Horak, 1982
	61	31	8	impalas	KNP	This study
	77	14	9	kudus	AVKR	Horak et al. 1992
	60	16	24	kudus	KNP	Horak et al. 1992
	71	16	13	nyalas	UGR	Horak et al. 1995
	72	5	23	nyalas	MGR	Horak et al. 1995
	56	22	22	cattle	Bucklands*	Horak & Knight 1986
	11	16	73	cattle	Nylsvley	Londt et al. 1979
	51	21	28	cattle	Nylsvley	Horak 1982
Rhipicephalus evertsi evertsi	70	28	2	impalas	Nylsvley	Horak 1982
	84	15	1	impalas	KNP	This study
	63	31	6	kudus	AVKR	Horak et al. 1992
	89	9	2	kudus	KNP	Horak et al. 1992
	98	0	2	nyalas	UGR	Horak et al. 1995
	50	46	4	cattle	Bucklands*	Horak & Knight 1986
	52	6	42	cattle	Nylsvley	Horak 1982
Rhipicephalus zambeziensis	71	23	6	impalas	KNP	This study
	80	12	8	kudus	KNP	Horak et al. 1992

AVKR = Andries Vosloos Kudu Reserve; KNP = Kruger National Park; MGR = Mkuzi Game Reserve; UGR Umfolozi Game Reserve; *Bucklands farm shares a boundary with the Andries Vosloo Kudu Reserve.

Reserve the ratios for *B. decoloratus* on impalas, kudus and nyalas were also fairly similar. Impalas harboured a greater percentage of nymphs, but a smaller proportion of adult *R. appendiculatus* than kudus and nyalas. The very high percentage (73%) of adults collected from cattle at Nylsvley can be attributed to the sampling method used (destructive *versus* live sampling). Live sampling of hosts as employed in the study by Londt, Horak & De Villiers (1979) will result in a bias towards adult ticks. In the case of *R. evertsi evertsi*, which is a two-host tick, impalas, kudus and nyalas harboured large percentages (94–98%) of larvae and nymphs combined but only between 1 and 6% of adults. The proportions of immature *R. zambeziensis* on impalas (94%) and kudus (92%) were similar.

When impalas and domestic stock such as sheep, goats and cattle are grazed together, the impalas will make an important contribution towards the adult tick burdens of these animals because they are efficient hosts for the immature stages. Impalas will, however, not be able to sustain large tick populations in the absence of animals such as cattle which are efficient hosts of the adult ticks (Horak 1982).

It has been suggested that the proportion of adult ticks carried by animals appears to be in direct relationship to the physical size of the host species (Horak *et al.* 1983; Horak 1984; Horak, MacIvor, Petney & De Vos 1987). Data presented in this study indicate that this is not universally true and that a high degree of variation can occur. For data of this nature to be comparable samples should be representative of the various seasons of the year. Because the seasonal occurrence of immature and adult three-host ticks is out of phase (Minshull & Norval 1982; Petney, Horak & Rechav 1987) short-term sampling and inadequate sample sizes will result in bias towards either immature or adult ticks.

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6 The Community Structure of Ticks on Kudu, *Tragelaphus strepsiceros*, in the Eastern Cape Province of South Africa

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6.1 Introduction

Arthropod and helminth parasites are classified together as macroparasites on the basis of ecological similarities (Anderson and May 1979). The relationship between each group and its host species for such parameters as ratio of body size, intrinsic population growth rate, life span and the pathological significance of their interaction are comparable but significantly different from microparasites (viruses, bacteria, protozoans) and parasitoids.

There are also major differences between arthropod parasites and helminths. Helminths, as endoparasites, live in a relatively constant internal environment once they have found a host. In such an environment, where they can remain for considerable times, they are not subject to seasonal influence and as a consequence their host is not subject to rapid changes in the structure of its helminth "infracommunity". Thus data on helminth communities are often restricted to a certain season (Bush and Holms 1986; Esch et al. 1988) or include the tacit assumption of constancy through time (Goater et al. 1987).

With few exceptions arthropod parasites are ectoparasitic and in many cases they are only temporary parasites with one or more free-living life history stages (mosquitoes, fleas) or with varying periods without contact with the host during the parasitic stage (mosquitoes, ticks). Such species are subject to seasonal changes in their environment which can significantly influence their presence or abundance (Demarais et al. 1987) which in turn is likely to subject each individual host to a changing spectrum of parasites.

There is a wealth of data available on the community structure of helminths which has been used to build the hypotheses dealing with the factors determining community structure for macroparasites (Holmes 1987; Esch et al. 1990). In comparison with the information available on helminths, that available on the community structure of ectoparasites is rudimentary. In this contribution, we offer an analysis of the influence of climate on the structure of infracommunities of ticks on a large African antelope, the greater kudu (*Tragelaphus strepsiceros*).

Ticks represent part of the guild of blood-feeding arthropods which includes mites, sucking lice and fleas as well as a variety of diptera. Ixodid ticks have three developmental stages which are parasitic although most of their duration is free living. The eggs hatch into larvae on the ground. These must

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then find a host on which they engorge. In most species the engorged larvae then detach from the host before moulting into nymphs on the ground. The nymphs must then find a new host before engorging, usually detaching, and then moulting into adults. Adults then find a new host and after mating, which, except in the genus *Ixodes*, takes place on the host, the female engorges, drops from the host and lays eggs before dying. Members of some genera use the same host for each developmental stage without detaching (one-host ticks) and in other genera the larvae and nymphs may share a common host (two-host ticks) while in the majority of genera larvae, nymphs and adults each have a separate host (three-host ticks). Although host specificity is common within some genera of ticks, many species feed on a wide range of hosts, in some cases ranging from reptiles through birds to mammals (Hoogstraal and Aeschlimann 1982). This is particularly true for many of the species infesting wild and domestic ungulates in Africa.

The greater kudu is a large antelope, with males reaching 1.4 m at the shoulder and weighing up to 250 kg. It prefers savannah woodland vegetation, is gregarious, and feeds by browsing (Smithers 1983).

6.2 Methods and Materials

Andries Vosloo Kudu Reserve (33°06′S; 26°41′E) comprises an area of 6497 ha of Valley Bushveld vegetation in the eastern Cape Province of South Africa. At the time of our study it was stocked with approximately 450 greater kudu, 140 eland (*Taurotragus oryx*), 100 African buffalo (*Syncerus caffer*), 54 red lartebeeste (*Alcelaphus buselaphus*), 80 bushbuck (*Tragelaphus scriptus*) and 18 springbok (*Antidorcas marsupialis*) (Petney and Horak 1987). A single greater kudu was shot on the reserve at monthly intervals from February 1985 until January 1986 and then at three monthly intervals from March to December 1986. All samples, except those for December, were collected in the last half of the month. Dead animals were transported to the laboratory as soon as possible and processed as indicated in MacIvor et al. (1987) to remove ticks.

Non-parametric Spearman-rank correlations were used to compare species richness and intensities of infestation for each sampling time. The Shannon Index was used to measure the diversity of ticks on each kudu sampled. This index was calculated for each developmental stage. Similarity in infestation patterns was determined by cluster analysis using the infestation intensities for all developmental stages of all tick species for all months excluding March 1986. This month was excluded from the analysis as it showed an exceptional intensity of infestation of larval *Amblyomma hebraeum*. This analysis was carried out using SPSS (Statistical Package for the Social Sciences).

The relationship between ln (intensity of infestation), species richness and diversity for each developmental stage and climate was investigated using

Table 6.1. The number and life history stage of each tick species collected on all of the kudu sampled

Species	*A. hebraeum*	*A. marmoreum*	*B. decoloratus*	*Haem. silacea*	*Hy. rufipes*	*Hy. truncatum*	*I. pilosus*	*R. appendiculatus*	*R. e. evertsi*	*R. exophthalmus*	*R. glabroscutatum*	*R. simus*
Larvae	32 009	2 112	14	10 003	0	0	0	4 391	296	0	13 596	0
Nymphs	3 408	0	36	2 305	0	0	14	775	145	0	7 069	0
Adults	682	0	54	1 825	3	2	14	514	28	145	1 597	6
Number of engorged females (%)	22/252 (8.7)	na	0/20	106/415 (25.5)	na	na	0/14	24/190 (12.6)	0/10	14/145 (9.6)	20/544 (3.7)	0/4

The nearly complete engorgement of females implies that mating has occurred and that the host is suitable.
na, not applicable.

multiple linear regressions. Both data for the month in which sampling occurred and for the previous month ("lag" prefix) were used in the analysis. The natural logarithm of the intensity of infestation was used to overcome problems associated with the usual aggregated dispersion pattern of ticks (Petney et al. 1989).

Climatic data were collected in Port Elizabeth, approximately 150 km to the southwest of the Andries Vosloo Kudu Reserve (Schulze 1972). Variables used for the analyses were: mean maximum monthly temperature (MAT), mean minimum monthly temperature (MIT), mean relative humidity (RH), mean rainfall (RAI), mean radiation/day (RAD) and evaporation (EVA). The climate of Port Elizabeth, with cool, sometimes moist winters and hot, often dry summers is qualitatively similar to that of the Kudu Reserve except that Port Elizabeth is situated on the coast. These analyses were carried out using Student SYSTAT.

6.3 Results

Of the 12 species of ticks collected only one, *Boophilus decoloratus*, has a one-host life cycle. *Rhipicephalus evertsi evertsi*, *Rhipicephalus glabroscutatum* and the two *Hyalomma* species are 2-host species with larvae and nymphs occurring on the same host individual. Of these four two-host species the two *Hyalomma* species were represented only by adults while both *R. e. evertsi* and *R. glabroscutatum* were represented by all stages of development All other species are three-host ticks (Table 6.1). Of these seven three-host species, three were represented by all developmental stages, two species only by adults, while *A. marmoreum* was represented only by larvae and *Ixodes pilosus* by nymphs and females. Females nearing complete engorgement were collected from five species. In four species, each represented by 20 or less females, no near complete engorgement was observed. Four species were represented by less than 20 individuals. All other species were represented by over 100 individuals ranging up to 36 099 *A. hebraeum*. Of these, 18 323 larvae came from a single kudu examined in March 1986.

Species richness ranged from 3 to 7 for larvae, 2 to 6 for nymphs, 4 to 8 for adults and 6 to 9 for all developmental stages (Table 6.2). The species richnesses were not significantly correlated for any pair of developmental stages. The intensity of infestation of adults was significantly negatively correlated with the intensities of both larvae ($r_s = -0.449$, $p < 0.05$) and nymphs ($r_s = -0.653$, $p < 0.05$), but there was no significant correlation between the intensities of infestation of larvae and nymphs. For the different developmental stages species richness was not significantly correlated with intensity of infestation for any stage except in larvae ($r_s = 0.790$, $p < 0.01$). Overall species richness was significantly correlated with that of adults ($r_s = 0.835$, $p < 0.01$) but not with that of either larvae or nymphs.

Table 6.2. Mean species richness (A; ±SE) and mean Shannon diversity (B; ±SE) for each developmental stage of tick and months of maximum and minimum infestation

A	Species richness					
	Max.	Month	Min.	Month	$\bar{x}$	SE
Larvae	7	May	3	Sept., Oct., Dec. 1986	4.88	0.32
Nymphs	6	April	2	Feb.	4.38	0.24
Adults	8	April	4	May, Aug., March 1986	5.56	0.29
B	Shannon diversity (H)					
	Max.	Month	Min.	Month	$\bar{x}$	SE
Larvae	1.80	Mar. 1986	0.25	Sept. 1985	4.88	0.32
Nymphs	1.24	April	0.26	Dec. 1985	4.38	0.24
Adults	1.48	Mar. 1986	0.61	Aug. 1985	5.56	0.29

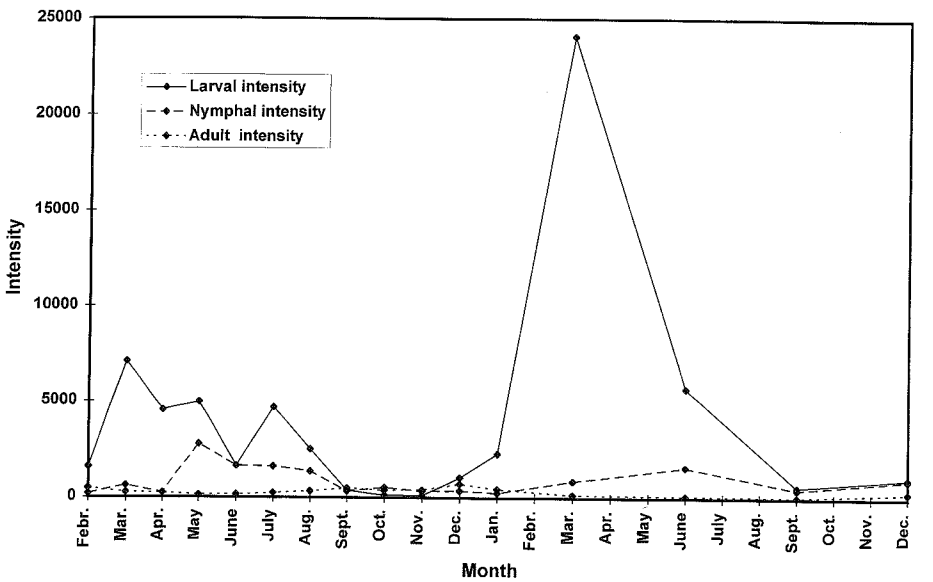

Fig. 6.1. The intensity of infestation for each developmental stage of ticks of each sampling month

Total tick burdens were seasonal with September to December (spring/early summer) 1985 and September to December 1986 showing low infestation intensities (Fig. 6.1). During this time the intensities of infestation of nymphs and larvae were low while adult intensities were high. High larval intensities of infestation occurred between March and August (autumn/winter) and high nymphal intensities between May and August. Ranks of total intensity of

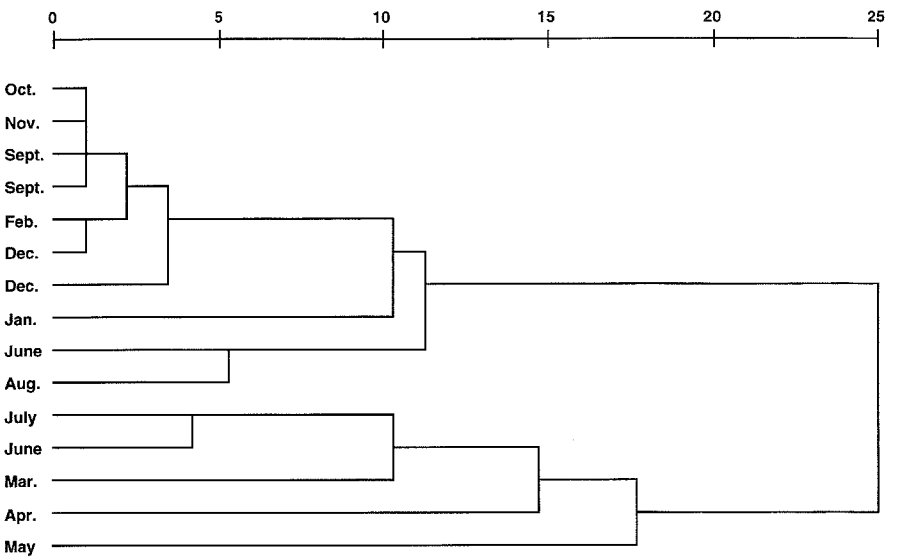

Fig. 6.2. The relationship between pattern of infestation and month of sampling

Table 6.3. Multiple regression analyses of species richness, intensity of infestation and Shannon diversity of larvae, nymphs and adults against climatic variables. No significant correlation was found for adult species richness

Variable	Predictors	Adj. multiple R^2	*F*-value	Probability
Larval species	lagMAT RAD	0.809	24.54	<0.001
Larval ln	lagRH lagRAD RAD	0.894	33.77	<0.001
H larvae	lagMAT MAT	0.512	6.83	<0.01
Nymphal species	lagMAT lagMIT MAT	0.589	5.74	<0.05
Nymphal ln	RAD	0.503	14.16	<0.01
H nymphs	lagRAI RAI lagRAI lagEVA	0.850	15.58	<0.001
Adult ln	RAD	0.434	10.75	<0.01
H adults	lagMAT	0.397	9.21	<0.01

H, Shannon diversity.

infestation for all collecting months show a strong correspondence between years (March 15, 16; June 9, 12; September 3, 4; and December 5, 7).

Two distinct clusters separated autumn and early winter samples (excepting June) from the spring/summer samples in relation to the overall intensity of infestation of ticks (Fig. 6.2). Considerable variation was present in the former group while the latter could be divided into two subgroups. The first of these subgroups, incorporating spring and summer, showed strong similarity between months; the second included January, June 1985 and August.

Regression analyses show significant relationships between climatic factors and the species richness, intensity of infestation and Shannon diversity for each developmental stage except for species richness of adults (Table 6.3). For the species richness and the intensity of infestation of larvae as well as for the Shannon diversity of nymphs over 80% of variability could be accounted for by climatic parameters. Total species richness was not significantly correlated with any climatic parameter.

6.4 Discussion

Ticks, particularly larvae which hatch together from an egg batch, usually have an aggregated dispersion pattern (Petney et al. 1989). Thus accurate estimates of mean intensities of infestation are difficult to determine even with large sample sizes. Our data, with a single kudu sampled each month, are clearly inadequate to give more than a rough approximation of reality. Unfortunately it is equally clear that sample sizes sufficient for an accurate determination of mean infestation intensity can rarely if ever be collected over a sufficient period of time and within a uniform habitat for large and/or uncommon hosts.

Host preferences account for much of the variation in the contribution to the tick community between adult and immature ticks of the same species. *A. marmoreum* adults occur almost exclusively on large reptiles, particularly the tortoise *Geochelone pardalis* (Dower et al. 1988). Immatures of the two *Hyalomma* species and *Rh. exophthalmus* feed predominantly on birds and/or lagomorphs (Walker 1991; Keirans et al. 1993). *Rh. simus* immatures parasitize various species of rodents (Walker 1991). All stages of *I. pilosus* can occur on the same host.

Each of the species uncommon on kudu has been recorded on a variety of other wild ungulates although all are consistently rare on this host (Horak et al. 1983). The concept of core/satellite species is only applicable for all developmental stages of some of the species examined. In other species only larvae (*A. marmoreum*) or adults (*R. exophthalmus*) can be considered as core "species".

The community structure of ticks on kudu is not static but varies greatly with season. Species richness for any developmental stage changes by a factor of 2 and intensity of infestation by an order of magnitude. The distinction

between late autumn/winter and spring/summer samples corresponds broadly with findings for other hosts sampled in the eastern Cape Province (Horak et al. 1991a,b).

The significance of climatic conditions for ticks is determined by the sensitivity of the free-living stages to high temperature and low humidity (Norval 1977). The larval stage is the most sensitive, desiccating rapidly at high temperatures and low humidities. This can account for the large degree of variability in species number and intensity of infestation of larvae explained by (lag) MAT, RH and RAD in the multilinear regressions. The nymphal and adult stages appear to show less sensitivity to climate although there are still significant climatic effects. The variability in the sensitivity of Shannon diversity to climatic variables can probably be at least partially explained by the strongly aggregated dispersion pattern to ticks which would tend to decrease evenness.

Climatic variables are only able to explain part of the dynamics of community structure in these ticks. The detailed interpretation of our results must await more finely tuned comparisons of potential direct and indirect interactions between the different tick species and between ticks and host. A variety of potentially important factors are already known. Different tick species or developmental stages within a species can occupy different anatomical sites on the host (niche segregation; Kaiser et al. 1982). Similar species which occupy the same or overlapping sites can compete for space (Andrews and Petney 1981; Norval and Short 1984) or interfere with one another's reproductive behaviour (Andrews et al. 1982). Some species are known to have an immunosuppressant effect on the host (Ribeiro et al. 1985) and in other cases infestation by one tick species can induce a cross immunity to another species (Bull et al. 1981). Pheromones can attract individuals of the same species to attach to an already infested host (Norval et al. 1989).

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Parasites of domestic and wild animals in South Africa. XLI. Arthropod parasites of impalas, *Aepyceros melampus*, in the Kruger National Park

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ABSTRACT

HORAK, I.G., GALLIVAN, G.J., BRAACK, L.E.O., BOOMKER, J. & DE VOS, V. 2003. Parasites of domestic and wild animals in South Africa. XLI. Arthropod parasites of impalas, *Aepyceros melampus*, in the Kruger National Park. *Onderstepoort Journal of Veterinary Research*, 70:131–163

Ectoparasites were collected from impalas, *Aepyceros melampus*, at four localities within the Kruger National Park, namely Skukuza, in the Biyamiti region, Crocodile Bridge and Pafuri. Animals were also examined at Skukuza during a severe drought and at Skukuza and Pafuri towards the end of a second drought. Parasite burdens were analysed in relation to locality, sex, age class, month and drought.

The impalas were infested with 13 ixodid ticks species, including two that were identified only to genus level. Except for four animals at Pafuri, all were infested with *Amblyomma hebraeum*. The highest intensity of infestation with larvae of this tick occurred from April to June and during November and December at Skukuza and in the Biyamiti region. Infestation with nymphs was highest during late winter. All animals were infested with *Boophilus decoloratus*, and the intensity of infestation was highest during spring. The intensity of infestation with *Rhipicephalus appendiculatus* was highest at Crocodile Bridge and at Pafuri, and that of *Rhipicephalus zambeziensis* at Skukuza. With both the latter species the intensity of infestation of larvae was highest from April to August, of nymphs from July to September or October and of adults during February and March. *Rhipicephalus kochi* was present only at Pafuri.

The impalas also harboured five louse species and two species of hippoboscid flies. The intensity of infestation with lice tended to be greater during late winter and spring than during other seasons and greater on lambs than on yearlings on which it was greater than on adult animals.

Keywords: *Aepyceros melampus*, drought, hippoboscid flies, impalas, intensity of infestation, ixodid ticks, Kruger National Park, lice, prevalence, seasonality

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INTRODUCTION

Impalas, *Aepyceros melampus*, are widely distributed in the eastern woodland regions of Africa, from northern Kenya south to northern KwaZulu-Natal, South Africa, with their southern distribution extending north-westward to south-eastern Angola and northern Namibia. They prefer light, open woodland communities and generally avoid open grassland unless it abuts on woodland (Skinner & Smithers 1990). Impalas are classified as intermediate mixed feeders as they both graze and browse (Skinner &

Smithers 1990), and within their range they are often the most numerous medium-sized antelopes. In South Africa they are present in national, provincial and privately owned nature reserves as well as on many mixed cattle and wildlife ranches.

With the possible exception of African buffaloes, *Syncerus caffer*, more surveys have been conducted on the arthropods infesting impalas than on those of any other wild African mammal. The ixodid tick species infesting impalas in sub-Saharan Africa have been listed by Theiler (1962); those in Kenya by Walker (1974); in Tanzania by Yeoman & Walker (1967); in Zambia by MacLeod (1970), Colbo (1973) and MacLeod & Mwanaumo (1978); in Botswana by Paine (1982); in Mozambique by Santos Dias (1993); in Swaziland by Gallivan & Surgeoner (1995); and in South Africa by Meeser (1952) and Baker & Keep (1970). Total, or calculated total tick burdens have been determined on these animals in Zambia (Zieger, Horak, Cauldwell, Uys & Bothma 1998), Zimbabwe (Colborne 1989; Mooring & McKenzie 1995; Mooring & Mazhowu 1995), Swaziland (Gallivan, Culverwell, Girdwood & Surgeoner 1995) and in South Africa in Limpopo Province (Horak 1982; Matthee, Meltzer & Horak 1997), Mpumalanga Province (Horak, Boomker, Kingsley & De Vos 1983c; Horak, Fourie & Van Zyl 1995c), North West Province (Van Dyk & McKenzie 1992) and KwaZulu-Natal (Horak, Keep, Flamand & Boomker 1988a). The louse species that infest impalas are listed by Ledger (1980), and their total louse burdens have been determined by Horak (1982), Horak *et al.* (1983c), Van Dyk & McKenzie (1992) and Matthee, Horak & Meltzer (1998). The flies recorded on these animals are listed by Haeselbarth, Segerman & Zumpt (1966).

The tick species infesting impalas are similar to those found on domestic cattle farmed in the same regions (Yeoman & Walker 1967; Walker 1974; Horak 1982; Colborne 1989), and those on sympatric antelope species (Gallivan & Surgeoner 1995; Horak 1998). Impalas appear to harbour larger tick infestations than other medium-sized antelope species (Gallivan & Horak 1997; Horak 1998), and may thus serve as an important reservoir of tick infestation on mixed cattle and wildlife farms (Horak 1982; Colborne 1989), and on game ranches or wildlife reserves, on which they are frequently the most numerous antelope species (Gallivan & Surgeoner 1995; Zieger *et al.* 1998). As lice are obligate permanent parasites, and those infesting impalas are host-specific, there is little possibility of cross-infestation with these parasites occurring with sympatric wild or domestic animals.

In this paper we compare the tick, louse and hippoboscid fly burdens of impalas examined in four landscape zones within the Kruger National Park (KNP). We also examine the seasonal intensity of infestation, and the relationships between infestation with the most abundant species of ectoparasites and host age and sex class.

MATERIALS AND METHODS

Survey animals

A total of 229 impalas were examined in several surveys in the Kruger National Park. Each animal was killed during the morning by a single shot in the neck from a small or large calibre rifle. The locations, seasons and age and sex classes of the animals are summarised in Table 1. Because parturition in these animals in southern Africa is generally confined to the months November to January (Skinner & Smithers 1990), it is possible to visually age impalas fairly accurately until the age of 2 years, particularly the males because of the age-associated changes in the shape of their horns. It is more difficult with the females that are hornless.

Parasite recovery

The impalas were processed for the recovery of arthropod parasites as described by Horak, Boomker, Spickett & De Vos (1992) for greater kudus, *Tragelaphus strepsiceros*. Ticks, lice and hippoboscid flies were collected from the processed material under stereoscopic microscopes, and identified and counted under the same microscopes. We estimate that the idiosoma of female *Boophilus decoloratus* would reach a minimum length of 4.0 mm 24 h before detachment, and the length of the idiosoma of engorging female ticks of this species was measured.

Survey localities

Skukuza (24°58'S, 31°36'E; Alt. 262 m)

Skukuza is a tourist rest camp, and is also the headquarters of the South African National Parks Kruger Park Management and Research divisions, situated in the south-western region of the KNP in a landscape zone described as Thickets of the Sabie and Crocodile Rivers (Gertenbach 1983) of which the vegetation is classified as Lowveld (Acocks 1988). The impalas examined in this region were shot within a 25 km radius of Skukuza. Three to seven animals were shot each month from January 1980 to January 1981, and always included a lamb (< 12

months of age), a yearling male (12– 23 months) and an adult (> 24 months). From February to May 1981 two to four animals were shot each month, always including an adult male and an adult female.

During the drought that occurred in 1982/83 a large number of impalas died from starvation in October and November 1982. Ten animals, considered terminally affected by the drought, were shot for survey purposes during these months. At the same time 14 apparently healthy animals were shot for comparison at the same locality. A severe drought occurred during 1991/92, and in March 1992 six 15-month-old impala males were shot and examined for parasites. Three yearling males were shot at the same locality and examined every month thereafter until April 1993.

Biyamiti region (25°06'–25°28'S, 31°25'–31°39'E; Alt. 200–350 m)

This survey site is located in the central southern region of the KNP in a landscape zone described as Mixed Bushwillow Woodlands (Gertenbach 1983) of which the vegetation is classified as Lowveld (Acocks 1988). It extended from north of the Biyamiti River to north of the Malelane entrance gate to the KNP. Each month from January 1980 to May 1981 two to six impalas, generally of the same ages and sexes as those shot at Skukuza, were shot in this locality and examined.

Crocodile Bridge (25°22'S, 31°54'E; Alt. 217 m)

Crocodile Bridge is a tourist rest camp close to the south-eastern border of the KNP. The vegetation is classified as Lowveld by Acocks (1988) and the landscape zone described as Marula/Knobthorn (*Sclerocarya caffra/Acacia nigrescens*) Savanna (Gertenbach 1983). Each month from January 1980 to January 1981 a single adult male impala was shot in the Crocodile Bridge region and examined for parasites.

Pafuri (23°27'S, 31°19'E; Alt. 305 m)

Pafuri is located in the far north-east of the KNP. The vegetation here is classified as Mixed Bushveld (Acocks 1988) and the landscape described as Limpopo/Levubu Floodplains by Gertenbach (1983). During July 1980, a lamb, a yearling, an adult male, and an adult female impala were shot and examined. From March 1992 to April 1993, three yearling males were shot and examined at 2–3 month intervals.

Climate

Monthly mean minimum and maximum atmospheric temperatures and total monthly rainfall were recorded at Skukuza, and are presented graphically in Fig. 1 for the periods 1979–1983 and 1990–1993.

Statistical analysis

Factors of interest in the analysis of the data were the effects of the location, season, age class, sex of the adult impalas, differences between years, and drought. However, because the collections were independent and factors were not balanced across studies it was not possible to analyse the data in a single multivariate analysis. Therefore, the data were subdivided and analysed in the following groups:

- Skukuza versus the Biyamiti region in 1980/81
- Skukuza, the Biyamiti region and Crocodile Bridge in 1980/81 (adult males only)
- Skukuza 1980/81 versus 1992/93
- Skukuza versus Pafuri in 1992/93
- Skukuza, Biyamiti and Pafuri in July 1980
- The 1982 drought

The factors analysed in each grouping are presented in Table 1. Differences in location and season were assessed by comparisons of the results of the individual analyses.

Most analyses compared both the prevalence and the intensity of infestation. Differences in prevalence were analysed using contingency tables with a x^2. For differences in the intensity of infestation, the parasite count data were logarithmically transformed to reduce the inequality of variance created by overdispersion (Petney, Van Ark & Spickett 1990). The data were then analysed using analysis of variance. In all of the analyses, factors were restricted to ensure equal balance among the groups. When factors were significant, a t-test was used to test between two groups and a Student-Newman-Keuls multiple range test was used to test among multiple groups. Because the 1980/81 and 1992/93 collections extended over 2 consecutive years and there was a potential for year-to-year variation, month was converted to a continuous variable starting in January of the first year (1980 or 1992). Animals less than 3 years old were aged to month; i.e., they were classed as lambs (0–11 months), yearlings (12–23 months) or adults (older than 24 months) in the analyses. In 1992/93, three to six yearling males per month were collected at Skukuza, and three

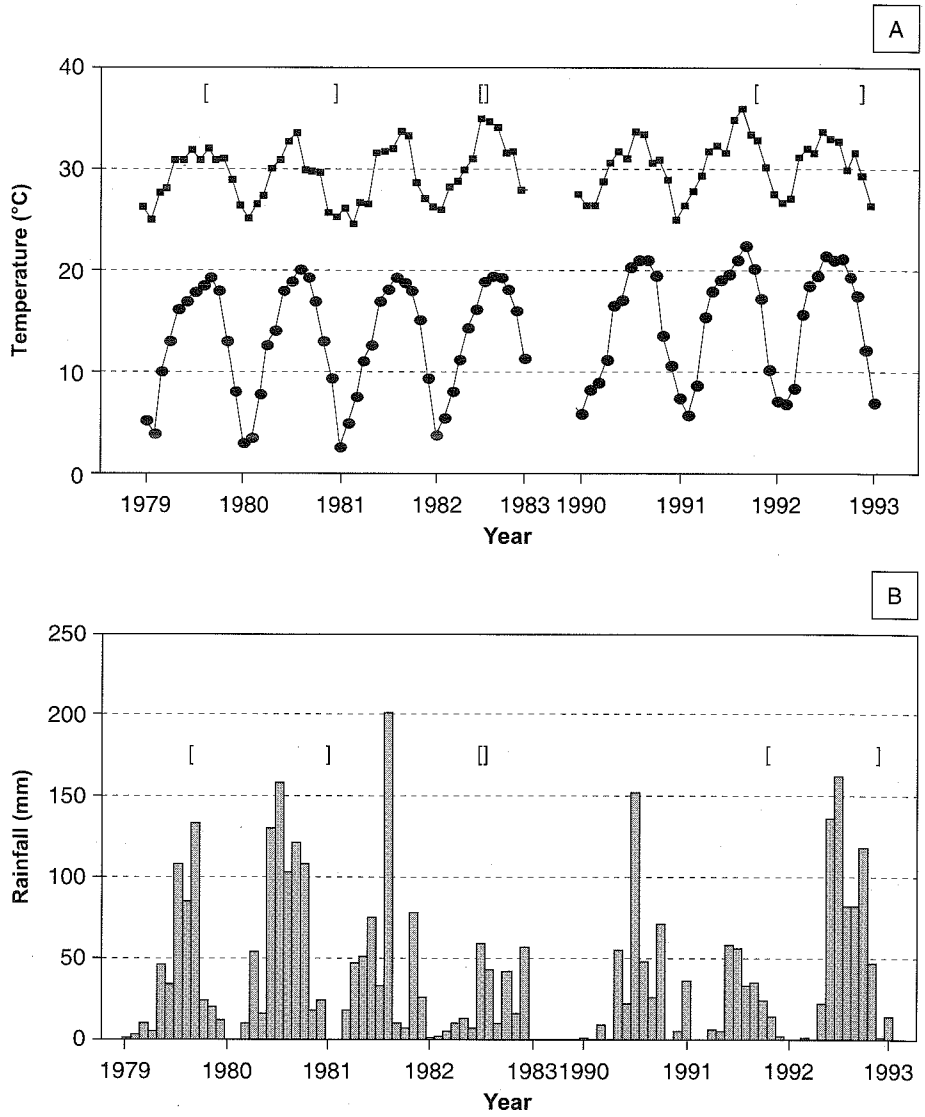

FIG. 1 [A] Average monthly minimum and maximum temperatures (°C) and [B] total monthly rainfall (mm) at Skukuza (1979–1983; and 1990–1993). Periods within brackets represent the survey periods

were collected at 2–3 month intervals at Pafuri. However, only one yearling was collected per month at Skukuza in 1980/81. To compare the parasite burdens at Skukuza in 1980/81 and 1992/93, the yearlings in 1992/93 were compared to the yearlings and adults in 1980/81 for the ticks, and to the lambs and yearlings for the lice. The groupings for 1980/81 were based on the results of the analysis for age effects. Because the 1982 drought potentially affected the parasite burdens of both the "terminal" and apparently healthy impalas, their parasite burdens were also compared to those from impalas collected during the same time period at Skukuza in 1980.

RESULTS AND DISCUSSION

IXODID TICKS

Total tick burdens

The impalas were infested with 13 species of ixodid ticks, of which 11 were identified to species level and two to genus level. Six species, *Amblyomma hebraeum, Amblyomma marmoreum, B. decoloratus, Rhipicephalus appendiculatus, Rhipicephalus evertsi evertsi and Rhipicephalus zambeziensis* were commonly collected at all locations, while *Rhipicephalus kochi* was only common at Pafuri (Table 2). The other species, *Amblyomma tholloni*,

TABLE 1 Groups, factors and ANOVA procedures used in the statistical analysis of the arthropod parasite burdens of impalas in the Kruger National Park

Group	Factors assessed	Statistical procedure	Comments
Skukuza vs Biyamiti	Location, month, age, sex	Three-factor ANOVAs: location, month and age; and location, month and sex	Location, month, age: month restricted to Jan 1980 to Jan 1981 Location, month, sex: adults only, month restricted to Mar 1980 to Apr 1981 (no adult females in Jan and Feb 1980)
Skukuza, Biyamiti and Crocodile Bridge	Location, month	Two-factor ANOVA	Adult males only, month restricted to Jan 1980 to Jan 1981
Skukuza 1980/81 vs 1992/93	Year, month	Two-factor ANOVA	Yearlings only in 1992/93 compared to yearlings and adults in 1980/81 for ticks; and to lambs and yearlings in 1980/81 for lice, months restricted to March 1980/92 to February 1981/93 (lice) or April 1981/93 (ticks)
Skukuza vs Pafuri 1992/93	Location, month	Two-factor ANOVA	Yearlings only, months matched to collections at Pafuri
Skukuza, Biyamiti and Pafuri	Location	One-factor ANOVA	July 1980 only, lamb, yearling and adults at each location
Skukuza 1982 drought	Group	One-factor ANOVA	"Terminal" vs "apparently healthy" impalas in 1982 compared to impalas collected in 1980 in same time period

TABLE 2 Proportional intensity of infestation of the major tick and louse species on impalas examined over a period of 12 months or more at four localities in the Kruger National Park

Arthropod species	Proportional intensity of infestation (%)				
	Skukuza (1980/81) (n = 63)	Skukuza (1992/93) (n = 45)	Biyamiti (1980/81) (n = 60)	Crocodile Bridge (1980/81) (n = 12)	Pafuri (1992/93) (n = 21)
Ticks					
Amblyomma hebraeum	24.07	25.05	10.56	21.49	6.31
Amblyomma marmoreum	0.60	1.38	0.05	0.14	0.07
Boophilus decoloratus	56.85	45.80	70.13	47.74	46.75
Rhipicephalus appendiculatus	2.13	0.64	5.37	24.03	15.82
Rhipicephalus evertsi evertsi	3.25	2.17	10.49	3.84	5.09
Rhipicephalus kochi	0.00	0.00	0.00	0.00	20.57
Rhipicephalus zambeziensis	13.08	24.95	3.39	2.75	5.34
Lice					
Damalinia aepycerus	18.57	22.75	21.02	10.05	18.93
Damalinia elongata	61.94	54.83	6.96	46.89	0.04
Linognathus aepycerus	11.35	18.14	34.53	42.82	65.20
Linognathus nevilli	6.58	3.17	33.68	0.24	14.33

n = Number of impalas examined

Haemaphysalis aciculifer, *Hyalomma truncatum*, *Ixodes* sp., *Rhipicephalus simus* and the *Rhipicephalus pravus* group were incidental or sporadic infestations (Tables 3–10).

The tick species infesting the impalas were similar to those collected from sympatric antelope species that had previously been examined in the KNP (Horak, Potgieter, Walker, De Vos & Boomker 1983a; Horak, De Vos & Brown 1983b; Horak *et al.* 1992; Horak 1998). Impalas appear to harbour disproportionately large tick burdens for their size (Gallivan & Horak 1997; Horak 1998), and the mean tick burden of the animals examined in the Biyamiti region was similar to the mean burden of greater kudus examined there 2 years later (Horak *et al.* 1992). However, a greater proportion of the ticks on the kudus consisted of adults, which supports the suggestion that larger ungulates are more important hosts for adult ticks (MacLeod 1970; Horak 1982). The tick burdens of the impalas would conceivably have been considerably larger if self-grooming, and probably also allogrooming, which are effective in removing ticks (A.A. McKenzie, unpublished data, cited by Hart & Hart 1992), are taken into account. Impalas are also one of the few smaller antelope species attended by red-billed oxpeckers, *Buphagus erythrorhynchus* (Stutterheim 1981), and these birds are capable of consuming large numbers of ticks (Bezuidenhout & Stutterheim 1980). In addition the method we used to collect ticks from the impalas was not the most efficient (Van Dyk & McKenzie 1992), but it did provide ticks, lice and flies that could all be identified.

The total tick burdens did not differ significantly among the locations, but there were differences in the prevalence and/or intensity of infestation of some species. These will be discussed in more detail below.

The total tick burden was significantly higher at Skukuza in 1980/81 than in 1992/93 ($P < 0.001$) (Table 11), and was higher at Pafuri in July 1980 than in August 1992 ($P < 0.1$). In contrast to 1992/93, the total tick burden of the impalas examined in 1980 at Skukuza was slightly higher than the burdens of the apparently healthy animals in the 1982 drought. The "terminal" impalas in 1982 had higher total tick burdens than the apparently healthy animals killed

TABLE 3 Arthropod parasites collected during 1980/81 from 63 impalas at Skukuza, Kruger National Park

Arthropod species	Number of arthropods collected				Total	Proportional abundance %	No. of impalas infested
Ixodid ticks	Larvae	Nymphs	Males	Females			
Amblyomma hebraeum	57 227	7 985	52	8	65 272	24.07	63
Amblyomma marmoreum	1 605	21	0	0	1 626	0.60	28
Boophilus decoloratus	88 620	43 029	15 148	7 353 (95)	154 150	56.85	63
Ixodes sp.	0	8	0	0	8	0.003	1
Rhipicephalus appendiculatus	3 298	1 387	737	355	5 777	2.13	53
Rhipicephalus evertsi evertsi	7 328	1 338	109	43	8 818	3.25	61
Rhipicephalus simus	16	0	0	0	16	0.006	1
Rhipicephalus zambeziensis	26 342	7 112	1 415	606	35 475	13.08	60
Lice	Nymphs		Adults				
Damalinia aepycerus	7 448		2 780		10 228	18.57	47
Damalinia elongata	22 188		11 928		34 116	61.94	47
Linognathus aepycerus	3 896		2 356		6 252	11.35	49
Linognathus nevilli	2 440		1 184		3 624	6.58	27
Linognathus sp.	428		428		856	1.55	18
Louse flies	Adults						
Hippobosca fulva	50				50	90.91	19
Lipoptena paradoxa	5				5	9.09	4

( ) = Number of maturing *B. decoloratus* females, i.e. idiosoma > 4.0 mm in length

TABLE 4 Arthropod parasites collected during 1980/81 from 60 impalas in the Biyamiti region, Kruger National Park

Arthropod species	Number of arthropods collected				Total	Proportional abundance %	No. of impalas infested
Ixodid ticks	Larvae	Nymphs	Males	Females			
Amblyomma hebraeum	27 225	3 559	25	4	30 813	10.56	60
Amblyomma marmoreum	159	0	0	0	159	0.05	8
Boophilus decoloratus	126 952	50 692	18 276	8 724 (134)	204 644	70.13	60
Haemaphysalis aciculifer	16	0	0	0	16	0.005	1
Rhipicephalus appendiculatus	9 393	5 892	225	151	15 661	5.37	54
Rhipicephalus evertsi evertsi	26 628	3 865	81	35	30 609	10.49	59
Rhipicephalus simus	0	0	1	0	1	0.0003	1
Rhipicephalus zambeziensis	7 575	1 889	303	123	9 890	3.39	54
Lice	Nymphs		Adults				
Damalinia aepycerus	1 328		944		2 272	21.02	37
Damalinia elongata	340		412		752	6.96	17
Linognathus aepycerus	2 164		1 568		3 732	34.53	37
Linognathus nevilli	2 388		1 252		3 640	33.68	34
Linognathus sp.	240		172		412	3.81	11
Louse flies	Adults						
Hippobosca fulva	117				117	97.50	18
Lipoptena paradoxa	3				3	2.50	1

( ) = Number of maturing *B. decoloratus* females, i.e. idiosoma > 4.0 mm in length

TABLE 5 Arthropod parasites collected during 1992/93 from 45 yearling impala males at Skukuza, Kruger National Park

Arthropod species	Number of arthropods collected				Total	Proportional abundance %	No. of impalas infested
Ixodid ticks	Larvae	Nymphs	Males	Females			
Amblyomma hebraeum	5 076	1 070	8	0	6 154	25.05	45
Amblyomma marmoreum	340	0	0	0	340	1.38	22
Boophilus decoloratus	4 678	3 792	1 619	1 164 (20)	11 253	45.80	45
Hyalomma truncatum	2	0	0	0	2	0.01	1
Rhipicephalus appendiculatus	12	4	96	46	158	0.64	18
Rhipicephalus evertsi evertsi	410	92	20	12	534	2.17	34
Rhipicephalus zambeziensis	3 840	936	942	412	6 130	24.95	40
Lice*	Nymphs		Adults				
Damalinia aepycerus	1 750		1 131		2 881	22.75	41
Damalinia elongata	2 707		4 237		6 944	54.83	29
Linognathus aepycerus	1 195		1 102		2 297	18.14	39
Linognathus nevilli	271		130		401	3.17	18
Linognathus sp.	66		75		141	1.11	16

* = Only 42 animals examined for lice

( ) = Number of maturing *B. decoloratus* females, i.e. idiosoma > 4.0 mm in length

TABLE 6 Arthropod parasites collected during 1980/81 from 12 adult male impalas at Crocodile Bridge, Kruger National Park

Arthropod species	Number of arthropods collected				Total	Proportional abundance %	No. of impalas infested
Ixodid ticks	Larvae	Nymphs	Males	Females			
Amblyomma hebraeum	9 679	1 811	9	2	11 501	21.49	12
Amblyomma marmoreum	77	0	0	0	77	0.14	2
Boophilus decoloratus	11 040	8 260	4 300	1 947 (126)	25 547	47.74	12
Rhipicephalus appendiculatus	10 420	1 888	286	265	12 859	24.03	–
Rhipicephalus evertsi evertsi	1 664	314	61	18	2 057	3.84	12
Rhipicephalus simus	0	0	1	0	1	0.002	1
Rhipicephalus zambeziensis	1 408	48	11	7	1 474	2.75	8
Lice	Nymphs		Adults				
Damalinia aepycerus	96		72		168	10.05	4
Damalinia elongata	552		232		784	46.89	5
Linognathus aepycerus	524		192		716	42.82	6
Linognathus nevilli	4		0		4	0.24	1
Louse flies	Adults						
Hippobosca fulva	4				4	100.00	2

( ) = Number of maturing *B. decoloratus* females, i.e. idiosoma > 4.0 mm in length

TABLE 7 Arthropod parasites collected during the 1982 drought from ten drought-affected "terminal" impalas at Skukuza, Kruger National Park

Arthropod species	Number of arthropods collected				Total	No. of impalas infested
Ixodid ticks	Larvae	Nymphs	Males	Females		
Amblyomma hebraeum	5 715	853	99	49	6 716	10
Amblyomma marmoreum	27	2	0	0	29	4
Boophilus decoloratus	34 964	16 437	8 354	4 967 (60)	64 722	10
Ixodes sp.	1	0	0	0	1	1
Rhipicephalus appendiculatus	56	48	15	21	140	8
Rhipicephalus evertsi evertsi	2 224	264	51	28	2 567	9
Rhipicephalus zambeziensis	80	315	41	48	484	10
Lice	Nymphs		Adults			
Damalinia aepycerus	272		517		789	9
Damalinia elongata	3 896		2 008		5 904	4
Linognathus aepycerus	7 582		8 359		15 941	9
Linognathus nevilli	552		265		817	6
Linognathus sp.	1 264		520		1 784	4
Louse flies	Adults					
Lipoptena paradoxa	4				4	2

( ) = Number of maturing *B. decoloratus* females, i.e. idiosoma > 4.0 mm in length

TABLE 8 Arthropod parasites collected during the 1982 drought from 14 apparently healthy impalas at Skukuza, Kruger National Park

Arthropod species	Number of arthropods collected				Total	No. of impalas infested
Ixodid ticks	Larvae	Nymphs	Males	Females		
Amblyomma hebraeum	11 127	1 160	35	6	12 328	14
Boophilus decoloratus	19 597	16 051	6 307	3 168 (43)	45 123	14
Ixodes sp.	0	17	0	0	17	2
Rhipicephalus appendiculatus	4	120	18	8	150	10
Rhipicephalus evertsi evertsi	1 393	260	16	13	1 682	14
Rhipicephalus zambeziensis	5	180	18	22	225	9
Lice	Nymphs		Adults			
Damalinia aepycerus	233		723		956	14
Damalinia elongata	266		558		824	7
Linognathus aepycerus	1 389		2 282		3 671	13
Linognathus nevilli	48		152		200	5
Linognathus sp.	90		216		306	7
Louse flies	Adults					
Hippobosca fulva	2				2	1
Lipoptena paradoxa	5				5	3

( ) = Number of maturing *B. decoloratus* females i.e. idiosoma > 4.0 mm in length

TABLE 9 Arthropod parasites collected during 1980 from an impala lamb, yearling and adult male, and adult female at Pafuri, Kruger National Park

Arthropod species	Number of arthropods collected				Total	No. of impalas infested
Ixodid ticks	Larvae	Nymphs	Males	Females		
Amblyomma hebraeum	1 105	196	0	0	1 301	4
Amblyomma marmoreum	11	0	0	0	11	1
Boophilus decoloratus	3 252	736	301	82	4 371	4
Rhipicephalus appendiculatus	3 832	2 280	1	1	6 114	4
Rhipicephalus evertsi evertsi	88	40	0	1	129	3
Rhipicephalus kochi	32	80	0	0	112	4
Rhipicephalus pravus group	8	0	0	0	8	1
Rhipicephalus zambeziensis	116	0	0	0	116	3
Lice	Nymphs		Adults			
Damalinia elongata	28		36		64	4
Linognathus aepycerus	16		0		16	1
Linognathus nevilli	432		168		600	4

TABLE 10 Arthropod parasites collected during 1992/93 from 21 yearling impala males at Pafuri, Kruger National Park

Arthropod species	Number of arthropods collected				Total	Proportional abundance %	No. of impalas infested
Ixodid ticks	Larvae	Nymphs	Males	Females			
Amblyomma hebraeum	440	308	4	0	752	6.31	17
Amblyomma marmoreum	8	0	0	0	8	0.07	2
Amblyomma tholloni	0	6	0	0	6	0.05	2
Boophilus decoloratus	1 842	1 982	1 032	712 (52)	5 568	46.75	21
Rhipicephalus appendiculatus	1 076	756	30	22	1 884	15.82	13
Rhipicephalus evertsi evertsi	464	112	28	2	606	5.09	20
Rhipicephalus kochi	1 884	416	118	32	2 450	20.57	17
Rhipicephalus zambeziensis	266	54	190	126	636	5.34	16
Lice	Nymphs		Adults				
Damalinia aepycerus	624		264		888	18.93	15
Damalinia elongata	0		2		2	0.04	1
Linognathus aepycerus	2 072		986		3 058	65.20	19
Linognathus nevilli	482		190		672	14.33	14
Linognathus sp.	40		30		70	1.49	5

( ) = Number of maturing *B. decoloratus* females i.e. idiosoma > 4.0 mm in length

at the same time ($P = 0.065$) (Table 11), but when the 1980 impalas were included, the differences among the groups were marginal ($P = 0.11$).

The apparent differences in the effects of drought on tick burdens may result from differences in the timing of the collections in relation to rainfall. The collections in 1992/93 began in March 1992. They were made in a year of above average rainfall following 2 years of below average rainfall at the end of a dry cycle, with particularly low rainfall during the summer of 1991/92. There was a marked reduction in the number of questing ticks collected by drag-sampling at Skukuza in 1992/93 (Horak, De Vos & Braack 1995b). This probably resulted from a reduction in the number of hosts and a loss of habitat for free-living ticks. Only 1 000 impalas were counted in the 1992 game counts, a quarter of the average count for other years, and there was a decrease in the amount of standing vegetation and loss of the grass mat which provide habitat for the free-living stages of ticks (Horak *et al.* 1995b). The 1982 collections were made in November and early December, at the beginning of the 1982/83 drought. The collections followed an extended period of low rainfall beginning in February 1982. However, this drought occurred at the end of the wet cycle of the 1970s (Whyte & Joubert 1988), and was preceded by 2 years of average to above average rainfall and impala populations (Horak *et al.* 1995b). There were no collections of questing ticks in 1982 but the numbers were probably higher than in 1992. The higher total tick burden on the "terminal" impalas in 1982 is similar to the observation that impalas in poor condition in the spring in the Mlawula-Mbuluzi-Simunye Nature Reserve complex in Swaziland were more heavily infested than those in better condition (Gallivan *et al.* 1995).

The seasonal patterns of infestation were similar in the three southern locations. The total tick burdens of the impalas examined at Skukuza and in the Biyamiti region during 1980/81 were lowest in the summer and highest in the late winter and spring ($P < 0.001$), with a secondary peak in April (Fig. 2). The late winter/spring peak coincides with the hatch and subsequent availability of *B. decoloratus* larvae, and the April peak coincides with the availability of *R. appendiculatus* and *R. zambeziensis* larvae. There was a significant month x location interaction ($P = 0.002$) caused by higher burdens at Skukuza from January to June 1980, and higher burdens in the Biyamiti region from July 1980 to January 1981. The higher burdens at Skukuza were caused by the higher intensity of infestation of *R. zambeziensis* larvae, while the higher burdens in the Biyamiti region were caused by the higher intensity of infestation of *B. decoloratus*.

TABLE 11 Mean intensities of infestations of arthropods on impalas during the 1982 and 1992 droughts in the Kruger National Park compared to animals examined during 1980/81

Arthropod species	Stage of development	1982			1992	
		"Terminal" (n = 10)	Healthy (n = 14)	1980 (n = 14)	1980/81 (n = 41)	1992/93 (n = 45)
Ixodid ticks						
Amblyomma hebraeum	Larvae	571.5	794.8	1 023.5	892.6	112.8
	Nymphs	85.3	82.9	138.4	138.3	23.8
	Adults	14.8	2.9	0.8	1.1	0.2
Amblyomma marmoreum	Larvae	2.7	0	13.6	29.9	7.6
Boophilus decoloratus	All	6 472.2	3 223.1	3 161.1	2 641.6	250.1
Rhipicephalus appendiculatus	Larvae	5.6	0.3	5.7	40.1	0.3
	Nymphs	4.8	8.6	1.1	23.1	0.1
	Adults	3.6	1.9	0.8	18.8	3.1
Rhipicephalus evertsi evertsi	Immatures	248.8	118.1	155.4	141.9	11.2
	Adults	7.9	2.1	3.0	2.8	0.7
Rhipicephalus zambeziensis	Larvae	8.0	0.4	0.0	342.5	85.3
	Nymphs	31.5	12.9	44.0	90.2	20.8
	Adults	8.9	2.9	2.1	37.3	30.1
Total ixodid ticks		7 492.7	4 251.8	4 549.6	4 400.9	546.0
Lice					*	*
Damalinia aepycerus	Nymphs, adults	78.9	68.3	108.0	249.3	70.2
Damalinia elongata	Nymphs, adults	590.4	58.9	207.4	1 029.3	175.0
Linognathus aepycerus	Nymphs, adults	1 594.1	262.2	89.7	97.5	58.5
Linognathus nevilli	Nymphs, adults	81.7	14.3	46.9	77.7	10.1
Linognathus sp.	Nymphs, adults	178.4	21.9	22.3	23.2	3.3
Total lice		2 523.5	425.5	474.3	1 477.1	317.2

* For lice n = 21 in 1980/81 and 39 in 1992/93

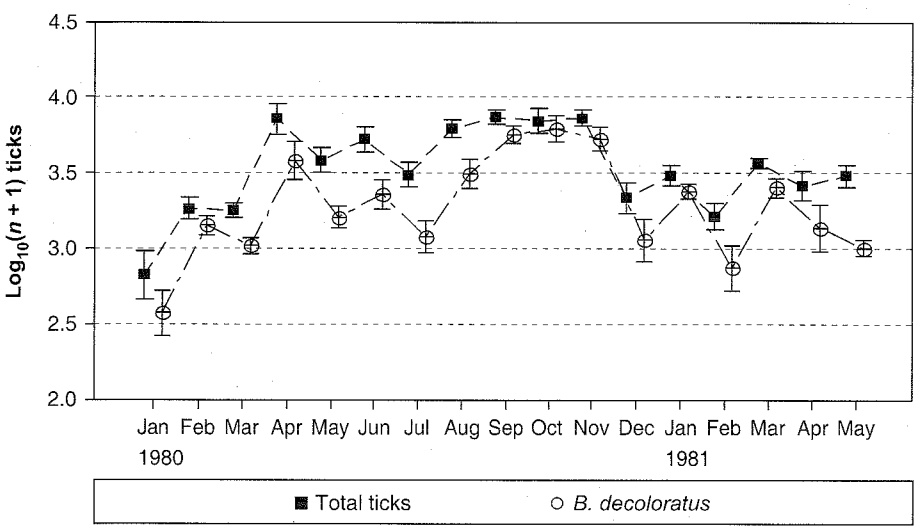

FIG. 2

Seasonal pattern of the total tick burden and intensity of infestation of all life stages of *Boophilus decoloratus* (x ± 1SE) on impalas at Skukuza and in the Biyamiti region in 1980/81. No lambs were collected after January 1981 and no yearlings after February 1981. The monthly sample at each locality ranged from two to six or seven impalas

The seasonal pattern at Skukuza was similar in 1980/81 and 1992/93. However, there was a significant month x location interaction (P = 0.004) between Skukuza and Pafuri in 1992/93. Burdens were significantly higher ($P < 0.05$) at Skukuza in the spring and summer, and tended to be higher at Pafuri in the autumn and winter, although the latter differences were not statistically significant ($P > 0.05$). The higher tick burdens at Pafuri corresponded to periods with the highest intensity of infestation of *B. decoloratus* and *R. kochi* at this location, and the higher burdens at Skukuza corresponded with the peak activity period of *B. decoloratus* at the southern locations in the KNP.

The total tick burdens during 1980/81 at Skukuza and in the Biyamiti region were significantly lower on lambs than on yearlings and adults ($P = 0.004$), with significant month x age ($P = 0.001$) and location x age ($P = 0.005$) interactions. The age x month interaction was caused by low burdens on newborn lambs relative to yearlings and adults in December, and higher burdens on yearlings in April, June and October. The location x age interaction resulted from high burdens on yearlings at Skukuza compared to those on yearlings in the Biyamiti region, and on lambs and adults at Skukuza. The intensity of infestation on lambs and adults did not differ between Skukuza and the Biyamiti region, and there was no difference between the age classes in the latter region. The total tick burdens of the adult male and female impalas did not differ significantly ($P = 0.38$).

Amblyomma hebraeum

Adult *A. hebraeum* prefer large herbivores as hosts, whereas the immature stages feed on these animals and on a variety of smaller herbivores, leporids and ground-nesting birds (Theiler 1962; Norval 1983; Horak, MacIvor, Petney & De Vos 1987). Impalas, which we consider to be medium-sized herbivores, are excellent hosts of the immature stages and harbour virtually identical burdens to those of greater kudus in the KNP (Horak *et al.* 1992; Horak 1998).

All the impalas were infested with *A. hebraeum* larvae and nymphs in 1980/81. The intensity of infestation of both stages was higher at Skukuza and Crocodile Bridge than in the Biyamiti region ($P \leq 0.001$), but the intensity of infestation did not differ significantly among Skukuza, Biyamiti and Pafuri in July 1980 ($P = 0.14$). All the yearling males were infested with nymphs and 96 % were infested with larvae at Skukuza in 1992/93, but the intensities of infestations of both stages were significantly lower ($P < 0.001$) than in 1980/81, reflecting the low number of questing larvae in 1992/93 (Horak *et al.* 1995b). Only 67 % of the yearling males collected at Pafuri during 1992/93 were infested with larvae, and the same percentage with nymphs. The prevalence and intensities of infestation of both stages were lower at Pafuri than at Skukuza ($P \leq 0.006$). This corresponds with observations on scrub hares, *Lepus saxatilis* (Horak, Spickett, Braack & Penzhorn 1993), that the intensity of infestation of *A. hebraeum* was lower in the north of the KNP.

While impalas appear to be good hosts for the immature stages, they are poor hosts for adult *A. hebraeum*. The prevalence of adults was 31.7 % in 1980/81, and did not differ among locations ($P \geq 0.19$). The largest infestation was seven ticks, with 33 of the 44 infested impalas only harbouring one or two ticks. At Skukuza the prevalence of *A. hebraeum* adults was significantly higher ($P < 0.001$) in 1980/81 (46 %) than in 1992/93 (9 %), but the prevalence of adults did not differ between Skukuza and Pafuri in 1992/93. The maximum infestation in 1992/93 was two ticks, and no females were collected.

The intensity of infestation of *A. hebraeum* larvae varied significantly by month ($P < 0.001$) at Skukuza and in the Biyamiti region in 1980/81. There appeared to be two peaks of infestation, one from April to June, and the other during November and December (Fig. 3). The intensity of infestation was significantly higher at Skukuza than in the Biyamiti region from June to August ($P < 0.05$). The seasonal patterns of *A. hebraeum* larvae did not differ significantly ($P > 0.18$) between Skukuza and Crocodile Bridge, or between 1980/81 and 1992/93 at Skukuza. The seasonal pattern was similar at Skukuza and Pafuri from March to August 1992, but the intensity of infestation increased at Skukuza in October 1992 and declined at Pafuri. The intensity of infestation remained lower at Pafuri through April 1993. The intensity of infestation of *A. hebraeum* nymphs was significantly higher ($P < 0.001$) in late winter than in the summer. The seasonal patterns of occurrence of nymphs were similar at Skukuza in 1980/81 and 1992/93, and at Skukuza and Pafuri in 1992/93. The prevalence of adults did not differ seasonally in any of the collections ($P > 0.2$).

In earlier surveys in the KNP there was no clear pattern of seasonal abundance of the immature stages of *A. hebraeum* on greater kudus, scrub hares and helmeted guineafowls, *Numida meleagris* (Horak, Spickett, Braack & Williams 1991; Horak

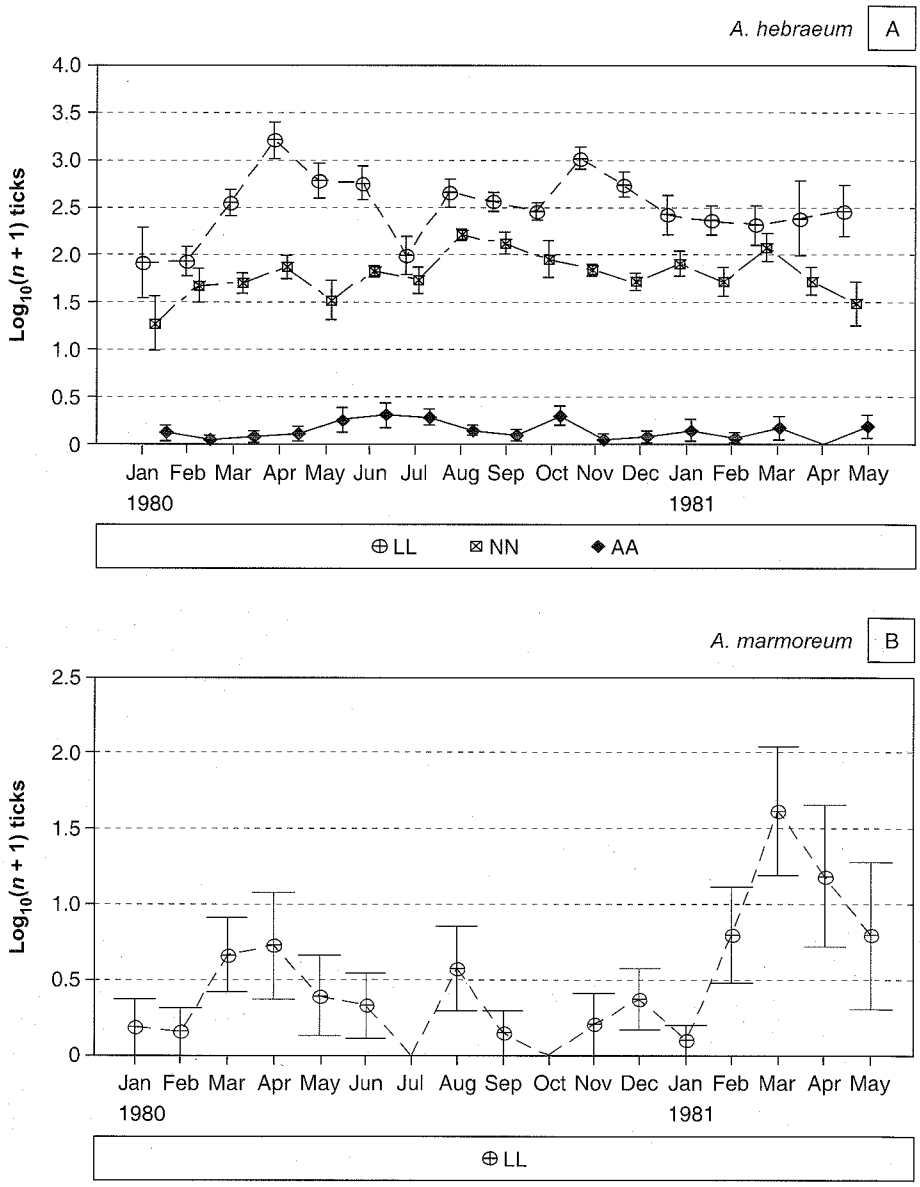

FIG. 3 Seasonal pattern of the intensity of infestation of [A] all life stages of *Amblyomma hebraeum* (x ± 1SE), and [B] larvae of *Amblyomma marmoreum* (x ± 1SE) on impalas at Skukuza and in the Biyamiti region during 1980/81. No lambs were collected after January 1981 and no yearlings after February 1981. The monthly sample at each locality ranged from two to six or seven impalas

et al. 1992; 1993). There were apparent peaks on warthogs, *Phacochoerus africanus* (Horak, Boomker, De Vos & Potgieter 1988b), and Burchell's zebras, *Equus burchellii* (Horak, De Vos & De Klerk 1984), but these seasonal patterns differ from those observed on impalas. The apparent seasonal patterns on some host species may be a function of the animals selected in the survey rather than the number of questing ticks as there does not appear to be a seasonal pattern in the number of questing *A. hebraeum* larvae (Spickett, Horak, Van Niekerk & Braack 1992).

The intensity of infestation of *A. hebraeum* larvae did not differ significantly among age classes ($P = 0.20$), but the intensity of infestation of nymphs was significantly higher on yearlings and adult impalas than on lambs ($P<0.001$). The prevalence of adults was also significantly higher ($P = 0.017$) on yearlings (40 %) and adults (43 %) than on lambs (11.5 %). The intensities of infestations of larvae

and nymphs did not differ significantly between the sexes in the adult animals ($P \geq 0.88$), but the prevalence of *A. hebraeum* adults was significantly higher ($P = 0.02$) on adult males (54 %) than on adult females (26 %). The higher prevalence and intensity of infestation of *A. hebraeum* adults on adult animals, and on adult males in particular, are consistent with the patterns reported for impalas in Swaziland (Gallivan *et al.* 1995) and kudus in the KNP (Horak *et al.* 1992).

The intensities of infestations of *A. hebraeum* larvae and nymphs did not differ significantly among the impalas examined at Skukuza in 1980 and those examined at the same locality during the 1982 drought. However, both the prevalence (100 %) and intensity of infestation of adults were significantly higher ($P < 0.002$) on the "terminal" impalas in 1982 than on the apparently healthy animals and on the impalas examined in 1980. In Swaziland, impalas infested with *A. hebraeum* adults were in poorer condition than uninfested animals, and the highest intensities of infestation with adult ticks were on adult males at the end of the dry season and after mating, periods in which these animals were already in poor condition (Gallivan *et al.* 1995). This suggests that the infestation may be secondary to the loss of resistance in stressed animals rather than a primary effect.

Amblyomma marmoreum

Amblyomma marmoreum prefers tortoises as hosts in all its stages of development (Norval 1975; Dower, Petney & Horak 1988), but the immature stages will feed on other reptiles and the larvae will also feed on carnivores, herbivores, leporids and ground-nesting birds (Norval 1975; Horak *et al.* 1987). In 1980/81, 37.6 % of the impalas were infested with *A. marmoreum* larvae. The prevalence was lower than that on helmeted guineafowls and scrub hares, but higher than on kudus examined in the KNP (Horak *et al.* 1991; 1992; 1993).

The intensity of infestation of *A. marmoreum* larvae on impalas ranged from 4–235, but 71 % of the infested animals harboured fewer than 50 larvae. The prevalence was significantly higher ($P = 0.001$) at Skukuza (34.6 %) than in the Biyamiti region (8.0 %). However, it did not differ among adult males at Skukuza, Crocodile Bridge and the Biyamiti region. This apparent contradiction occurred because the prevalences of *A. marmoreum* larvae on lambs and yearlings were much higher at Skukuza (50 %) than in the Biyamiti region (8 %) while the prevalence on adult impalas did not differ significantly between the two areas ($P = 0.24$). The prevalence at Skukuza did not differ significantly between 1980/81 and 1992/93, but the intensity of infestation was marginally higher in 1980/81 than in 1992/93 ($P = 0.07$). Prevalence at Skukuza in 1992/93 (48 %) was significantly higher ($P = 0.004$) than at Pafuri (9.5 %). This is similar to the differences recorded on scrub hares at Skukuza and in the north of the KNP (Horak *et al.* 1993). Only two impalas, both at Skukuza in 1981, were infested with *A. marmoreum* nymphs.

The prevalence and intensity of infestation of *A. marmoreum* larvae did not differ significantly ($P \geq 0.25$) on impalas at Skukuza and in the Biyamiti region from January 1980 to January 1981. However, the intensity of infestation was higher from February to May 1981 (Fig. 3). The pattern was similar in the 1992/93 ($P = 0.51$) samples where the intensity of infestation was higher in March and April in 1993 than in 1992. The higher larval burdens from March to May reflect the seasonal pattern of questing larvae on the vegetation in the park during these months (Spickett *et al.* 1992), and are similar to the patterns recorded on helmeted guineafowls, greater kudus and scrub hares in the KNP (Horak *et al.* 1991; 1992; 1993).

The prevalence and intensity of infestation of *A. marmoreum* larvae did not differ significantly among age classes ($P \geq 0.10$), or between sexes in the adult impalas ($P = 0.97$). The intensity of infestation of *A. marmoreum* larvae was higher on the "terminal" impalas in the 1982 drought at Skukuza than on the apparently healthy animals ($P = 0.05$). It was also marginally higher ($P = 0.08$) on the impalas examined in 1980 than on the apparently healthy animals in 1982.

Amblyomma tholloni

African elephants, *Loxodonta africana*, are the preferred hosts of all stages of *A. tholloni*, but the immature stages will also infest birds, reptiles, other wild mammals, and domestic cattle, sheep and goats (Theiler 1962; Norval 1983; Walker 1991). The recovery of nymphs from two impalas at Pafuri must be viewed as accidental infestations in a habitat in which there are many elephants.

Boophilus decoloratus

All the impalas were infested with *B. decoloratus*. Considering their relatively small size, impalas are remarkably good hosts of this tick as the burdens in

the Biyamiti region were similar to those on greater kudus in the same region (Horak *et al.* 1992; Horak 1998). *Boophilus decoloratus* accounted for 5.6–98.6 % (mean = 57.8 %) of the total tick burden on individual impalas, and also accounted for most of the tick burden on blue wildebeest, *Connochaetes taurinus*, Burchell's zebras and greater kudus in the KNP (Horak *et al.* 1983b; 1984; 1992). However, questing larvae of *B. decoloratus* are not the most abundant species on the vegetation in the Crocodile Bridge region or at Skukuza (Spickett *et al.* 1992; Horak *et al.* 1995b; Spickett, Horak, Heyne & Braack 1995; Horak 1998), even though it was the most common tick on impalas at both localities (Table 2). Its predominance on host animals is probably because it is present throughout the year in the KNP, infests a wide range of medium to large-size ungulates, and, because it is a one-host tick, survival from one developmental stage to the next is high (Baker & Ducasse 1967; Mason & Norval 1980; Horak *et al.* 1983a; 1984; 1992).

The one-host life cycle strategy of *B. decoloratus* reduces the losses between developmental stages that occur in the multi-host ticks during their moults off the host. The mean ratio of *B. decoloratus* larvae to nymphs to adults on all the impalas examined in the KNP was 3.49:1.69:0.00, and the ratio of males to females 1.97:1.00. These ratios imply a very satisfactory transition from one developmental stage to the next on impalas. Colborne (1989) recorded a ratio of 2.31:1.31:1.00 for larvae to nymphs to adults and a ratio of males to females of 1.89:1.00 on impalas in the south-eastern lowveld of Zimbabwe. The ratio of larvae to nymphs to adults on impalas is also within the range recorded on Burchell's zebras, bushbuck, *Tragelaphus scriptus* and greater kudus in the KNP (Horak *et al.* 1983a; 1984; 1992).

In 1980/81 the intensity of infestation was higher and *B. decoloratus* accounted for a greater proportion of the tick burden in the Biyamiti region than at Skukuza ($P \leq 0.001$). At Skukuza the intensity of infestation was lower in 1992/93 than in 1980/81, and *B. decoloratus* accounted for a lower proportion of the total tick burden ($P < 0.001$). The intensity of infestation did not differ significantly between Skukuza and Pafuri in 1992/93, but *B. decoloratus* accounted for a higher proportion of the total tick burden at Pafuri ($P = 0.001$). (The latter observation appears to contradict the data in the tables. However, the tabulated data summarize all of the ticks collected, whereas this compares the percentages on individual animals). The intensity of infestation was higher on adult males in the Biyamiti region than at Crocodile Bridge, and on impalas in the Biyamiti region than at Pafuri in July 1980, but the differences were not statistically significant ($P > 0.1$). *Boophilus decoloratus* accounted for a greater proportion of the total tick burden on adult males in the Biyamiti region than at Crocodile Bridge (69 % vs 50 %; $P = 0.003$), and in the Biyamiti region than at Pafuri in July, 1980 (55 % vs 36 %), although the latter difference was not statistically significant.

The differences in the intensity of infestation of *B. decoloratus* and its proportion of the total tick burden among regions and between years may result from a number of factors, particularly climate and host availability. There appears to be a close association between the number of questing *B. decoloratus* larvae and rainfall during the preceding year at Skukuza (Horak *et al.* 1995b), and in the present study, the intensity of infestation of *B. decoloratus* appears to be higher in regions where *R. appendiculatus* predominates over *R. zambeziensis*, a tick normally found in drier areas (Norval, Walker & Colborne 1982). In addition, the availability of hosts may play an important role as exemplified by the decrease in the number of questing *B. decoloratus* larvae at Skukuza in 1992/93 following the decline in the impala population in 1992.

The seasonal patterns in the intensity of infestation of *B. decoloratus* on impalas were similar in the three southern locations. In 1980/81 the intensity was lowest in the summer and highest in the spring at Skukuza and in the Biyamiti region ($P < 0.001$; Fig. 2). *Boophilus decoloratus* accounted for the highest proportion of the total tick burden in the spring and early summer, and the lowest proportion in the late autumn and winter ($P < 0.001$). The intensity of infestation did not differ between Skukuza and the Biyamiti region in the autumn and winter, but was significantly higher in the Biyamiti region during the winter and spring. *Boophilus decoloratus* accounted for a greater proportion of the tick burden in the Biyamiti region than at Skukuza during July and August, and November and December ($P < 0.05$). The seasonal pattern was similar at Skukuza in 1980/81 and 1992/93, but *B. decoloratus* accounted for a greater proportion of the tick burden from March to September in 1980 than in 1992. The proportion was similar from October 1980 to April 1981 and from October 1992 to April 1993. In 1992/1993, the intensity of infestation was higher at Pafuri from March to August 1992, and higher at Skukuza from October 1992 to April 1993 ($P = 0.002$). Peak intensity of infestation occurred in August at Pafuri and in October at Skukuza.

The seasonal pattern in the intensity of infestation of *B. decoloratus* on impalas is similar to that on blue wildebeest, Burchell's zebras and greater kudus in the KNP (Horak *et al.* 1983b; 1984; 1992). The pre-hatch period of *B. decoloratus* eggs is longer in the cooler winter months than in the warmer months, and eggs laid in the winter hatch synchronously with those produced at higher temperatures in the spring (Robertson 1981; Spickett & Heyne 1990). The synchronous hatch and extended period of larval survival during the winter (Spickett & Heyne 1990) result in an increase in the number of questing free-living *B. decoloratus* larvae on the vegetation in the southern KNP from August to November (Spickett *et al.* 1992; Horak, Spickett & Braack 2000a). Impalas may also have a reduced resistance to tick infestation at this time because they are on a lower plane of nutrition during the dry winter season and are in poorer condition (Gallivan *et al.* 1995), which reduces their resistance to tick infestation. The higher burdens in the autumn and winter at Pafuri, and the peak in infestation during August, may be due to the 2 °C higher average winter temperature there, resulting in earlier hatching of larvae than at Skukuza.

The intensity of infestation of *B. decoloratus* was highest on yearlings and lowest on lambs ($P < 0.001$) at Skukuza and in the Biyamiti region during 1980/81. This was caused by the low intensity of infestation on newborn lambs in December and the high intensity on yearlings in April. The intensity of infestation did not differ among the age classes in the other months. The intensities of infestations of all stages of *B. decoloratus* were significantly lower on lambs in December ($P < 0.01$) indicating that the low intensity did not occur simply because there was not sufficient time for the development of the nymph and adult stages. In the other months, the intensity of infestation of larvae was lower on adult impalas ($P = 0.004$) and the intensity of infestation of adult *B. decoloratus* was lower on lambs ($P = 0.003$) while the intensity of infestation of nymphs was highest on yearlings ($P = 0.05$). The proportion of the total tick burden did not differ among the age classes ($P = 0.20$), except in December when it was significantly lower on lambs than on yearlings and adults ($P < 0.001$). The intensity of infestation and proportion of the total tick burden on adult impalas did not differ between the sexes ($P \geq 0.27$). The age/sex pattern in the distribution of *B. decoloratus* on impalas differs from that on kudus in the KNP on which there was no difference in the intensity of infestation between age classes (Horak *et al.* 1992). However, the intensity of infestation of adult *B. decoloratus* was higher on adult male kudus than on adult females. There was no difference in the intensities of infestations of any stage of development of *B. decoloratus* between the sexes of adult impalas.

The "terminal" impalas at Skukuza in the 1982 drought were more heavily infested with *B. decoloratus* than the apparently healthy animals examined at the same time or the animals examined in 1980. *Boophilus decoloratus* also accounted for a higher percentage of the total tick burden on the impalas in 1982 than in 1980 ($P = 0.002$). Comparing only the two groups of impalas examined in 1982, the percentage was marginally higher on the "terminal" animals than on the apparently healthy animals ($P = 0.07$). The collections in the 1982 drought were made during the period of peak infestations of *B. decoloratus*, and followed 2 years of above average rainfall. A reduction in resistance in impalas on a low plane of nutrition and the potentially high number of questing *B. decoloratus* larvae probably contributed to the higher burdens in 1982, particularly on the "terminal" animals.

Haemaphysalis aciculifer

The preferred hosts of the adults of this tick are wild bovids, on which it seldom occurs in large numbers (Walker 1991; Horak, Keep, Spickett & Boomker 1989). The immature stages parasitize rodents and ground-nesting birds (Horak & Boomker 1998). Since 1977 one of us (I.G.H.) has examined more than 1 200 animals belonging to many species in the KNP and has collected a total of only two male *H. aciculifer* from an eland, *Taurotragus oryx*, and 15 adults from a honey badger, *Mellivora capensis* (Horak *et al.* 1983a; Horak, Braack, Fourie & Walker 2000b), the collection of 16 larvae from a single impala must be viewed as an accidental infestation with a tick that is apparently rare in the KNP.

Hyalomma truncatum

Adult *H. truncatum* prefer large ungulates, and frequently those with thick skins as hosts (Walker 1991). This tick is abundant in the KNP judging by the large numbers of its immature stages collected from scrub hares (Horak *et al.* 1993; Horak, Spickett, Braack, Penzhorn, Bagnall & Uys 1995a), and the presence of adults on giraffes, *Giraffa camelopardalis*, and Burchell's zebras (Horak *et al.* 1983a; 1984). No adults were collected from the impalas confirming that they are not good hosts of this stage of development. The recovery of larvae from a single impala examined at Skukuza is unusual because the

preferred hosts of the immature stages at this locality, and elsewhere, are scrub hares, bushveld gerbils, *Tatera leucogaster* and other rodents (Walker 1991; Horak *et al.* 1993; Braack, Horak, Jordaan, Segerman & Louw 1996).

Rhipicephalus appendiculatus

All stages of development of *R. appendiculatus* prefer the larger bovids as hosts (Yeoman & Walker 1967; Walker 1974; Norval *et al.*1982; Walker, Keirans & Horak 2000). Large numbers of adults have also been collected from lions, *Panthera leo*, in the KNP (Horak *et al.* 2000b). The immature stages are found on medium-sized and smaller antelope species, on carnivores and on hares, as well as on the larger bovids (Norval *et al.* 1982; Walker *et al.* 2000). The intensities of infestations of *R. appendiculatus* larvae and nymphs on impalas in the Biyamiti region were similar to those on greater kudus in the same area (Horak *et al.* 1992), but the intensity of infestation of *R. appendiculatus* adults was much higher on kudus.

Rhipicephalus appendiculatus larvae were present from March to October with a peak in April to June at Skukuza and in the Biyamiti region during 1980/81. Nymphs were present from March or April to December with a June to September peak, and adults were present from October to June with a February to March peak (Fig. 4). With minor differences, the seasonal patterns were similar in all locations, and were similar to those on greater kudus in the Biyamiti region (Horak *et al.* 1992) and on impalas in the Limpopo Province (Horak 1982) and in Swaziland (Gallivan & Surgeoner 1995). The seasonal patterns of *R. appendiculatus* larvae and adults were similar to their activity periods on the vegetation near Crocodile Bridge 8 to 10 years later (Spickett *et al.* 1992), but the peak activity period of the nymphs was later (August to January) on the vegetation. Although varying in intensity, *R. appendiculatus* adults were present throughout the year on the greater kudus, while their activity period appeared to be delayed on impalas in Swaziland. However, these differences, like the minor differences between locations in the present study, may reflect differences in microclimatic conditions and the spatial distributions of the hosts, two factors which influence the activity of *R. appendiculatus* (Minshull & Norval 1982).

The intensities of infestations of *R. appendiculatus* larvae and nymphs were higher in the Biyamiti region than at Skukuza during 1980/81 ($P = 0.005$ and $P < 0.001$ respectively), but the intensity of infestation of adults was higher at Skukuza ($P = 0.039$). The intensity of infestation of *R. appendiculatus* larvae was significantly higher on adult male impalas at Crocodile Bridge than at Skukuza and in the Biyamiti region ($P < 0.001$). The intensities of infestations of nymphs were higher at Crocodile Bridge and in the Biyamiti region than at Skukuza ($P = 0.008$), but the intensity of infestation of adults did not differ among the three locations ($P = 0.91$).

At Skukuza the prevalences of *R. appendiculatus* larvae, nymphs and adults on the impalas examined during 1992/93 (6.7 %, 4.4 % and 33.3 %, respectively) were significantly lower ($P = 0.02$) than in 1980/81 (48.8%, 31.7% and 61 %, respectively). Only four *R. appendiculatus* larvae and two nymphs were collected from each of the infested impala in 1992/93. The mean intensity of infestation of *R. appendiculatus* adults was also lower in 1992/93 than in 1980/81 ($P < 0.001$) and no adults were collected from June 1992 to January 1993. The reduction in 1992/93 may reflect both the lack of hosts (Horak *et al.* 1995b) and the reduced survival of all life stages of *R. appendiculatus* under dry conditions and reduced cover (Short, Floyd, Norval & Sutherst 1989).

The intensities of infestations of *R. appendiculatus* larvae and nymphs were higher at Pafuri and in the Biyamiti region than at Skukuza ($P = 0.04$ and 0.001, respectively) during July 1980. The prevalence of larvae was significantly higher at Pafuri ($P = 0.002$) in 1992/93, where larvae were collected in May and August 1992 and April 1993. Nymphs were present at Pafuri from May to October 1992 and in April 1993. The prevalence and intensity of infestation were higher at Pafuri than at Skukuza ($P = 0.022$ and $P < 0.001$ respectively). The prevalence of *R. appendiculatus* adults did not differ between the two locations ($P = 0.60$). The intensity of infestation was significantly higher ($P < 0.05$) at Skukuza in March 1992, but did not differ between the two locations in the other months. No adults were collected in October and December 1992.

The intensity of infestation of *R. appendiculatus* larvae did not differ among age classes ($P = 0.66$), but the intensities of infestations of nymphs and adults were higher on yearling and adult impalas than on lambs ($P = 0.001$). The intensity of infestation of larvae was higher on adult female impalas than on adult males ($P = 0.044$), whereas the intensity of infestation of the nymphs did not differ between the sexes ($P = 0.29$). The intensity of infestation of adults was higher on adult male impalas than on adult females ($P = 0.001$), particularly from March

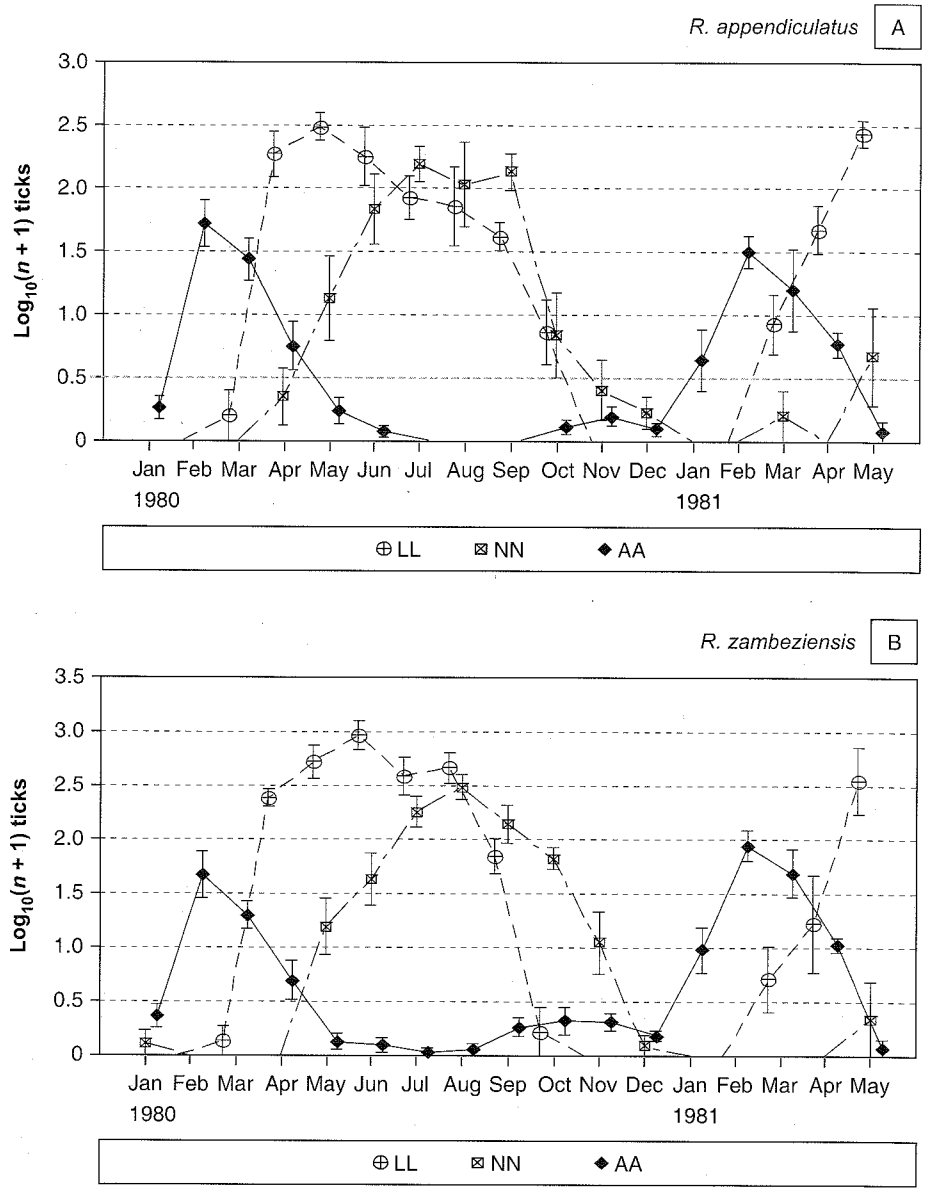

FIG. 4 Seasonal pattern of the intensity of infestation of [A] *Rhipicephalus appendiculatus* (x ± 1SE), and [B] *Rhipicephalus zambeziensis* (x ± 1SE) on impalas at Skukuza and in the Biyamiti region during 1980/81. No lambs were collected after January 1981 and no yearlings after February 1981. The monthly sample at each locality ranged from two to six or seven impalas

to May. The age/sex distribution of *R. appendiculatus* adults was similar to that reported for impalas in Swaziland (Gallivan *et al.* 1995). The low numbers of *R. appendiculatus* adults on lambs probably result from the higher allogrooming rates of lambs (Mooring & Hart 1992). Grooming would be effective in removing the adult ticks and nymphs, but possibly less so with the larvae. The peak activity of *R. appendiculatus* adults corresponds with the advent of breeding activity in impalas. Adult male impalas become less tolerant of other males several weeks prior to the rut, and territorial males do not tolerate other males (Murray 1982). This intolerance would reduce allogroomimg, and both auto- and allogrooming are reduced in territorial males (Mooring & Hart 1995), allowing an increase in the burden of adult ticks.

The intensities of infestations of *R. appendiculatus* larvae and nymphs did not differ among the two groups of impalas examined during the 1982 drought at Skukuza and those examined in 1980 (*P*

= 0.27 and 0.14, respectively), but the "terminal" impalas had a higher intensity of infestation of adults (P = 0.03) than the apparently healthy impalas in 1982 and the impalas examined in 1980.

Rhipicephalus evertsi evertsi

All stages of development of this two-host tick prefer equids and elands as hosts (Norval 1981). However, a large variety of herbivorous domestic and wild animals, including leporids, can serve as hosts for the immature stages (Walker *et al.* 2000). In 1980/81, 96.4 % of the impalas were infested with the immature stages of *R. evertsi evertsi*, and 64 % were infested with adults. The intensity of infestation of the immature stages was higher on impalas than on kudus in the Biyamiti region, but the intensity of infestation of adults was higher on kudus (Horak *et al.* 1992).

Horak (1982) reported a larvae to nymph ratio of 2.5:1.0 on impalas in the Limpopo Province, and Colborne (1989) reported a larvae to nymph ratio of 2.0:1.0 on impalas in south-eastern Zimbabwe. Colborne (1989) considered impalas to be good hosts of the immature stages of *R. evertsi evertsi* because of the high translation from one developmental stage to the next. These larvae to nymph ratios were similar to that on Burchell's zebras in the KNP (2.3:1.0), but higher than on Cape mountain zebras, *Equus zebra zebra*, in the Mountain Zebra National Park, Eastern Cape Province (1.3:1.0) (Horak *et al.* 1984; Horak, Knight & De Vos 1986a). Both these equid species are considered to be the preferred hosts of all stages of development of this tick (Walker *et al.* 2000). Excluding the impalas examined at Pafuri during July 1980, the ratio of *R. evertsi evertsi* larvae to nymphs on impalas in the KNP ranged from 4.1:1.0 to 8.4:1.0 (Tables 3–8, 10). The ratio on impalas in the Biyamiti region (6.9:1.0) was lower than the ratio of 9.6:1.0 on greater kudus (Horak *et al.* 1992), but still represents a poor translation from one developmental stage to the next, particularly as the moult takes place on the host.

The ratio of *R. evertsi evertsi* larvae to nymphs on impalas in the KNP was correlated with the intensity of infestation of *R. evertsi evertsi* larvae (r = 0.72; P = 0.066) and the total tick burden (r = 0.90; P = 0.005). Inclusion of the data from impalas in the Limpopo Province (Horak 1982) reduced the correlation between the larvae to nymph ratio and intensity of infestation of the larvae (r = 0.55; P = 0.16), but did not change the correlation between the larvae to nymph ratio and total tick burden (r = 0.91; P = 0.002). Rechav and co-workers (Clarke, Els, Heller-Haupt, Rechav & Varma 1989; Rechav, Dauth, Varma, Clarke, Els, Heller-Haupt & Dreyer 1989) have demonstrated an increase in serum globulin in the hosts and a reduction in the recovery and body weight of *R. evertsi evertsi* nymphs following successive challenges with larvae on guinea pigs and rabbits, suggesting that hosts develop immunity. However, there was a weak correlation between the intensity of infestation of *R. evertsi evertsi* larvae and the larvae to nymph ratio on impalas. Cross-resistance between tick species may explain the correlation between total tick burden and the ratio of *R. evertsi evertsi* larvae to nymphs on impalas. Cross-resistance has been demonstrated in laboratory and domestic animals, but a considerable variation in the degree of this resistance was reported in the studies (De Castro, Newsom & Herbert 1989).

During 1980/81 the intensity of infestation of the immature stages of *R. evertsi evertsi* at Skukuza and in the Biyamiti region varied significantly among months (P = 0.003). The lowest intensities of infestation were in January 1980 and 1981 (Fig. 5), and the highest intensities were in April and September 1980 and May 1981. However, there was considerable month-to-month variation throughout the remainder of the year, and the patterns were not consistent between the two locations. There was no seasonal pattern on adult male impalas at Crocodile Bridge, or on greater kudus in the Biyamiti region (Horak *et al.* 1992). On yearling male impalas at Skukuza in 1992/93, the lowest intensities were in April 1992 and February and March 1993, and the highest in May and October and November 1992. The prevalence of *R. evertsi evertsi* adults on impalas at Skukuza and in the Biyamiti region during 1980/81 was 100 % in April and May 1980, but did not differ significantly among months (P = 0.10). The intensity of infestation of adults was significantly higher in April 1980, but did not differ among the other months. There was no seasonal pattern in the infestation of *R. evertsi evertsi* adults on adult male impalas at Crocodile Bridge, on the yearling male impalas at Skukuza in 1992/92, or on greater kudus in the Biyamiti region.

Based on developmental periods obtained in the laboratory (Rechav, Knight & Norval 1977), *R. evertsi evertsi* can complete more than one life cycle per year at the temperatures prevailing in the KNP. There was no seasonal pattern for *R. evertsi evertsi* larvae questing on vegetation in the south of the KNP (Spickett *et al.* 1992), and the month-to-month variability in the number of questing larvae was

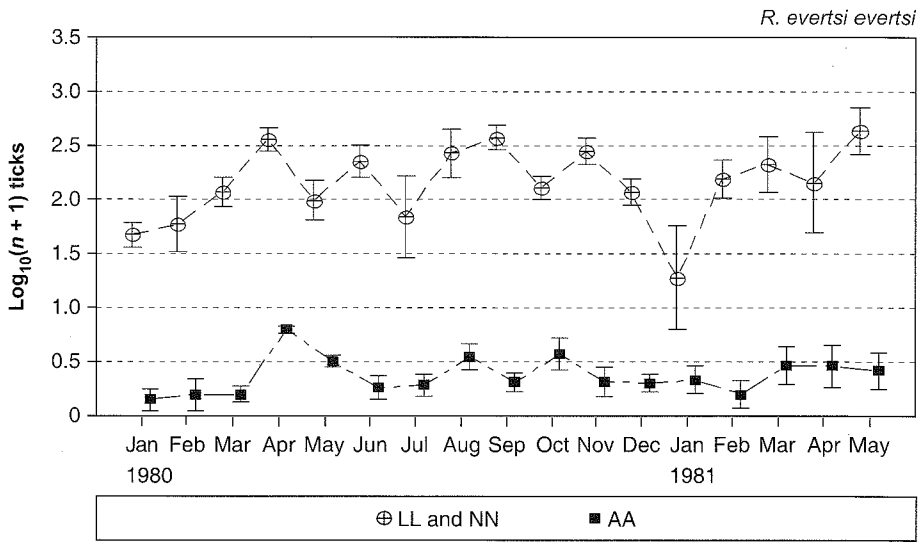

FIG. 5 Seasonal pattern of the intensity of infestation of *Rhipicephalus evertsi evertsi* (x ± 1SE) on impalas at Skukuza and in the Biyamiti region during 1980/81. No lambs were collected after January 1981 and no yearlings after February 1981. The monthly sample at each locality ranged from two to six or seven impalas

similar to the variability on impalas and kudus. The apparent peaks on impalas also differ from those on Burchell's zebras (Horak *et al.* 1984), one of the preferred hosts in the KNP. Based on the lack of a seasonal pattern and month-to-month variability in the number of questing larvae, the apparent seasonal patterns in the intensity of infestation of *R. evertsi evertsi* on impalas may simply reflect differences in the number of questing larvae and differences in the intensity of infestations among hosts.

The intensity of infestation of the immature stages of *R. evertsi evertsi* was higher in the Biyamiti region than at Skukuza in 1980/81 ($P < 0.001$), particularly during July and August, and was higher in the Biyamiti region than at Crocodile Bridge on adult male impalas ($P < 0.05$). The intensity of infestation was lowest at Pafuri in July 1980, but did not differ significantly among the three locations ($P = 0.09$). The prevalence and intensity of infestation of *R. evertsi evertsi* adults did not differ among the locations in 1980/81 ($P \leq 0.15$).

At Skukuza, the prevalences and intensities of infestations of the immature stages and adults of *R. evertsi evertsi* were significantly lower in 1992/93 than in 1980/81 ($P < 0.002$). The prevalence of the immature stages was higher ($P = 0.05$) on the yearling male impalas examined at Pafuri during 1992/93 (95.3 %) than on those at Skukuza (71 %). The intensity of infestation of the immature stages was also higher at Pafuri ($P = 0.022$), but the difference between the two locations was only significant in August 1992. The prevalence and intensity of infestation of adults did not differ significantly between the two locations 1992/93 ($P \geq 34$).

The intensity of infestation of the immature stages did not differ significantly among the age classes ($P = 0.42$), or between sexes of the adult impalas ($P = 0.72$). The prevalence of *R. evertsi evertsi* adults on adult impalas (76.5 %) was significantly higher ($P = 0.04$) than on lambs (50 %) and yearlings (56 %), and the intensity of infestation was significantly higher on adults than on lambs ($P = 0.013$). The prevalence and intensity of infestation with adult ticks did not differ between the sexes in adult animals ($P = 0.15$). These patterns are similar to those in Swaziland where the prevalence of *R. evertsi evertsi* nymphs did not differ among the age classes, the prevalence of adults was higher on adult and yearling impalas than on lambs, and the prevalence of adults did not differ between the sexes on adult impalas (Gallivan *et al.* 1995).

The intensity of infestation of the immature stages of *R. evertsi evertsi* did not differ significantly among the "terminal" impalas and the apparently healthy impalas in the 1982 drought at Skukuza and the impalas in 1980 ($P = 0.43$). The intenstity of infestation of adults was significantly higher on the "terminal" impalas than on the apparently healthy animals in 1982 ($P = 0.05$), but did not differ from the impalas examined in 1980 ($P > 0.20$).

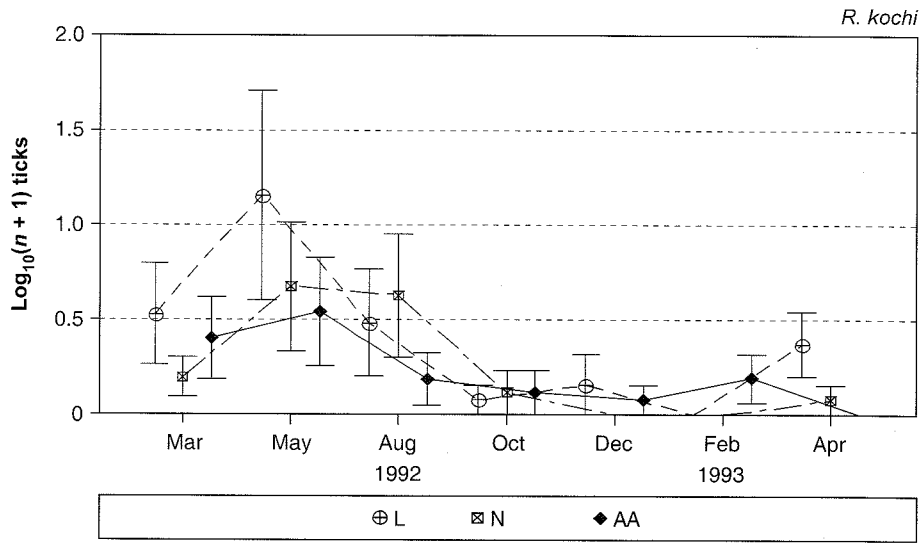

FIG. 6 Seasonal pattern of the intensity of infestation of *Rhipicephalus kochi* (x ± 1SE) on yearling male impalas at Pafuri during 1992/93. Three impalas were examined at 2–3 month intervals

Rhipicephalus kochi

Rhipicephalus kochi was only collected from impalas examined at Pafuri, and in South Africa it has been collected only in the far north-east of the Limpopo Province and of KwaZulu-Natal Province (Walker *et al.* 2000). The preferred hosts of all stages of development are medium-sized and larger antelopes and scrub hares (Walker *et al.* 2000). The prevalence and intensities of infestation of *R. kochi* larvae and nymphs were significantly higher ($P < 0.05$) from March to August 1992 than from October 1992 to February 1993 (Fig. 6). The prevalence and intensity of infestation of adults appeared to decline from March 1992 to April 1993.

Rhipicephalus pravus group

The presence on a single impala of the larvae of a *Rhipicephalus pravus*-like tick that parasitizes scrub hares in the north of the KNP (Horak *et al.* 1993) represents an accidental infestation. This tick has been described by Walker *et al.* (2000) as belonging to a *Rhipicephalus* sp. near *R. pravus*.

Rhipicephalus simus

The adults of *R. simus* prefer equids, suids, large carnivores and large ruminants as hosts, and the immature stages prefer murid rodents (Norval & Mason 1981; Braack *et al.* 1996; Walker *et al.* 2000). The collection of only one male tick each from two impalas in regions where adults are plentiful on Burchell's zebras, warthogs and large carnivores (Horak *et al.* 1984; 1988b; 2000b), supports the view that impalas are not suitable hosts. The 16 larvae collected from a single impala at Skukuza, where the majority of red veld rats, *Aethomys chrysophilus*, are infested with the immature stages of *R. simus* (Braack *et al.* 1996), also represent an accidental infestation.

Rhipicephalus zambeziensis

The preferred hosts of all stages of development of *R. zambeziensis* are domestic and wild ruminants (Norval *et al.* 1982; Walker *et al.* 2000). Numerous adults have also been collected from lions and leopards, *Panthera pardus* (Horak *et al.* 2000b). The intensities of infestations of *R. zambeziensis* larvae and nymphs on impalas in the Biyamiti region were similar to those on greater kudus (Horak *et al.* 1992), but the intensity of infestation of adults was higher on kudus, similar to the pattern for *R. appendiculatus*.

The marked seasonal changes ($P < 0.001$) in the prevalences and intensities of infestations of all stages of *R. zambeziensis* were similar to those for *R. appendiculatus*. At Skukuza and in the Biyamiti region during 1980/81, *R. zambeziensis* larvae were present from March to October with a peak from April to August, nymphs were present from May to December with a July to October peak, and adults were present in all months except July 1980, with a

February to March peak (Fig. 4). With minor differences, the seasonal patterns were similar in all locations, and were similar to those on greater kudus in the Biyamiti region (Horak *et al.* 1992)

During 1980/81, the intensities of infestations of all three stages of *R. zambeziensis* were significantly higher at Skukuza than in the Biyamiti region ($P < 0.007$) and at Crocodile Bridge ($P < 0.05$). The intensity of infestation of larvae was also significantly higher at Skukuza and Biyamiti than at Pafuri in July 1980 ($P = 0.003$), but no nymphs or adults were collected at Pafuri at this time. The intensities of infestations of all three stages were significantly higher at Skukuza than at Pafuri in 1992/93 ($P = 0.001$), particularly during the peak periods.

In South Africa *R. zambeziensis* occurs in north-eastern Mpumalanga Province, in Limpopo Province and in the north-western regions of North West Province (Walker *et al.* 2000), and its distribution overlaps that of *R. appendiculatus* in the KNP. It is the more common species at Skukuza, whereas *R. appendiculatus* is more common at Crocodile Bridge and Pafuri. In Zimbabwe *R. zambeziensis* occurs in the lower, drier regions with mean annual rainfall of 400–700 mm, and *R. appendiculatus* is found in the higher, wetter regions with 500–2 000 mm mean annual rainfall. There is an overlap of the two species in the regions with 500–700 mm rainfall (Norval *et al.* 1982). The locations where impalas were collected in the KNP receive an average of 500–700 mm of rainfall, but the ratios of *R. zambeziensis* to *R. appendiculatus* were not consistent with the rainfall between locations. Not only was *R. appendiculatus* more common at Crocodile Bridge, which receives more rainfall than Skukuza, but also at Pafuri which receives less (Gertenbach 1980). Thus other factors such as local microclimatic conditions and habitats may influence the apparent abundance of the two species.

At Skukuza the prevalences of *R. zambeziensis* larvae and nymphs did not differ significantly between 1980/81 and 1992/93 ($P \geq 0.4$), but the intensities of infestations of both stages were significantly higher ($P \leq 0.001$) in 1980/81 than in 1992/93. There was a significant month x year interaction for both stages ($P \leq 0.035$) caused by the lower peak intensities of infestation in 1992/93. There was no difference in the prevalence or intensity of infestation of adults between years ($P \geq 0.54$), but there was a significant month x year interaction ($P < 0.001$) as the intensity of infestation was higher from March to May 1992 than from March to May 1980, and higher from January to March 1981 than from January to March 1993. The lower intensities of infestations of *R. zambeziensis* larvae and nymphs in 1992/93 and the lower intensity of infestation of adults in 1993 probably reflect the influence of the 1992 drought on the free-living stages. However, the relative decrease was much less than the decrease in the numbers of *R. appendiculatus*, which exhibited marked decreases in the prevalences and intensities of infestation of all developmental stages. This is consistent with the greater sensitivity of *R. appendiculatus* to dry conditions.

The age/sex distribution of *R. zambeziensis* was similar to that of *R. appendiculatus*. In 1980/81 the prevalences and intensities of infestations of *R. zambeziensis* larvae and nymphs did not differ among the age classes ($P = 0.79$). The prevalence of adults did not differ among the age classes ($P = 0.55$), but the intensities of infestations were higher on yearlings and adults than on lambs ($P < 0.001$), particularly during the peak periods. The prevalence of the three life stages of *R. zambeziensis* did not differ on adult male and female impalas ($P = 0.26$), but the intensity of infestation of larvae was higher on adult female impalas than on adult males ($P = 0.005$), particularly during March and April 1981. The intensity of infestation of adults was higher on adult male impalas ($P = 0.029$), particularly during April and May. Combining the burdens of adult *R. zambeziensis* and *R. appendiculatus*, adult male impalas were more heavily infested than adult females ($P = 0.01$), with the largest differences from March to May. The prevalence and intensity of infestation of adult *R. zambeziensis* and *R. appendiculatus* combined was similar at Skukuza, Biyamiti and Crocodile Bridge ($P = 0.45$).

The intensities of infestations of *R. zambeziensis* larvae and adults were significantly higher ($P < 0.001$ and $P = 0.03$ respectively) on the "terminal" impalas at Skukuza in the 1982 drought than on the apparently healthy impalas killed at the same time or on the impalas examined in 1980. The intensity of infestation of nymphs did not differ between the three groups. When the burdens of adult *R. appendiculatus* and *R. zambeziensis* were combined, the prevalence was higher ($P = 0.004$) on the impalas examined in 1980 (93 %) and on the "terminal" impalas in 1982 (90 %) than on the apparently healthy animals in 1982 (43 %). However, the intensity of infestation of the adult ticks was higher on the "terminal" impalas in 1982 than on those examined in 1980 or on the apparently healthy impalas killed in 1982 ($P = 0.01$).

LICE

Total louse burdens

The impalas were infested with five louse species, one of which, a *Linognathus* sp., has not been described. The four described species are regularly collected from impalas (Ledger 1973; 1980; Horak 1982; Horak *et al.* 1983c; Matthee *et al.* 1998). The dominant species differed among areas in the KNP, with *Damalinia elongata* the most numerous at Skukuza, *Linognathus aepycerus* the most numerous at Pafuri, *D. elongata* and *L. aepycerus* the primary species at Crocodile Bridge, and *L. aepycerus* and *Linognathus nevilli* the most common species in the Biyamiti region (Table 2).

The highest total louse burdens were recorded in the late winter/early spring (August to October) (P = 0.026–0.17) and the lowest burdens in the summer (December to February) (Fig. 7). The seasonal patterns were the result of seasonal changes in the intensities of infestations of *Damalinia aepycerus* and *Linognathus aepycerus* (see below), and the decline in the summer is possibly related to the higher temperatures during this period. The seasonal pattern conforms to that observed in other studies of lice infesting impalas and other antelopes (Horak *et al.* 1983b; Horak, Sheppey, Knight & Beuthin 1986b; Matthee *et al.* 1998).

The total lice burdens were significantly higher at Skukuza than in the Biyamiti region (P = 0.001) in 1980/81. On adult males, the prevalence of lice at Skukuza (100 %) was significantly higher (P = 0.031) than in the Biyamiti region (77 %) and at Crocodile Bridge (58 %), and the total louse burden was higher at Skukuza than in the Biyamiti region and at Crocodile Bridge (P = 0.06). The total louse burdens were significantly higher at Skukuza during 1980/81 than during 1992/93 (P < 0.001) (Table 11), but did not differ significantly between Skukuza and Pafuri during the latter period (P = 0.46).

Lice tend to be parasites of young animals (Horak *et al.* 1983b; 1986b), and the total burdens were significantly higher on lambs and yearlings than on adult impalas (P = 0.002). Most louse species were present on lambs within a month of birth suggesting that they were passed from the dam. The burdens on adult impalas were higher on females than on males, but the differences were not statistically significant (P = 0.17).

The "terminal" impalas in 1982 had significantly higher total louse burdens than the apparently healthy impalas and those killed in 1980 (P = 0.03) (Table 11). The "terminal" impalas were obviously stressed and this probably lowered their resistance to lice, allowing effective and rapid translation from one developmental stage to the next. In addition, they probably lacked the energy to groom properly or conserved energy by reducing their grooming rate, thus allowing sustained levels of infestation.

Damalinia aepycerus

Damalinia aepycerus was collected at all locations in the KNP, and although it was the most numerous species on impalas in the Nylsvley Nature Reserve, Limpopo Province (Horak 1982), it was never so in the KNP. The preferred biotopes of *D. aepycerus* are the body and tail, with 60.4 % of the population present in the former and 36.0 % in the latter site (Matthee *et al.* 1998).

The intensity of infestation of *D. aepycerus* was significantly higher at Skukuza than in the Biyamiti region and at Crocodile Bridge in 1980/81 (P < 0.03). At Skukuza, the intensity of infestation did not differ significantly between 1980/81 and 1992/93 (P > 0.17), nor did the intensity of infestation differ significantly between Skukuza and Pafuri during 1992/93 (P = 0.34). In 1980/81 there were two apparent peaks in the intensity of infestation (Fig. 7), one in April or March caused by high infestations on lambs and yearlings, and a more generalized peak in the late winter/spring (August to October). However, in 1992/93 the peak infestations occurred from March to May 1992 and the intensity of infestation declined through 1993. There was no clear seasonal pattern in the intensity of infestation on impalas in the Nylsvley Nature Reserve (Horak 1982), while Matthee *et al.* (1998) reported the highest intensities of infestation in February and July on impala ewes examined on Letaba Ranch, Limpopo Province during February, July and October.

The intensity of infestation of *D. aepycerus* was higher on lambs and yearlings than on adult impalas (P = 0.065). Infestation of lambs occurred within a month after birth. The prevalence and intensity of infestation on adult impalas did not differ significantly between sexes (P = 0.12). The prevalence and intensity of infestation did not differ among the three groups of impalas at Skukuza compared for the effects of the 1982 drought (P = 0.18 and 0.81 respectively). The prevalence of adult lice was higher on the "terminal" and apparently healthy impalas in the 1982 drought (100 % and 90 % respectively) than on those examined in

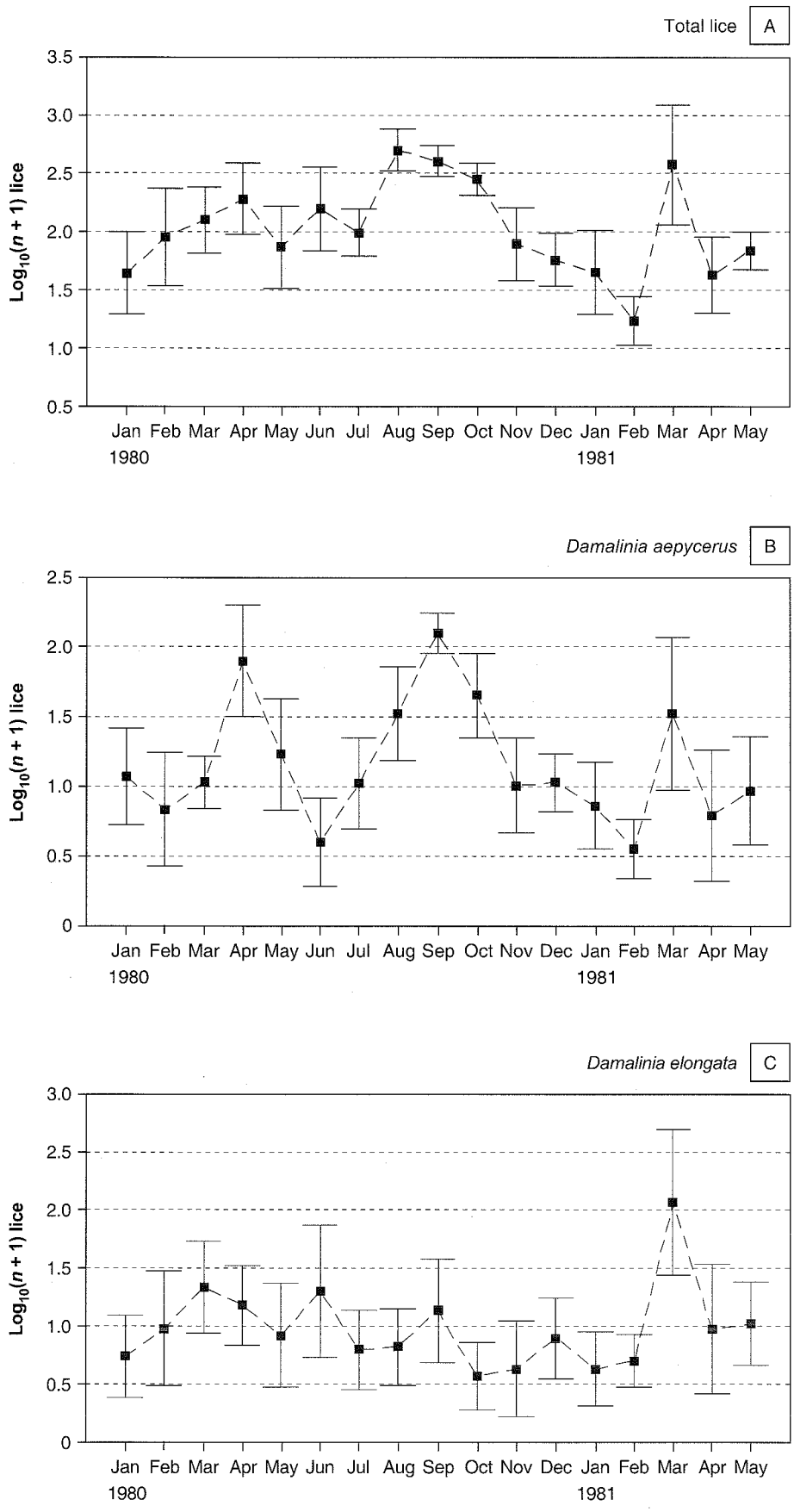

FIG. 7

Seasonal pattern of the intensity of infestation of [A] the total lice burden (x ± 1SE), [B] *Damalinia aepyceus* (x ± 1SE), and [C] *Damalinia elongata* (x ± 1SE) on impalas at Skukuza and in the Biyamiti region during 1980/81. No lambs were collected after January 1981 and no yearlings after February 1981. The monthly sample at each locality ranged from two to six or seven impalas

1980 (57 %), but the intensity of infestation did not differ among the three groups ($P = 0.13$).

Damalinia elongata

Damalinia elongata was the most numerous louse species on impalas at Skukuza in 1980/81 and 1992/93, and accounted for much of the higher louse burden at this locality in 1980/81. The prevalence and intensity of infestation were significantly higher ($P > 0.014$) at Skukuza than in the Biyamiti region in 1980/81. Although the intensity of infestation was higher on adult male impalas at Skukuza than at Crocodile Bridge, the difference was not statistically significant ($P > 0.1$). The prevalence of *D. elongata* at Skukuza did not differ significantly between 1980/81 and 1992/93 ($P > 0.25$), but the intensity of infestation was significantly higher in 1980/81 than in 1992/93 ($P = 0.004$). The intensity of infestation was similar at Skukuza and Pafuri in July 1980, but only two adult *D. elongata* were collected at Pafuri in 1992/93.

There was no seasonal pattern in the prevalence or intensity of infestation of *D. elongata* (Fig. 7). Lambs were infested by 2 months of age. The intensity of infestation was higher on yearlings than on adult impalas ($P = 0.044$), with the most pronounced differences at Skukuza. The prevalence and intensity of infestation on adult impalas did not differ significantly between sexes ($P > 0.31$). At Skukuza, the prevalence and intensity of infestation did not differ among the three groups of animals compared to assess the effect of the 1982 drought ($P = 0.46$). The intensity of infestation appears to be much higher on the "terminal" impalas, but one individual accounted for > 91 % of the total burden, and only four of ten "terminal" animals were infested.

Linognathus aepycerus

Even though the greatest numbers of *L. aepycerus* were collected from the body, this louse appears to be spread fairly evenly over the whole skin surface if the much larger surface area of the body, as opposed to those of the head, neck, legs and tail is taken into account (Matthee *et al.* 1998). It was the most common louse at Pafuri, and was also common in the Biyamiti region and at Crocodile Bridge. The prevalence of *L. aepycerus* on adult male impalas did not differ between Skukuza, the Biyamiti region and Crocodile Bridge in 1980/81 ($P > 0.3$), but the intensity of infestation was marginally higher at Skukuza than in the Biyamiti region ($P = 0.078$). At Skukuza the prevalence of *L. aepycerus* did not differ significantly between 1980/81 and 1992/93 ($P > 0.58$), but the intensity of infestation was higher in 1980/81 than in 1992/93 ($P = 0.02$). The prevalence of infestation (100 % and 87.5 % respectively) did not differ significantly ($P = 0.12$) between Pafuri and Skukuza in 1992/93, but its intensity was significantly higher at Pafuri than at Skukuza ($P < 0.02$).

There was a strong seasonal pattern in both the prevalence and intensity of infestation ($P < 0.02$) of *L. aepycerus* at Skukuza and in the Biyamiti region during 1980/81, with the highest prevalence and intensity of infestation from July to October (Fig. 8). The intensity of infestation was similar in the two areas from July to October, but tended to be higher at Skukuza in the other months. The seasonal pattern was similar at Skukuza in 1980/81 and 1992/93, but there was a significant month x location interaction between Skukuza and Pafuri in 1992/93. The intensity of infestation at Pafuri declined from March 1992 to February 1993, with only a slight increase in October 1992, whereas the pattern at Skukuza was similar to that in Fig. 11. Matthee *et al.* (1998) recorded the highest intensity of infestation with *L. aepycerus* during October on Letaba Ranch, but there was no clear seasonal pattern on impalas in the Nylsvley Nature Reserve (Horak 1982).

Lambs were infested with *L. aepycerus* within the first month after birth, and the prevalence and intensity of infestation were significantly higher on lambs than on adult impalas ($P \leq 0.004$). The prevalence and intensity of infestation on adult animals did not differ significantly between the sexes ($P > 0.16$). The prevalence and intensity of infestation of *L. aepycerus* were higher on impalas in the 1982 drought than on the animals examined in 1980 ($P \leq 0.04$), but did not differ ($P > 0.1$) between the "terminal" and the apparently healthy animals in 1982.

Linognathus nevilli

Linognathus nevilli was originally collected and described from around the feet of impalas (Ledger 1973), and is most commonly found on the feet and hind legs (Matthee *et al.* 1998). Small numbers may also be present on the head, neck and body, possibly transferred there when these regions are scratch-groomed with the hind feet, an action illustrated by Mooring (1995).

The prevalence and intensity of infestation of *L. nevilli* did not differ between Skukuza, the Biyamiti region and Crocodile Bridge in 1980/81 ($P > 0.3$). At Skukuza, the prevalence was marginally higher

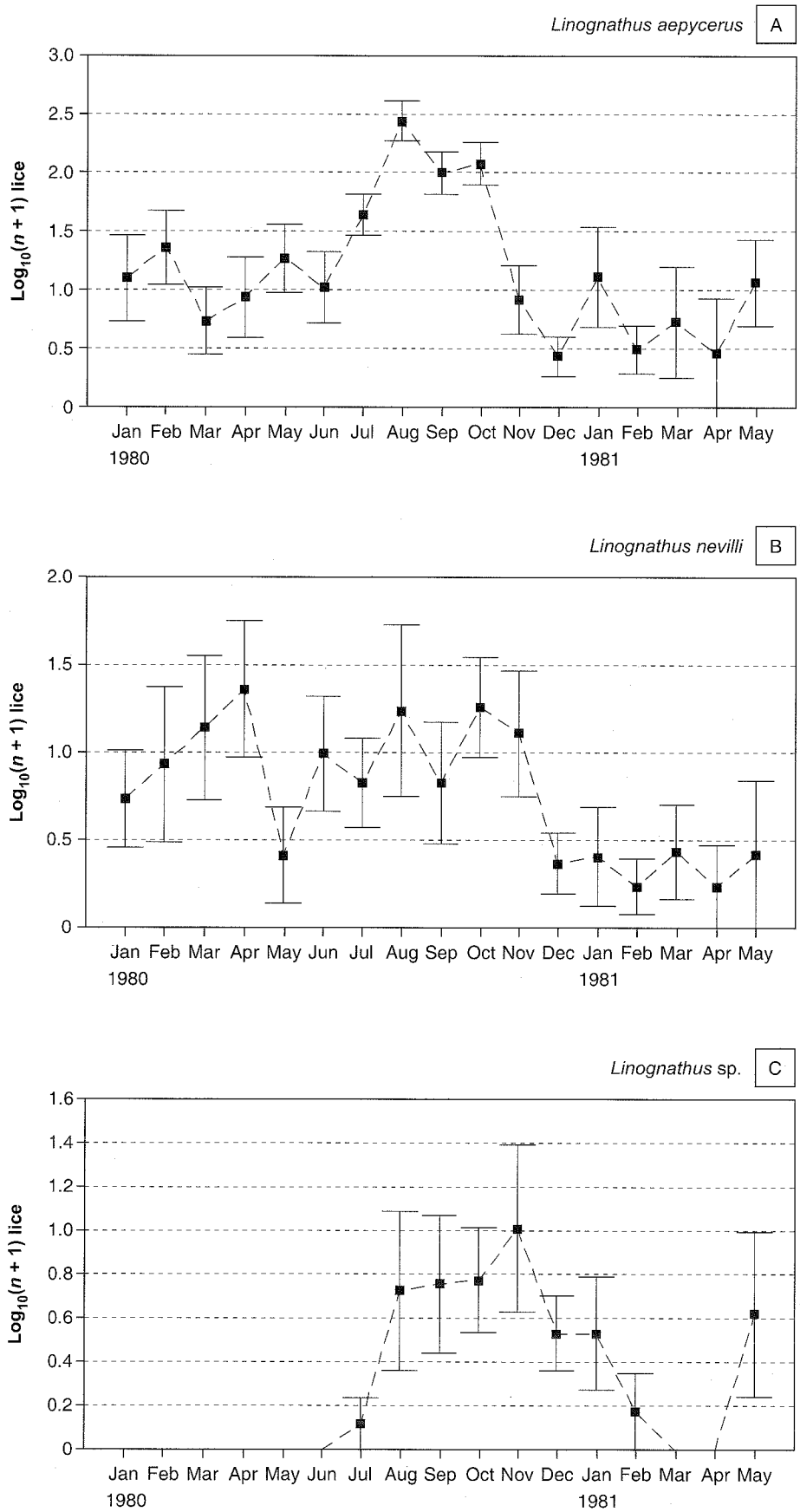

FIG. 8

Seasonal pattern of the intensity of infestation of [A] *Linognathus aepycerus* (x ± 1SE), [B] *Linognathus nevilli* (x ± 1SE), and [C] *Linognathus* sp. (x ± 1SE) on impalas at Skukuza and in the Biyamiti region during 1980/81. No lambs were collected after January 1981 and no yearlings after February 1981. The monthly sample at each locality ranged from two to six or seven impalas

($P = 0.09$) and the mean intensity of infestation was significantly higher ($P < 0.001$) in 1980/81 than in 1992/93. The prevalence did not differ significantly between Pafuri and Skukuza ($P = 0.15$), but the intensity of infestation was significantly higher at Pafuri ($P = 0.023$).

Although there were two apparent peaks, one in the late summer and early autumn, and another in the late winter and spring, there was no clear seasonal pattern in the intensity of infestation of *L. nevilli* at Skukuza and in the Biyamiti region during 1980/81 (Fig. 8). The seasonal patterns at Skukuza were statistically significant ($P = 0.008$) in the comparison of 1980/81 and 1992/93, and were more pronounced in 1980/81. No seasonal pattern was evident in the comparison of Skukuza and Pafuri in 1992/93 ($P = 0.41$). The prevalence of *L. nevilli* was significantly higher ($P < 0.001$) on lambs (81 %) and yearlings (68 %) than on adult impalas (37 %), and the intensity of infestation was significantly higher on lambs than on yearlings ($P < 0.05$), and higher on yearlings than on adult impalas ($P < 0.01$). No *L. nevilli* were collected from lambs until they were a month old. The prevalence and intensity of infestation of *L. nevilli* were significantly higher on adult female impalas than on adult males ($P \leq 0.006$).

Although the prevalence and intensity of infestation of nymphs were higher on the "terminal" impalas than on the apparently healthy animals in 1982 ($P = 0.05$ and 0.09, respectively), the prevalence and intensity of infestation of *L. nevilli* did not differ significantly between the three groups of animals ($P = 0.21$).

Linognathus sp.

Although this louse accounted for only a small percentage of the lice collected, it was common, with an overall prevalence of 27.4 %. The prevalence and intensity of infestation did not differ between Skukuza and the Biyamiti region in 1980/81, or between Skukuza and Pafuri in 1992/93 ($P = 0.35$). At Skukuza the prevalence did not differ between 1980/81 and 1992/93 ($P = 0.74$) but the intensity of infestation was higher in 1980/81 than in 1992/93 ($P = 0.01$). The prevalence was considerably lower ($P = 0.004$) on adult male impalas (9 %) than on adult females (39 %), and none were collected from the adult males at Crocodile Bridge.

The intensity of infestation of *Linognathus* sp. peaked in late winter to early summer (Fig. 8). None were collected at Skukuza or in the Biyamiti region from January to June 1980, but they were present during some of these months in 1981 and 1992/93. The1992/93 peak at Skukuza occurred in September and was of shorter duration than the peak in 1980/81. The prevalence of *Linognathus* sp. did not differ among age classes ($P = 0.44$), but the intensity of infestation was higher on lambs than on yearlings and adults ($P = 0.01$). Infestation of the lambs took place within the first month after birth. The prevalence and intensity of infestation did not differ among the "terminal" and apparently healthy impalas examined during the 1982 drought and those examined in 1980 ($P = 0.49$).

FLIES

The impalas were infested with the hippoboscid flies *Hippobosca fulva* and *Lipoptena paradoxa*.

Hippobosca fulva

According to Haeselbarth *et al.* (1966) the main hosts of *H. fulva* are probably small antelopes such as steenbok, *Raphicerus campestris*, common duikers, *Sylvicapra grimmia*, and Kirk's dik-diks, *Madoqua kirkii*, with impalas also being infested. However, we have not collected this fly from steenbok or common duikers in South Africa (I.G.H. unpublished observations 1999), and although they were collected from impalas in Swaziland, none were collected from common duikers (Gallivan & Surgeoner 1995).

The *H. fulva* collected in the current surveys do not represent the actual numbers infesting impalas in the KNP. Large numbers of these flies are visible on the white underside and perineum of impalas, where they are frequently mistaken for ticks. However, when the impalas were shot, many of them took flight and only those still present in the haircoat were collected when the carcasses were processed for tick recovery.

The prevalence and intensity of infestation of *H. fulva* were significantly higher ($P = 0.003$) on impalas in the Biyamiti region than at Skukuza during 1980/81. On adult males the prevalence was higher ($P = 0.05$) in the Biyamiti region (62 %) than at Skukuza (29 %) and Crocodile Bridge (17 %), but the intensity of infestation did not differ significantly among the three locations ($P = 0.10$). The prevalence and intensity of infestation of *H. fulva* were significantly lower (P 0.001) in spring and mid-summer than in autumn and winter (Fig. 9) on the impalas at Skukuza and in the Biyamiti region during 1980/81. The seasonal pattern in the intensity

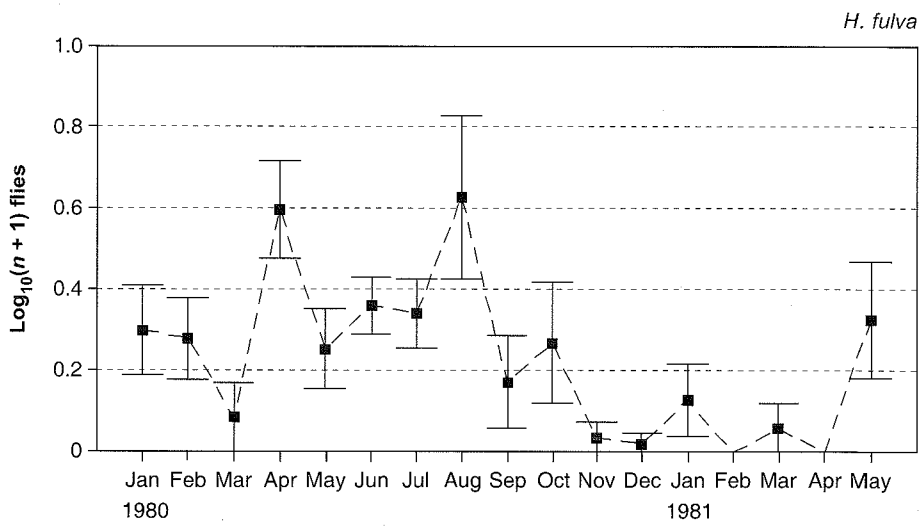

FIG. 9 Seasonal pattern of the intensity of infestation of *Hippobosca fulva* (x ± 1SE) on impalas at Skukuza and in the Biyamiti region during 1980/81. No lambs were collected after January 1981 and no yearlings after February 1981. The monthly sample at each locality ranged from two to six or seven impalas

of infestation of *H. fulva* on impalas at these localities during 1980/81 was almost the exact opposite to that noted for *L. paradoxa* on greater kudus in the Biyamiti region (Visagie, Horak & Boomker 1992). These different seasonal patterns could reflect differences in the months during which the majority of flies of the two species emerge from pupae, or differences in seasonal habitat usage by the two host species.

The prevalence and intensity of infestation of *H. fulva* did not differ among age classes ($P > 0.43$), or between the sexes of adult impalas ($P > 0.26$). Prevalence did not differ among the groups of impalas examined during the drought of 1982 and the group examined during 1980 at Skukuza ($P = 0.44$), it was, however, low during the months in which these animals were examined.

Lipoptena paradoxa

Lipoptena paradoxa is common on nyalas, bushbuck and greater kudus, and is also frequently encountered on common duikers (Visagie *et al.* 1992). All these antelopes utilize woodland habitats (Skinner & Smithers 1990). Once the fly has found a host its wings break off and it becomes a permanent parasite. Only five impalas examined during 1980/81 were infested with *L. paradoxa*, one in the Biyamiti region and four at Skukuza, and no flies were collected from adult male animals at Crocodile Bridge. Its presence on impalas must be regarded as coincidental as they frequently share woodland habitats with greater kudus.

General discussion

This paper summarises the results of several collections of arthropod parasites of impalas made over a 13-year period in the KNP. Despite differences in the age and sex composition of the animals in the surveys, we were able to examine the effects of location, season, age, sex, and two droughts. The seasonal patterns for each species of tick and louse are discussed above. The remaining factors are summarized below.

There were several differences in the ixodid tick species among locations. *Boophilus decoloratus* was most common in the Biyamiti region, while *A. hebraeum* larvae and nymphs were most common at Skukuza and Crocodile Bridge, *A. marmoreum* larvae at Skukuza, *R. evertsi evertsi* in the Biyamiti region and at Pafuri, and *R. zambeziensis* at Skukuza. *Rhipicephalus appendiculatus* larvae and nymphs were more common in the Biyamiti region and at Crocodile Bridge and Pafuri than at Skukuza, but *R. appendiculatus* adults were most common at Skukuza. [Several of the adult ticks collected from impalas at Skukuza, and identified as *R. appendiculatus*, could actually have been *R. zambeziensis* because of the difficulty of distinguishing between these species in the adult stage (Walker *et al.* 2000)]. Rainfall and temperature are important factors determining the distribution and abundance of tick species. However, the apparent abundance of tick species was not consistent with the rainfall and temperature patterns within the KNP. Part of this inconsistency may be caused by differential

habitat use within heterogenous landscape types where differences in microclimates create marked differences in tick challenge (Minshull & Norval 1982). The presence of preferred or alternate hosts may also be a factor. The higher intensity of infestation of *R. appendiculatus* adults at Skukuza differs from the patterns in the intensities of infestation of the larvae and nymphs. This may, however, be due to the difficulty experienced in specifically identifying the adults as discussed above. Impalas appear to be good hosts for the immature stages of *R. appendiculatus* but poor hosts for the adults. However, in Swaziland where impalas were the most numerous ungulate species and there were few large ungulates, they were important hosts of *R. appendiculatus* adults (Gallivan & Surgeoner 1995).

The intensities of infestation of the lice *D. aepycerus* and *D. elongata* were higher at Skukuza than in the Biyamiti region and at Crocodile Bridge, while *L. aepycerus* and *L. nevilli* were more common at Pafuri. These differences in the louse populations are not easily explained, but may be due to climatic differences, or differences in the age composition of the impala populations. At Pafuri impalas tend to become older than elsewhere in the KNP because of a lower density of lions, and very old animals in this region are often unable to groom effectively because their dental grooming apparatus has become worn down (McKenzie 1990).

It is often assumed that young animals are the most prone to infestation, but the total tick burdens, and the burdens of *B. decoloratus* and *B. decoloratus* adults, *A. hebraeum* nymphs and adults, *R. appendiculatus* nymphs and adults, *R. zambeziensis* nymphs and adults, and *R. evertsi evertsi* adults were higher on yearling and adult impalas than on lambs. In contrast, with the exception of *D. elongata*, the intensity of infestation of lice was higher on lambs. The lower burdens of *B. decoloratus* on lambs were caused by a low intensity of infestation on newborn lambs in December, and the low intensity of infestation of larvae indicates that these lambs had not yet been exposed. With the exception of *B. decoloratus*, the differences among age classes were similar to those reported for tick prevalence on impalas in Swaziland (Gallivan *et al.* 1995). The lower intensities of infestations of the nymph and adult stages of ixodid ticks on impala lambs may be a function of the higher allogrooming rate of these animals (Mooring & Hart 1992). This would presumably be effective in removing the larger nymphal and adult ticks, but less so in removing the larvae. The age distribution of lice infestation conforms to observations on other species that lice tend to be parasites of young animals and that infestation occurs early in life (Horak *et al.* 1983b; 1986b; Horak, MacIvor & Greeff 2001).

The prevalence of adult *A. hebraeum* and the intensities of infestations of adult *R. appendiculatus* and *R. zambeziensis* were higher on adult male impalas than on adult females, while the intensities of infestations of *R. zambeziensis* and *R. appendiculatus* larvae were higher on adult female impalas. The higher prevalence of adult *A. hebraeum* and intensity of infestation of adult *R. appendiculatus* on adult male impalas are similar to the pattern in Swaziland (Gallivan *et al.* 1995). Gallivan *et al.* (1995) reported an increased prevalence of *B. decoloratus* adults on male impalas, and Mooring & Hart (1995) reported increased infestations of *B. decoloratus* and *R. zambeziensis* on adult male impalas during the rut in the Omay Communal lands in Zimbabwe. The differences reported for *B. decoloratus* may be caused by variations in sampling techniques among the three studies.

The contrasts in the intensities of infestations of adult *R. appendiculatus* and *R. zambeziensis* between the sexes were most pronounced during the rut. Mooring & Hart (1995) suggest that the increase in testosterone during the rut reduces immunity in the males. However, this should cause an increase in the intensity of infestation of all stages of ticks. The intensities of infestations of *R. appendiculatus* and *R. zambeziensis* larvae were actually higher on the adult female than on the adult male impalas during the rut. The higher intensities of infestations of adult *R. appendiculatus* and *R. zambeziensis* on adult male impalas during the rut are most likely caused by a reduction in grooming activity (Mooring & Hart 1995). The higher intensities of infestations of *R. appendiculatus* and *R. zambeziensis* larvae on the adult female impalas may be the consequence of increased exposure. Adult male impalas have restricted home ranges during the rut, whereas the home range of the females encompasses several male territories (Murray 1982). Because peak activity of *R. appendiculatus* and *R. zambeziensis* larvae occurs during the rut, the mobile female impalas are more likely to be exposed to them.

In contrast to the ticks, lice tended to be more common on adult female impalas than on adult males, and the differences were statistically significant for *L. nevilli* and *Linognathus* sp. Female impalas occur in larger herds, maintain shorter distances between neighbours and allogroom more frequently than

males (Mooring 1995), all factors that could facilitate the transfer of lice between individuals. Both *L. nevilli* and *Linognathus* sp. have relatively low prevalences and intensities of infestation, and increased interaction among females may be essential to maintain transmission.

The collections included two droughts, in 1982 and in 1992 (Fig. 1). The 1982 collections were made in November and early December, following an extended period of low rainfall beginning in February 1982, and the 1992/93 collections began at the end of the summer after a year of low rainfall and continued through a year of normal rainfall. Consequently the collections represent different phases of the drought. The 1982 collections were also preceded by two years of above normal rainfall and impala populations, while the 1992/93 collections were preceded by two years of below average rainfall and impala populations.

In 1982 there was an increase in the total tick and louse burdens on the "terminal" impalas, primarily because of the increase in the intensities of infestations of *B. decoloratus* and *L. aepycerus*, and the burden of *D. elongata* on one individual. There was also an increase in the intensities of infestations of adult *A. hebraeum*, *R. appendiculatus*, *R. evertsi evertsi* and *R. zambeziensis*. These patterns reflect the seasonal activity of the ticks and lice, and are consistent with a reduction in resistance in animals in poor condition. There were few differences in the tick and louse burdens between the "apparently healthy" impalas in 1982 and those examined in 1980. In 1992/93 there was a reduction in the intensities of infestations of all tick and louse species relative to 1980/81. The reductions in the louse burdens and intensities of infestations of *R. zambeziensis* larvae and nymphs were proportional to the reduction in the size of the impala population, indicating that the availability of the hosts was a major factor in maintaining ectoparasite populations. The reductions in the infestations of *A. hebraeum*, *B. decoloratus*, *R. evertsi evertsi* and *R. appendiculatus* in 1992/93 relative to 1980/81 were greater than the reduction in the impala population. The drier environmental conditions probably reduced the survival of the free-living stages of these species as there was a greater reduction in the number of questing *B. decoloratus* larvae than *R. zambeziensis* larvae (Spickett *et al.* 1995), and *R. zambeziensis* tolerates drier conditions than *R. appendiculatus*. Thus, while the collections in the 1982 drought indicate that the immediate impact of a drought may be an increase in ectoparasite infestations because of the nutritional stress, the collections in the 1992 drought suggest that a reduction in impala populations as well as reduced survival of the free-living ticks may reduce the ectoparasite burdens over time.

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The host status of African buffaloes, *Syncerus caffer*, for *Rhipicephalus (Boophilus) decoloratus*

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ABSTRACT

HORAK, I.G., GOLEZARDY, H. & UYS, A.C. 2006. The host status of African buffaloes, *Syncerus caffer*, for *Rhipicephalus (Boophilus) decoloratus*. *Onderstepoort Journal of Veterinary Research*, 73: 193–198

The objective of this study was to assess the host status of African buffaloes, *Syncerus caffer*, for the one-host tick *Rhipicephalus (Boophilus) decoloratus*. To this end the *R. (B.) decoloratus* burdens of ten buffaloes examined in three north-eastern KwaZulu-Natal Province (KZN) nature reserves were compared with those of medium-sized to large antelope species in these reserves and in the southern Kruger National Park (KNP), Mpumalanga Province. The *R. (B.) decoloratus* burdens of the buffaloes were considerably smaller than those of the antelopes in the KNP, but not those in the KZN reserves. The life-stage structure of the *R. (B.) decoloratus* populations on the buffaloes, in which larvae predominated, was closer to that of this tick on blue wildebeest, *Connochaetes taurinus*, a tick-resistant animal, than to that on other antelopes. A single buffalo examined in the KNP was not infested with *R. (B.) decoloratus*, whereas a giraffe, *Giraffa camelopardalis*, examined at the same locality and time, harboured a small number of ticks. In a nature reserve in Mpumalanga Province adjacent to the KNP, two immobilized buffaloes, from which only adult ticks were collected, were not infested with *R. (B.) decoloratus*, whereas greater kudus, *Tragelaphus strepsiceros*, examined during the same time of year in the KNP harboured large numbers of adult ticks of this species. African buffaloes would thus appear to be resistant to infestation with *R. (B.) decoloratus*, and this resistance is expressed as the prevention of the majority of tick larvae from developing to nymphs.

Keywords: African buffaloes, ixodid tick, *Rhipicephalus (Boophilus) decoloratus*, *Syncerus caffer*, tick resistance

INTRODUCTION

African buffaloes, *Syncerus caffer,* are large bovids that prefer savanna-type habitats and require a plentiful supply of grass, shade and water for optimal survival. They occur in herds, which increase in size in the dry season, but decrease during the wet season because of the usual abundance of both food and water (Skinner & Smithers 1990). Large numbers of these animals are present in the Kruger National Park (KNP) in north-eastern Mpumalanga and Limpopo Provinces, and in the Umfolozi and Hluhluwe Nature Reserves (recently combined to form the Hluhluwe-iMfolozi Park) in the north-eastern regions of KwaZulu-Natal Province (KZN), with smaller populations in national, provincial and privately owned reserves or in buffalo breeding projects in these and nearly all other provinces of South Africa.

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African buffaloes may be infested with exceptionally large numbers and species of ixodid ticks (Yeoman & Walker 1967; Walker 1974; Horak, Potgieter, Walker, De Vos & Boomker 1983a), and because of their own large size a large percentage of these ticks are usually adults (Horak, MacIvor, Petney & De Vos 1987; Gallivan & Horak 1997). There is, however, some doubt as to their suitability as hosts for the one-host tick *Rhipicephalus (Boophilus) decoloratus*. In Tanzania no *R. (B.) decoloratus* were present in 25 collections from buffaloes examined by Yeoman & Walker (1967), while in Kenya and Zimbabwe only one of 119, and one of 135 collections, respectively, were positive (Walker 1974; Mason & Norval 1980). In north-eastern KZN, South Africa, only one of four fairly exhaustive collections made from buffaloes was positive, and it contained only larvae of this species (Horak *et al.* 1983a).

In an attempt to confirm this observation Norval (1984) infested a tame, hand-reared, tick-free, year-old African buffalo with 10 000 larvae of *R. (B.) decoloratus* on each of three occasions over a period of 3 months. The first infestation yielded 201 engorged females, the second 421, and the third, which was accompanied by considerable irritation and grooming, only 63 engorged females. According to Norval (1984) the latter result is similar to what one would expect on Brahman cattle resistant to *Rhipicephalus (Boophilus) microplus*.

An opportunity to do tick counts on African buffaloes arose when one of these animals was slaughtered in the KNP for survey purposes and ten were slaughtered during a survey to determine the prevalence of bovine tuberculosis in buffaloes in the north-eastern KZN nature reserves. An additional two animals were immobilized for other purposes in a north-eastern Mpumalanga Province nature reserve and were also examined for ticks. The main objective of the present communication is to compare the *R. (B.) decoloratus* burdens of these buffaloes with those of medium-sized and large antelopes in the KZN nature reserves and in the KNP.

MATERIALS AND METHODS

During September 1985 a single buffalo was shot near Satara tourist rest camp in the southern KNP, Mpumalanga Province. During June and July 1994 four buffaloes were darted and then shot in the Umfolozi Nature Reserve, four in the Hluhluwe Nature Reserve, and two in the Eastern Shores Nature Reserve, all in north-eastern KZN. The animals were skinned and their skins were processed for tick recovery as described by Horak, Boomker, Spickett & De Vos (1992). Two buffaloes were immobilized and carefully examined for adult ticks in the Mtethomusha Nature Reserve, Mpumalanga Province, adjacent to the south-western boundary of the KNP. The ticks recovered from all the buffaloes were identified and counted. Their burdens of *R. (B.) decoloratus* are compared with those of medium-sized and large antelopes processed in the same way, namely impalas, *Aepyceros melampus*, greater kudus, *Tragelaphus strepsiceros*, and blue wildebeest, *Connochaetes taurinus*, in the KNP, and nyalas, *Tragelaphus angasii*, in the north-eastern KZN nature reserves (Horak, De Vos & Brown 1983b; Horak *et al.* 1992; Horak, Boomker & Flamand 1995; Horak, Gallivan, Braack, Boomker & De Vos 2003). The tick burden of the single buffalo examined in the KNP is also compared to that of a giraffe, *Giraffa camelopardalis*, shot at the same time and place. The tick burdens of the KZN buffaloes are compared with those of nyalas and impalas examined in north-eastern KZN reserves during the same time of year, but not in the same year as the buffaloes. While the adult tick burdens of the buffaloes examined in the Mtethomusha Nature Reserve during July 1999 are compared with those of greater kudus examined in the south of the KNP during July 1981 and 1982. With the exception of some of the nyalas, the length of the idiosoma of engorging female *R. (B.) decoloratus* collected from the animals was measured. Those ticks of which the idiosoma measured 4.0 mm or more, were regarded as standard females, i.e. female ticks that will engorge and detach within the next 24 h.

RESULTS

The *R. (B.) decoloratus* burdens of individual buffaloes are summarized in Table 1. The largest number of ticks of this species were collected from the only buffalo calf examined, an animal approximately 6 months of age. The overall ratio of larvae to nymphs to males and females on all the buffaloes was 10.5: 1.8: 1.6: 1.0. If, however, the tick burden of the calf is excluded from the comparison, the ratios are 36.1: 2.8: 1.6: 1.0.

The numbers of *R. (B.) decoloratus* on the slaughtered buffaloes are compared with those on impalas and greater kudus in the KNP, and on nyalas in the north-eastern KZN reserves in Table 2. The overall ratio of the various life stages on the 305 antelopes examined is 10.7: 5.7: 2.0: 1.0.

In Table 3 the *R. (B.) decoloratus* burdens of the buffaloes are compared with those of nyalas, im-

TABLE 1 Numbers of *Rhipicephalus (Boophilus) decoloratus* collected from African buffaloes in five nature reserves in South Africa

Host	Date	Locality	Number of *Rhipicephalus (Boophilus) decoloratus*				
			Larvae	Nymphs	Males	Females	Total
Buffalo 1*	July 1999	Mtethomusha reserve	–	–	0	0	0
Buffalo 2*	July 1999	Mtethomusha reserve	–	–	0	0	0
Buffalo 3	Sept 1985	Kruger National Park	0	0	0	0	0
Buffalo 4	June 1994	Umfolozi reserve	590	28	8	4 (0)	630
Buffalo 5**	June 1994	Umfolozi reserve	234	178	186	120 (8)	718
Buffalo 6	June 1994	Umfolozi reserve	180	0	2	0	182
Buffalo 7	June 1994	Umfolozi reserve	200	0	0	0	200
Buffalo 8	June 1994	Hluhluwe reserve	288	82	48	28 (2)	446
Buffalo 9	June 1994	Hluhluwe reserve	6	0	0	6 (0)	12
Buffalo 10	June 1994	Hluhluwe reserve	10	2	2	2 (0)	16
Buffalo 11	June 1994	Hluhluwe reserve	116	0	2	0	118
Buffalo 12	July 1994	Eastern Shores	8	0	0	0	8
Buffalo 13	July 1994	Eastern Shores	44	0	0	0	44
Total			**1 676**	**290**	**248**	**160 (10)**	**2 374**
Ratio			**10.5**	**1.8**	**1.6**	**1.0**	
Total excluding buffalo calf no. 5			**1 442**	**112**	**62**	**40 (2)**	**1 656**
Ratio			**36.1**	**2.8**	**1.6**	**1.0**	

* = Immobilized and examined only for adult ticks
** = Calf, approximately 6 months old
( ) = Number of standard female ticks, i.e. with idiosoma > 4.0 mm in length

TABLE 2 Total numbers of *Rhipicephalus (Boophilus) decoloratus* collected from African buffaloes and antelopes at various localities in South Africa

Host (number examined)	Locality	Number of *Rhipicephalus (Boophilus) decoloratus*				
		Larvae	Nymphs	Males	Females	Total
Buffalo (1)	Kruger National Park	0	0	0	0	0
Buffaloes (10)	KwaZulu-Natal	1 676	290	248	160 (10)	2 374
Ratio		**10.5**	**1.8**	**1.6**	**1.0**	
Impalas (135)	Kruger National Park	226 612	101 981	37 724	18 024 (355)	384 341
Kudus (95)	Kruger National Park	161 815	107 711	35 959	18 140 (360)	323 625
Nyalas (75)	KwaZulu-Natal	11 905	5 355	2 100	1 313*	20 673
Total (305)		**400 332**	**215 047**	**75 783**	**37 477**	**728 639**
Ratio		**10.7**	**5.7**	**2.0**	**1.0**	

( ) = Number of standard female ticks, i.e. with idiosoma > 4.0 mm in length
* = Length of idiosoma of maturing females not measured

palas and kudus examined during the same time of year (but not in the same year), at the same localities, or in a locality adjacent to that in which the buffaloes were examined. The mean tick burdens of the buffaloes examined in KZN exceeded those of nyalas and impalas examined at the same localities, but the life-stage ratios on the buffaloes were markedly skewed in favour of larvae. The buffalo examined in the KNP was not infested, but a giraffe examined at the same time and locality harboured a small burden of *R. (B.) decoloratus*. The immobilized buffaloes examined for adult ticks in the Mthetomusha Nature Reserve, adjacent to the KNP, were not infested, whereas all eight kudus examined in the south of the KNP were infested with adult ticks.

The life-stage structure of the *R. (B.) decoloratus* population on buffaloes in north-eastern KZN is compared in Table 4 to that of this tick on blue wildebeest in the KNP. The tick life-stage ratios on the wildebeest, which are tick-resistant animals, were 21.0 larvae: 4.0 nymphs: 1.4 males: 1.0 females.

TABLE 3 Total numbers of *Rhipicephalus (Boophilus) decoloratus* collected from African buffaloes and antelopes examined during the same time of year at the same or adjacent localities

Host (number examined)	Locality	Number of *Rhipicephalus (Boophilus) decoloratus*				
		Larvae	Nymphs	Males	Females	Total
Buffaloes (10)	KwaZulu-Natal reserves	1 676	290	248	160 (10)	2 374
Nyalas (13)	KwaZulu-Natal reserves	452	200	26	36 (10)	714
Impalas (2)	KwaZulu-Natal reserves	52	34	30	36 (0)	152
Buffalo (1)	Kruger National Park	0	0	0	0	0
Giraffe (1)	Kruger National Park	0	4	37	8 (2)	47
Buffaloes (2)*	Mtethomusha reserve	–	–	0	0	0
Kudus (8)**	Kruger National Park	–	–	2 448	1 245 (38)	3 693

* = Immobized and only adult ticks collected
** = Only adult ticks taken into consideration
( ) = Number of standard female ticks, i.e. with idiosoma > 4.0 mm in length

TABLE 4 Numbers of *Rhipicephalus (Boophilus) decoloratus* collected from African buffaloes and blue wildebeest

Host (number examined)	Locality	Number of *Rhipicephalus (Boophilus) decoloratus*				
		Larvae	Nymphs	Males	Females	Total
African buffaloes (10)	KwaZulu-Natal reserves	1 676	290	248	160 (10)	2 374
Mean **Ratio** **Ratio excluding buffalo calf no. 5 in Table 1**		167.6 **10.5** **36.1**	29.0 **1.8** **2.8**	24.8 **1.6** **1.6**	16.0 (1.0) **1.0** **1.0**	237.4
Blue wildebeest (47)	Kruger National Park	19 722	3 805	1 271	940 (88)	25 738
Mean **Ratio**		419.6 **21.0**	81 **4.0**	27 **1.4**	20 (1.9) **1**	547.6

( ) = Number of standard female ticks, i.e. with idiosoma > 4.0 mm in length

DISCUSSION

It is arguable as to whether *R. (B.) decoloratus* was brought to southern Africa on the cattle of the early herdsmen that came to this country from further north in Africa or whether it is actually a parasite of wild herbivores in this country and has adapted to cattle. Whatever the tick's origin, wherever its distribution overlaps that of cattle, impalas, bushbuck, *Tragelaphus scriptus*, greater kudus, nyalas and Burchell's zebras, *Equus burchelli*, in South Africa these animals have all proved to be excellent hosts (Baker & Ducasse 1967; Horak *et al.* 1983a, 1992, 1995, 2003; Horak, De Vos & De Klerk 1984).

Rhipicephalus (Boophilus) decoloratus is a one-host tick and where exhaustive tick collections have been made the approximate life-stage structure of parasitic populations is larvae 11: nymphs 6: males 2: females 1 (Table 2). This stepped-down population structure probably results from the loss of larvae and newly-moulted nymphs, followed by the loss of nymphs and newly-moulted adults at the time of the larval and nymphal moults respectively. The 2: 1 ratio of males to females is most likely a consequence of two factors, namely the greater loss of engorging females, because of their larger size, than of males during grooming, and the persistence of males on cattle, and probably other hosts, after females originating from the same infestation have detached (Londt 1976). In systems in which tick predation by red-billed oxpeckers, *Buphagus erythrorhynchus,* occurs naturally, or is encouraged, engorged female *R. (B.) decoloratus* would be a preferred food item of these birds (Bezuidenhout & Stutterheim 1980), thus further affecting the male: female ratio.

Not all large wild herbivores are susceptible to infestation with *R. (B.) decoloratus*, and blue wildebeest seem to have an innate resistance to infestation with this and other ticks (Horak *et al.* 1983b). Although larval burdens may be fairly large on blue wildebeest, there is a sharp decline in numbers between the larval and the nymphal stages, resulting in a life-

stage structure of larvae 21: nymphs 4 (Table 4). If one were to exclude the tick burden of the KZN buffalo calf, which harboured fairly substantial numbers of nymphs and adult ticks, the life-stage structure on buffaloes would be 36.1 larvae to only 2.8 nymphs. This skewed life-stage distribution is underscored by the fact that only one of four buffaloes exhaustively examined for ticks in the Hluhluwe Nature Reserve during September 1978 was infested with *R. (B.) decoloratus* and then harboured only 64 larvae (Horak *et al.* 1983a). The apparent resistance of African buffaloes to infestation with *R. (B.) decoloratus* probably stems from an ancient association between these animals and the tick, and seems to be similar to that in indigenous Nguni cattle in South Africa (Spickett, De Klerk, Enslin & Scholtz 1989).

The resistance of hosts to ticks can be expressed in several ways. In the case of *R. (B.) decoloratus* on African buffaloes and blue wildebeest, resistance interferes with the development of larvae to nymphs, but apparently not with the development of nymphs to adults, nor with the engorgement of female ticks (Table 4). In blue wildebeest this resistance appears to be innate and is present in very young calves (Horak *et al.* 1983b). In African buffaloes resistance would seem to be acquired in that young calves and tick-naïve animals are susceptible to infestation with *R. (B.) decoloratus* and only become resistant after repeated infestations (Norval 1984, Table 1). Although a large proportion of *R. (B.) decoloratus* larvae may develop to adults on apparently susceptible hosts such as impalas and greater kudus (Horak *et al.* 1992, 2003), only a small percentage of the resultant females engorge (Table 2), seemingly because of a degree of resistance in these animals. Of the total of 36164 female ticks on the impalas and kudus examined in the KNP only 715 (2%) were of standard size (Table 2). Furthermore females that do mature on resistant animals may fail to reach full engorgement before detaching, and these smaller ticks will produce fewer eggs than fully engorged females.

In contrast to blue wildebeest, which are resistant to infestation with a large variety of tick species (Horak *et al.* 1983b), African buffaloes seem to be resistant only to infestation with *R. (B.) decoloratus.* In support of this contention the ten buffaloes examined in the north-eastern KZN nature reserves during the current surveys were infested with a total of ten ixodid tick species and their total burdens varied from 5911 to 58498 ticks. *Rhipicephalus (Boophilus) decoloratus* accounted for only 2374 out of the total of 236845 ticks collected from these animals, of which 229920 of the latter were immature and 6925 adults. This is still a large number of adult ticks considering that it was midwinter and that most adult ticks are encountered on wildlife and on domestic cattle in South Africa during summer (Baker & Ducasse 1967; Rechav 1982; Horak *et al.* 1984, 1992, 1995, 2003). However, this large number of adult ticks on buffaloes even during winter is not surprising considering that the larger the host species the more adult ticks it is likely to harbour (Horak *et al.* 1987; Gallivan & Horak 1997). African buffaloes and eland, *Taurotragus oryx,* are the largest wild bovids in South Africa and consequently, irrespective of the season, are usually infested with more adult ticks than other host species (Horak *et al.* 1983a, 1987). The absence, or virtual absence, of adult *R. (B.) decoloratus* on the buffaloes is thus the more conspicuous.

Judging by the small tick burdens of impalas and nyalas examined at the same localities in north-eastern KZN as the buffaloes (Table 3), this region is marginal for *R. (B.) decoloratus.* Because of their large size and hence the amount of meat that can be obtained from them, buffaloes that are to be culled are usually slaughtered in winter to avoid the carcass being exposed to both the heat of the sun and to exploitation by blowflies. The same applies in respect of heat stress in buffaloes that are to be chemically immobilized for any length of time. Winter is a season during which the numbers of *R. (B.) decoloratus* on wildlife may be at their lowest (Horak *et al.* 1984, 1992), and hence it is not an ideal time during which to compare the tick burdens of various host species, particularly if the region is marginal for *R. (B.) decoloratus.*

CONCLUSION

African buffaloes appear to acquire resistance to infestation with the one-host tick *R. (B.) decoloratus,* and this resistance is expressed as the prevention of the majority of tick larvae from developing to nymphs. The correctness of this conclusion can, however, only be verified when buffaloes are exhaustively examined for ticks at a locality in which susceptible hosts belonging to other species are heavily infested with *R. (B.) decoloratus.*

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Ticks associated with the three largest wild ruminant species in southern Africa

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ABSTRACT

HORAK, I.G., GOLEZARDY, H. & UYS, A.C. 2007. Ticks associated with the three largest wild ruminant species in southern Africa. *Onderstepoort Journal of Veterinary Research*, 74:231–242

The objective of this study was to assess the host status of the three largest southern African wild ruminants, namely giraffes, *Giraffa camelopardalis*, African buffaloes, *Syncerus caffer*, and eland, *Taurotragus oryx* for ixodid ticks. To this end recently acquired unpublished data are added here to already published findings on the tick burdens of these animals, and the total numbers and species of ticks recorded on 12 giraffes, 18 buffaloes and 36 eland are summarized and discussed. Twenty-eight ixodid tick species were recovered. All stages of development of ten species, namely *Amblyomma hebraeum*, *Rhipicephalus* (*Boophilus*) *decoloratus*, *Haemaphysalis silacea*, *Ixodes pilosus* group, *Margaropus winthemi*, *Rhipicephalus appendiculatus*, *Rhipicephalus evertsi evertsi*, *Rhipicephalus glabroscutatum*, *Rhipicephalus maculatus* and *Rhipicephalus muehlensi* were collected. The adults of 13 species, of which the immature stages use small mammals as hosts, namely *Haemaphysalis aciculifer*, *Hyalomma glabrum*, *Hyalomma marginatum rufipes*, *Hyalomma truncatum*, *Ixodes rubicundus*, *Rhipicephalus capensis*, *Rhipicephalus exophthalmos*, *Rhipicephalus follis*, *Rhipicephalus gertrudae*, *Rhipicephalus lounsburyi*, *Rhipicephalus lunulatus*, *Rhipicephalus pravus* group and *Rhipicephalus simus*, were also collected.

Keywords: African buffaloes, eland, *Giraffa camelopardalis*, giraffes, ixodid ticks, *Syncerus caffer*, *Taurotragus oryx*, tick burdens

INTRODUCTION

Although numerous collections of ticks have been made from giraffes, *Giraffa camelopardalis*, African buffaloes, *Syncerus caffer* and eland, *Taurotragus oryx* (Theiler 1962; Yeoman & Walker 1967; Baker & Keep 1970; Walker 1974; Norval 1983), it would seem that few attempts have been made to determine the total tick burdens of these large animals. This is perhaps not surprising considering the amount of assistance required to collect ticks from dead or immobilized animals of this size, and the time that has to be spent identifying and counting immature ticks in representative samples of these collections and often all the several thousand adult ticks that a single large herbivore may harbour. Amongst those who have attempted to do so are Horak, Potgieter, Walker, De Vos & Boomker (1983), Rechav, Zeederberg & Zeller (1987), Horak, Fourie, Novellie & Williams (1991a), Horak, Anthonissen, Krecek & Boomker (1992a) and Zieger, Horak, Cauldwell & Uys (1998). Prior as well as subsequent to these published studies the opportunity to sam-

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ple more of these large herbivores has arisen and the present paper reports the results of the latter collections. However, since we thought it unlikely that, in the near future, similar exhaustive tick collections would be made from such large animals in southern Africa, we decided to combine the earlier published data with the more recent findings in order to give a more comprehensive overview of the numbers and species of ticks that may infest giraffes, African buffaloes and eland in a variety of habitats.

Giraffes occur in several associations of dry savanna, varying from scrub to woodland. They do not occur in forest or desert and generally are not found in open plains. They are present in north-eastern Limpopo and Mpumalanga Provinces, South Africa, and in the north-eastern parts of Namibia (Skinner & Smithers 1990), but in recent times have been introduced into a number of regions in South Africa in which they previously did not occur.

African buffaloes prefer savanna-type habitats and need a plentiful supply of grass, shade and water. They occur in herds, which increase in size in the dry season, but become more fragmented during the wet season because of the usual plentiful supply of water and grazing (Skinner & Smithers 1990). The current distribution of African buffaloes in South Africa is mostly patchy. Large numbers are present in the Kruger National Park (KNP) and the HluhluweiMfolozi Park in the north-eastern regions of the Limpopo, Mpumalanga and KwaZulu-Natal Provinces, with smaller populations in national, provincial and privately owned reserves in these and nearly all other provinces of South Africa.

Eland are gregarious animals usually occurring in small herds, and are as at home in arid semi-desert scrub associations as they are in montane grassland (Skinner & Smithers 1990). Historically they were present virtually throughout South Africa, but overexploitation reduced their numbers. However, because they are a sought after species, reintroductions have resulted in their now occupying virtually the same regions in which they originally occurred.

One of the serious shortcomings of the past and current studies is that they are biased towards localities and seasons at which animals were, or have been, made available for survey purposes and are thus not necessarily representative of the entire ixodid tick fauna present within the geographic distribution of the host species being examined. Nevertheless a remarkably large number of tick species were recovered. Moreover, because of the large size of the hosts, large numbers of adult ticks were collected (Gallivan & Horak 1997), and the greater certainty with which the adult ticks can be identified has augmented the accuracy of our identification of the immature stages, and hence our results.

MATERIALS AND METHODS

The localities at which animals were examined, including those of the earlier studies of Horak *et al.* (1983, 1991a, 1992a), Rechav *et al.* (1987) and Zieger *et al.* (1998), are summarized in Table 1. With the exception of Free State and Gauteng Provinces at least one of the three large wild ruminant species was sampled in each province of the Republic of South Africa. In addition, six of the giraffes were examined in the Etosha National Park in northern Namibia (Horak *et al.* 1992a), and two of the eland on a game ranch in Central Province, Zambia (Zieger *et al.* 1998).

Ticks were recovered from the animals in the earlier surveys as described by the authors of those studies. The carcasses of giraffes, African buffaloes and eland in the present surveys were processed for tick recovery and the ticks identified and counted as described by Horak, Boomker, Spickett & De Vos (1992b). When animals had been immobilized, and not killed, an attempt was made to collect as many adult ticks as possible, with particular attention being paid to the preferred sites of attachment of the various species.

A total of 12 giraffes, 18 African buffaloes and 36 eland were examined, but in the tables devoted to each host species only the results for those animals sampled within a particular tick species' distribution range are given for that particular tick.

RESULTS AND DISCUSSION

The species and numbers of ticks collected from the giraffes, buffaloes and eland are summarized in Tables 2, 3 and 4, and the total numbers of male and female ticks recovered and, where it was possible to calculate this, the ratio of males to females for each species are summarized in Table 5.

A calculated total of 450 709 ticks, belonging to 28 species and three subspecies, were collected from the 66 animals examined. Of these 57 688 were adults, of which at least half were identified and counted. Although this may seem like a large number of ticks, probably three times as many would

TABLE 1 Localities at which large wild ruminants were examined for ixodid ticks

Country and province	Locality	Co-ordinates	Vegetation type (Van der Merwe 1983; White 1983; Acocks 1988)
South Africa			
Western Cape	West Coast National Park	33°06' S, 17°59' E	Strandveld and patches of Coastal Fynbos
Eastern Cape	Thomas Baines Nature Reserve	33°23' S, 26°28' E	False Macchia, Eastern Province Thornveld and Valley Bushveld
	Andries Vosloo Kudu Reserve	33°07' S, 26°40' E	Valley Bushveld
	Mountain Zebra National Park	32°15' S, 25°27' E	Karroid *Merxmeullera* Mountain Veld, replaced by Karoo on the higher slopes and Karroid Broken Veld in the north
Northern Cape	Kgalagadi Transfrontier Park	24°45'–26°28' S, 20°00'–20°50' E	Lightly wooded grassland on dune crests and grassland in depressions between dunes
KwaZulu-Natal	Eastern Shores Park	28°08' S, 32°30' E	Zululand Palm Veld, subdivision of Coastal Thornveld and Coastal communities
	iMfolozi Nature Reserve	28°15' S, 31°57' E	Zululand Thornveld and Lowveld
North West	SA Lombaard Reserve	27°35' S, 25°29' E	Dry *Cymbopogon-Themeda* veld
Mpumalanga	Pretoriuskop (KNP)	25°10' S, 31°16' E	Lowveld Sour Bushveld
	Lower Sabie (KNP)	25°07' S, 31°55' E	Lowveld
	Mtethomusha Nature Reserve	25°29' S, 31°17' E	Lowveld
Namibia			
	Okaukuejo, Etosha National Park	19°11' S, 15°55' E	Mopane savanna
Zambia			
Central	Mtendere Game Ranch	15°05' S, 28°16' E	Miombo Woodland

KNP = Kruger National Park

have been recovered had the digestion technique of Van Dyk & McKenzie (1992) been used. However, the fine structures of tick larvae and nymphs are often damaged during the period of digestion required in the latter technique, and thus, although tick recovery may be more complete, it is achieved at the expense of accurate species determination.

Two of the 28 species recovered are one-host ticks, namely *Margaropus winthemi* and *Rhipicephalus* (*Boophilus*) *decoloratus*. Five are two-host ticks, these being *Hyalomma glabrum*, *Hyalomma marginatum rufipes*, *Hyalomma truncatum*, *Rhipicephalus glabroscutatum* and *Rhipicephalus evertsi* of which both subspecies of the latter, namely *evertsi* and *mimeticus* were collected. The remaining 21 species are all three-host ticks. All stages of development of *Amblyomma hebraeum*, *R.* (*Boophilus*) *decoloratus*, *Haemaphysalis silacea*, *Ixodes pilosus* group, *M. winthemi*, *Rhipicephalus appendiculatus*, *R. evertsi evertsi*, *R. glabroscutatum*, *Rhipicephalus maculatus* and *Rhipicephalus muehlensi* were collected. Only the adults of 13 species, namely *Haemaphysalis aciculifer*, *H. glabrum*, *H. marginatum rufipes*, *H. truncatum*, *Ixodes rubicundus*, *Rhipicephalus capensis*, *Rhipicephalus exophthalmos*, *Rhipicephalus follis*, *Rhipicephalus gertrudae*, *Rhipicephalus lounsburyi*, *Rhipicephalus lunulatus*, *Rhipicephalus pravus* group and *Rhipicephalus simus*, of which the immature stages use small mammals as hosts, were recovered. In addition the larvae and nymphs of the South African tortoise tick, *Amblyomma marmoreum*, nymphs and adults of the tropical bont tick, *Amblyomma variegatum*, a single male *Rhipicephalus longiceps*, 30 *Rhipicephalus supertritus* males and 16 *Rhipicephalus zambeziensis* nymphs were re-

TABLE 2 Giraffes examined and the number infested within the distribution range of each tick

Tick species	Hosts examined (infested)	Life stage	Total No. of ticks	Locality
Amblyomma hebraeum	6 (6)	Larvae Nymphs Males Females	773 554 2 406 512	KNP
Hyalomma marginatum rufipes	12 (8)	Males Females	374 77	KNP, Etosha
Hyalomma truncatum	12 (12)	Males Females	1 649 619	KNP, Etosha
Rhipicephalus (*Boophilus*) *decoloratus*	6 (6)	Larvae Nymphs Males Females	2 472 2 538 1 503 821	KNP
Rhipicephalus appendiculatus	6 (6)	Larvae Nymphs Males Females	168 682 49 4	KNP
Rhipicephalus evertsi evertsi	6 (6)	Larvae Nymphs Males Females	452 190 106 20	KNP
Rhipicephalus evertsi mimeticus	6 (5)	Males Females	14 5	Etosha
Rhipicephalus longiceps	6 (1)	Males	1	Etosha
Rhipicephalus pravus group	6 (3)	Males Females	32 20	KNP
Rhipicephalus simus	6 (4)	Males Females	22 6	KNP

KNP = Kruger National Park

covered. Ten of the 28 tick species recovered occur only in South Africa. They are *H. silacea*, *H. glabrum*, *I. pilosus*, *I. rubicundus*, *M. winthemi*, *R. capensis*, *R. follis*, *R. glabroscutatum* and *R. lounsburyi*.

With the exception of ticks of the *I. pilosus* group and *I. rubicundus*, of which more females than males were recovered, considerably more males than females of all other species, of which both sexes were present, were collected. Mating in *Ixodes* species may occur in the preparasitic phase of the life cycle (Fourie & Horak 1994), and many males thus never attach. This behaviour is probably largely responsible for the female-biased parasitic populations of the two ticks in this genus in the present study. The male-biased populations of the other tick species is due to the propensity of parasitic male ixodid ticks of several species to spend extended periods on their hosts (Londt 1976; Jordaan & Baker 1981), whereas the females may require only a few days to two weeks to mate and engorge before detaching. Furthermore the larger size of engorging females is likely to make them more susceptible to removal by grooming or predation than the considerably smaller males.

Amblyomma species

The larvae of *Amblyomma hebraeum* infest a wide variety of hosts, including ungulates, carnivores, lagomorphs and birds, and all stages of development, but particularly the adults, infest very large hosts (Horak, MacIvor, Petney & De Vos 1987a). The males may remain attached for several months (Jordaan & Baker 1981), thus augmenting the already male-biased population of adult ticks. *Ambly-*

TABLE 3 African buffaloes examined and the number infested within the distribution range of each tick

Tick species	Hosts examined (infested)	Life stage	Total No. of ticks	Locality
Amblyomma hebraeum	18 (18)	Larvae Nymphs Males Females	47 815 6 437 6 154 1 764	KNP, Eastern Shores, iMfolozi, Thomas Baines, Mtethomusha
Amblyomma marmoreum	18 (4)	Larvae Nymphs	8 26	KNP, Eastern Shores, iMfolozi, Thomas Baines, Mtethomusha
Haemaphysalis silacea	15 (7)	Larvae Nymphs Males Females	81 357 135 78	Eastern Shores, iMfolozi, Thomas Baines
Hyalomma truncatum	17 (2)	Males Females	6 0	KNP, iMfolozi, Mtethomusha
Rhipicepalus (Boophilus) decoloratus	18 (11)	Larvae Nymphs Males Females	1 640 290 248 160	Eastern Shores, iMfolozi, Thomas Baines, Mtethomusha
Rhipicephalus appendiculatus	18 (17)	Larvae Nymphs Males Females	139 389 32 715 1 360 774	KNP, Eastern Shores, iMfolozi, Thomas Baines, Mtethomusha
Rhipicephalus evertsi evertsi	18 (15)	Larvae Nymphs Males Females	721 35 96 45	KNP, Eastern Shores, iMfolozi, Thomas Baines, Mtethomusha
Rhipicephalus follis	1 (1)	Males Females	40 32	Thomas Baines
Rhipicephalus maculatus	14 (14)	Larvae Nymphs Males Females	15 379 16 772 946 398	Eastern Shores, iMfolozi
Rhipicephalus muehlensi	16 (15)	Larvae Nymphs Males Females	11 775 495 193 141	Eastern Shores, iMfolozi, Mtethomusha
Rhipicephalus simus	18 (9)	Males Females	121 64	KNP, Eastern Shores, iMfolozi, Mtethomusha

KNP = Kruger National Park

omma hebraeum is present in the Bushveld and Lowveld regions of northern, eastern and south-eastern South Africa (Walker & Olwage 1987).

Amblyomma marmoreum is known as the South African tortoise tick, and all stages of development may be found on a variety of these reptiles, with leopard tortoises, *Geochelone pardalis*, generally the most heavily infested (Horak, McKay, Heyne & Spickett 2006). The larvae infest a wide variety of mammals and birds, and are often found on mammals and birds of several species that are present within the tick's distribution range (Horak *et al.* 2006).

Amblyomma variegatum does not occur in South Africa, but is present in most sub-Saharan countries

TABLE 4 Eland examined and the number infested within the distribution range of each tick

Tick species	Hosts examined (infested)	Life stage	Total No. of ticks	Locality
Amblyomma hebraeum	4 (4)	Larvae Nymphs Males Females	32 394 2 405 3 488 530	KNP, Andries Vosloo Kudu Reserve, Thomas Baines NR
Amblyomma marmoreum	15 (8)	Larvae	167	KNP, Mountain Zebra NP, AV Kudu Reserve, Thomas Baines NR
Amblyomma variegatum	2 (2)	Nymphs Males Females	4 60 26	Mtendere Game Ranch
Haemaphysalis aciculifer	2 (1)	Males	2	KNP
Haemaphysalis silacea	4 (4)	Larvae Nymphs Males Females	7 686 933 1 409 386	Andries Vosloo Kudu Reserve, Thomas Baines NR
Hyalomma glabrum	11 (11)	Males Females	955 191	Mountain Zebra NP
Hyalomma marginatum rufipes	16 (16)	Males Females	907 470	Kgalagadi Transfrontier Park, Thomas Baines NR, SA Lombaard NR
Hyalomma truncatum	32 (27)	Males Females	1 702 650	Mountain Zebra NP, Kgalagadi Transfrontier Park, West Coast NP, SA Lombaard NR
Ixodes pilosus group	4 (4)	Larvae Nymphs Males Females	2 817 177 22 64	Andries Vosloo Kudu Reserve, Thomas Baines NR
Ixodes rubicundus	11 (7)	Males Females	34 81	Mountain Zebra NP
Margaropus winthemi	11 (9)	Larvae Nymphs Males Females	12 792 6 874 1 915 893	Mountain Zebra NP
Rhipicephalus (Boophilus) decoloratus	8 (5)	Larvae Nymphs Males Females	3 106 3 988 3 581 848	KNP, AV Kudu Reserve, Thomas Baines NR, Mtendere Game Ranch
Rhipicephalus appendiculatus	8 (8)	Larvae Nymphs Males Females	18 025 1 489 8 106 3 345	KNP, AV Kudu Reserve, Thomas Baines NR, Mtendere Game Ranch
Rhipicephalus capensis	2 (2)	Males Females	1 506 408	West Coast NP
Rhipicephalus evertsi evertsi	34 (31)	Larvae Nymphs Males Females	6 900 2 128 1 574 392	KNP, Mountain Zebra NP, AV Kudu Reserve, Thomas Baines NR, West Coast NP, SA Lombaard NR, Mtendere Game Ranch

TABLE 4 *Cont.*

Tick species	Hosts examined (infested)	Life stage	Total No. of ticks	Locality
Rhipicephalus exophthalmos	11 (1)	Males Females	0 2	Mountain Zebra NP
Rhipicephalus follis	11 (11)	Males Females	983 447	Mountain Zebra NP, Thomas Baines NR
Rhipicephalus gertrudae	2 (1)	Males Females	4 2	West Coast NP
Rhipicephalus glabroscutatum	14 (13)	Larvae Nymphs Males Females	6 510 2 846 868 499	Mountain Zebra NP, Andries Vosloo Kudu Reserve, West Coast NP
Rhipicephalus lounsburyi	11 (2)	Males	3	Mountain Zebra NP
Rhipicephalus lunulatus	2 (2)	Males Females	218 48	Mtendere Game Ranch
Rhipicephalus simus	6 (4)	Males Females	39 5	KNP, AV Kudu Reserve, Thomas Baines NR
Rhipicephalus supertritus	2 (2)	Males	30	Mtendere Game Ranch
Rhipicephalus zambeziensis	2 (1)	Nymphs	16	KNP

KNP = Kruger National Park
NP = National Park
NR = Nature Reserve

to the north (Walker & Olwage 1987). Its host spectrum is similar to that of *A. hebraeum* and its presence on the two eland examined in Zambia is thus to be expected.

Haemaphysalis species

The two male *Haemaphysalis aciculifer* recovered from an eland in the KNP during September 1979 (Horak *et al.* 1983; Table 4), were the only specimens of this species reported in the park until 2000, when Horak, Braack, Fourie & Walker (2000) recorded 13 males and two females from a honey badger, *Mellivora capensis*. This tick is seldom recovered in large numbers but appears to be present in north-eastern Mpumalanga Province and thence along the eastern and southern coastal and adjacent inland regions to the south-western region of the Cape Province (Theiler 1962; Horak, Keep, Spickett & Boomker 1989; Horak & Boomker 1998).

Haemaphysalis silacea is present in north-eastern KwaZulu-Natal and in the Eastern Cape Provinces (Walker 1991), and is associated with vegetation classified as Valley Bushveld (Acocks 1988) and with greater kudus, *Tragelaphus strepsiceros*, common duikers, *Sylvicapra grimmia*, Cape grysbok, *Rhaphicerus melanotis*, and helmeted guineafowls, *Numida meleagris* (Horak & Knight 1986; MacIvor & Horak 2003). Seven of the 18 buffaloes and all four eland examined in Valley Bushveld-type vegetation in the north-eastern KwaZulu-Natal and the Eastern Cape Provinces were infested.

Hyalomma species

Delpy (1949) described the tick now known as *Hyalomma glabrum* as *Hyalomma rufipes glabrum*, and the latter name persisted until Theiler (1956) raised it to species level as *Hyalomma glabrum*. In the same year Hoogstraal (1956) synonymized it with Asian *Hyalomma marginatum turanicum*, and since then it has been considered identical to the latter tick. Recent studies have, however, revealed that it is a separate taxon, and Apanaskevich & Horak (2006) have subsequently reinstated it as *Hyalomma glabrum*. Howell, Walker & Nevill (1978) have illustrated its distribution (as *H. m. turanicum*) in the central and western regions of South Africa. The adults prefer large animals such as eland and Cape mountain zebras, *Equus zebra zebra*, and its immature stages infest scrub hares, *Lepus saxatilis*, and ground-frequenting birds (Apanaskevich & Horak 2006).

TABLE 5 Male to female ratios of tick species collected from giraffes, African buffaloes and eland in southern Africa

Tick species	Total No. of adult ticks		Male:female ratio	
	Male	Female	Male	Female
Amblyomma hebraeum	12 048	2 806	4.29	1.0
Amblyomma variegatum	60	26	2.31	1.0
Haemaphysalis aciculifer	2	0	–	–
Haemaphysalis silacea	1 544	464	3.33	1.0
Hyalomma glabrum	955	191	5.00	1.0
Hyalomma marginatum rufipes	1 281	547	2.34	1.0
Hyalomma truncatum	3 357	1 269	2.65	1.0
Ixodes pilosus group	22	64	0.34	1.0
Ixodes rubicundus	34	81	0.42	1.0
Margaropus winthemi	1 915	893	2.14	1.0
Rhipicephalus (Boophilus) decoloratus	5 332	1 829	2.92	1.0
Rhipicephalus appendiculatus	9 515	4 123	2.31	1.0
Rhipicephalus capensis	1 506	408	3.69	1.0
Rhipicephalus evertsi evertsi	1 776	457	3.89	1.0
Rhipicephalus evertsi mimeticus	14	5	2.80	1.0
Rhipicephalus exophthalmos	0	2	–	–
Rhipicephalus follis	1 023	479	2.14	1.0
Rhipicephalus gertrudae	4	2	2.00	1.0
Rhipicephalus glabroscutatum	868	499	1.74	1.0
Rhipicephalus longiceps	1	0	–	–
Rhipicephalus lounsburyi	3	0	–	–
Rhipicephalus lunulatus	218	48	4.54	1.0
Rhipicephalus maculatus	946	398	2.38	1.0
Rhipicephalus muehlensi	193	141	1.37	1.0
Rhipicephalus pravus group	32	20	1.60	1.0
Rhipicephalus simus	182	75	2.43	1.0
Rhipicephalus supertritus	30	0	–	–
Total (excluding *Ixodes* spp.)	**42 805**	**14 682**	**2.92**	**1.0**

The distribution of *Hyalomma marginatum rufipes* is more extensive than that of *H. glabrum*, which it almost entirely overlaps (Howell *et al.* 1978). Its host preferences are the same as those of the latter tick (Walker 1991), but include giraffes and buffaloes, which are generally not present within the distribution range of *H. glabrum* (Tables 2 and 3).

With the exception of the eastern coastal regions and some adjacent inland areas and the southern coastal regions, *Hyalomma truncatum* is present virtually throughout the country (Howell *et al.* 1978). The adults are found on the same large hosts as the former two ticks, and its immature stages infest scrub hares and rodents (Walker 1991).

Ixodes species

Ticks of the *Ixodes pilosus* group are present in the southern coastal and adjacent regions of the Western and Eastern Cape Provinces and in south-eastern KwaZulu-Natal Province, where all stages of development may be encountered on antelopes, caracals, *Caracal caracal* and domestic dogs (Horak, Jacot Guillarmod, Moolman & De Vos 1987b; Horak *et al.* 1989; Horak & Boomker 1998; Horak & Matthee 2003).

The colloquial name given to *Ixodes rubicundus* is Karoo paralysis tick, because of the paralysis associated with infestation of small domestic livestock in the Karoo regions of the country (Howell *et al.* 1978; Fourie & Horak 1994). The hosts of the adults are wild and domestic ruminants, caracals and domestic dogs (Horak *et al.* 1987b, 1991a; Fourie & Horak 1993; Horak & Matthee 2003). The immature stages infest Smith's red rock rabbits, *Pronolagus rupestris*, caracals and rock elephant shrews, *Elephantulus myurus* (Horak *et al.* 1991a; Fourie, Horak & Woodall 2005).

Margaropus winthemi

This tick is commonly known as the winter horse tick, and its distribution in the cooler higher-lying regions of the country suggests that its original hosts

were Cape mountain zebras, on which it still occurs in very large numbers during the winter months (Horak *et al.* 1991a). The burdens of the eland (Table 4), examined at the same time as zebras in the Mountain Zebra National Park, although large, did not nearly approach those of the latter animals.

Rhipicephalus species

Rhipicephalus (Boophilus) decoloratus. Using molecular analyses supported by an analysis of morphological characters Murrell, Campbell & Barker (2000) and Beati & Keirans (2001) decided that the genus *Rhipicephalus* is paraphyletic with respect to the genus *Boophilus* and consequently Murrell & Barker (2003) proposed the use of the above nomenclature. We have chosen to follow their proposal, although many people prefer to retain *Boophilus* as a generic name. Giraffes and eland can generally be considered as good hosts of this tick, whereas African buffaloes appear to be resistant to infestation, with more than half of the adult ticks reported here coming from a single, approximately 6-month-old calf. Norval (1984) and Horak, Golezardy & Uys (2006) have discussed the apparent resistance of African buffaloes to artificial and natural infestations with this tick, and it would seem that this resistance is acquired, rather than innate.

Adult *Rhipicephalus appendiculatus* are common parasites of African buffaloes, eland, greater kudus, male nyalas, *Tragelaphus angasii*, and domestic cattle in wooded savannas from south-eastern South Africa in the south to Kenya and Uganda in the north (Walker, Keirans & Horak 2000). The immature stages are found on the same hosts as the adults, but also infest smaller antelopes and scrub hares (Walker *et al.* 2000). The eland included in the present study and more particularly those from Zambia, were heavily infested with adult ticks (Table 4). The buffaloes, which were examined mainly during the early winter months, harboured very large numbers of larvae (Table 3).

Rhipicephalus capensis, Rhipicephalus follis, Rhipicephalus gertrudae and *Rhipicephalus simus* have several morphological characteristics in common and also have similar life cycles during which the immature stages infest murid rodents and the adults the larger species of antelopes (Walker *et al.* 2000). Adult *R. gertrudae* also infest domestic dogs and primates, including humans (Brain & Bohrmann 1992; Horak, Fourie, Heyne, Walker & Needham 2002; Horak & Matthee 2003), while those of *R. simus* infest domestic and wild equids, suids and carnivores (Horak *et al.* 1987b, 2000; Walker *et al.* 2000). *Rhipicephalus capensis* occurs almost exclusively in the western coastal regions of the Western Cape Province, South Africa; *R. gertrudae* is present in the same western regions, but its distribution extends east to the southern and southern-central regions of the country and north into Namibia; *R. follis* is only found in South Africa and is present to the east and north-east of *R. gertrudae*'s distribution range and generally in mountainous terrain; while, with the exception of the more arid regions of central and western South Africa and southern Namibia, the distribution range of *R. simus* effectively overlays those of the other three species and extends north into Africa to a latitude of approximately 9° south.

Rhipicephalus evertsi evertsi and *Rhipicephalus evertsi mimeticus* are two-host ticks and all stages of development may infest the same host species. Excluding the deserts and regions of high rainfall, the former tick is found throughout sub-Saharan Africa, whereas the latter is confined to the arid and semi-arid regions of Namibia, western Botswana and parts of Angola (Walker *et al.* 2000).

The adults of *Rhipicephalus exophthalmos* parasitize antelopes, domestic ruminants and scrub hares in the south-eastern and north-western regions of South Africa and in a broad, central band from the south to the north of Namibia (Walker *et al.* 2000). Its immature stages prefer elephant shrews, *Elephantulus* spp., as hosts (Fourie *et al.* 2005).

The two-host tick, *Rhipicephalus glabroscutatum*, is present in the fynbos and Karoo regions of the Western Cape Province, and also in the Karoo and the Valley Bushveld regions of the Eastern Cape Province (Walker *et al.* 2000). It is a common parasite of the feet and lower legs of small and large antelope in these regions (Horak & Boomker 1998; MacIvor & Horak 2003). Infestation with its adults is a contributory cause of foot abscess in domestic goats in the Valley Bushveld regions of the Eastern Cape Province (MacIvor & Horak 1987).

The distribution in South Africa of *Rhipicephalus maculatus* and *Rhipicephalus muehlensi* is confined to the coastal bush and adjacent inland regions of north-eastern KwaZulu-Natal (Walker *et al.* 2000). The recovery of an *R. maculatus* nymph from the vegetation and adults from an elephant, *Loxodonta africana*, in the southern regions of the KNP (Braack, Maggs, Zeller & Horak 1995), and of *R. muehlensi* adults from one of the buffaloes examined in the Mtethomusha Nature reserve, just south of the KNP, suggest that they have been introduced into these

reserves on animals translocated from north-eastern KwaZulu-Natal. All stages of development of both ticks may infest the same host species, but the adults of *R. maculatus* prefer thick-skinned animals such as buffaloes and bush pigs, *Potamochoerus larvatus*, and those of *R. muehlensi* nyalas (Horak, Boomker & Flamand 1991b; 1995).

Rhipicephalus longiceps is a rarely encountered tick and apparently is present only in certain regions of Namibia and Angola (Walker *et al.* 2000).

Rhipicephalus lounsburyi prefers the higher mountainous regions of the Eastern Cape Province (Walker *et al.* 2000) and two eland in the Mountain Zebra National Park were infested. The adults attach around the feet of their antelope and sheep hosts, while the only known hosts of its immature stages are four-striped grass mice, *Rhabdomys pumilio*, from which a larva and two nymphs have been collected (Walker *et al.* 2000; Horak, Fourie & Braack 2005).

Although *Rhipicephalus lunulatus* is fairly widespread in sub-Saharan Africa its distribution in South Africa is limited to the eastern regions (Walker *et al.* 2000). The adults have a wide host range and would seem to attach around the feet and lower legs of their hosts (Walker *et al.* 2000). The eland examined in Zambia had fairly large burdens of adult ticks (Table 4), while a multimammate mouse, *Mastomys* sp., and a scrub hare examined on the same ranch as the eland were infested with nymphs (Zieger *et al.* 1998).

Ticks belonging to the *Rhipicephalus pravus* group have been collected from scrub hares in the KNP (Horak, Spickett, Braack & Penzhorn 1993), and were assigned to *Rhipicephalus* sp. near *pravus* by Walker *et al.* (2000). However, the ticks collected in the same park from three of the giraffes, appear to us to be very similar, if not identical to the true *R. pravus* of East Africa.

The immature stages of *Rhipicephalus supertritus* are unknown, but are assumed to be similar in appearance to those of *R. appendiculatus*. It is apparently commonest in Central Africa, including northern Zimbabwe and Mozambique, parts of Zambia and southern Tanzania (Walker *et al.* 2000), and both eland examined in Zambia were infested.

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Warthogs and rhinoceroses

Two surveys on the parasites of warthogs, *Phacochoerus africanus* (at the time referred to as *Phacochoerus aethiopicus*), have been conducted in the Mpumalanga Province lowveld. One in the Kruger National Park (Horak, Boomker, De Vos & Potgieter 1988) and the other in the Hoedspruit Nature Reserve (Boomker, Horak, Booyse & Meyer 1991). At both localities the most commonly collected ticks were all stages of development of *Amblyomma hebraeum* and the adults of *Rhipicephalus simus*.

The single publication on the ticks of black and white rhinoceroses, *Diceros bicornis*, and *Ceratotherium simum*, represents an anthology of results obtained whenever and wherever these large animals became available for parasite collection (Knapp, Krecek, Horak & Penzhorn 1997). Black and white rhinoceroses were infested with *Amblyomma hebraeum*, and in addition the black rhinoceroses from KwaZulu-Natal were infested with *Dermacentor rhinocerinus* and *Rhipicephalus maculatus*, while the white rhinos from the Kruger National Park harboured *D. rhinocerinus* and *R. simus*.

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PARASITES OF DOMESTIC AND WILD ANIMALS IN SOUTH AFRICA. XXIII. HELMINTH AND ARTHROPOD PARASITES OF WARTHOGS, *PHACOCHOERUS AETHIOPICUS*, IN THE EASTERN TRANSVAAL LOWVELD

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ABSTRACT

HORAK, I. G., BOOMKER, J., DE VOS, V. & POTGIETER, F. T., 1988. Parasites of domestic and wild animals in South Africa. XXIII. Helminth and arthropod parasites of warthogs, *Phacochoerus aethiopicus*, in the eastern Transvaal Lowveld. *Onderstepoort Journal of Veterinary Research*, 55, 145–152 (1988).

A total of 69 warthogs, *Phacochoerus aethiopicus*, were collected from 4 localities within the Kruger National Park, eastern Transvaal Lowveld. These animals harboured 16 nematode species, 2 trematodes, 1 or 2 species of adult cestodes and the larval stages of 4 cestodes. No pattern of seasonal abundance could be determined for any of the helminths.

The warthogs were also infested with 3 flea species, 1 louse species, 8 ixodid tick species. 1 argasid tick and the nymphae of a pentastomid. The seasonal abundance of fleas of the genus *Echidnophaga*, of the sucking louse *Haematopinus phacochoeri* and the ixodid ticks *Amblyomma hebraeum*, *Rhipicephalus appendiculatus*, *Rhipicephalus simus* and *Rhipicephalus zambeziensis* was determined.

INTRODUCTION

The prevalence of several endo- and ectoparasites of warthogs, *Phacochoerus aethiopicus*, in South West Africa/Namibia has recently been reported (Horak, Biggs, Hanssen & Hanssen, 1983). The warthogs were infested with 9 nematode species, 1 or 2 cestode species, 6 species of ixodid ticks, 1 argasid tick species, a flea and a louse species and the larvae of a dipteran fly. Only the spirurid stomach worm *Physocephalus sexalatus* and the sucking louse *Haematopinus phacochoeri* exhibited clear patterns of seasonal abundance.

The present paper describes a similar survey conducted on warthogs in the Kruger National Park in the eastern Transvaal Lowveld.

MATERIALS AND METHODS

Survey region

Warthogs were collected from 4 localities within the Kruger National Park. These were Skukuza (24° 58′ S, 31° 36′ E; Alt. 262 m), Crocodile Bridge (25° 22′ S, 31° 54′ E; Alt. 217 m) and Lower Sabie (25° 07′ S, 31° 55′ E; Alt. 180 m) all situated in a vegetation zone classified as Lowveld; and Pafuri (23° 27′ S, 31° 19′ E; Alt. 305 m) where the vegetation is classified as Mixed Bushveld (Acocks, 1975). Gertenbach (1983) has identified 35 landscape types within the Park. According to his classification Skukuza lies within a region classified as Thickets of the Sabie and Crocodile Rivers; Crocodile Bridge and Lower Sabie in *Sclerocarya caffra/Acacia nigrescens* Savanna; and Pafuri within the Limpopo/Levumbu Flood plains.

Survey animals

With the exception of June 1980, when 1 extra warthog was shot, 1 animal from the most recent litter of piglets (which are generally born in November or December) and 1 older animal were shot at Skukuza each month from January 1980 to January 1981. Except for 1 animal of approximately 11 months of age, 2 warthogs of 12 months or older were shot each month at Crocodile Bridge over the same period. A total of 53 warthogs were collected at the 2 localities in this manner.

In addition 5 warthogs were shot at Pafuri during July 1980 and 2 during October 1981; 2 were shot at Lower Sabie during July 1980, 3 were shot at Skukuza during October and November 1982; and 4 animals were shot at Crocodile Bridge during November 1982.

Parasite recovery

The carcasses of the warthogs shot at Skukuza, Crocodile Bridge and Lower Sabie were transported to the laboratory at Skukuza where they were processed for parasite recovery. Those shot near Pafuri were transported to a nearby field laboratory where they were similarly processed.

At the laboratories unattached fleas and ticks were collected and stored in 70 % alcohol. Thereafter the carcasses were skinned and the skins were processed for ectoparasite recovery as described by Horak, De Vos & De Klerk (1984).

Numerous fleas being deeply imbedded in the skin, were not loosened by the parasite recovery process, and could not be removed with forceps without damage. Consequently, they were counted *in situ* and a small number removed for identification. This procedure, however, made it impossible to determine the exact numbers of the stick-tight fleas *Echidnophaga inexpectata* and *Echidnophaga larina* separately.

The nasal passages and paranasal sinuses of the first 13 warthogs shot were cut open and examined for oestrid larvae as described by Horak (1977). When these contained no larvae no further nasal passages were examined.

The carcasses were eviscerated and all visible cestode cysts collected. The lungs, the livers and the gastro-intestinal tracts were processed for helminth recovery as described by Horak, De Vos & Brown (1983).

Parasite counts

The lung and liver washings were examined *in toto* under a stereoscopic microscope for helminths as were several of the digests of the gastro-intestinal mucosae. Representative samples of the remaining digests as well as of all the gastro-intestinal ingesta were examined under the same microscope. The remains of the gastro-intenstinal contents were examined macroscopically for large nematodes and for cestodes in a flat-bottomed tray.

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TABLE 1 The helminth parasite recovered from 52 warthogs in the Kruger National Park

Helminth species	Total numbers of helminths recovered				Number of warthogs infested
	3rd stage	4th stage	Adult	Total	
Ascaris phacochoeri	25	2	35	62	16
Impalaia tuberculata	0	236	566	802	11
Murshidia spp.	0	4 411	—	4 411	17
Murshidia hamata	—	—	87 506	87 506	39
Murshidia pugnicaudata	—	—	18 706	18 706	35
Oesophagostomum spp.	0	2 256	—	2 256	17
Oesophagostomum mocambiquei	—	—	52 291	52 291	43
Oesophagostomum mwanzae	—	—	5 185	5 185	26
Physocephalus sexalatus	196	36	666	898	25
Probstmayria vivipara	—	Millions	—	—	52
Strongyloides sp.	0	0	116	116	3
Trichostrongylus spp.	0	139	—	139	8
Trichostrongylus falculatus	—	—	50	50	1
Trichostrongylus instabilis	—	—	793	793	4
Trichostrongylus thomasi	—	—	7 892	7 892	39
Trichuris sp.	0	10	0	10	1
Schistosoma sp.	—	—	15	15	1
Moniezia/Paramoniezia sp.	—	—	58*	58	11
Echinococcus sp.		Cysts			8
Taenia crocutae		Cysticerci			4
Taenia hyaenae		Cysticerci			3
Taenia regis		Cysticerci			15

* Scolices

TABLE 2 The arthropod parasites recovered from 51 warthogs in the Kruger National Park

Arthropod species	Total numbers of arthropods recovered					Number of warthogs infested
Fleas	Adults				Total	
Echidnophaga inexpectata/larina	12 932				12 932	46
Moeopsylla sjoestedti	143				143	23
Lice	Nymphae		Adults		Total	
Haematopinus phacochoeri	2 902		533		3 435	34
Ixodid ticks	Larvae	Nymphae	Males	Females	Total	
Amblyomma hebraeum	3 777	3 014	1 028*	348* (24)	8 167	51
Boophilus decoloratus	112	63	39	24 (0)	238	29
Hyalomma truncatum	0	0	7	3 (0)	10	7
Rhipicephalus appendiculatus	—	1 537	—	—	1 537	23
Rhipicephalus appendiculatus/zambeziensis	904	—	27	10 (0)	941	20
Rhipicephalus evertsi evertsi	8	9	0	0	17	11
Rhipicephalus simus	0	0	387	173 (5)	560	27
Rhipicephalus zambeziensis	—	526	—	—	526	19
Argasid ticks	Larvae	Nymphae	Adults		Total	
Ornithodoros porcinus porcinus	0	374	0		374	27
Pentastomids		Nymphae			Total	
Linguatula nuttalli		91			91	18

* Including *A. hebraeum* 525 males, 128 females collected from a single male adult warthog

() Number of maturing female ticks, i.e. the idiosoma of *A. hebraeum* >9,0 mm; *B. decoloratus* >4,0 mm; *H. truncatum* >7,5 mm; *R. appendiculatus/zambeziensis* >5,0 mm, *R. simus* >6,0 mm

The cestodes were not specifically identified but belonged to the genera *Moniezia* or *Paramoniezia*. Ticks, lice and unattached fleas were counted by the methods described by Horak, Potgieter, Walker, De Vos & Boomker (1983). The larvae and adults of *Rhipicephalus appendiculatus* and *Rhipicephalus zambeziensis* were not separated and these were lumped as *Rhipicephalus appendiculatus/zambeziensis*. The length of the idiosoma of adult engorging female ticks of all species was measured. The *Ornithodoros* ticks recovered from the warthogs have been assigned to *Ornithodoros porcinus porcinus* on host preference as suggested by Walton (1962).

Blood parasites

Blood smears were prepared as soon as possible after death. Impression smears of the spleen and lymphnodes were made during necropsy. Smears were made from 18 animals in 3 localities: 8 each from Skukuza and Crocodile Bridge and 2 from Pafuri. All the smears were fixed in methanol, stained in 10 % Giemsa stain for 35

TABLE 3 A comparison of the burdens of *Amblyomma hebraeum* of warthogs examined during a normal and a dry year using the Mann-Whitney U-test

Months examined	Rainfall (mm) Feb–Nov	Number of warthogs examined (sex rations)	Mean numbers (range) of *A. hebraeum* recovered								
			Larvae	U (sign)	Nymphae	U (sign)	Males	U (sign)	Females	U (sign)	Total
Oct/Nov 1980	414,5	8 (1 male: 7 females)*	18,6 (0–35)		24,4 (11–44)		7,6 (2–28)		3,3 (1–11)		53,9
Oct/Nov 1982	175,4	7 (5 males: 2 females)*	416,0 (56–1233)	0 (<0,001)	259,7 (27–858)	8 (<0,01)	203,1 (12–75)	8 (<0,01)	88,6 (5–308)	16 (=0,052)	967,4

* There is no statistical difference between the burdens of the male and female warthogs (sign) = (significance)

min and examined in immersion oil under 1 000 × magnification.

Climatic data

Mean monthly minimum and maximum atmospheric temperatures and monthly rainfall were recorded at Skukuza.

RESULTS

Helminths

The total numbers of helminths recovered from 52 warthogs slaughtered at monthly intervals at Skukuza and Crocodile Bridge are summarized in Table 1 (the ingesta of 1 animal were mislaid).

Thirteen nematode species, 1 trematode, 1 or 2 cestode species and the larval stages of 4 cestodes were recovered. *Probstmayria vivipara, Murshidia hamata* and *Oesophagostomum mocambiquei* were the most abundant helminths recovered. A large proportion of the total numbers of the latter 2 worms came from a single animal, which harboured 5 000 adult *O. mocambiquei* and 38 200 adult *M. hamata*.

All the *Impalaia tuberculata* recocvered from the warthogs were considerably smaller than normal and the males' spicules were markedly reduced in length.

A young warthog, 1 month of age, was infested with *Strongyloides* sp. This was the only helminth recovered from this animal. No *Strongyloides* sp. were recovered from the piglets of 2 or 3 months of age, but the 4-month-old animal and an adult animal from Crocodile Bridge were also infested. No other warthogs harboured this parasite.

Ascaris phacochoeri, O. mocambiquei, P. sexalatus, Trichostrongylus thomasi and *Trichostrongylus instabilis* and *Moniezia/Paramoniezia* sp. were recovered from the 2-month-old warthog. *M. hamata* and *Murshidia pugnicaudata* were first encountered when the warthogs were 6 months of age and *Oesophagostomum mwanzae* in a 7-month-old animal.

No pattern of seasonal abundance could be determined for any of the helminths.

The animals shot at Skukuza and Crocodile Bridge during October and November 1982 harboured the same parasites as those examined 2 years earlier at these localities and in addition 1 harboured 28 adult *Haemonchus krugeri* and another 100 adult *Oesophagostomum santos-diasi*. Those examined at Pafuri harboured only *A. phacochoeri, I. tuberculata, M. hamata, M. pugnicaudata, O. mocambiquei, P. vivipara* and *Moniezia/Paramoniezia* sp. One was also infested with 2 *Gastrodiscus aegyptiacus*. The 2 arthogs examined at Lower Sabie harboured only *M. hamata, M. pugnicaudata, O. mocambiquei* and *T. thomasi*.

Two of the warthogs had unidentified adult filarid nematodes in the lymphatic vessels adjacent to peripheral and visceral lymph nodes and 13 had microfilariae in the lymph nodes and the circulating blood (Palmieri, Pletcher, De Vos & Boomker, 1985).

Arthropods

The total numbers of ectoparasites recovered from 51 warthogs slaughtered at monthly intervals at Skukuza and Crocodile Bridge are summarized in Table 2 (no preservative had been added to the skin scrubbings of 2 animals and these could not be examined).

These animals harboured 3 flea species, a louse species, 7 ixodid tick species, 1 argasid tick and the nymphae of a pentastomid. All the animals were infested with *Amblyomma hebraeum* and the majority with 1 or both *Echidnophaga* species.

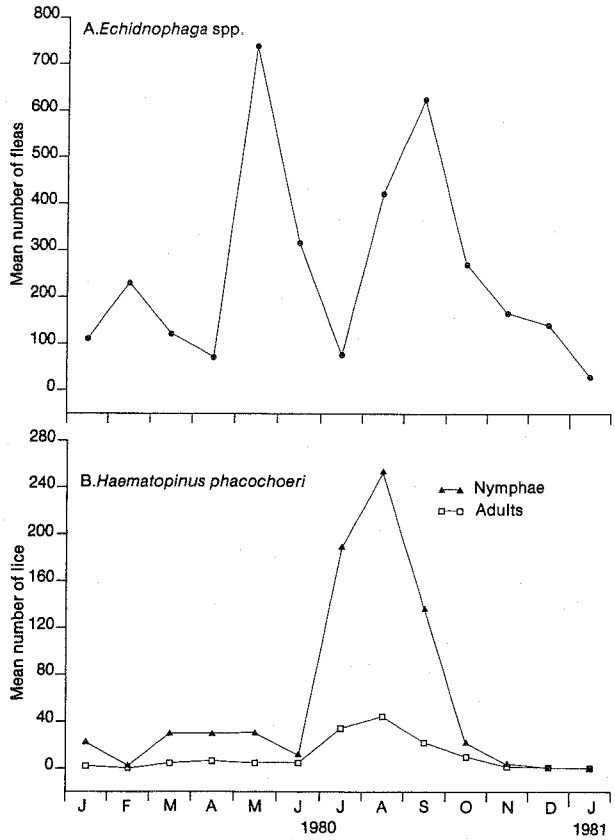

FIG. 1 The seasonal abundance of
A. *Echidnophaga* spp. and
B. *Haematopinus phacochoeri*
on warthogs in the Kruger National Park

At 1 month of age a warthog piglet had acquired infestation with *H. phacochoeri* and with 3 ixodid tick species. At 2 months of age a piglet harboured *H. phacochoeri, Echidnophaga* spp., 4 ixodid tick species and *Ornithodoros porcinus porcinus*. The piglets were 5 months old before the nymphae of *Linguatula nuttalli* were recovered from 1 of them.

The numbers of *A. hebraeum* larvae, nymphae and males recovered from the animals shot at Skukuza and Crocodile Bridge in October and Novemvber 1982, during a severe drought, were significantly greater ($P<0,01$) than those recovered from the animals shot at the same sites during the same months in 1980, a year of normal rainfall. The tick burdens of the 2 groups of animals are summarized in Table 3.

With the exception of adult *Rhipicephalus kochi*, which were recovered in small numbers from 4 out of the 7 warthogs shot at Pafuri, the animals from Pafuri and those from Lower Sabie were infested with the same parasites as those shot at Skukuza and Crocodile Bridge.

Some of the arthropod parasites exhibited distinct patterns of seasonal abundance. These are graphically illustrated in Fig. 1 & 2.

Peak burdens of the 2 *Echidnophaga* species were present during May and September. Peak numbers of *H. phacochoeri* were recovered from July to September.

The larvae of *A. hebraeum* peaked from February to May, the nymphae during May and during August and September, while peak adult burdens were recovered from January to March and during September 1980 and January 1981. The larvae of *R. appendiculatus/zambeziensis* were recovered in the greatest numbers from April to June and the adults from March to May. The nymphae of both *R. appendiculatus* and *R. zambeziensis*

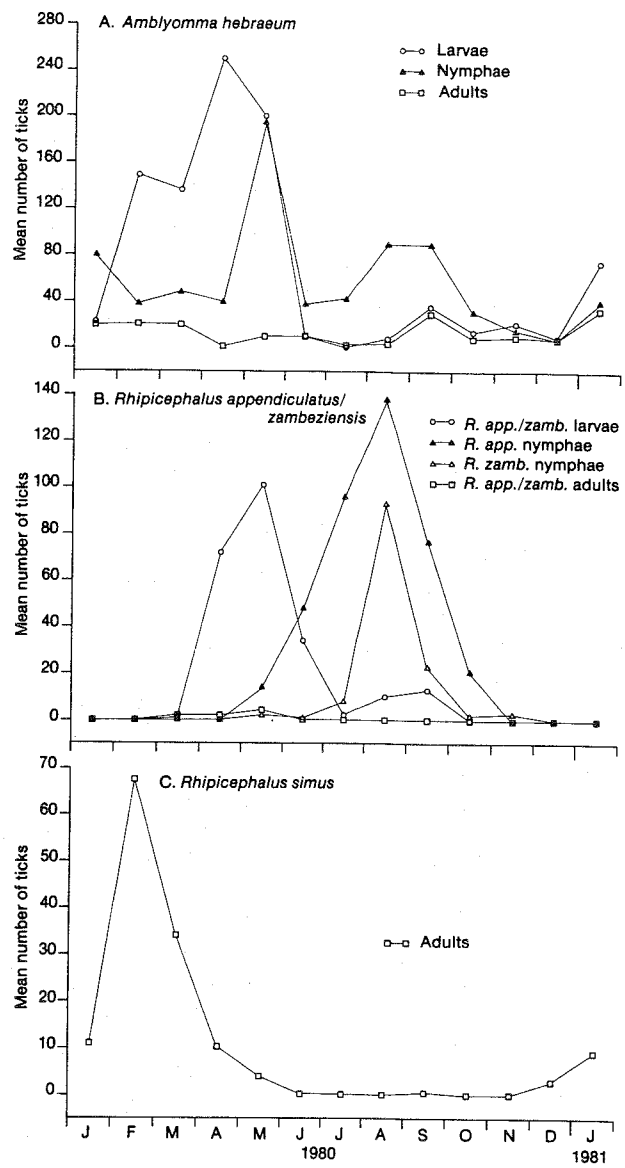

FIG. 2 The seasonal abundance of
A. *Amblyomma hebraeum* (excluding 1 animal with an exceptionally large adult burden)
B. *Rhipicephalus appendiculatus/zambeziensis* and
C. *Rhipicephalus simus*
on warthogs in the Kruger National Park

peaked during August. Peak burdens of adult *Rhipicephalus simus* were present during February.

Blood parasites

All smears examined were negative for blood parasites.

Climate

The mean monthly atmospheric temperatures and total monthly rainfall at Skukuza for the period January 1980 to January 1981 are graphically illustrated in Fig. 3.

The highest maximum temperatures were recorded during January to April and December 1980 and during January 1981, and the lowest minimum temperatures during June and July 1980. Rain fell mainly during January and February 1980 and during November 1980 to January 1981. Total annual rainfall for 1980 at Skukuza was 660,0 mm. Total annual rainfall during 1982 (the year of the severe drought) was 437,2 mm, 202,5 mm of which fell during January 1982 and 59,3 mm during December 1982, leaving 175,4 mm for the remaining 10 months.

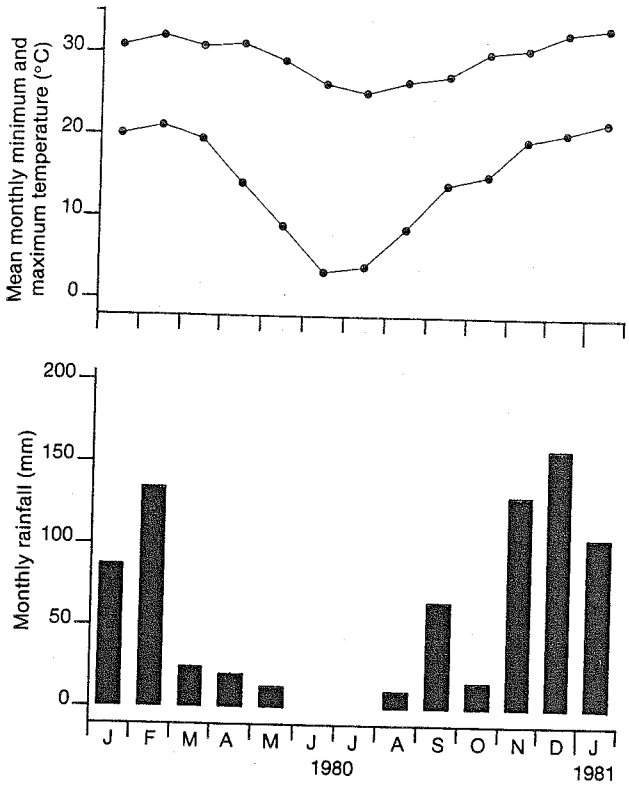

FIG. 3 Monthly mean minimum and maximum atmospheric temperatures and monthly rainfall at Skukuza from January 1980 to January 1981

Comment: The 60 year mean rainfall for February to November at Skukuza is 375,1 mm (Gertenbach, unpublished data, 1981). If the annual rainfall is calculated per season, i.e. from 1 July to 30 June (Gertenbach, 1980), the total for 1982/83 (275,6 mm) is the lowest ever recorded at Skukuza since records were started in 1919 (Gertenbach, unpublished data, 1985).

DISCUSSION

The warthogs examined in Namibia by Horak, Biggs, Hanssen & Hanssen (1983) harboured at least 10 helminth species and 10 arthropod species. Those examined in the Kruger National Park were infested with at least 19 helminth species (plus the larval stages of 4 cestodes), and 14 species of arthropod parasites. The helminths harboured in common by the 2 groups of warthogs are *O. mwanzae, P. sexalatus, P. vivipara* and *Moniezia/Paramoniezia* sp. and the arthropods are *E. larina, H. phacochoeri, Hyalomma truncatum, R. simus* and *O. porcinus porcinus*.

Helminths

Ascaris phacochoeri

This helminth has previously been recovered from warthogs in Zululand by Ortlepp (1939). The percentage of warthogs infested (30,8 %) in the present survey is identical to that of a group of domestic pigs infested with *Ascaris suum* (Horak, 1978a). These pigs had been consigned by farmers to the Pretoria Municipal Abattoir over a period of 1 year. The mean burden of adult *A. phacochoeri* (0,67 worms, range 0–7 worms) in the warthogs is, however, slightly lower than that of adult *A. suum* in the domestic pigs (2 worms, range 0–15 worms).

Impalaia tuberculata

This nematode, and the related species *Impalaia nudicollis,* are usually recovered from antelope, particularly impala *(Aepyceros melampus)* (Horak, 1978d) and blesbok *(Damaliscus dorcas phillipsi)* (Horak, 1978c). However, *I. nudicollis* has been recovered from warthogs in Namibia (Horak, Biggs, Hanssen & Hanssen, 1983), while those examined in the Kruger National Park harboured *I. tuberculata*. The measurements of both these worms from the warthogs were considerably smaller than those given by Gibbons, Durette-Desset & Daynes (1977) and Boomker (1977) in their reviews of the genus *Impalaia*. Contrary to the findings for *I. nudicollis* in the Namibian warthogs, in which few worms were adult, the majority of *I. tuberculata* in the Kruger National Park warthogs were adult (Table 1). Nevertheless the small size of the latter worms indicates that warthogs are not definitive hosts of this nematode.

Mushidia *spp.*

Ortlepp (1964) noted that there were no worms of the genus *Murshidia* in warthogs from Moçambique, while warthogs at Pilgrim's Rest and in Zululand were infested. Moçambique lies to the east and north of the Kruger National Park, Pilgrim's Rest to the west and Zululand to the south-east. It is possible that the warthogs from Moçambique examined by Ortlepp (1964), were by chance not infested with *Murshidia* spp. If, however, *Mushidia* spp. are indeed absent in warthogs in Moçambique it would be interesting to determine the exact boundary of infestation between the Kruger National Park and that territory. Very large burdens of worms of this genus are possible as 1 of the warthogs from Crocodile Bridge harboured a total of 48 000 immature and adult *M. hamata* and *M. pugnicaudata* and 1 from Pafuri harboured 40 775 immature and adult *M. hamata*.

Oesophagostomum *spp.*

Ortlepp (1964) identified *O. mocambiquei, O. mwanzae* and *O. santos-diasi* in material collected from warthogs in Moçambique and Pilgrims' Rest. No oesophagostomes were present in the specimens he examined from warthogs in Zululand. *O. mwanzae* has a very widespread distribution being present in warthogs in northern Moçambique and at Pilgrim's Rest (Ortlepp, 1964), in the Kruger National Park (present survey) and in northern Namibia (Horak, Biggs, Hanssen & Hanssen, 1983). In both Namibia and the Kruger National Park it was not the dominant oesophagostome, being outnumbered by *Oesophagostomum mpwapwae* at the former and *O. mocambiquei* at the latter locality.

The largest total number of immature and adult *Oesophagostomum* spp. recovered from a single warthog in the present survey was 7 400 worms, compared with 30 510 adult worms from a warthog in Namibia (Horak, Biggs, Hanssen & Hanssen, 1983).

Physocephalus sexalatus

Horak, Biggs, Hanssen & Hanssen (1983) recovered speak burdens of this nematode from January to March in warthogs from northern Namibia, while Horak (1978b) found that the related *Ascarops strongylina* was most abundant in domestic pigs in the Transvaal from November to March. No pattern of seasonal abundance could be determined in the present survey. Ortlepp (1964) has recorded both *A. strongylina* and *P. sexalatus* from bushpigs *(Potamochoerus porcus)* in the northern Transvaal, but *A. strongylina* has apparently not been recovered from warthogs (Round, 1968).

Probstmayria vivipara

As in the case of the animals in Namibia (Horak, Biggs, Hanssen & Hanssen, 1983) extremely large burdens, of which we did not attempt to ascertain the numbers, were present.

Strongyloides *sp.*

The fact that a 1-month-old animal and another young animal were infested with this worm seems to indicate a milk-borne route of infestation as in the case of *Strongyloides papillosus* in sheep and goats (Moncol & Grice, 1974).

Trichostrongylus *spp.*

We think that the small number of warthogs infested with *Trichostrongylus falculatus* and *T. instabialis,* and the small burdens of these worms in the infested warthogs, indicate that these are accidental infestations, as the true hosts are 1 or more of the antelope species in the park.

In the same way that *Trichostrongylus axei* appears to be an abomasal parasite in both domestic ruminants and horses (Soulsby, 1968), *T. thomasi* fills this niche in antelope (Round, 1968; Horak, Meltzer & De Vos, 1982; Horak, Brown, Boomker, De Vos & Van Zyl, 1982; Horak, De Vos & Brown, 1983; Boomker, Horak & De Vos, 1986), Burchell's zebras (Scialdo, Reinecke & De Vos, 1982) and warthogs (present survey).

Larval cestodes

The *Echinococcus* sp. cysts could have originated from adult cestodes of this genus present in a variety of carnivore species in the park. Adult *Taenia crocutae* and *Taenia hyaenae* are parasites of hyaenas while adult *Taenia regis* is found in lions (Round, 1968).

Arthropods

Echidnophaga *spp.*

Both *E. inexpectata* and *E. larina* are stick-tight fleas found firmly attached mainly along the softer undersides of the warthogs. *E. larina* is frequently encountered on warthogs, while *E. inexpectata* is supposedly a rarer parasite of these animals (Haeselbarth, Segerman & Zumpt, 1966). Although because of their stick-tight habit, it was not possible to obtain exact counts for either species in the present survey, the numbers of *E. inexpectata* generally seemed to exceed those of *E. larina.*

Whether the peak early winter and spring abundances of these fleas were real or due to large variations in individual burdens could not be ascertained. In Namibia no clear pattern of seasonal abundance of *E. larina* on warthogs could be determined (Horak, Biggs, Hanssen & Hanssen, 1983).

Moeopsylla sjoestedti

This is a jumping flea and was found mainly around the necks and heads of the warthogs. This species has been recovered from warthogs in east Africa from Kenya in the north to the eastern Transvaal Lowveld in the south (Haeselbarth *et al.,* 1966).

Haematopinus phacochoeri

This is the large sucking louse of warthogs (Ledger, 1980). In Namibia peak burdens were present on the warthogs in September of 1 year and during June of the following year (Horak, Biggs, Hanssen & Hanssen, 1983). In the present survey there was a clear peak of abundance of both nymphae and adults from July to September.

The months of peak abundance are also the months during which the available feed is at its driest. Perhaps the warthogs conserve energy during this time of nutritional stress by reducing the time spent on grooming and increasing the time devoted to foraging, hence the increasae in lice burdens.

Amblyomma hebraeum

Excluding the burdens of the 1 warthog carrying exceptionally large numbers of adult ticks (Table 2), warthogs must still be considered 1 of the preferred hosts of the adults of this tick. They carry more adult ticks than do blue wildebeest (Horak, De Vos & Brown, 1983), Burchell's zebras (Horak *et al.,* 1984), large and small carnivores (Horak, Jacot Guillarmmod, Moolman & De Vos, 1987) and impala (Horak, Boomker & De Vos, unpublished data, 1987) examined in the park. The ratio of larvae to nymphae to adults indicates a high proportion of adults, and this suggests that the warthog is a better host of adult *A. hebraeum* than of the immature stages.

The very large burdens of *A. hebraeum* recovered from the warthogs shot during the drought of 1982 do not imply that these ticks prefer dry conditions. They reflect rather that the animals' resistance was markedly reduced because of nutritional stress, and that they probably conserved energy by reducing grooming to a minimum, both these factors presumably leading to increased tick burdens (O'Kelly & Seifert, 1969).

The seasonal abundance of immature *A. hebraeum* on the warthogs is similar to that observed by Knight & Rechav (1978) on kudu, by Rechav (1982) on cattle, and by MacIvor & Horak (1984) on goats in the eastern Cape Province. The period of adult abundance on the warthogs, however, was longer than that observed on the other hosts.

Rhipicephalus appendiculatus/zambeziensis

Judging by the numbers recovered, warthogs are not important hosts of these ticks and particularly not of the adults. Burchell's zebra (Horak *et al.,* 1984) and more particularly impala and kudu (Horak, Boomker & De Vos, unpublished data, 1987) are better hosts. The seasonal abundance of all stages of development is similar to that of *R. appendiculatus* on impala and cattle in the northern Transvaal (Horak, 1982). The larvae of the 2 species were most abundant on the warthogs during the same months in which maximum abundance of this developmental stage has been recorded on blue wildebeest in the park (Horak, De Vos & Brown, 1983). The nymphal peak of *R. appendiculatus* on the warthogs corresponds to that on blue wildebeest and Burchell's zebra in the park (Horak, De Vos & Brown, 1983; Horak *et al.,* 1984).

Not only are *R. appendiculatus* and *R. zambeziensis* similar in appearance (Walker, Norval & Corwin, 1981), but their distributions overlap in certain regions and their seasonal abundance is similar (Norval, Walker & Colborne, 1982; present study).

Rhipicephalus kochi

This tick has previously been recovered from animals at Pafuri (Gertrud Theiler, unpublished data, 1964, as *Rhipicephalus neavei;* Horak, Potgieter, Walker, De Vos & Boomker, 1983). This is as yet the only site in the Republic of South Africa at which *R. kochi* is known to occur (Clifford, Walker & Keirans, 1983). The warthog does not appear to be a preferred host of this tick as no immature stages and few adults were recovered. Kudu, nyala and bushbuck examined at Pafuri during October 1981 harboured fairly large numbers of nymphae and adults (Horak, Potgieter, Walker, De Vos & Boomker, 1983), while only 1 of the 2 warthogs examined at the same time was infested and that with only 4 male *R. kochi.*

Rhipicephalus simus

In the park the adults of this tick seem to prefer monogastric animals such as Burchell's zebra (Horak *et al.*, 1984), carnivores (Horak *et al.*, 1987) and warthogs (present survey) rather than ruminants. Norval & Mason (1981) state that the larger ungulate and carnivore species are the most important wild hosts with warthogs frequently being parasitized.

The seasonal abundance on the warthogs roughly corresponds to the times of maximum abundance on Burchell's zebra in the park (Horak *et al.*, 1984) and on cattle in the northern Transvaal (Horak, 1982).

Other ixodid ticks

We consider *Boophilus decoloratus, H. truncatum* and *Rhipicephalus evertsi evertsi* to be accidental infestations on the warthogs. They are more a reflection of ticks present in the environment rather than host preference.

Ornithodoros porcinus porcinus

Chorley (1943) cited by Hoogstraal (1956) and Horak, Biggs, Hanssen & Hanssen (1983) recovered this tick on warthogs, although it is usually encountered in their burrows (Hoogstraal, 1956). In the present study 1 animal harboured 97 nymphae and another 107. These ticks had probably not completed feeding when the warthogs left their burrows in the mornings and some would presumably have remained on the animals until they returned to the burrows in the evenings. This would probably explain how the ticks spread from 1 burrow to the next.

Linguatula nuttalli

The recovery of the nymphae of this pentastomid from a high proportion of warthogs is a reflection of the large number of lions, the final host of this parasite, in the park. Horak, De Vos & Brown (1983) have recovered the nymphae of *L. nuttalli* from a fairly large proportion of blue wildebeest in the park.

Blood parasites

Trypanosomes, resembling *Trypanosoma vivax*, were seen by Curson (1928) in the blood of a single warthog in Zululand. Neitz (1931) examined blood, spleen and lymphnode smears of 56 warthogs from Zululand and, with the exception of 5 animals with microfilarial infections, no other haemoparasites were observed. In a subsequent investigation, 7 out of 34 warthogs in Zululand were found to be infected with microfilariae and a small *Theileria*-like piroplasm was found in the blood of 1 of these animals (Neitz, 1933). According to Neitz (1933) this was the 1st observation of small piros in the red cells of a warthog. No trypanosomes were seen.

In the persent survey an effort was made to detect *Theileria*-like parasites in the blood smears of the warthogs, but none were found. More animals from different geographical regions should be examined, however, as vector distribution may play a role in the prevalence of this parasite.

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PARASITES OF SOUTH AFRICAN WILDLIFE. VIII. HELMINTH AND ARTHROPOD PARASITES OF WARTHOGS, *PHACOCHOERUS AETHIOPICUS*, IN THE EASTERN TRANSVAAL

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ABSTRACT

BOOMKER, J., HORAK, I. G., BOOYSE, D. G. & MEYER, SANTA, 1991. Parasites of South African wildlife. VIII. Helminth and arthropod parasites of warthogs, *Phacochoerus aethiopicus*, in the eastern Transvaal. *Onderstepoort Journal of Veterinary Research*, 58, 195–202 (1991)

Helminth and arthropod parasites were collected from 41 warthogs, *Phacochoerus aethiopicus*, in the Hoedspruit Nature Reserve, eastern Transvaal. This reserve consists of a military base, which is a restricted area and is surrounded by a reserve, which is open to the public. Eleven nematode species, 1 or 2 cestode species and the larvae of 2 cestode species were recovered from the animals in the reserve, and 8 nematode species and 1 or 2 cestode species were recovered from those in the military base.

Oesophagostomum spp. were generally most abundant in warthogs in the reserve during the cooler months of the year, while *Probstmayria vivipara* also occurred in peak numbers during the cooler months, with an additional peak in October and November 1988 in warthogs in the reserve and the base, respectively. No pattern of seasonal abundance could be determined for the other helminth species.

The warthogs also harboured 8 ixodid and 1 argasid tick species, 3 flea species and 1 louse species. Adult and immature *Haematopinus phacochoeri* were most numerous during August and September, and the largest numbers of adult *Rhipicephalus simus* were present from December to April.

INTRODUCTION

The seasonal abundance of endo- and ectoparasites of warthogs, *Phacochoerus aethiopicus*, in northern Namibia and in the Kruger National Park (KNP) in the eastern Transvaal have recently been reported (Horak, Biggs, Hanssen & Hanssen, 1983; Horak, Boomker, De Vos & Potgieter, 1988). The warthogs from Namibia were infested with 9 nematode species, 1 or 2 cestode species, 6 ixodid tick species, 1 argasid tick species, a flea and a louse species and the larvae of a calliphorid fly. Those from the KNP harboured 13 nematode species, 1 trematode species, 1 or 2 cestode species, the larval stages of 4 cestode species, 7 ixodid tick species, 1 species of argasid, 3 flea species, 1 louse species and the nymphs of a pentastomid.

This paper describes a similar survey conducted on warthogs in the Hoedspruit Nature Reserve which is also situated in the eastern Transvaal Lowveld.

MATERIALS AND METHODS

Survey area

The warthogs were all shot in the Hoedspruit Nature Reserve (HNR) which is situated in a vegetation zone classified as Lowveld (Acocks, 1988). The temperature is warm to hot in summer and mild in winter, and frost does not occur.

The HNR is owned by the South African Defence Force and comprises approximately 4 000 ha. It consists of an inner area of about 2 000 ha, the restricted military base, around which lies another 2 000 ha, the reserve, which is open to the public. The base is separated from the reserve by a series of security fences, thus making it impossible for warthogs on either side to pass through. The outer fence of the reserve, however, is of such a nature that warthogs from the surrounding privately owned game farms can pass through with ease.

Climatological data

The mean monthly maximum and minimum atmospheric tempatures as well as the total monthly rainfall were recorded during the survey period.

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Survey animals

With the exception of March 1989, when none could be located, warthogs were shot each month for 12 consecutive months from August 1988 to July 1989. Although often unsuccessful, an attempt was made at each occasion to collect the same number of warthogs of the same ages and sexes from the reserve and the base. A total of 41 warthogs was shot, of which 5 adult males, 11 adult females, 5 subadult males, 2 subadult females 1 juvenile male and 4 juvenile females were shot in the reserve and 1 adult male, 4 adult females, 2 subadult males, 2 subadult females, 1 juvenile male and 3 juvenile females were shot on the base.

Parasite recovery

The carcasses were transported to a field laboratory where they were eviscerated and macroscopically visible parasites removed and preserved in 70 % alcohol.

The carcasses were skinned and eviscerated, and the gastro-intestinal tracts were divided into the stomachs, the small intestines and the large intestines, and placed in shallow, flat-bottomed plastic trays. The stomachs were cut open and the ingesta carefully removed so as not to disturb the underlying mucosa. The ingesta were discarded, but the stomach was thoroughly washed in normal saline and the volume of the resulting suspension measured. The small and the large intestines were opened separately with bowel scissors and washed in saline. The washings were added to the respective ingesta. The volumes of the ingesta were measured and poured into separate plastic buckets. A $\frac{1}{4}$th aliquot by volume was made of the ingesta of each of the small intestines and a $\frac{1}{5}$th aliquot of the ingesta of each of the large intestines. The worms in the various aliquots as well as those in the various stomach contents were killed by adding an equal volume of boiling saline to each. The suspensions were then individually washed over a sieve with apertures of 0,15 mm and the residues preserved in separate bottles in 10 % formalin. Digests of the gastro-intestinal mucosae were not done.

The hearts, lungs and livers of the first 16 animals were processed for helminth recovery as described by Boomker, Horak & De Vos (1989) and examined. When no parasites were found, these organs were no longer processed or examined.

TABLE 1 Amended list of the helminth parasites of warthogs in the Republics of South Africa and Namibia with reference to the first record and the authors of the descriptions used to assist with the identification

Helminth species	First record	Identification
Trematodes		
Gastrodiscus aegyptiacus Railliet, 1893	Horak *et al.*, 1988	+
Schistosoma sp.	Horak *et al.*, 1988	+
Cestodes		
Echinococcus sp. larvae	Horak *et al.*, 1988	+
Moniezia mettami Baylis, 1934	Ortlepp, 1964	Baylis, 1934
Paramoniezia phacochoeri Baylis, 1927	Baylis, 1927	Baylis, 1927
Taenia crocutae larvae	Horak *et al.*, 1988	+
Taenia hyaenae larvae	Horak *et al.*, 1988	+
Taenia regis larvae	Horak *et al.*, 1988	+
Nematodes		
Ascaris phacochoeri Gedoelst, 1916	Ortlepp, 1939	Ortlepp, 1939
Cooperia hungi Mönnig, 1931	This paper	Gibbons, 1981
Haemonchus krugeri Ortlepp, 1964	Horak *et al.*, 1988	+
Impalaia nudicollis Mönnig, 1931	Horak *et al.*, 1983	+
Impalaia tuberculata Mönnig, 1923	Horak *et al.*, 1988	Boomker, 1977
Microfilaria sp. (*sensu* Neitz, 1931)	Neitz, 1931	+
Microfilariae	Palmieri *et al.*, 1985	+
Murshidia hamata Daubney, 1923	Daubney, 1923	Daubney, 1923
Murshidia pugnicaudata (Leiper, 1909)	Daubney, 1923	Daubney, 1923
Odontogeton phacochoeri Allgrén 1921	Allgrén, 1921*	+
Oesophagostomum mocambiquei Ortlepp, 1964	Ortlepp, 1964	Ortlepp, 1964
Oesophagostomum mpwapwae Duthy, 1947	Horak *et al.*, 1983	+
Oesophagostomum mwanzae Daubney, 1924	Ortlepp, 1964	Ortlepp, 1964
Oesophagostomum roubaudi Daubney, 1926	Horak *et al.*, 1983	+
Oesophagostomum santosdiasi Ortlepp, 1964	Ortlepp, 1964	+
Oesophagostomum simpsoni Goodey, 1924	Ortlepp, 1964	+
Physocephalus sexalatus Diesing, 1861	Horak *et al.*, 1983	Yorke & Maplestone, 1926
Probstmayria vivipara Ransom, 1911	Le Roux, 1940	Yorke & Maplestone, 1926
Strongyloides spp.	Horak *et al.*, 1988	+
Trichostrongylus falculatus Ransom, 1911	Horak *et al.*, 1988	+
Trichostrongylus deflexus Boomker & Reinecke, 1989	Horak *et al.*, 1983	Boomker & Reinecke, 1989
Trichostrongylus thomasi Mönnig, 1932	Horak *et al.*, 1988	Mönnig, 1932
Trichuris sp.	Horak *et al.*, 1988	+

\+ Not found in this survey

* After Round (1968)

The ectoparasites were collected as described by Horak *et al.* (1988).

Parasite counts and identification

The lung, heart and liver washings of the first 16 animals, as well as the washings of the stomach walls and the aliquots of the small intestinal ingesta were examined under a stereoscopic microscope and all the worms removed.

The ingesta of the large intestines were examined in a flat-bottomed tray and all the macroscopically visible worms removed. Because of the large numbers of *Probstmayria vivipara* present, a 1/100th aliquot was made of each of the large intestinal ingesta after they had been macroscopically examined. The aliquot was examined under a stereoscopic microscope and *Probstmayria vivipara* counted.

With the exception of *Probstmayria vivipara,* all the worms were cleared in lactophenol and examined under a standard microscope with Nomarski's differential intereference illumination. They were identified with the aid of the descriptions by the authors listed in Table 1. This table also lists the helminth recovered to date from warthogs in South Africa and Namibia.

The ectoparasites were counted as described by Horak *et al.* (1988).

RESULTS

The total monthly rainfall and the mean monthly minimum and maximum atmospheric temperatures for the period August 1988–July 1989 are graphically illustrated in Fig. 1.

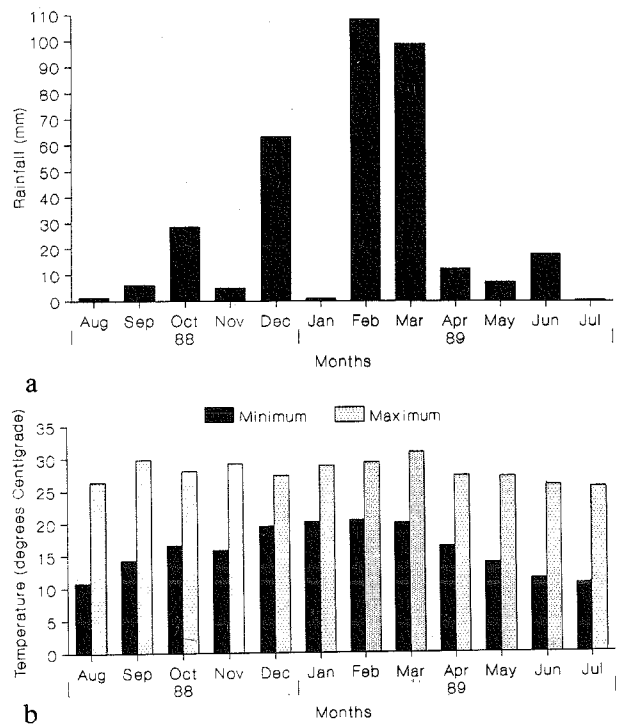

FIG. 1 Mean monthly rainfall (a) and minimum and maximum temperatures (b) at the Hoedspruit Nature Reserve

Helminths

The total numbers of helminths recovered from all the warthogs are summarised in Table 2.

TABLE 2 The helminths recovered from 41 warthogs from the Hoedspruit Nature Reserve

Helminth species	Larvae	Adults	Total	Number of warthogs infected
Reserve (28 warthogs)				
*Moniezia/Paramoniezia**	#	109	109	12
Taenia regis	2	#	2	2
Echinococcus	1	#	1	1
Ascaris phacochoeri	0	114	114	13
Cooperia hungi	0	100	100	1
Impalaia tuberculata	0	150	150	5
Murshidia hamata	+	34 361	34 361	28
Murshidia pugnicaudata	+	6 215	6 215	28
Murshidia spp.	118	—	118	8
Oesophagostomum mocambiquei	+	90 058	90 058	27
Oesophagostomum mwanzae	+	37 684	37 684	28
Oesophagostomum spp.	2 901	—	2 901	13
Physocephalus sexalatus	80	9 494	9 574	23
Probstmayria vivipara	$	$	267,255 million	28
Trichostrongylus deflexus	0	20	20	2
Trichostrongylus thomasi	0	60	60	4
Trichostrongylus spp. females	—	50	50	5
Mean nematode burden**	111	6 368	6 479	
Base (13 warthogs)				
*Moniezia/Paramoniezia**	#	53	53	5
Ascaris phacochoeri	0	32	32	5
Murshidia hamata	+	21 734	21 734	13
Murshidia pugnicaudata	+	4 588	4 588	12
Murshidia spp.	222	—	222	5
Oesophagostomum mocambiquei	+	8 507	8 507	12
Oesophagostomum mwanzae	+	4 090	4 090	12
Oesophagostomum spp.	94	—	94	3
Physocephalus sexalatus	0	610	610	10
Probstmayria vivipara	$	$	148,331 million	13
Trichostrongylus spp. females	—	10	10	1
Mean nematode burden**	24	3 044	3 068	

* Scoleces
** Excluding *Probstmayria vivipara*
\# Not found in warthogs
$ Larvae and adults not counted separately
\+ Counted together under the respective genera
— Not applicable

Eleven namatode species, 1 or 2 cestode species and the larval stages of 2 cestode were recovered from warthogs shot in the reserve. Of these, *Murshidia hamata, Murshidia pugnicaudata, Oesophagostomum mwanzae,* and *Probstmayria vivipara* occurred in all the warthogs. *Oesophagostomum mocambiquei* was recovered from 27 warthogs and *Physocephalus sexalatus* from 23. The remaining nematodes occured in less than 50 % of the animals examined.

Probstmayria vivipara was the most abundant of the nematodes, followed by *Oesophagostomum mocambiquei, Oesophagostomum mwanzae, Murshidia hamata, Physocephalus sexalatus* and *Murshidia pugnicaudata.*

Individual adult nematode burdens, excluding *Probstmayria vivipara* varied from 445 to 41 950 and the mean total adult nematode burden, excluding *Probstmayria vivipara,* was 6 368.

Eight species of nematodes and 1 or 2 cestode species were recovered from the 13 warthogs shot in the base. *Probstmayria vivipara* and *Murshidia hamata* were recovered from all these warthogs and *Murshidia pugnicaudata, Oesophagostomum mocambiquei* and *Oesophagostomum mwanzae* from 12 warthogs each. *Physocephalus sexalatus* occurred in 10 animals.

Probstmayria vivipara was again the most abundant nematode, followed by *Murshidia hamata, Oesophagostomum mocambiquei, Murshidia pugnicaudata* and *Oesophagostomum mwanzae.*

The individual adult nematode burdens, excluding *Probstmayria vivipara,* varied from 91 to 7 260 and the mean total adult nematode burden, excluding *Probstmayria vivipara,* was 3 044.

Ascaris phacochoeri and the *Moniezia/Paramoniezia* spp. were only recovered from animals younger than 18 months, while *Oesophagostomum* spp., *Murshidia* spp., *Physocephalus sexalatus* and *Probstmayria vivipara* were already present in the youngest animal in the survey, a male, 3–4 months old, shot in the reserve during August 1988.

No differences in the mean monthly nematode burdens or nematode species composition between the ages or the sexes of the warthogs shot at either locality, were evident.

The seasonal fluctuations of *Oesophagostomum* spp., *Murshidia* spp. and *Probstmayria vivipara* are graphically illustrated in Fig. 2–4.

In both groups of warthogs, peaks in the numbers of *Oesophagostomum* spp. occurred during the cooler months of the year. The high peak seen in warthogs from the reserve shot during August 1988, however, is due to 1 animal harbouring 30 700 *O. mocambiquei,* and probably does not reflect the true situation. No seasonal pattern of abundance was evident for the *Murshidia* spp. The largest numbers of *Probstmayria vivipara* were recovered during the cooler months of the year, with a peak occurring during October and November 1988 in the warthogs from the reserve and the base, respectively.

TABLE 3 Arthropod parasites recovered from 28 warthogs from the Hoedspruit Nature Reserve, eastern Transvaal

Arthropod species	Total numbers of arthropods recovered					Number of warthogs infested
Fleas	Males		Females		Total	
Echidnophaga inexpectata/larina	7 098*				7 098	27
Moeopsylla sjoestedti	72		132		204	18
Lice	Nymphs	Males	Females		Total	
Haematopinus phacochoeri	1 228	170	200		1 598	14
Ixodid ticks	Larvae	Nymphs	Males	Females	Total	
Amblyomma hebraeum	158	1 228	254	80 (0)	1 720	28
Amblyomma marmoreum	2	0	0	0	2	1
Boophilus decoloratus	126	0	0	0	126	3
Hyalomma truncatum	0	0	10	4 (0)	14	3
Rhipicephalus appendiculatus	2	0	0	0	2	1
Rhipicephalus evertsi evertsi	2	2	0	0	4	2
Rhipicephalus simus	0	0	82	40 (2)	122	16
Rhipicephalus zambeziensis	0	4	2	0	6	2
Argasid ticks	Larvae	Nymphs	Adults		Total	
Ornithodoros porcinus porcinus	0	232	0		232	13

() = Number of maturing female ticks, i.e. the idiosoma of *A. hebraeum* > 9,0 mm; *H. truncatum* > 7,5 mm; *R. simus* > 6,0 mm
* = Sexes not determined

TABLE 4 Arthropod parasites recovered from 13 warthogs on a military base near Hoedspruit, eastern Transvaal

Arthropod species	Total numbers of arthropods recovered				Number of warthogs infested
Fleas	Males	Females		Total	
Echidnophaga inexpectata/larina	1 036*			1 036	13
Moeopsylla sjoestedti	2	6		8	3
Lice	Nymphs	Males	Females	Total	
Haematopinus phacochoeri	534	46	68	648	8
Ixodid ticks	Larvae	Nymphs	Males	Females	Total	
Amblyomma hebraeum	0	18	2	2 (2)	30	8
Rhipicephalus simus	0	0	40	12 (2)	52	8
Argasid ticks	Larvae	Nymphs	Adults		Total	
Ornithodoros porcinus porcinus	0	2	2		4	2

() = Number of maturing female ticks, i.e. the idiosoma of *A. hebraeum* > 9,0 mm and *R. simus* > 6,0 mm
* = Sexes not determined

Arthropods

The total numbers of arthropods recovered from the warthogs in the reserve and on the base are summarised in Tables 3 and 4.

The warthogs harboured 3 flea species, 1 louse species 8 ixodid tick species and 1 argasid tick species. The animals in the reserve not only harboured a greater variety but also greater numbers of parasites than the animals on the base.

The seasonal abundance of the adults of the tick *Rhipicephalus simus,* the fleas *Echidnophaga inexpectata* and *Echidnophaga larina* combined and the louse *Haematopinus phacochoeri* for both groups of warthogs are graphically illustrated in Fig. 5–7. Because of the large variation in the burdens of the lice, the burdens have been transformed to their square roots (Fig. 7).

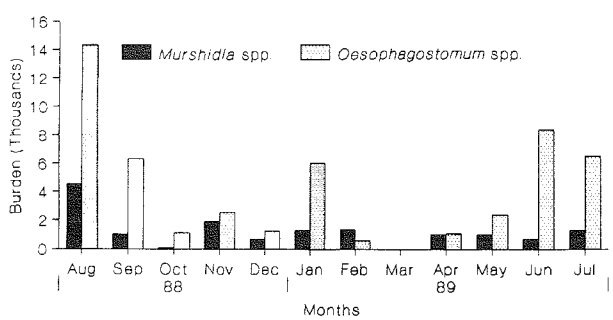

FIG. 2 Seasonal fluctuation in the numbers of *Oesophagostomum* spp. and *Murshidia* spp. in warthogs in the reserve

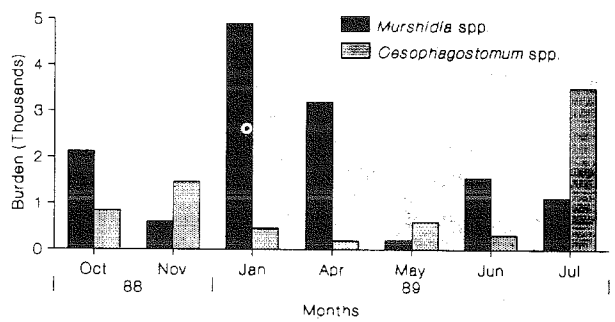

FIG. 3. Seasonal fluctuation in the numbers of *Oesophagostomum* spp. and *Murshidia* spp. in warthogs on the military base

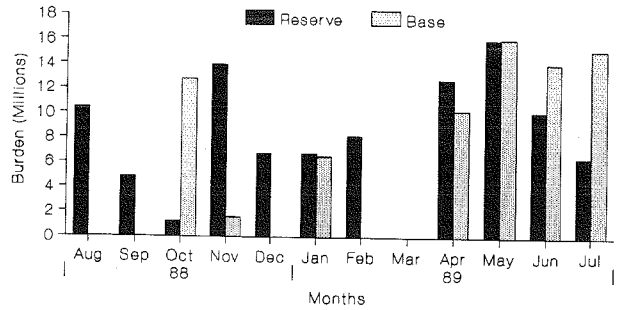

FIG. 4 Seasonal fluctuation in the numbers of *Probstmayria vivipara* in warthogs in the reserve and the military base

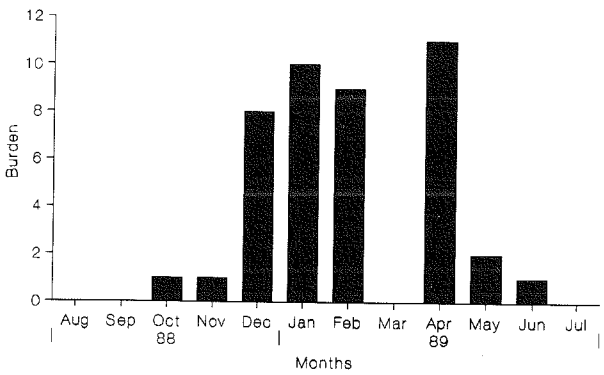

FIG. 5 Seasonal fluctuation in the numbers of *Rhipicephalus simus* on warthogs in the Hoedspruit Nature Reserve

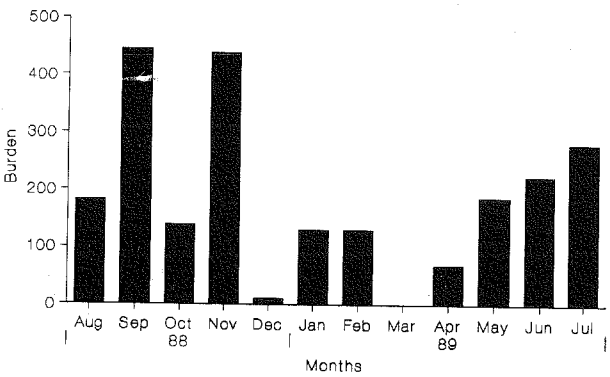

FIG. 6 Seasonal fluctuation in the numbers of *Echidnophaga* spp. on warthogs in the Hoedspruit Nature Reserve

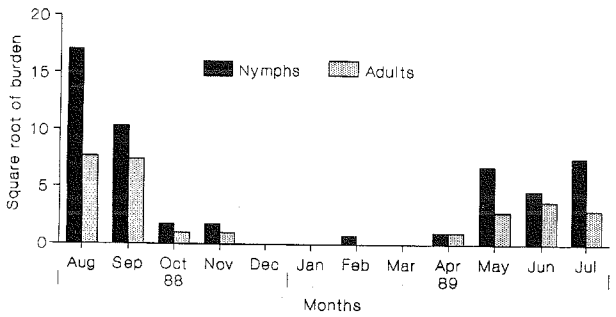

FIG. 7 Seasonal fluctuation in the numbers of *Haematopinus phacochoeri* on warthogs in the Hoedspruit Nature Reserve.

Although variation was considerable, peak flea burdens were generally recorded from August to November and May to July, while peak burdens of immature and adult *H. phacochoeri* were present during August and September. No lice were recovered during December and January. Adult *R. simus* were present from October to June, with the largest numbers being recovered from December to April. The other ectoparasites did not exhibit clear patterns of seasonal abundance.

DISCUSSION

Helminths

Fourteen helminth species were recovered in this study from the warthogs in the reserve. This is 5 species fewer than from warthogs in the KNP, but 4 more than from warthogs in Namibia (Horak, Biggs, Hanssen & Hanssen, 1983; Horak *et al.*, 1988). At least 9 helminths species were recovered from the animals on the base.

The small number of species recovered from warthogs on the base is probably firstly due to the fact that they are an isolated population, consisting of about 80 animals, that has no contact with other warthogs, and secondly because very few other animals species occur on the base. Thus, if cross-infection does take place it can only occur to a limited degree. Neither the carnivore associated *Taenia* sp. and *Echinococcus* sp. larvae, nor *Cooperia hungi, Impalaia tuberculata* or the *Trichostrongylus* spp. were recovered from these warthogs, although they were present in those in the reserve.

The difference in the mean total adult nematode burdens between the 2 groups of warthogs is presumably also due to the above-mentioned factors.

Ascaris phacochoeri, which we consider a definitive parasite of warthogs, has previously been recorded from warthogs from Zululand (Ortlepp, 1939, 1964) and the KNP (Horak *et al.*, 1988). The mean adult burden of the warthogs from the reserve was approximately double that of those in the KNP, while that of the warthogs from the base was about the same (Horak *et al.*, 1988). Only 1 immature *Ascaris* sp. was recovered from the warthogs from Namibia (Horak, Biggs, Hanssen & Hanssen, 1983).

C. hungi is a common parasite of impala, *Aepyceros melampus* (Horak, 1978b). Although the spicules of the specimens recovered during this survey were of normal size, the fact that they were present in only 1 animal confirms their status as an accidental parasite of warthogs. This assumption is augmented by the fact that although large numbers of impala occur in the area in the KNP where warthogs were previously surveyed, *C. hungi* was not found in a single warthog (Horak *et al.*, 1988).

All the *I. tuberculata* recovered in this survey were considerably smaller and the males' spicules shorter than those in antelope (Boomker, 1977; Gibbons, Durette-Desset & Daynes, 1977). This agrees with the findings of Horak *et al.* (1988) for *I. tuberculata* from warthogs in the KNP and those of Horak, Biggs, Hanssen & Hanssen (1983) for *Impalaia nudicollis* from warthogs in Namibia. It indicates that both *Impalaia* species can survive in warthogs but that these animals are not preferred hosts.

Worms of the genus *Murshidia* were not recovered from warthogs in Mozambique or Namibia (Ortlepp, 1964; Horak, Biggs, Hanssen & Hanssen, 1983). Two species of this genus were, however, present in warthogs in the Central African Republic (Troncy, Graber & Thal, 1972), Zululand (Daubney, 1923; Ortlepp, 1964), on the escarpment of the eastern Transvaal and in the eastern Transvaal Lowveld (Ortlepp, 1964; Horak *et al.*, 1988). Only

Murshidia hamata was present in a warthog from the north-western Transvaal (Boomker & Horak, unpublished data, 1989). Horak *et al.* (1988) found large numbers of *Murshidia* spp. in warthogs in the KNP but only moderate numbers were recovered during this survey.

It appears that certain individuals harbour large numbers of *Oesophagostomum* spp. or *Murshidia* spp. but the factors predisposing to such burdens are not known.

With the exception of *Oesophagostomum santosdiasi,* which was recovered from only 1 warthog in the KNP (Horak *et al.,* 1988), the same *Oesophagostomum* spp. as those in the KNP were present in warthogs in this survey. *Oesophagostomum mwanzae* appears to have a very wide distribution and has been recovered from warthogs in the Central African Republic (Troncy *et al.,* 1972), in Uganda, Kenya, Tanzania and Malawi (Daubney 1924; Goodey, 1924), in northern Mozambique and on the escarpment of the eastern Transvaal (Ortlepp, 1964), in the eastern Transvaal Lowveld (Horak *et al.,* 1988), in the north-western Transvaal (Boomker & Horak, unpublished data, 1989) and in northern Namibia (Horak, Biggs, Hanssen & Hanssen, 1983). In the survey of warthogs in Namibia it was outnumbered by *Oesophagostomum mpwapwae* and in the eastern Transvaal Lowveld by *Oesophagostomum mocambiquei.* The latter worm has only been recorded from warthogs on the eastern side of the continent, namely northern Mozambique (Ortlepp, 1964) and the eastern Transvaal escarpment and Lowveld (Ortlepp, 1964; Horak *et al.,* 1988; present survey).

The largest number of *Oesophagostomum* spp. recovered from a single warthog in the present survey was 35 000 worms. This is 4 490 more than recovered from a single animal in Namibia (Horak, Biggs, Hanssen & Hanssen, 1983) and 27 600 more than from an animal in the KNP (Horak *et al.,* 1988). As is apparent from the various surveys, burdens of nematodes of this genus may vary considerably.

From Fig. 1a & 2 it seems that peak numbers of *Oesophagostomum* spp. occurred in warthogs in the reserve approximately 3 months after good rainfall, and that the size of the peak depends on the amount of rain. During October 1988 approximately 30 mm rain fell and a small peak occurred during January 1989. Rainfall in excess of 100 mm was measured during February 1989 and 98 mm during March 1989. Small numbers of *Oesophagostomum* spp. were recovered during May 1989 but a peak was reached during June 1989. No such pattern was, however, seen in the warthogs on the base, nor was it apparent for the *Murshidia* spp. or *Probstmayria vivipara* in both groups of warthogs.

Physocephalus sexalatus occurs in warthogs, bushpigs and domestic pigs in South Africa (Ortlepp, 1964, Horak, 1978a; Reinecke, 1983; Horak *et al.,* 1988). The numbers of *Physocephalus sexalatus* recovered during this survey are similar to those in warthogs in Namibia, but are considerably greater than those in warthogs in the KNP. Contrary to the findings of Horak *et al.* (1988), no seasonal pattern of abundance was evident in this survey.

The related *Ascarops strongylina* has been recorded from bushpigs in the northern Transvaal (Ortlepp, 1964) and domestic pigs (Horak, 1978a) but has as yet not been recorded from warthogs.

As in the case of the warthogs in Namibia and the KNP, *Probstmayria vivipara* occurred in vast numbers and peak burdens were present during the cooler months of the year.

Trichostrongylus deflexus (= Trichostrongylus colubriformis of Horak, Biggs, Hanssen & Hanssen, 1983 and *Trichostrongylus instabilis* of Horak *et al.,* 1988) is a recently described nematode of several antelope species (Boomker & Reinecke, 1989). It appears to infect a wide range of hosts, but its presence in warthogs should be regarded as accidental.

Trichostrongylus thomasi is an abomasal parasite of a number of antelope species (Round, 1968; Horak, Meltzer & De Vos, 1982; Horak, Brown, Boomker, De Vos & Van Zyl, 1982; Horak, De Vos & Brown, 1983; Boomker, Horak & De Vos, 1986, 1989) and also occurs in the stomach of Burchell's zebra (Scialdo, Reinecke & De Vos, 1982) and warthogs (Horak *et al.,* 1988; present survey). It fills the same niche in wild animals as is occupied by *Trichostrongylus axei* in domestic animals, but should be regarded as an accidental parasite of warthogs.

Since *Moniezia/Paramoniezia* sp. were recovered only from the younger animals, we postulate that immunity against these tapeworms develops after initial infection, similar to that seen in domestic ruminants infected with *Moniezia expansa* (Reinecke, 1983).

Arthropods

The smaller numbers of species and smaller overall numbers of ectoparasites recovered from the warthogs on the military base than from those in the nature reserve are probably due to the same factors affecting their respective helminth burdens, as mentioned earlier.

Only *Echidnophaga larina* was recovered from the warthogs in Namibia (Horak, Biggs, Hanssen & Hanssen, 1983), while the animals in the KNP and the present survey harboured both *Echidnophaga larina* and *Echidnophaga inexpectata* (Horak *et al.,* 1988). As in the case of the KNP warthogs, the 2 flea species could not be counted separately because of their stick-tight habit, and consequently many were counted *in situ.* This also prevented the determination of their sex. Although considerable variation occurred in the monthly mean flea burdens of the warthogs in Namiba, the KNP and the present survey, it would appear as if the largest numbers of fleas are present during the period May or June to November or December.

The mean burdens of *Moeopsylla sjoestedti* on the warthogs in the HNR were higher than those on the warthogs in the KNP (Horak *et al.,* 1988). The warthogs examined in Namibia did not harbour this flea (Horak, Biggs, Hanssen & Hanssen, 1983). No pattern of seasonal abundance was evident and more female than male fleas were recovered.

In Namibia peak burdens of *Haematopinus phacochoeri* were recorded on warthogs in September of 1 year and June the following year (Horak, Biggs, Hanssen & Hanssen, 1983), while in the KNP peak burdens were present from July to September (Horak *et al.,* 1988). The recovery of large numbers of lice during August and September in the present survey confirms the winter to early spring abundance of this species.

The complete absence of lice on the KNP warthogs during January 1981 (Horak *et al.,* 1988) and during December and January in this survey leads

one to speculate as to where and in what stage these permanent ectoparasites oversummer. The most likely explanation would seem to be as eggs attached to the hair of the warthogs or loose in the burrows of the animals. It could also be that the piglets, which are generally born during November or December in South Africa (Smithers, 1983), acquire infestation from their dams and ensure the survival of the lice during the summer months. This was indeed so in the KNP where a 1-month old piglet examined during January 1980 was fairly heavily infested compared with the absence of infestation on the other warthogs slaughtered at the same time. The same, however, did not apply in the case of a similarly aged warthog examined during January 1981.

If one excludes the adult ticks of the single warthog in the KNP that carried an exceptionally large burden of *Amblyomma hebraeum,* then the mean burdens for the warthogs examined there were 74 larvae, 59 nymphs and 14 adults (Horak *et al.,* 1988). The mean burden for the warthogs examined in the reserve in the present survey was 6 larvae, 44 nymphs and 12 adults. With the exception of the larval numbers (for which we have no explanation), the mean burdens of the 2 groups of warthogs were thus reasonably similar. These findings confirm that warthogs are one of the preferred hosts of adult ticks of this species. The immature stages, and more particularly the larvae, feed on a large variety of mammals and also one some ground-nesting birds (Theiler, 1962; Horak, MacIvor, Petney & De Vos, 1987). Consequently, the immature stages which feed on warthogs are not solely responsible for generating the adult burdens on the same animals.

The warthogs in Namibia, the KNP and the present survey were infested with adult *Hyalomma truncatum* but burdens were never very large (Horak, Biggs, Hanssen & Hanssen, 1983: Horak *et al.,* 1988). Preferred hosts of the adults are large herbivores such as zebras, eland and cattle (Horak, 1982; Rechav, 1986; Horak & MacIvor, 1987). Scrub hares are preferred hosts of the immature stages, which are also found on rodents (Rechav, 1986: Horak & MacIvor, 1987).

Horak *et al.* (1988) state that in the KNP adult *Rhipicephalus simus* seem to prefer monogastric animals such as Burchell's zebras, carnivores and wart-hogs rather than ruminants. The fairly large numbers of adults recovered from the warthogs in the present investigation confirm their observations for this host species. The immature stages of *R. simus* feed on rodents (Norval & Mason, 1981).

The period of peak adult abundance from December to April corresponds to that of January to April with a peak in February on the warthogs in the KNP (Horak *et al.,* 1988). The mean burden of *R. simus* on the warthogs in that survey was more than double that in the present study.

The larvae of *Amblyomma marmoreum* utilise a large number of mammals and some ground-frequenting birds as hosts (Horak *et al.,* 1987). Their presence on the warthogs, albeit in small numbers, is therefore not unexpected. We consider *Boophilus decoloratus, Rhipicephalus appendiculatus, Rhipicephalus evertsi evertsi* and *Rhipicephalus zambeziensis* to be accidental infestations. Their occurrence on the warthogs probably reflects their periods of peak seasonal abundance rather than host preference.

The presence of *Ornithodoros porcinus porcinus* on warthogs that are out of their burrows has been discussed by Horak *et al.* (1988). Its recovery from warthogs in Namibia, the KNP and the present survey indicates that this must be considered a normal occurrence.

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HELMINTHS AND ARTHROPODS OF BLACK AND WHITE RHINOCEROSES IN SOUTHERN AFRICA

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ABSTRACT: Helminths and arthropods were collected and quantified from two black rhinoceroses (*Diceros bicornis bicornis*) and one white rhinoceros (*Ceratotherium simum*), and ticks from an additional four black and two white rhinoceroses in southern Africa. The helminths of a black rhinoceros from the Republic of South Africa and one from Namibia were quantitatively measured and recorded for each compartment of the alimentary tract. *Probstmayria vivipara* was the most abundant parasite in each animal. A recently described nematode, *Diceronema versterae*, was found in the stomach of one animal. *Draschia megastoma* was present in the descending colon of the same animal, but it was twice the size of similar specimens reported from equids and the typical granulomatous lesions caused by this nematode in horses were not observed. New records of other helminths from rhinoceroses include *Parabronema roundi*, *Kiluluma* sp., *Kiluluma goodeyi*, *Kiluluma magna*, *Khalilia rhinocerotis*, *Oxyuris karamoja* and *Anoplocephala gigantea*. The stomach bot, *Gyrostigma pavesii*, was collected from one black and one white rhinoceros. Ticks collected from the black rhinoceroses were *Amblyomma hebraeum*, *Dermacentor rhinocerinus*, *Rhipicephalus maculatus*, *Rhipicephalus muehlensi* and *Haemaphysalis silacea*. The two white rhinoceroses were infected with *A. hebraeum*, *D. rhinocerinus*, *Hyalomma truncatum*, *Rhipicephalus simus*, *Rhipicephalus appendiculatus* and *Rhipicephalus zambeziensis*.

Key words: Black rhinoceros, *Diceros bicornis bicornis*, white rhinoceros, *Ceratotherium simum*, nematodes, cestodes, acari, bots.

INTRODUCTION

The rhinoceroses, both black (*Diceros bicornis bicornis*) and white (*Ceratotherium simum*) are endangered species. In southern Africa there is great interest in the management and protection of these animals (Walker, 1994) with particular concern for their diseases (Meltzer, 1994) and parasites (Penzhorn et al., 1994). Von Linstow (1907) published the first description of a helminth from a rhinoceros. Since then, there have been numerous reports of arthropods and helminths from these animals (Zumpt, 1964). Most of the parasite studies have been taxonomic, although there have been a few reports describing nematode-induced skin lesions (Round, 1964; Young, 1966; Hitchins and Keep, 1970; Kock and Kock, 1990). Checklists of the helminths of rhinoceroses compiled by Round (1968) and Penzhorn et al. (1994) provided a comprehensive documentation of all the parasites that have been recorded from both black and white rhinoceroses.

Zumpt (1965) reported larvae of the gasterophilid fly *Gyrostigma pavesii* from both black and white rhinoceroses, and indicated that this fly may be expected wherever its hosts still occur in Africa. Checklists of the ixodid ticks collected from black and white rhinoceroses south of the Sahara Desert have been prepared by Theiler (1962), while Baker and Keep (1970) have compiled such lists for black and white rhinoceroses in KwaZulu-Natal (Republic of South Africa). Walker (1991), in a review of ixodid ticks occurring in southern Africa, mentioned that adults of two ticks, *Amblyomma rhinocerotis* and *Dermacentor rhinocerinus*, feed primarily on black and white rhinoceros. While the immature stages of *A. rhinocerotis* are unknown (Walker, 1991), the larva of *D. rhinocerinus* recently has been described for the first time and the nymph and adults were redescribed (Keirans, 1993).

In this study, we present quantitative data on the helminths and arthropods collected from a black rhinoceros in the Re-

public of South Africa and another in Namibia. Also included are the identifications of some parasites collected from a white rhinoceros in the Republic of South Africa. In addition, quantitative data are presented for ticks collected on another four black and two white rhinoceroses in the Republic of South Africa.

MATERIALS AND METHODS

A female black rhinoceros with calf died during June 1993 in the Umfolozi section of the Hluhluwe-Umfolozi Park (KwaZulu-Natal, Republic of South Africa; 28°12′ to 28°21′S, 31°42′ to 31°59′E). The two vegetation types recognized in this reserve are Zululand Thornveld along the slopes and crests of the hills and Lowveld in the valleys (Acocks, 1988).

In Namibia, a 30-yr-old male black rhinoceros was killed in July 1989 because its lip and lower mandible were injured, resulting in deterioration of its condition. This rhinoceros ranged in the western part of the Etosha National Park (Namibia; 18°55′S, 15°31′E). The dominant vegetation type is saline desert with dwarf shrub savanna fringe and mopane savanna (Giess, 1971).

The death of a white rhinoceros, in June 1991 in the Hluhluwe-Umfolozi Park provided the opportunity to collect internal parasites. Unfortunately, the animal had been dead for 1 day before ingesta samples were collected so quantitative estimates of parasite species were not performed. A few helminths could be identified and these are reported herein.

The culling of a problem black rhinoceros in the Addo Elephant National Park (Eastern Cape Province, Republic of South Africa; 33°27′S, 25°44′E) in a vegetation zone classified as Valley Bushveld (Acocks, 1988); the immobilization of three black rhinoceroses in the Ndumu Game Reserve northern KwaZulu-Natal, Republic of South Africa; 26°53′S, 32°15′E) in a vegetation zone classified as a Lowveld subtype of Tropical Bush and Savannah (Acocks, 1988); and the death, due to injuries, of two white rhinoceroses in the southern region of Kruger National Park (northeastern Mpumalanga, Republic of South Africa; south of 24°24′S, 31°15′ to 31°55′E) in a vegetation zone classified as Arid Lowveld and Lowveld (Acocks, 1988), presented the opportunity for collecting additional ticks.

Each rhinoceros, excluding the six involved in the tick study, was processed for the collection of internal parasites following procedures used in equids (Malan et al., 1981a, 1981b). All organs were examined and samples from the gastrointestinal tracts collected. Quantitative samples were collected from the ingesta in the stomach, small intestine and the four sections of the large intestine. Aliquot sizes of the ingesta from rhinoceroses in Namibia were limited because of the high financial costs of carrying these samples as accompanying baggage on an airline flight. Samples (5% of the mass) were collected for transport back to the laboratory and the remainder examined macroscopically at post-mortem examination. The ingesta from the black rhinoceros from KwaZulu-Natal was collected totally. A 1% sample of the total was examined microscopically, if counts were <100 helminths, a second 1% sample was examined. For the white rhinoceros, 20% of stomach and small intestine ingesta were collected and 10% of the remaining material came from compartments of the alimentary tract. Up to 10% of the remaining ingesta was examined macroscopically. Usually 10% of the intestinal serosa was frozen and then examined with an illuminated diamond sorting lamp for fourth stage larvae of cyathostome nematodes. Many of these parasites were in such poor condition that specific identifications could not be determined and quantitative counts were not completed. Samples of all organs were placed in 10% formalin for histopathological examination, but pathological lesions were not noted. Thin blood smears were made from the Namibian black rhinocerous and stained with Giemsa's stain, according to standard procedures, for the presence of protozoan parasites. Larvae of the gasterophilid fly *G. pavesii* were collected from the mucosal wall and contents of the stomach. Ixodid ticks were collected from the skins of the dead black rhinoceros and the two dead white rhinoceroses as described by Horak et al. (1992b). Ticks were collected by hand from three black rhinoceroses after the animals had been immobilized. All the ticks were identified and counted using a stereoscopic microscope.

Nematodes were identified to genus using the descriptive data and keys in Anderson et al. (1974) and Lichtenfels (1975), as well as various checklists (Round, 1968; Penzhorn et al., 1994) or descriptive reports (Thapar, 1924; 1925; Fitzsimmons, 1962; Neveu-Lemaire, 1924; Baylis, 1939; Usui and Horii, 1985; Ezzat, 1945). Stunkard (1926) was used as the authority for identification of cestodes. Stomach bots were identified from descriptions given by Zumpt (1964). Representative specimens of helminths and arthropods collected in this study are deposited in the United States National Parasite Collection (Biosystematics and National Parasite Collection Unit, United States Department of Agriculture, Beltsville,

TABLE 1. Helminth and gasterophilid parasites from black rhinoceros in the Republic of South Africa and Namibia.

Species of parasites	South Africa (n=2)[b]		Namibia (n=2)[b]	
	Preferred sites in host[a]	Total numbers	Preferred sites in host[a]	Total numbers
Nematoda				
Kiluluma goodeyi	C	1,310		
Kiluluma magna	A	5,420		
Kiluluma rhinocerotis	C	18,490	C, A	2,720
Diceronema versterae	S	2,100		
Probstmayria vivipara	C	17,858,200	C, A, D	385,360,000
Draschia megastoma	D	100		
Parabronema roundi	S	4,200		
Oxyuris karamoja	A	250	C, A	80
Cestoda				
Anoplocephala gigantea	I	1,698	I	1,400
Diptera				
Gyrostigma pavesii	S	168		

[a] S, stomach; I, small intestine; C, cecum; A, ascending colon; D, descending colon.
[b] n = number of hosts examined.

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RESULTS AND DISCUSSION

Three nematode and one cestode species were collected from the black rhinoceros in Namibia (Table 1). Protozoa were not found in the blood smears. *Probstmayria vivipara* was the most numerous of the helminths collected and was present in the cecum, descending colon and ascending colon. *Kiluluma rhinocerotis* was present in substantial numbers in the cecum and the ascending colon. A large number of scoleces of the cestode *Anoplocephala gigantea* were present in the small intestine.

A greater variety of helminths, gasterophilid and arthropods were found in the black rhinoceros from the Hluhluwe-Umfolozi Park (Tables 1 to 3). A recently described genus and species of nematode, *Diceronema versterae* (Atractidae), was found in the stomach (Gibbons et al., 1996). *Parabronema roundi* also occurred in substantial numbers in the stomach as well as *Gyrostigma pavesii*, the stomach bot. The small intestine contained a few *Kiluluma* sp., *K. goodeyi* and *K. magna*. *Parahronema vivipara* were abundant and many scoleces of *A. gigantea* were present. The cecum contained the greatest numbers of the three *Kiluluma* spp. *Parahronema vivipara* were present in enormous numbers. A few specimens of *Kiluluma* spp. were found in the descending colon along with a substantial number of *P. vivipara* and small numbers of *Oxyuris karamoja* and *Draschia megastoma*. The three *Kiluluma* spp. were present in the colon, with *K. magna* being the most abundant followed by *Kiluluma* sp. and *K. goodeyi*. *Oxyuris karamoja* was abundant in the ascending colon as was *P. vivipara*. Immature nematodes were not identified.

In the white rhinoceros from KwaZulu-Natal, we identified only a few specimens of internal parasites since most of the helminths in the ingesta had deteriorated and could not be identified. These included four second instar and two third instar larvae of *G. pavesii* from the stomach; *K. rhinocerotis* from the cecum; *K. rhinocerotis* and *O. karamoja* from the descending colon and *P. vivipara* from the ventral colon (Table 1).

The numbers of ticks collected from the black and white rhinoceroses are summa-

rized in Tables 2 and 3. The black rhinoceros from the Addo Elephant National Park had two species of ticks while the three from the Ndumu Game Reserve were infected with four species of ticks. The two white rhinoceroses from the Kruger National Park had six species of ixodid ticks.

Scanning electron micrographs of six *Kiluluma* spp., *Khalilia rhinocerotis* and *Draschia megastoma* are presented in Figures 1–8. These were used in the identification and differentiation of these species (see below).

Anoplocephala gigantea (Cestoda, Anoplocephalidae) was originally described from a black rhinoceros from Mozambique (Peters, 1856) and subsequently reported from a white rhinoceros from Zaire (Stunkard, 1926) and the Republic of South Africa (Mönnig, 1928) and from both black and white rhinoceroses (Zumpt, 1964) in the Republic of South Africa. It was present in the small intestines of both black rhinoceroses we examined and this is the first report for this parasite from Namibia.

Kiluluma rhinocerotis (Nematoda, Cyathostominae) was first described by Neveu-Lemaire (1924) from a black rhinoceros in Ethiopia. We found this species in both the black rhinoceros from Namibia and the white rhinoceros from the Republic of South Africa. Body measurements for nematodes from both hosts were similar to those of the original description. This is the first report of this parasite subsequent to its original description and our findings represent a new host record for the white rhinoceros and new geographic records for southern Africa.

The genus *Kiluluma* was created by Skrjabin (1916) in response to a need for a more appropriate generic name for a rhinoceros nematode that had been described earlier by von Linstow (1907); *Deletocephalus stylosus* of von Linstow (1907) did not exhibit generic characteristics in common with the type species *D. dimidiatus* and the first recorded strongylid nematode of the rhinoceros was re-

TABLE 2. Ixodid ticks on four black and two white rhinoceroses in the Republic of South Africa.

Rhinoceros		Total numbers of ticks collected								
		Amblyomma hebraeum			*Dermacentor rhinocerinus*	*Hyalomma truncatum*	*Rhipicephalus maculatus*		*Rhipicephalus simus*	
Age	Sex	Larvae	Nymphs	Adults	Adults	Adults	Nymphs	Adults	Adults	Other ticks
Addo Elephant National Park (Black rhinoceros)										
Adult	M	293	394	1,211	0	0	0	0	0	*Haemaphysalis silacea*
Ndumu Game Reserve (Black rhinoceroses)										
Calf	F	0	8	48	8	0	40	352	0	*Rhipicephalus muehlensi*
Adult	F	0	0	62	2	0	28	266	0	
Adult	M	0	6	66	8	0	114	504	0	*Rhipicephalus muehlensi*
Kruger National Park (White rhinoceroses)										
Adult	F	122	222	686	116	4	0	0	66	*Rhipicephalus appendiculatus*
Adult	M	22	220	987	72	2	0	0	7	*Rhipicephalus zambeziensis*

TABLE 3. Ixodid tick species reported on white and black rhinoceroses in the Republic of South Africa and Zimbabwe.

	Republic of South Africa		Zimbabwe	
	Theiler (1962), Baker and Keep (1970), present study		Norval (1985)	
Tick species	White	Black	White	Black
Amblyomma hebraeum	+	+	+	–
Amblyomma rhinocerotis	+	+	–	+
Amblyomma sparsum	–	–	–	+
Amblyomma tholloni	–	+	–	–
Dermacentor rhinocerinus	+	+	+	+
Haemaphysalis silacea[a]	–	+[b]	–	–
Hyalomma marginatum rufipes	–	+	+	–
Hyalomma truncatum	+	+	+	–
Rhipicephalus appendiculatus	+	+	+	–
Rhipicephalus capensis	–	+	–	–
Rhipicephalus compositus	–	–	–	+
Rhipicephalus evertsi evertsi	–	–	+	–
Rhipicephalus lunulatus	–	–	–	+
Rhipicephalus maculatus	+	+	–	–
Rhipicephalus muehlensi	–	+	–	–
Rhipicephalus simus	+	+	+	–
Rhipicephalus zambeziensis[a]	+[c]	–	–	–
Rhipicephalus zumpti	–	+	–	–

[a] New record.
[b] Only larvae.
[c] Single nymph only.

named *Kiluluma stylosa* by Skrjabin (1916). Thapar (1924) rejected the species description on the basis that the measurements cited by Skrjabin (1916) were different from those given by von Linstow (1907). He subsequently described six new species of this genus *Kiluluma* from a collection of strongylid nematodes collected by R. T. Leiper from the large intestine of a black rhinoceros in Uganda and named them *K. rhinocerotis*, *K. africana*, *K. pachyderma*, *K. macdonaldi*, *K. solitaria* and *K. magna*. Later, Thapar (1925), studying the same collection, described four additional species as *K. goodeyi*, *K. brevicauda*, *K. brevivaginata* and *K. cylindrica*. Taylor (1925) concluded that all of the species described above except *K. magna* were probably the same species; *K. rhinocerotis*, *K. africana*, *K. pachyderma* and *K. solitaria* were considered as synonyms and it was suggested that *K. macdonaldi* also might belong with this group. However, Taylor (1925) did not suggest which species names should be used. A nearly similar conclusion was recorded by Yorke and Maplestone (1926) after examining the same collection of parasites as Taylor (1925); they observed that only one species of the genus was present.

An eleventh species of the genus was described by Mönnig (1926) from a collection of parasites from rhinoceroses from the Republic of South Africa. One of these had been labeled as *K. stylosa*. Mönnig (1926) accepted that Thapar (1924) was correct in assuming that *K. stylosa* consisted of several specifically different species, accepted the six new species as valid, reported *K. rhinocerotis*, *K. africana*, *K. pachyderma* and *K. solitaria* in his collection, and described a new species, *Kiluluma longispiculata*, which was later synonymized with *K. goodeyi* in an addendum to his paper (Round, 1968). In a parasite-host checklist for the rhinoceros, Round

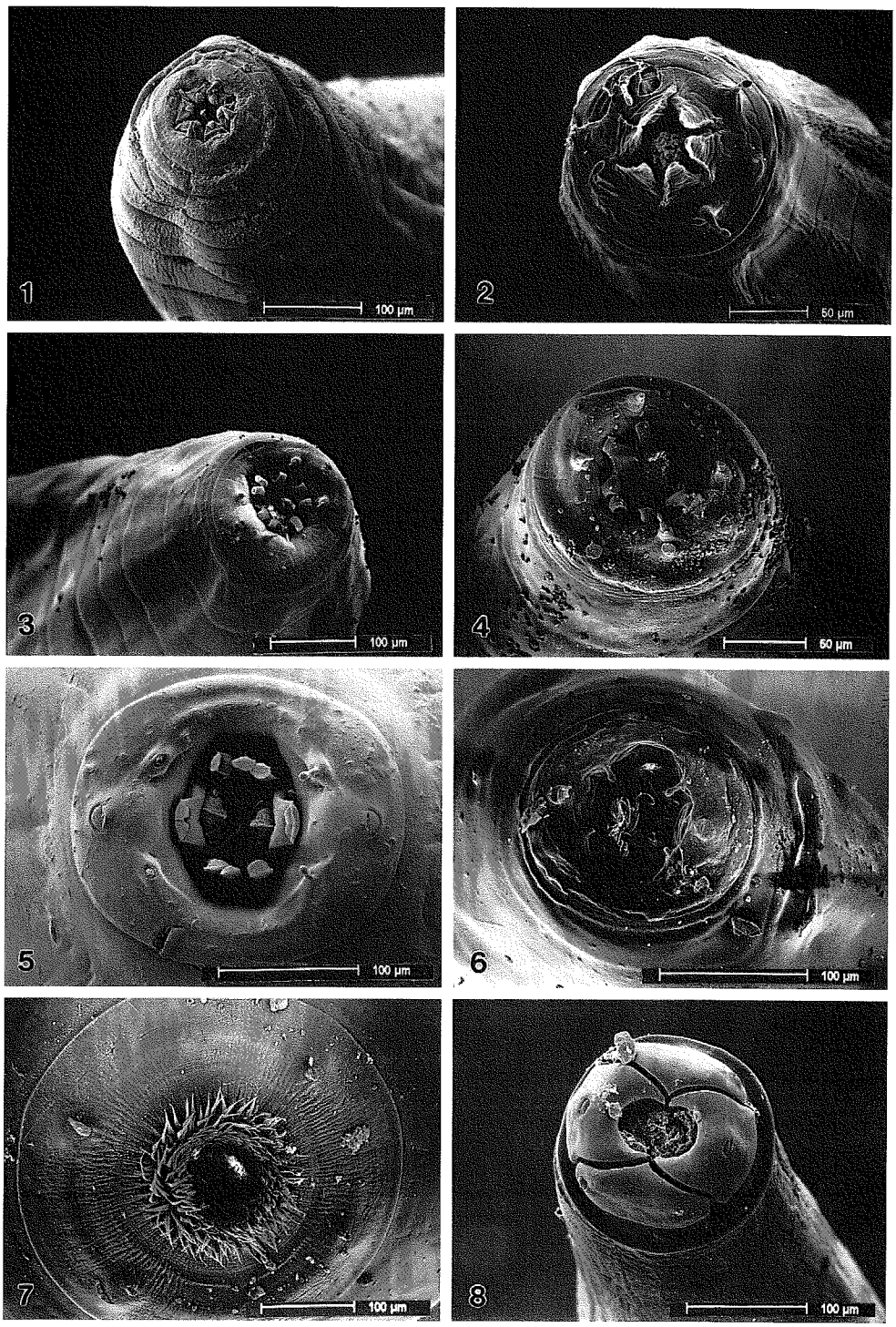
(1968) lists all of the above species for the genus *Kiluluma* but acknowledges that Sandground (1933) admonishes "With the possible exception of *K. magna*, which is slightly larger and *K. goodeyi*, *K. brevivaginata* and perhaps *K. brevicauda* in which the male can be distinguished by its longer spicules, the remaining species do not possess clear differential characters." Round (1968) concludes that " . . . a reexamination of this genus is obviously necessary."

The larger specimens of *Kiluluma* spp. we collected from the black rhinoceros in the Hluhluwe-Umfolozi Park resemble specimens described by Thapar (1924) and Mönnig (1926) as *K. magna* and *K. goodeyi*. We have identified specimens as belonging to these two species based on body size, spicule length and morphology, bursal ray architecture and mouthpart arrangement. Scanning electron microscope photos were made of Mönnig's (1926) specimens and those from our study; these helped to confirm that the species present in both collections were similar (Figs. 1 to 6). In the case of the remaining specimens of the genus *Kiluluma*, we believe these should be referred to as *Kiluluma* spp. until their taxonomic status can be determined. We propose applying molecular biological techniques which have been used to separate eggs of *Strongylus* spp. (Campbell et al., 1995) to differentiate the *Kiluluma* spp. There were 217 specimens examined in this group. All came from the black rhinoceros from the Hluhluwe-Umfolozi Park. Most of the specimens came from the cecum although some were in the small intestine, ascending colon and descending colon. Excluding *K. magna*, these nematodes ranged in body length from 11 to 23 mm and resembled those described by Thapar (1924). Except for differences in body length, they appeared to be a single species.

Diceronema versterae, recently described by Gibbons et al. (1996), was found in the stomach of the black rhinoceros from the Hluhluwe-Umfolozi Park (Table 1). A few specimens of *D. megastoma* also were found in the descending colon of this animal (Fig. 8). This is the first report for this parasite from the rhinoceros in a location other than the stomach where it usually produces tumor-like lesions. There were no intestinal lesions in the rhinoceros. In southern Africa, this parasite has been reported from Burchell's (*Equus burchelli antiquorum*) and Hartmann's (*Equus zebra hartmannae*) zebras (Scialdo-Krecek, 1984), and it is frequently found in horses (Lichtenfels, 1975). The specimens from the rhinoceros were twice the length of those from equids, ranging from 19–21 mm and 15–16 mm for females and males, respectively. Other than size, the nematodes from rhinoceros were morphologically similar to those from the zebra and horse. The nematode *Oesophagostomum columbianum*, which infects both sheep and certain antelopes, produces a visible tissue reaction only in sheep (Horak, 1981), another nematode *Impalaia nudicollis*, which infects various antelopes, is considerably smaller than normal when collected from warthogs (*Phacochoerus aethiopicus*) (Horak et al., 1983a). It was suggested that this could indicate that antelopes are the normal definitive hosts for these parasites and not sheep or warthogs. This also may be the case for *D. megastoma* in the rhinoceros in which there appears to be no tissue damage, but considerably larger specimens of the parasite are found in a different region of the alimentary tract than was reported previously.

Parabronema roundi was found in the stomach of the black rhinoceros in the Hluhluwe-Umfolozi Park. This parasite was first recorded from the intestine of a black rhinoceros in Kenya by Fitzsimmons (1962). This is the first report for this parasite in southern Africa. Another species, *P. rhinocerotis*, has been recorded in the black rhinoceros in Ethiopia (Khalil, 1927).

The pinworm, *O. karamoja* was described by Baylis (1939) from specimens from a black rhinoceros in Uganda. Sub-



FIGURES 1–8. Scanning electron micrographs of anterior extremities of nematodes from black and white rhinoceroses from southern Africa. 1. *Kiluluma rhinocerotis* from the Mönnig collection at Onderstepoort Veterinary Institute (OVI), Republic of South Africa (SA). 2. *Kiluluma* spp. from a black rhinoceros female, (SA). 3. *Kiluluma goodeyi* from a black rhinoceros female, (SA). 4. *K. goodeyi* from the Mönnig collection (OVI). 5. *Kiluluma magna* from a black rhinoceros female, (SA). 6. *K. magna* from the Mönnig collection (OVI). 7. *Khalilia rhinocerotis* from a black rhinoceros from Namibia. 8. *Draschia megastoma* from a black rhinoceros female from the Republic of South Africa.

sequently it was reported from a white rhinoceros in southern Africa that had been sent to a zoological garden in Oita Prefecture, Japan (Usui and Horii, 1985) following antihelmintic treatment of the host. We found this parasite from white and black rhinoceroses in the Republic of South Africa and a black rhinoceros in Namibia. *Oxyuris equi* has been reported from the black rhinoceros in South Africa by Mönnig (1926) 13 yr prior to the description of *O. karamoja* and it was probably the latter species.

According to Zumpt (1965) the immature stages of *G. pavesii* are found in both black and white rhinoceroses. The eggs are firmly attached to the skin of the head, but the conditions under which they hatch, how the larvae reach the stomach and where the second and third instars occur are unknown (Zumpt, 1965). The black rhinoceros from Umfolozi had only third instar larvae.

Using the checklists of Theiler (1962) and Baker and Keep (1970), our data, and records published in Norval (1985), we constructed checklists of the ixodid ticks reported on black and white rhinoceroses in the Republic of South Africa and Zimbabwe (Tables 2 and 3). Thirteen tick species are reported on black rhinoceroses in the Republic of South Africa and five are reported in Zimbabwe. White rhinoceroses in the Republic of South Africa may have eight ixodid tick species and those in Zimbabwe have seven. Two of these ticks, *A. rhinocerotis* and *D. rhinocerinus*, are virtually specific to rhinoceroses (Walker, 1991), while *A. hebraeum*, *A. sparsum*, *H. marginatum rufipes*, *H. truncatum*, *Rhipicephalus maculatus* and *Rhipicephalus simus* are common parasites of these and other large hosts in the Republic of South Africa and/or Zimbabwe. Of the 10 ornate tick species occurring in southern Africa, five (*A. hebraeum*, *A. rhinocerotis*, *A. sparsum*, *D. rhinocerinus*, *R. maculatus*) are regularly found on rhinoceroses within their distribution ranges.

Excluding elephants, the adults of *A. hebraeum* prefer the large ungulates, while the larvae and nymphs feed on the same hosts as well as on many smaller animals (Horak et al., 1987). The large numbers of adults collected, particularly from the black rhinoceros in the Addo Elephant National Park and the two white rhinoceroses in the Kruger National Park, indicate that these animals may be among the preferred hosts of this tick.

Amblyomma rhinocerotis were not collected in our study, although Baker and Keep (1970) recorded it on animals in the Ndumu Game Reserve. Duncan (1989) counted large numbers of adults on black rhinoceroses in Zimbabwe. *Amblyomma sparsum* is found on rhinoceros in Zimbabwe (Duncan, 1989), but it does not occur in the Republic of South Africa and there are only two records from northern Namibia (Walker, 1991).

With the exception of the rhinoceros in the Addo Elephant National Park, all the animals we examined had *D. rhinocerinus*. According to Theiler (1962) this park lies outside the distribution range of the tick which at the time had been recorded only from KwaZulu-Natal. With the reintroduction of rhinoceroses into the Kruger National Park, this tick also was introduced or reintroduced, as is evident from the tick infections on the two white rhinoceroses examined there (Braack et al., 1995). The hosts of the immature stages are unknown.

Keirans (1993) suggests that *D. rhinocerinus* may soon become another member of the world's extinct fauna considering the current threatened status of its hosts. The success of the Republic of South Africa in the conservation of rhinoceroses will, at least in the short term, ensure the survival of this tick.

Despite the few *Hyalomma* sp. collected in this study, substantial numbers may occur on rhinoceroses (Duncan, 1989). Other large wild mammals may have considerable numbers of these ticks (Rechav et al., 1987; Horak et al., 1992a). These are two-host ticks and the immature stages prefer Cape hares (*Lepus capensis*) or

scrub hares (*Lepus saxatilis*) (Horak and Fourie, 1991).

With the exception of *R. maculatus* and *R. simus*, the *Rhipicephalus* spp. that are collected from rhinoceroses in southern Africa should probably be considered accidental parasites. In addition to rhinoceroses all the stages of *R. maculatus* seem to prefer large mammals such as buffaloes (*Syncerus caffer*) and bushpigs (*Potamochoerus porcus*) (Horak et al., 1983b; 1991), while the immature stages also will attach to many smaller animals (Horak et al., 1983b; 1988; 1991). In the Republic of South Africa this tick is confined to the coastal and closely adjacent regions in northern KwaZulu-Natal (Walker, 1991).

The adults of *R. simus* seem to prefer monogastric animals and are found on the larger carnivores, and on warthogs (*Phacochoerus aethiopicus*), zebras and rhinoceroses (Baker and Keep, 1970; Walker, 1991). The immature stages occur on rodents (Walker, 1991).

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Carnivores

The survey on the ticks of yellow mongooses, *Cynictis penicillata*, was a by-product of a rabies survey. A number of these animals were killed in various provinces in order to determine their rabies status, and as an adjunct their skins were processed for parasite recovery (Horak, Chaparro, Beaucournu & Louw 1999). The yellow mongooses were infested with *Rhipicephalus theileri*, a tick that they share with meercats, *Suricata suricatta*, and Cape ground squirrels, *Xerus inauris*, with which they incidentally also share their burrows.

The large number of carnivore species included in the other study (Horak, Braack, Fourie & Walker 2000a), also came from all over the country and were either shot because of their nuisance status, or killed in accidents or fights or because they were injured or sick. A total of 104 wild carnivores were examined and 24 tick species recovered. With the exception of *Rhipicephalus sanguineus*, which was not collected from a single animal, the tick species recovered from the carnivores were fairly similar to those found on domestic dogs, with adult *Haemaphysalis elliptica* (*H. leachi*) and *Rhipicephalus simus* accounting for a large proportion of the adult ticks collected.

Horak, I.G., Chaparro, F., Beaucournu, J.-C. & Louw, J.P. 1999. Parasites of domestic and wild animals in South Africa. XXXVI. Arthropod parasites of yellow mongooses, *Cynictis penicillata* (G. Cuvier, 1829). *Onderstepoort Journal of Veterinary Research,* 66: 33-38.

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Parasites of domestic and wild animals in South Africa. XXXVI. Arthropod parasites of yellow mongooses, *Cynictis penicillata* (G. Cuvier, 1829)

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ABSTRACT

HORAK, I.G., CHAPARRO, F., BEAUCOURNU, J.-C. & LOUW, J.P. 1999. Parasites of domestic and wild animals in South Africa. XXXVI. Arthropod parasites of yellow mongooses, *Cynictis penicillata* (G. Cuvier, 1829). *Onderstepoort Journal of Veterinary Research*, 66:33–38

Eighty yellow mongooses, *Cynictis penicillata*, from five localities in South Africa were examined for arthropod parasites. Ten ixodid tick species, of which *Haemaphysalis zumpti* was the most abundant, prevalent and widely distributed, were collected. The mongooses were also infested with two mite species. *Echidnophaga gallinacea* was the most abundant of the eight flea species collected. It and *Ctenocephalides connatus* were present at every locality. A single biting louse species, *Felicola cynictis*, was recovered and it was the most prevalent ectoparasite on the mongooses.

Keywords: *Cynictis penicillata*, fleas, ixodid ticks, lice, mites, yellow mongooses

INTRODUCTION

Yellow mongooses, *Cynictis penicillata* (G. Cuvier, 1829), are inhabitants of the South West Arid zone of southern Africa (Skinner & Smithers 1990). Their distribution, however, also extends into the savannas of the North West, Northern, Gauteng and Mpumalanga Provinces of South Africa and also into north-west KwaZulu-Natal. They do not occur in desert, or in thick bush or forest, but prefer open country such as that in the Free State Province and the Karoo. They are gregarious animals, living in warrens in colonies of up to 20 individuals or more. According to Lynch (1980) they share these warrens with Cape ground squirrels, *Xerus inauris*, and also with suricates, *Suricata suricatta*, in much of their habitat. Because of the close physical association of these three small mammal species it is not surprising that they harbour several ectoparasites in common.

The ixodid ticks collected from yellow mongooses have been listed by Theiler (1962) and Lynch (1980). They are preferred hosts of *Haemaphysalis zumpti* and of *Rhipicephalus theileri* (Theiler 1947; Hoogstraal & El Kammah 1974). They also harbour the mite, *Nihelia cynictis* (Fain 1979). In addition several flea species and a single biting louse species, *Felicola cynictis*, have been collected from yellow mongooses (De Meillon, Davis & Hardy 1961; Ledger 1980; Segerman 1995).

Yellow mongooses are of considerable veterinary importance in South Africa. They are not only the main cause of viverrid rabies in this country but also serve as a maintenance host of the rabies virus (Swanepoel 1994). A survey to determine the prevalence of antibodies to rabies in yellow mongooses necessitated the killing of 96 animals (Chaparro 1996). In order to make the maximum use of these mongooses, arthropods were collected from 80 individuals and the present paper describes the results of this survey.

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MATERIALS AND METHODS

Survey localities

Mongooses were collected from around Ermelo (26°32′S, 29°59′E), Mpumalanga Province; Kuruman (27°28′S, 23°26′E), Northern Cape Province; Kroonstad (27°40′S, 27°14′E) and Bloemfontein (29°08′S, 26°10′E), north and central Free State Province respectively; and Queenstown (31°54′S, 26°53′E), Eastern Cape Province. The vegetation around Ermelo is classified as north-eastern Sandy Highveld; that around Kuruman as Kalahari Thorn and Shrub Bushveld; and that around Kroonstad, Bloemfontein and Queenstown as dry *Cymbopogon-Themeda* veld (Acocks 1988).

Parasite collection

The mongooses were caught in baited boxtraps which were placed close to inhabited burrows. The traps were checked in mid-morning and at dusk as the animals have been reported to feed mainly in the early morning and the late afternoon (Skinner & Smithers 1990). Each mongoose captured was restrained by placing a loop of thin rope around its neck. It was then pulled to the side of the trap and injected intramuscularly with 15 mg of ketamine (Ketalar: Warner-Lambert S.A.) and 1 mg of xylazine (Rompun: Bayer Animal Health). After collecting a blood sample the animal was killed by injecting 150 mg of pentobarbitone sodium (Euthatal: Maybaker S.A.) into its heart. Thereafter its skull was opened and the whole brain collected. The blood and the brain samples were used in the concurrent rabies research project which was being conducted on the mongooses (Chaparro 1996).

The dead mongooses were skinned and the skin of each animal was placed separately in a sturdy polythene bag into which the tick-detaching agent amitraz (Triatix: Hoechst Roussel) was poured. After 3–4 h in the bag the skin was removed and thoroughly washed and scrubbed in a large plastic tray using a brush with stiff metal bristles. The contents of the polythene bag and the plastic tray were sieved over a sieve with 150 µm apertures. The material remaining in the sieve was collected, transferred to a labelled bottle and preserved with 10% formalin. The contents of the bottle were later examined for arthropod parasites under a stereoscopic microscope and these were collected, identified and counted.

RESULTS AND DISCUSSION

The species and numbers of ixodid ticks collected and the presence of mites on the mongooses are summarized in Table 1. The flea and louse species taken from the mongooses are summarized in Table 2, and the locality prevalences of the most abundant tick and flea species as well as those of the mites and the biting louse, *F. cynictis*, are summarized in Table 3.

Ixodid ticks

The ten tick species present on the mongooses can be divided into two distinct groups, those that are warren or burrow associated and those that are encountered while the animals are foraging. The former group comprises *H. zumpti* and *R. theileri*. All parasitic stages of development of these ticks utilize yellow mongooses as hosts (Hoogstraal & El Kammah 1974; Table 1). They are also found on Cape ground

TABLE 1 Ixodid ticks and mites collected from 80 yellow mongooses at five localities in South Africa

Acarid species	Numbers of acarines collected					No. of animals infested
	Larvae	Nymphs	Males	Females	Total	
Ixodid ticks						
Amblyomma hebraeum	2	0	0	0	2	2
Amblyomma marmoreum	11	0	0	0	11	3
Boophilus sp.	1	0	0	0	1	1
Haemaphysalis zumpti	136	69	116	42	363	48
Hyalomma marginatum rufipes	5	0	0	0	5	4
Rhipicephalus evertsi evertsi	1	0	0	0	1	1
Rhipicephalus exophthalmos	2	0	0	0	2	1
Rhipicephalus follis/simus	3	0	0	0	3	2
Rhipicephalus theileri	12	30	1	2	45	19
Rhipicephalus turanicus	1	0	0	0	1	1
Mites						
Androlaelaps sp.	Life stages, sexes and numbers not determined					39
Nihelia cynictis	Life stages, sexes and numbers not determined					35

TABLE 2 Fleas and lice collected from 80 yellow mongooses at five localities in South Africa

Flea or louse species	Numbers of fleas or lice collected			No. of animals infested
	Males	Females	Total	
Fleas				
Ctenocephalides connatus	97	157	254	45
Ctenocephalides damarensis	1	9	10	6
Echidnophaga bradyta	14	42	56	22
Echidnophaga gallinacea	340	881	1 221	39
Synosternus caffer	15	33	48	8
Xenopsylla cryptonella	4	6	10	9
Xenopsylla erilli	0	2	2	1
Xenopsylla piriei	0	1	1	1
Lice				
Felicola cynictis	Sexes not determined		6 887	78

TABLE 3 The prevalence of ticks, mites, fleas and lice on yellow mongooses at five localities in South Africa

Arthropod species	Percentage of animals infested at each locality				
	Ermelo (n = 38)	Kuruman (n = 20)	Kroonstad (n = 12)	Bloemfontein (n = 4)	Queenstown (n = 6)
Ixodid ticks					
Haemaphysalis zumpti	60	20	92	100	100
Rhipicephalus theileri	0	70	17	50	17
Mites					
Androlaelaps sp.	26	85	75	25	33
Nihelia cynictis	37	80	33	0	17
Fleas					
Ctenocephalides connatus	47	45	83	75	83
Ctenocephalides damarensis	0	20	0	0	33
Echidnophaga bradyta	47	0	33	0	0
Echidnophaga gallinacea	3	95	92	100	67
Synosternus caffer	0	40	0	0	0
Xenopsylla cryptonella	0	20	33	25	0
Lice					
Felicola cynictis	97	100	100	75	100

n = number examined

squirrels and suricates (Theiler 1962; Hoogstraal & El Kammah 1974). This multi-host/parasite relationship could only be possible if the ticks themselves and the free-living phases of their life cycles are warren associated. Apparently *H. zumpti* prefers the moister, cooler climate of the Mpumalanga, Free State and Eastern Cape Provinces in contrast to *R. theileri* which seems to thrive in the hotter, more arid climate of the Northern Cape Province around Kuruman.

Yellow mongooses are subject to infection with the haemoparasite *Babesia cynicti*, which was first described by Neitz (1938). In a recent survey, Penzhorn & Chaparro (1994) recorded *B. cynicti* in blood smears from 50 of 56 yellow mongooses at Rooiwal, north of Pretoria, Gauteng Province, 13 of 18 animals from near Ermelo, Mpumalanga Province, and 22 of 23 mongooses at Potchefstroom, North West Province. As the preferred vectors of most *Babesia* spp. are ixodid ticks, the vector of this protozoan is likely

to be either *H. zumpti* or *R. theileri*, or perhaps both. Circumstantial evidence favours the former species as none of the mongooses examined near Ermelo in the present survey was infested with *R. theileri*, while the majority of animals examined at this locality were infested with *H. zumpti* and infected with *B. cynicti* (Table 3; Penzhorn & Chaparro 1994).

The adults of the second group of ticks collected from the mongooses prefer either cattle (*Amblyomma hebraeum, Boophilus* sp., *Hyalomma marginatum rufipes, Rhipicephalus evertsi evertsi, Rhipicephalus exophthalmos* and *Rhipicephalus follis/simus*); tortoises (*Amblyomma marmoreum*); or scrub hares, *Lepus saxatilis* (*Rhipicephalus turanicus* and *R. exophthalmos*) (Theiler 1962; Walker 1991; Keirans, Walker, Horak & Heyne 1993; Horak, Spickett, Braack, Penzhorn, Bagnall & Uys 1995). The eggs laid by these ticks, and consequently their larvae, would therefore be most abundant in localities frequented by their preferred hosts. The mongooses probably become infested with larvae of these species during their foraging excursions, which for some individuals can range from 600–3 000 m from their warrens (Zumpt 1976). All the latter infestations should be regarded as accidental. This assumption is supported by the small numbers of animals infested and the small numbers of larvae collected from individual animals. Furthermore not a single nymph of any of these ticks was collected from a mongoose.

The present results indicate that within the regions in which the surveys were conducted yellow mongooses play virtually no role in the maintenance of ixodid tick populations of veterinary importance.

Mites

Because of the time it took to arrive at a specific identification for each mite we did not critically examine all the *Androlaelaps* sp. mites collected. Those we did examine were all *Androlaelaps capensis*. Mites of the genus *Androlaelaps* parasitize mainly rodents and more specifically gerbils, mice, rats and mole-rats [Zumpt 1961 (as *Haemolaelaps* and *Androlaelaps*); Till 1963]. Mites provisionaly asigned to *Androlaelaps marshalli* have, however, been collected from suricates at Queenstown, Eastern Cape Province and from zorillas, *Ictonyx striatus*, from Muguga, Kenya, as well as from various rodents (Till 1963). The recorded hosts of *A. capensis* are various species of mole-rats (Till 1963). Mongooses at each of the survey localities were infested with *Androlaelaps* sp., and infestation appeared to be particularly prevalent at Kuruman and at Kroonstad.

Nihelia cynictis, which was present on 35 animals, is a specific parasite of the yellow mongoose (Fain 1979) and was originally collected from an animal at Bloemhof in the North West Province. Judging by the number of mongooses infested at Kuruman, in the adjacent province, conditions in this region are particularly suitable for this mite.

Fleas

Eight flea species were recovered. The yellow mongoose, suricate and Cape ground squirrel are preferred hosts of the same three flea species (De Meillon *et al.* 1961; Segerman 1995), namely *Ctenocephalides connatus, Echidnophaga bradyta* and *Xenopsylla cryptonella,* all of which were collected in the present survey. Ermelo is a new locality record for both *C. connatus* and *E. bradyta* and Kuruman for *X. cryptonella*. Kuruman is also the most westerly record for the latter flea (Segerman 1995). These records do not represent a recent increase in the various fleas' distributions but rather a dearth of collections from the principal hosts at these localities.

Beaucournu & Ménier (1998) have recently reaffirmed that *Ctenocephalides damarensis*, as described by Jordan (1936), is a valid species, not merely a subspecies of *Ctenocephalides felis*. The small number of mongooses infested with *C. damarensis* indicates that it is probably an accidental parasite. Its preferred hosts are the non-colonial species of small carnivores and hares (De Meillon *et al.* 1961; Louw, Horak & Braack 1993). It has been suggested that its comparative scarcity on yellow mongooses could be due to competition with *C. connatus* (De Meillon *et al.* 1961). However, it may also be because it breeds more successfully in lairs or in the forms of hares than in the mongoose warrens.

Only one animal at Ermelo, compared to nearly all those around Kuruman and in the Free State, was infested with *Echidnophaga gallinacea*. The principal host of this flea is the domestic fowl (De Meillon *et al.* 1961). It is also found on a number of wild birds, many of the small mammals, including yellow mongooses, and some of the larger carnivores, and can probably survive on any bird or mammalian host (Segerman 1995). Nine of the 39 animals infested with *E. gallinacea* each harboured more than 50 fleas of this species. The large numbers collected in this study and its widespread occurrence indicate that it is probably well-adapted to the warren ecology of the mongooses. It might even compete with *E. bradyta* to the detriment of that species.

The principal host of *Synosternus caffer* is the springhare, *Pedetes capensis*. De Meillon *et al.* (1961) ascribe its presence on yellow mongooses to "straggling" as springhare warrens are frequently associated with those of the mongooses. Seven of the eight mongooses infested in the present survey carried one, two or three fleas each but the eighth harboured 11 males and 23 females. The collection of *S. caffer* solely from mongooses around Kuruman supports the assertion of De Meillon *et al.* (1961) that this flea only thrives under dry sandveld conditions.

Although suricates and ground squirrels are preferred hosts of *Xenopsylla erilli* this flea has apparently not been recorded previously on a yellow mongoose (Segerman 1995). The two fleas of this species collected now, from a single animal, must be regarded as an accidental infestation probably resulting from the communal use of warrens.

The short-tailed gerbil, *Desmodillus auricularis*, is the preferred host of *Xenopsylla piriei* but it has also been recorded on other gerbils as well as on the yellow mongoose (Segerman 1995).

Lice

The close association between the biting louse *F. cynictis* and the yellow mongoose, its type host (Bedford 1928), is amply demonstrated by its presence on nearly every animal at each of the collection localities. The intensity of infestation was fairly similar at Ermelo, Kroonstad, Bloemfontein and Queenstown, with mean burdens varying between 25 and 75 lice. At Kuruman, however, the mean louse burden was 237, with one animal harbouring 788 lice. As the mongooses at each of the localities were examined between the second week of July and the first week of October these differences cannot be ascribed to variations in seasonal abundance at the times of collection. The large burdens on the animals at Kuruman suggest that the immunity of the mongooses was possibly compromised because of unidentified adverse environmental factors. Stressed animals generally harbour increased lice burdens (Kettle 1984). The same factors are probably also responsible for the high prevalence of mite infestations on these animals.

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Parasites of domestic and wild animals in South Africa. XXXVIII. Ixodid ticks collected from 23 wild carnivore species

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ABSTRACT

HORAK, I.G., BRAACK, L.E.O., FOURIE, L.J. & WALKER, JANE B. 2000. Parasites of domestic and wild animals in South Africa. XXXVIII. Ixodid ticks collected from 23 wild carnivore species. *Onderstepoort Journal of Veterinary Research*, 67:239–250

Ixodid ticks were collected from 104 wild carnivores belonging to 23 species in various nature reserves and on several farms in all nine provinces of South Africa. Seven feral cats in a nature reserve were also examined. Twenty-four tick species belonging to seven genera were recovered and identified. Amongst these ticks we consider the adults of *Haemaphysalis leachi*, *Haemaphysalis spinulosa*, *Haemaphysalis zumpti*, *Ixodes rubicundus*, *Rhipicentor nuttalli*, *Rhipicephalus simus* and *Rhipicephalus turanicus* to be true parasites of wild carnivores. Although numerous adult *Rhipicephalus appendiculatus* and *Rhipicephalus zambeziensis* were collected from some lions these were either sick or old animals. The immature stages of seven species regularly utilized wild carnivores as hosts on an opportunistic basis.

Keywords: Ixodid ticks, South Africa, wild carnivores

INTRODUCTION

Many ixodid tick species have been recorded from wild carnivores in Africa, but few actually prefer these animals as hosts. Theiler (1962) records 19 species in the sub-Saharan region as frequently present on wild carnivores, while in a review of the 77 ixodid tick species occurring in South Africa Walker (1991) considers that 20 are often present on these animals. Norval & Mason (1981), Norval (1984; 1985) and Norval & Colborne (1985) list five species as preferring carnivores in Zimbabwe. Walker, Keirans & Horak (2000) document 43 species of rhipicephalids that have been recorded from wild carnivores in Africa, of which they consider seven species to be true parasites of these animals.

In South Africa *Haemaphysalis leachi*, *Rhipicentor nuttalli*, *Rhipicephalus simus* and *Rhipicephalus turanicus* are parasites of the larger wild carnivores, whereas *Haemaphysalis spinulosa*, *Haemaphysalis zumpti*, *Ixodes rubicundus*, ticks of the *Ixodes pilosus* group and *Rhipicephalus theileri* prefer the smaller species (Stampa 1959; Hoogstraal & El Kammah 1974; Horak, Jacot Guillarmod, Moolman & De Vos 1987b; Walker 1991; Horak, Chaparro, Beaucournu & Louw 1999). Records of *Rhipicephalus sanguineus* from wild carnivores probably refer to *R. turanicus*, with which it has often been confused in the past (Pegram, Clifford, Walker & Keirans 1987; Walker *et al.* 2000).

The present paper records the ixodid tick species collected from various wild carnivore species in several habitats in South Africa.

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MATERIALS AND METHODS

Wild carnivores in the Kruger National Park, South Africa are from time to time killed in fights, or in road accidents, or are shot because they have become nuisance animals, or because they are severely injured or ill. Provided the carcasses of these animals were obtained shortly after death they were considered suitable for tick recovery. At various other localities in South Africa wild carnivores were shot because they were considered nuisance animals or specifically for various survey purposes. In the Kruger National Park and in the Free State Province the carcasses of most of the larger carnivores were processed for tick recovery as described by Horak, Boomker, Spickett & De Vos (1992) for greater kudus (*Tragelaphus strepsiceros*). Those of the smaller animals in this park and in the Free State as well as some of those in the Northern Cape Province were treated as described for scrub hares (*Lepus saxatilis*) by Horak, Sheppey, Knight & Beuthin (1986) and Horak & Fourie (1991). Ticks were collected from other animals in a similar fashion, or collected manually from dead or chemically-immobilized carnivores. All the ticks collected were identified and counted under a stereoscopic microscope.

These collections have proceeded from the 1970s until 2000 at which time we considered that there were sufficient data to warrant publication. The scientific nomenclature that we have used for the wild carnivore hosts is based on that suggested by Wilson & Reeder (1993), and where practicable we have treated or listed these animals in the same sequence as that given by these authors. The animals and the localities at which they were sampled are summarized in Table 1.

RESULTS AND DISCUSSION

The numbers of ticks collected from wild carnivores in the Kruger National Park, in nearby provincial nature reserves in Mpumalanga Province, in the Madikwe Nature Reserve, North West Province, and in the Hluhluwe and Umfolozi Game Reserve and on a private game farm in north-eastern KwaZulu-Natal are summarized in Tables 2–14.

Thirteen species of wild carnivores, of which the majority were lions, were examined at these localities. Seven feral cats were also examined in the Kruger National Park. Seventeen ixodid tick species were identified to species level on these animals.

The ticks collected from wild carnivores in the provinces of Gauteng, Free State, Northern, Western and Eastern Cape are summarized in Tables 15–19.

TABLE 1 Carnivores and the localities at which they were examined for ixodid ticks

Carnivore species		Number examined	Province or locality
Common name	Scientific name		
Black-backed jackal	*Canis mesomelas*	5	KNP; central Free State; north-western Northern Cape; Eastern Cape
Hunting dog	*Lycaon pictus*	6	KNP; North West Province
Bat-eared fox	*Otocyon megalotis*	2	South-western Free State
Cape fox	*Vulpes chama*	3	South-western Free State; Eastern Cape
Cheetah	*Acinonyx jubatus*	3	KNP
Caracal	*Caracal caracal*	2	South-western Free State; north-western Northern Cape
African wild cat	*Felis lybica*	3	KNP; south-western Free State; north-western Northern Cape
Feral cats	*Felis catus*	7	KNP
Lion	*Panthera leo*	23	KNP; north-eastern KwaZulu-Natal
Leopard	*Panthera pardus*	5	KNP; Gauteng
Yellow mongoose	*Cynictis penicillata*	1	Eastern Cape
Slender mongoose	*Galerella sanguinea*	2	KNP; north-eastern Mpumalanga
Small grey mongoose	*Galerella pulverulenta*	3	North-western Northern Cape; Eastern Cape
White-tailed mongoose	*Ichneumia albicauda*	2	KNP
Banded mongoose	*Mungos mungo*	2	KNP
Meercat	*Suricata suricatta*	1	North-western Northern Cape
Spotted hyaena	*Crocuta crocuta*	9	KNP; north-eastern KwaZulu-Natal
Brown hyaena	*Parahyaena brunnea*	1	Gauteng
Aardwolf	*Proteles cristatus*	2	South-western Free State; Eastern Cape
Ratel (Honey badger)	*Mellivora capensis*	9	KNP, northern Northern Cape, Western Cape
Zorilla	*Ictonyx striatus*	2	South-western Free State; Eastern Cape
Civet cat	*Civettictis civetta*	6	KNP; north-eastern Mpumalanga
Small-spotted genet	*Genetta genetta*	1	Eastern Cape
Large-spotted genet	*Genetta tigrina*	8	KNP; north-eastern Mpumalanga
"Genet"	*Genetta* sp.	3	Eastern Cape

KNP = Kruger National Park

TABLE 2 Ixodid ticks collected from a black-backed jackal in the Kruger National Park

Tick species	Number of ticks collected				
	Larvae	Nymphs	Males	Females	Total
Amblyomma hebraeum	15	100	0	0	115
Amblyomma marmoreum	183	21	0	0	204
Haemaphysalis leachi	0	0	3	1	4
Rhipicephalus evertsi evertsi	2	0	0	0	2
Rhipicephalus simus	13	0	0	0	13
Rhipicephalus zambeziensis	193	35	1	1	230

TABLE 3 Ixodid ticks collected from six hunting dogs, two in the Kruger National Park and four in the Madikwe Nature Reserve, North West Province

Tick species	Number of ticks collected					No. of dogs infested
	Larvae	Nymphs	Males	Females	Total	
Amblyomma hebraeum	2	14	0	0	16	2
Rhipicephalus simus	2	0	18	6	26	6
Rhipicephalus turanicus	0	0	0	2	2	2
Rhipicephalus zambeziensis	47	3	0	1	51	3

TABLE 4 Ixodid ticks collected from three cheetahs in the Kruger National Park

Tick species	No. of ticks collected					No. of cheetahs infested
	Larvae	Nymphs	Males	Females	Total	
Amblyomma hebraeum	23 960	1 301	15	0	25 276	3
Amblyomma marmoreum	26	18	0	0	44	2
Boophilus decoloratus	5	0	0	0	5	2
Haemaphysalis leachi/zumpti	1	0	–	–	1	1
Haemaphysalis leachi	–	–	159	34	193	3
Haemaphysalis zumpti	–	–	9	0	9	1
Hyalomma truncatum	0	0	1	0	1	1
Rhipicephalus appendiculatus	667	78	23	2	770	3
Rhipicephalus evertsi evertsi	14	0	1	0	15	3
Rhipicephalus simus	10	0	292	46	348	2
Rhipicephalus turanicus	0	0	2	6	8	1
Rhipicephalus zambeziensis	65	10	10	3	88	3

TABLE 5 Ixodid ticks collected from an African wild cat and seven feral cats in the Kruger National Park

Tick species	Number of ticks collected					No. of cats infested
	Larvae	Nymphs	Males	Females	Total	
Amblyomma hebraeum	32	8	0	0	40	7
Amblyomma marmoreum	60	1	0	0	61	6
Haemaphysalis leachi/zumpti	72	90	–	–	162	6
Haemaphysalis leachi	–	–	2	3	5	4
Haemaphysalis zumpti	–	–	32	18	50	6
Rhipicephalus simus	0	1	0	0	1	1
Rhipicephalus turanicus	0	0	0	2	2	1
Rhipicephalus zambeziensis	4	7	0	0	11	3

TABLE 6 Ixodid ticks collected from 22 lions in the Kruger National Park and from one in the Hluhluwe and Umfolozi Game Reserve in north-eastern KwaZulu-Natal

Tick species	Number of ticks collected					No. of lions infested
	Larvae	Nymphs	Males	Females	Total	
Amblyomma hebraeum	15 852	3 396	277	49	19 574	22
Amblyomma marmoreum	43	203	0	0	246	16
Amblyomma tholloni	0	2	0	0	2	1
Boophilus decoloratus	5	0	8	1	14	7
Haemaphysalis leachi/zumpti	2	2	–	–	4	3
Haemaphysalis leachi	–	–	2 198	831	3 029	19
Haemaphysalis zumpti	–	–	65	31	96	17
Hyalomma truncatum	1	2	2	0	5	3
Ixodes sp.	0	4	0	2	6	1
Rhipicephalus appendiculatus	96	230	1 835	804	2 965	21
Rhipicephalus evertsi evertsi	38	0	2	0	40	7
Rhipicephalus simus	3	6	968	603	1 580	17
Rhipicephalus turanicus	0	0	5	5	10	3
Rhipicephalus zambeziensis	39	20	3 343	1 481	4 883	19

TABLE 7 Ixodid ticks collected from four leopards in the Kruger National Park

Tick species	Number of ticks collected					No. of leopards infested
	Larvae	Nymphs	Males	Females	Total	
Amblyomma hebraeum	1 728	93	1	0	1 822	4
Amblyomma marmoreum	43	10	0	0	53	4
Haemaphysalis leachi/zumpti	16	1	–	–	17	2
Haemaphysalis leachi	–	–	63	26	89	3
Haemaphysalis zumpti	–	–	48	13	61	4
Rhipicephalus appendiculatus	1	0	56	8	65	3
Rhipicephalus simus	0	0	20	12	32	2
Rhipicephalus turanicus	0	0	0	2	2	1
Rhipicephalus zambeziensis	0	0	31	13	44	3

TABLE 8 Ixodid ticks collected from a slender mongoose in the Kruger National Park and from one in the Mthethomusha Nature Reserve, Mpumalanga Province

Tick species	Number of ticks collected					No. of mongooses infested
	Larvae	Nymphs	Males	Females	Total	
Haemaphysalis spinulosa	0	0	3	1	4	1
Haemaphysalis zumpti	0	0	6	4	10	1
Ixodes sp.	0	1	0	0	1	1
Rhipicephalus appendiculatus	1	6	0	0	7	1
Rhipicephalus zambeziensis	27	173	0	0	200	2

TABLE 9 Ixodid ticks collected from two white-tailed mongooses in the Kruger National Park

Tick species	Number of ticks collected					No. of mongooses infested
	Larvae	Nymphs	Males	Females	Total	
Amblyomma hebraeum	23	0	0	0	23	1
Amblyomma marmoreum	7	0	0	0	7	2
Haemaphysalis zumpti	0	0	0	1	1	1
Hyalomma truncatum	1	0	0	0	1	1
Rhipicephalus appendiculatus	0	8	0	0	8	2
Rhipicephalus zambeziensis	15	3	0	0	18	2

TABLE 10 Ixodid ticks collected from two banded mongooses in the Kruger National Park

Tick species	Number of ticks collected					No. of mongooses infested
	Larvae	Nymphs	Males	Females	Total	
Amblyomma hebraeum	0	4	0	0	4	2
Amblyomma marmoreum	7	0	0	0	7	1
Haemaphysalis leachi/zumpti	2	0	–	–	2	1
Haemaphysalis zumpti	–	–	1	1	2	1
Rhipicephalus appendiculatus	1	0	0	0	1	1
Rhipicephalus simus	2	0	0	0	2	1
Rhipicephalus zambeziensis	653	99	0	0	752	2

TABLE 11 Ixodid ticks collected from six spotted hyaenas in the Kruger National Park and three on a wildlife farm in north-eastern KwaZulu-Natal

Tick species	Number of ticks collected					No. of hyaenas infested
	Larvae	Nymphs	Males	Females	Total	
Amblyomma hebraeum	792	454	0	0	1 246	7
Amblyomma marmoreum	0	15	0	0	15	2
Haemaphysalis leachi/zumpti	18	2	–	–	20	1
Haemaphysalis leachi	–	–	2	0	2	1
Haemaphysalis zumpti	–	–	6	2	8	3
Ixodes sp.	2	0	0	1	3	2
Rhipicephalus appendiculatus	0	2	2	0	4	2
*Rhipicephalus maculatus**	0	0	1	0	1	1
Rhipicephalus simus	0	0	23	18	41	6
*Rhipicephalus zambeziensis***	4	28	0	0	32	4

* Present only in north-eastern KwaZulu-Natal

** Present only in the Kruger National Park

TABLE 12 Ixodid ticks collected from an old ratel (honey badger) in the Kruger National Park

Tick species	Number of ticks collected				
	Larvae	Nymphs	Males	Females	Total
Amblyomma hebraeum	152	62	34	18	266
Boophilus decoloratus	415	1 454	1 139	605	3 613
Haemaphysalis aciculifer	0	0	13	2	15
Hyalomma truncatum	0	0	4	4	8
Rhipicephalus appendiculatus	61	230	8	4	303
Rhipicephalus evertsi evertsi	24	34	26	10	94
Rhipicephalus simus	0	0	2	0	2

TABLE 13 Ixodid ticks collected from five civet cats in the Kruger National Park and one in a nearby Mpumalanga Parks Board nature reserve

Tick species	Number of ticks collected					No. of civets infested
	Larvae	Nymphs	Males	Females	Total	
Amblyomma hebraeum	1 301	254	12	3	1 570	5
Amblyomma marmoreum	16	20	0	0	36	4
Boophilus decoloratus	58	14	0	0	72	2
Haemaphysalis leachi/zumpti	5	3	–	–	8	4
Haemaphysalis leachi	–	–	85	23	108	4
Haemaphysalis zumpti	–	–	80	12	92	3
Ixodes sp.	268	41	0	2	311	2
Rhipicephalus appendiculatus	19	21	9	2	51	4
*Rhipicephalus kochi**	0	1	0	0	1	1
Rhipicephalus simus	1	0	92	33	126	3
Rhipicephalus zambeziensis	97	13	4	2	116	4
*Rhipicephalus zumpti**	0	0	1	0	1	1

* Present on a single civet cat at Pafuri in the north-east of the Kruger National Park

TABLE 14 Ixodid ticks collected from four large spotted genets in the Kruger National Park and from four in the Mthethomusha Nature Reserve, Mpumalanga Province

Tick species	Number of ticks collected					No. of genets infested
	Larvae	Nymphs	Males	Females	Total	
Amblyomma hebraeum	22	9	1	1	33	5
Amblyomma marmoreum	13	3	0	0	16	6
Boophilus decoloratus	2	0	0	0	2	1
Haemaphysalis leachi/zumpti	11	12	–	–	23	5
Haemaphysalis zumpti	–	–	98	20	118	8
Ixodes sp.	0	1	0	0	1	1
Rhipicephalus appendiculatus	26	1	0	0	27	4
Rhipicephalus simus	1	0	0	0	1	1
Rhipicephalus zambeziensis	1	0	0	0	1	1

TABLE 15 Ticks collected from a black-backed jackal, a leopard and a brown hyaena

Carnivore species	Locality	Number of ticks collected					
		H. leachi		*R. nuttalli*		*R. simus*	
		Males	Females	Males	Females	Males	Females
Black-backed jackal	Verkeerdevlei, Free State	4	5	1	0	0	0
Leopard	Roodeplaat Dam, Gauteng	1	6	9	10	0	0
Brown hyaena	Bon Accord, Gauteng	8	7	1	0	5	0

R. nuttalli = *Rhipicentor nuttalli*

TABLE 16 Ixodid ticks collected from wild carnivores in the Kammieskroon district, north-western Northern Cape Province

Carnivore species	No. examined	No. of ticks collected			
		H. zumpti		*I. rubicundus*	
		Males	Females	Males	Females
Black-backed jackal	1	0	1	19	26
Caracal	1	3	0	0	1
African wild cat*	1	1	3	5	3
Small grey mongoose	1	28	15	0	0
Meercat	1	1	0	0	0

* *Ixodes pilosus* group 2 females

TABLE 17 Ixodid ticks collected from seven ratels (honey badgers) in the south-west of the Kgalagadi Transfrontier Park, northern Northern Cape Province and one near Bredasdorp in the Western Cape Province

Tick species	Number of ticks collected			No. of ratels infested
	Males	Females	Total	
Haemaphysalis zumpti	6	13	19	7
Rhipicephalus theileri	0	1	1	1

TABLE 18 Ixodid ticks collected from wild carnivores in the south-western Free State

Carnivore species	Number of ticks collected							
	A. marmoreum		*H. lea/zumpt*		*H. zumpti*		*R. warburtoni*	
	LL	NN	LL	NN	Males	Females	LL	Males
Black-backed jackal	48	1	0	0	4	1	0	0
Bat-eared fox	1	0	1	1	0	0	0	0
Bat-eared fox	0	0	3	5	0	0	0	0
Cape fox	0	0	1	8	1	0	0	0
Cape fox	0	0	0	2	0	0	0	0
Caracal*	8	0	0	0	6	3	1	0
African wild cat**	0	0	0	0	0	0	0	1
Aardwolf	0	0	0	2	1	0	0	0
Zorilla	0	0	0	5	6	0	0	0

* *Ixodes rubicundus* 1 larva, 3 females
** *Haemaphysalis leachi* 4 males, 21 females

Fourteen species of wild carnivores were examined in the five provinces. Four genets, of undetermined species were also examined. Fourteen ticks were identified to species level on these animals.

Twenty-four ixodid tick species belonging to seven genera were collected from the 111 carnivores examined. Five of these species belonged to the genus *Haemaphysalis* and 12 to the genus *Rhipicephalus*. The presence of a species on a particular animal depended upon host preference, host size and geographic distribution. Thus adult *H. leachi*, *H. zumpti*, and *R. simus*, all species that prefer carnivores as hosts, were collected from nine, 19 and 10 carnivore species respectively. Both *Amblyomma hebraeum* and *Amblyomma marmoreum* have widespread distributions (Theiler 1962; Howell, Walker & Nevill 1978; Walker & Olwage 1987), and their immature stages infest a large variety of hosts (Theiler 1962; Norval 1975; 1983; Horak, MacIvor, Petney & De Vos 1987a). The latter were collected from 14 and 13 host species respectively. In contrast *Rhipicephalus kochi*, that has a very restricted distribution range in the far north-east of South Africa (Walker *et al.* 2000), was collected from a single civet cat examined near Pafuri in the Northern Province.

Some of the animals examined in the Kruger National Park, notably three of the lions, the ratel and a civet cat, were injured, emaciated or old. These animals were generally heavily infested, sometimes with ticks that do not normally favour carnivores as hosts. However, we feel their inclusion in this communication is warranted for the benefit of other acarologists or for zoologists and other scientists studying carnivores.

Amblyomma spp.

The adults of the three species collected in this genus, namely *A. hebraeum*, *A. marmoreum* and *A. tholloni*, prefer large herbivores, tortoises and African elephants (*Loxodonta africana*) respectively as hosts (Norval 1983; Horak *et al.* 1987a; Petney, Horak & Rechav 1987; Walker & Olwage 1987). The immature stages of the former two may be found on the same hosts as the adults as well as on a large variety of smaller mammals, excluding rodents, and also on birds (Theiler 1962; Norval 1975; 1983; Horak *et al.* 1987a).

The presence of more than one or two adult *A. hebraeum* on a wild carnivore smaller than a lion must be viewed as unusual and evidence of stress in the host animal. Even healthy lions should not harbour more than a few adults in an environment that is otherwise heavily infested. The hosts of the immature stages of *A. tholloni* are elephants, but birds, reptiles and other wild mammals can also be infested (Hoogstraal 1956; Theiler 1962; Petney *et al.* 1987; Walker 1991). Larvae and nymphs have also been collected from domestic cattle, sheep and goats (MacKenzie & Norval 1980; Norval 1983). The recovery of two nymphs from one of the lions must be viewed as an accidental infestation in a habitat in which there are many elephants.

Boophilus decoloratus

The preferred hosts of this one-host tick are domestic and wild ruminants and equids, with cattle, tragelaphine antelopes and impalas (*Aepyceros melampus*) being particularly favoured (Mason & Norval 1980; Horak *et al.* 1992). Infestation of carnivores, suids, rodents and other groups of mammals must be regarded as accidental and usually occurs in habitats in which the preferred hosts of this tick abound. Large infestations on the former animals, such as that on the ratel in the Kruger National Park, are probably due to an immune-compromised system coupled with ineffective grooming.

TABLE 19 Ixodid ticks collected from wild carnivores in the Eastern Cape Province

Carnivore species	Number of ticks collected													
	A. hebraeum	*A. marmoreum*		*H. silacea*		*H. zumpti*				*Ixodes* sp.		*R. evertsi*		*R. simus*
	Larvae	LL	NN	LL	NN	LL	NN	MM	FF	LL	NN	LL	NN	Males
Black-backed jackal	4	0	22	113	0	0	0	0	0	0	0	12	0	1
Cape fox	0	0	0	1	0	0	0	0	0	0	0	0	2	0
Yellow mongoose	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Small grey mongoose	0	1	0	0	0	0	0	1	0	0	1	0	0	0
Small grey mongoose*	0	64	0	0	0	0	0	6	0	2	0	0	0	0
Aardwolf**	0	0	0	0	2	55	177	3	3	0	0	0	3	1
Zorilla	0	0	0	0	0	0	0	3	0	0	0	0	0	0
Small-spotted genet	1	0	0	1	0	1	2	53	15	0	0	0	0	0
"Genet"	0	0	0	0	0	0	0	0	1	0	0	0	0	0
"Genet"	0	0	0	0	0	0	0	3	1	0	1	0	0	0
"Genet"	0	0	0	0	0	0	0	3	0	21	15	0	0	0

* *Rhipicephalus arnoldi* 1 larva; *Rhipicephalus follis* 16 larvae, 1 nymph
** *Boophilus decoloratus* 8 larvae

Haemaphysalis spp.

The adults of *H. leachi* and *H. spinulosa* are parasites of domestic and wild carnivores, with the former tick preferring the larger species and the latter smaller animals (Walker 1991). Although some of their immature stages can be present on the same animals as the adults, rodents are their preferred hosts (Hoogstraal 1956; Norval 1984). *Haemaphysalis zumpti* is a parasite of small carnivores, particularly yellow mongooses and meercats (Hoogstraal & El Kammah 1974; Walker 1991; Horak *et al.* 1999). Yellow mongooses and Cape ground squirrels (*Xerus inauris*), which often share burrows with the mongooses, are hosts of the immature stages (Walker 1991; Horak *et al.* 1999). The presence of these *Haemaphysalis* species on the animals from which they were collected thus confirms earlier observations on their host preferences. However, *H. zumpti* is far more prevalent and widespread than previously suspected. The numerous immature *Haemaphysalis* spp. collected from the carnivores could well be *H. zumpti*, of which the pre-imaginal stages prefer these animals as hosts.

Haemaphysalis leachi is widespread in the warm, moist eastern regions of South Africa (Howell *et al.* 1978), but will probably occur wherever sufficient, suitable rodent and carnivore hosts are present (Norval 1984). *Haemaphysalis zumpti* appears to be present wherever the hosts of its adults occur (Walker 1991; Horak *et al.* 1999).

Adult *H. aciculifer* has been recorded on carnivores (Norval 1985), but its preferred hosts are wild bovids, both large and small, on which, however, it seldom occurs in large numbers (Walker 1991; Horak, Keep, Spickett & Boomker 1989). Since 1977 one of us (I.G.H.) has examined well over 1 200 animals belonging to many species in the Kruger National Park and has collected a total of only two male *H. aciculifer* from a single eland (*Taurotragus oryx*) (Horak, Potgieter, Walker, De Vos & Boomker 1983). The collection of 15 adults from the ratel examined in the Park is thus remarkable and probably reflects unique conditions within its immediate surroundings. *Haemaphysalis silacea* is a parasite of domestic and wild ruminants and occurs only in South Africa, where it is found in Valley Bushveld in the Eastern Cape Province and in north-eastern KwaZulu-Natal (Baker & Keep 1970; Walker 1991; Horak *et al.* 1992). Its recovery from some of the animals examined in the present survey is more a reflection of its superabundance at a particular locality than of host preference.

Hyalomma truncatum

The small numbers of adult ticks collected confirm that carnivores are not good hosts of this tick. It prefers large ungulates, usually with thick skins (Walker 1991). The recovery of immature ticks from some of the carnivores is unusual and must be considered accidental because their preferred hosts are hares and rodents (Horak & Fourie 1991; Walker 1991).

Ixodes spp.

Considerable doubt as to the identity of some of the *Ixodes* spp. in the *I. pilosus* group exists (Walker 1991), hence our failure to identify them specifically. Both the immature and adult stages of *I. rubicundus* have previously been collected from medium-sized wild carnivores in the Karoo, South Africa (Stampa 1959), and caracals have been identified as preferred hosts of this tick (Horak *et al.* 1987b). The present collection of adults from two caracals, an African wild cat and a black-backed jackal, indicates that medium-sized carnivores should be considered amongst its preferred hosts.

Rhipicentor nuttalli

Adults of this tick have been collected from a number of wild carnivores and Norval & Colborne (1985) consider the leopard to be the host of choice in Zimbabwe. Other common hosts are the South African hedgehog (*Atelerix frontalis*) and porcupine (*Hystrix africaeaustralis*) (Norval & Colborne 1985; Walker 1991). The preferred hosts of the immature stages are rock elephant shrews (*Elephantulus myurus*) (Du Toit 1993). No adult *R. nuttalli* were found on any of the carnivores in the Kruger National Park, but the immature stages have been collected from rock elephant shrews in the north of the Park (Horak & Braack, unpublished data 1999). In the present survey adults were collected from a leopard and a brown hyaena near Pretoria, Gauteng Province, and from a black-backed jackal in the central Free State.

Rhipicephalus spp.

Although 12 species of *Rhipicephalus* were collected from the wild carnivores, we consider only two, namely *R. simus* and *R. turanicus*, to be true parasites of these animals. However, the adults of both these ticks also parasitize a variety of other hosts. *Rhipicephalus simus* is found on equids, suids and large ruminants and *R. turanicus* on ruminants, hares and large birds (Walker *et al.* 2000). The immature stages of *R. simus* prefer murid rodents as hosts, while those of *R. turanicus* are found on rodents and other small mammals (Norval & Mason 1981; Walker *et al.* 2000). *Rhipicephalus simus* is widespread in South Africa, particularly in the moister northern, eastern and southern regions of the country. *Rhipicephalus turanicus* is present in the northern provinces, north-eastern KwaZulu-Natal and in the arid southern regions around Oudtshoorn, Western Cape Province (Walker *et al.* 2000). The abundance of the adults of both ticks is closely related to the availability of rodent hosts for the immature stages. Peak

numbers of adults have been collected from the vegetation in the south east of the Kruger National Park 8 months after a rodent population explosion (Horak, Spickett & Braack 2000). *Rhipicephalus sanguineus*, which is closely related to *R. turanicus* (Pegram *et al.* 1987; Walker *et al.* 2000), is commonly encountered on domestic dogs in South Africa (Horak 1995; Bryson, Höhn, Horak & Kirkpatrick 1998), but was not collected from any of the wild carnivores examined.

The preferred hosts of all stages of development of *R. appendiculatus*, *R. zambeziensis* and *R. evertsi evertsi* are domestic and wild ruminants, and of the latter tick also equids (Norval 1981; Norval, Walker & Colborne 1982; Walker *et al.* 2000).

Numerous adults of the former two species have also been collected from a lion and a leopard (Horak *et al.* 1987b). However, we do not believe that this and the present findings on lions make them preferred hosts. *Rhipicephalus evertsi evertsi* is particularly widespread in South Africa (Theiler 1950), and its immature stages have been collected from a large variety of hosts (Theiler 1962; Walker *et al.* 2000). The small numbers collected from the carnivores are hence not unexpected. The many adults collected from the ratel in the Kruger National Park can probably be ascribed to its debilitated state.

Immature and adult *Rhipicephalus theileri* prefer yellow mongooses and meercats as hosts, and are also found on Cape ground squirrels (Horak *et al.* 1999; Walker *et al.* 2000). This tick occurs mainly in the dryer western regions of South Africa and Namibia (Walker *et al.* 2000), and its presence on one of the ratels examined in the south-western Kgalagadi Transfrontier Park within the Northern Cape Province is thus not surprising.

One of the Cape grey mongooses examined in the Eastern Cape Province was collected in the Mountain Zebra National Park and in addition to other ticks harboured a single *Rhipicephalus arnoldi* larva and several larvae and a nymph of *Rhipicephalus follis*. Both these ticks are common in this park, the first on Smith's red rock rabbits (*Pronolagus rupestris*) and the latter on eland, while their immature stages infest a variety of small mammals (Horak, Fourie, Novellie & Williams 1991).

The adults of *R. kochi* and *R. zumpti* may occur on carnivores but have restricted distributions in South Africa. Both are present in the far north-eastern regions of the country and the latter tick also in the south (Walker *et al.* 2000). The adults of *R. maculatus* are parasites of thick-skinned mammals such as white and black rhinoceroses (*Ceratotherium simum* and *Diceros bicornis*), warthogs (*Phacochoerus africanus*) and African buffaloes (*Syncerus caffer*) in the north-eastern coastal regions of South Africa (Baker & Keep 1970; Walker *et al.* 2000). The presence of a single male on one of the spotted hyaenas in KwaZulu-Natal must be considered an accidental infestation.

Rhipicephalus warburtoni is virtually confined to the central, western and south-western Free State where its adults parasitize domestic and wild ruminants and scrub hares and its immature stages scrub hares and rock elephant shrews (Walker *et al.* 2000). Infestation of wild carnivores would seem to be accidental.

General

Of all the tick species collected in this survey we consider the adults of *H. leachi*, *H. spinulosa*, *H. zumpti*, *I. rubicundus*, *R. nuttalli*, *R. simus* and *R. turanicus* to be true parasites of wild carnivores. All these species may parasitize various wild carnivores, and some are also true parasites of animals belonging to completely different classes. Adult *H. leachi*, *H. spinulosa*, *R. simus* and *R. turanicus* are also frequently collected from domestic dogs (Horak *et al.* 1987b; Horak 1995; Walker *et al.* 2000). Excluding *H. zumpti*, the immature stages of the other six ticks prefer hosts other than wild carnivores, and more especially murid rodents or elephant shrews (Norval & Mason 1981; Norval 1984; Walker 1991; Fourie, Horak & Van Heerden 1992; Du Toit 1993; Walker *et al.* 2000). This is in sharp contrast to the kennel tick, *R. sanguineus*, which in all its developmental stages virtually parasitizes only domestic dogs (Walker *et al.* 2000).

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Lagomorphs

Hares are without doubt the preferred hosts of all stages of development of *Rhipicephalus oculatus*. They also play an essential role in the life cycles of the three *Hyalomma* spp., known as bont-legged ticks that are present in southern Africa, in that they serve as hosts of the immature stages. Adult *Hyalomma* ticks are responsible for the transmission of the virus of Crimean Congo haemorrhagic fever to people. Hares, and particularly scrub hares, *Lepus saxatilis* are co-hosts of the immature stages of a large number of other tick species, many of them important as vectors or causes of diseases that affect domestic livestock. Furthermore, along with other animals they are co-hosts of all stages of development of ticks of the *Ixodes pilosus* group, *Rhipicephalus kochi*, *Rhipicephalus nitens*, *Rhipicephalus warburtoni* and ticks of the *Rhipicephalus pravus* group, as well as the adults of *Rhipicephalus exopthalmos* and *Rhipicephalus turanicus* (Horak & Fourie 1991; Horak, Spickett, Braack & Penzhorn 1993; Horak, Spickett, Braack, Penzhorn, Bagnall & Uys 1995b). [See also Horak, Fourie, Novellie & Williams (1991b) and Horak & Boomker (1998) in the section on sympatric wildlife, and MacIvor & Horak (2003) in the section on sympatric wild and domestic animals)]. In the three studies in this section of the thesis devoted to ticks infesting hares (Horak & Fourie 1991; Horak *et al.* 1993, 1995b), and in the three studies referred to only in the text above, 27 tick species that could not be just be regarded as accidental infestations, were recovered from scrub hares, either as adults, or as immature stages, or both. Red rock rabbits, possibly because of their more specialised habitat requirements, are parasitized by fewer species. They are, however, good hosts of the immature stages of the Karoo paralysis tick, *Ixodes rubicundus*, and are the preferred hosts of all stages of development of *Rhipicephalus arnoldi* (Horak & Fourie 1991). [See also Horak *et al*. (1991b) in the section on sympatric wildlife)].

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PARASITES OF DOMESTIC AND WILD ANIMALS IN SOUTH AFRICA. XXIX. IXODID TICKS ON HARES IN THE CAPE PROVINCE AND ON HARES AND RED ROCK RABBITS IN THE ORANGE FREE STATE

I. G. HORAK[1] and L. J. FOURIE[2]

ABSTRACT

HORAK, I. G. & FOURIE, L. J., 1991. Parasites of domestic and wild animals in South Africa. XXIX. Ixodid ticks on hares in the Cape Province and on hares and red rock rabbits in the Orange Free State. *Onderstepoort Journal of Veterinary Research*, 58, 261–270 (1991).

One hundred and seventeen scrub hares, *Lepus saxatilis*, were examined for ixodid ticks in various regions of the Cape Province. They were infested with 18 tick species and the seasonal abundances of the immature stages of *Amblyomma hebraeum*, *Amblyomma marmoreum*, *Hyalomma marginatum rufipes*, *Rhipicephalus appendiculatus* and *Rhipicephalus glabroscutatum* and all stages of *Rhipicephalus oculatus* and the adults of a *Rhipicephalus* sp. (near *R. oculatus*) were determined.

Seventy-two scrub hares on 3 farms in the Orange Free State harboured 10 ixodid tick species and the seasonal abundances of the immature stages of *H. marginatum rufipes* and *Hyalomma truncatum* and all stages of *Rhipicephalus punctatus* were determined.

Thirty Cape hares, *Lepus capensis*, examined in the northern Cape Province harboured 5 tick species and the seasonal abundances of the immature stages of *H. marginatum rufipes* and *H. truncatum* were determined. Thirty-four Cape hares examined in the south-western Orange Free State carried 6 tick species and the seasonal abundance of immature *H. marginatum rufipes* was determined on these animals.

Twenty-eight Smith's red rock rabbits examined on 2 farms in the south-western Orange Free State were infested with 7 tick species.

INTRODUCTION

The scrub hare, *Lepus saxatilis*, the Cape hare, *Lepus capensis*, and Smith's red rock rabbit, *Pronolagus rupestris*, are indigenous to Africa. According to Smithers (1983) the scrub hare is widely distributed in South Africa except in forested areas and in the arid country bordering the Orange River in the north-western Cape Province. The Cape hare occurs in south-western Transvaal, throughout most of the Orange Free State and the Cape Province excluding the south-eastern sector. Smith's red rock rabbit is present in the extreme southern Transvaal, central and southern Orange Free State, central and southern Natal and is widely distributed in the Cape Province excluding the northern parts and the coastal forested areas (Smithers, 1983). Although their distributions overlap in large parts of the country, their habitat preferences keep them fairly separate within specific localities. Scrub hares prefer savanna woodland and scrub, where there is grass cover. Cape hares prefer arid open habitat, while Smith's red rock rabbit is closely confined to rocky hillsides, boulder-strewn koppies and rocky ravines with some grass or shrub cover (Smithers, 1983).

All 3 are nocturnal, although scrub and Cape hares may forage during the day in overcast weather (Smithers, 1983). None of them burrow, and the scrub and Cape hare inhabit temporary forms where their precocial young are born. Smith's red rock rabbits utilize rocky shelters and the females make nests where their young, which are probably altricial, are born (Smithers, 1983).

According to Theiler (1962) hares and rock rabbits in South Africa may be infested with 23 ixodid tick species. In recent years a number of surveys of the ticks infesting these animals have been conducted in this country (Horak, Sheppey, Knight & Beuthin, 1986; Horak & Knight, 1986; Horak & MacIvor, 1987; Rechav, Zeederberg & Zeller, 1987; Petney & Horak, 1987; Horak, Fourie, Novellie & Williams, 1991). Similar surveys have also been conducted in Kenya (Clifford, Flux & Hoogstraal, 1976) and New Zealand (Heath, Tenquist & Bishop, 1987). From these it would appear that hares and rabbits are good hosts of the immature stages of a large number of tick species. In South Africa scrub hares are also good hosts of the adults of *Ixodes pilosus*, *Rhipicephalus nitens*, *Rhipicephalus oculatus* and a *Rhipicephalus* sp. (near *R. oculatus*) (Horak *et al.*, 1986; Horak & Knight, 1986), while Smith's red rock rabbit is the preferred host of adult *Rhipicephalus arnoldi* (Horak, Fourie, Novellie & Williams, 1991).

Because of their importance as hosts of ixodid ticks it was decided to examine hares and red rock rabbits from a number of localities in South Africa for these parasites. The results of the surveys done in the Cape Province and the Orange Free State are presented here, while those in the Transvaal will appear later. The surveys conducted north-east of Grahamstown in the eastern Cape Province and described here are an extension of those of Horak & Knight (1986) and include the tick burdens of an additional 47 hares. The results for the south-western Cape Province were obtained from 5 scrub hares examined at the same locality as that reported in an earlier survey by Horak *et al.* (1986).

MATERIALS AND METHODS

Survey animals

A total of 189 scrub hares, 64 Cape hares and 28 Smith's red rock rabbits were examined. They were shot at night using a single-shot rifle or a shotgun.

Tick recovery

The hares and rabbits were processed for tick recovery as described by Horak *et al.* (1986). The hair and scrapings collected by their method were poured on to a sieve with 20 mm apertures held over a sieve with 150 µm appertures and thoroughly washed. The hair retained on the upper sieve was squeezed and the fluid expressed from it was poured through the finer sieve. The contents of the latter sieve were examined *in toto* under a stereoscopic microscope and the ticks collected, identified and counted. The partially dry hair was mass-measured and a representative sample taken for microscopic examination.

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TABLE 1 Ixodid ticks recovered from 47 scrub hares on the farm "Bucklands", eastern Cape Province

Tick species	Total numbers recovered					No. of hares infested
	Larvae	Nymphs	Males	Females	Total	
Amblyomma hebraeum	10	3	0	0	13	9
Amblyomma marmoreum	123	3	0	0	126	12
Boophilus sp.	7	0	0	0	7	2
Haemaphysalis leachi	1	2	0	0	3	3
Haemaphysalis silacea	26	22	2	0	50	16
Hyalomma marginatum rufipes	168	90	0	0	258	12
Hyalomma truncatum	1	2	0	0	3	1
Ixodes pilosus	1	0	0	0	1	1
Rhipicephalus appendiculatus	507	281	0	0	788	28
Rhipicephalus evertsi evertsi	237	171	0	0	408	24
Rhipicephalus glabroscutatum	2 175	769	0	0	2 944	28
Rhipicephalus oculatus	6 010	1 397	97	80 (28)	7 584	41
Rhipicephalus sp. (near *R. oculatus*)	11	8	21	6	46	15

( ) = Number of maturing female ticks i.e. idiosoma of *R. oculatus* > 5,0 mm in length

TABLE 2 Ixodid ticks recovered from 42 scrub hares in the Andries Vosloo Kudu Reserve, eastern Cape Province

Tick species	Total numbers recovered					No. of hares infested
	Larvae	Nymphs	Males	Females	Total	
Amblyomma hebraeum	1 948	638	0	0	2 586	42
Amblyomma marmoreum	65	6	0	0	71	11
Haemaphysalis silacea	45	33	0	0	78	18
Hyalomma marginatum rufipes	370	324	0	0	694	28
Ixodes pilosus	3	1	0	0	4	3
Rhipicephalus appendiculatus	348	438	0	0	786	31
Rhipicephalus evertsi evertsi	299	405	0	0	704	36
Rhipicephalus glabroscutatum	930	303	0	0	1 233	21
Rhipicephalus oculatus	1 196	839	118	70 (29)	2 223	37
Rhipicephalus sp. (near *R. oculatus*)	28	4	18	12 (3)	62	14
Rhipicephalus simus	14	2	0	0	16	6

( ) = Number of maturing female ticks, i.e. idiosoma of *R. oculatus* and *Rhipicephalus* sp. (near *R. oculatus*) > 5,0 mm in length

The remainder of the hair was examined macroscopically in a white plastic tray and all the adult ticks collected, identified and counted. The length of the idiosoma of maturing females of each species was measured under a stereoscopic microscope. The minimum length assigned to each species was that length which we estimated the maturing female tick would reach 24 h before detaching.

Comment: We are unable to distinguish between the immature stages of *Hyalomma marginatum rufipes* and *Hyalomma marginatum turanicum*. Where the distributions of these ticks overlap (Howell, Walker & Nevill, 1978) we have identified the immatures only to specific level. Where in other surveys we have recovered the adults of only one subspecies we have assigned the immatures recovered now to that subspecies.

DESCRIPTIONS OF SURVEY LOCALITIES AND RESULTS

Scrub hares

Eastern Cape Province

The farm "Bucklands" and the adjacent Andries Vosloo Kudu Reserve are situated around 33° 07′ S and 26° 42′ E, approximately 25 km north-east of Grahamstown in a vegetation zone classified as Valley Bushveld (Acocks, 1988). The vegetation has been described in greater detail by Rechav (1982), while Horak & Knight (1986) have listed some of the fauna on both properties.

An attempt was made to shoot 2 scrub hares on each property at monthly intervals from February 1985 to January 1987. This was not always possible and only 1 hare was obtained on the farm during December 1985 and none during October 1986. In the reserve only 1 hare was obtained during April and 1 during July 1985 and none during December 1985 and May 1986.

The Thomas Baines Nature Reserve (33° 23′ S, 26° 30′ E) lies approximately 12 km south-west of Grahamstown within a vegetation zone categorized as False Macchia, Eastern Province Thornveld and Valley Bushveld (Acocks, 1988). Five scrub hares were examined in this reserve.

The numbers of ticks recovered from hares on the farm "Bucklands" and the Andries Vosloo Kudu Reserve are summarized in Tables 1 and 2.

The hares on the farm "Bucklands" were infested with 13 ixodid tick species of which *R. oculatus* was the most abundant and prevalent. Eleven species were recovered from the hares in the Andries Vos-

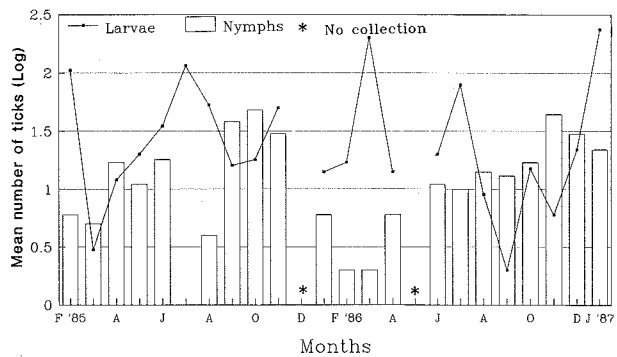

FIG. 1 The seasonal abundance of *Amblyomma hebraeum* on scrub hares in the Andries Vosloo Kudu Reserve, eastern Cape Province.

TABLE 3 Ixodid ticks recovered from 5 scrub hares in the Thomas Baines Nature Reserve, eastern Cape Province

Tick species	Total numbers recovered					No. of hares infested
	Larvae	Nymphs	Males	Females	Total	
Amblyomma hebraeum	460	46	0	0	506	5
Haemaphysalis silacea	0	62	0	0	62	4
Ixodes pilosus	12	18	1	1	32	4
Rhipicephalus appendiculatus	2 189	133	0	0	2 322	5
Rhipicephalus evertsi evertsi	46	47	0	0	93	5
Rhipicephalus follis/R. simus	26	0	0	0	26	4

TABLE 4 Ixodid ticks recovered from 3 scrub hares on the farm "Henham" in the Colesberg district, Karoo

Tick species	Total numbers recovered					No. of hares infested
	Larvae	Nymphs	Males	Females	Total	
Hyalomma marginatum	9	33	0	0	42	3
Ixodes rubicundus	0	0	0	2	2	1
Rhipicephalus oculatus	19	5	0	0	24	1
Rhipicephalus punctatus	8	1	1	0	10	1

TABLE 5 Ixodid ticks recovered from 5 scrub hares in the Bontebok National Park, south-western Cape Province

Tick species	Total numbers recovered					No. of hares infested
	Larvae	Nymphs	Males	Females	Total	
Amblyomma marmoreum	5	2	0	0	7	2
Boophilus sp.	9	0	0	0	9	2
Hyalomma truncatum	5	9	0	0	14	2
Ixodes pilosus	10	1	1	7	19	4
Rhipicephalus evertsi evertsi	6	19	0	0	25	2
Rhipicephalus glabroscutatum	4	1	0	0	5	2
Rhipicephalus nitens	93	113	57	33 (10)	296	5

( ) = Number of maturing female ticks, i.e. idiosoma of *R. nitens* > 5,0 mm in length

loo Kudu Reserve. Of these *Amblyomma hebraeum* was the most abundant and prevalent, closely followed by *R. oculatus*.

Both the abundance and prevalence of the immature stages of *A. hebraeum* were markedly reduced on the hares on the farm compared with those on the reserve. For this reason the seasonal abundance of this tick was determined only on the hares in the reserve (Fig. 1). The seasonal abundances of the immature stages of *H. marginatum rufipes, Rhipicephalus appendiculatus* and *Rhipicephalus glabroscutatum* and all stages of development of *R. oculatus* on the hares on the farm and reserve have been combined for each species and are illustrated in Fig. 2–5.

The larvae of *A. hebraeum* reached the largest numbers during February and July of 1985 and during March and July of 1986 and January of 1987. The nymphs peaked during September and October of 1985 and during November and December of 1986. The immature stages of *H. marginatum rufipes* were most commonly present from February to August,

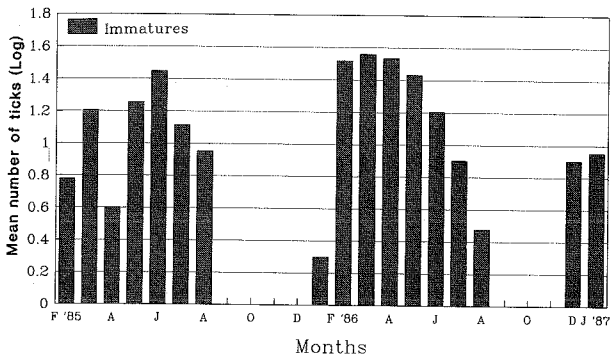

FIG. 2 The seasonal abundance of *Hyalomma marginatum rufipes* on scrub hares on the farm "Bucklands" and in the Andries Vosloo Kudu Reserve, eastern Cape Province.

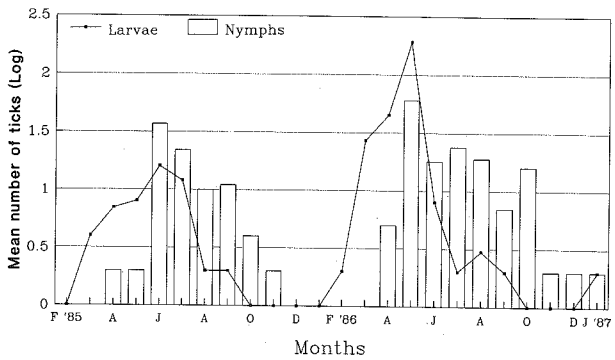

FIG. 3 The seasonal abundance of *Rhipicephalus appendiculatus* on scrub hares on the farm "Bucklands" and in the Andries Vosloo Kudu Reserve, eastern Cape Province.

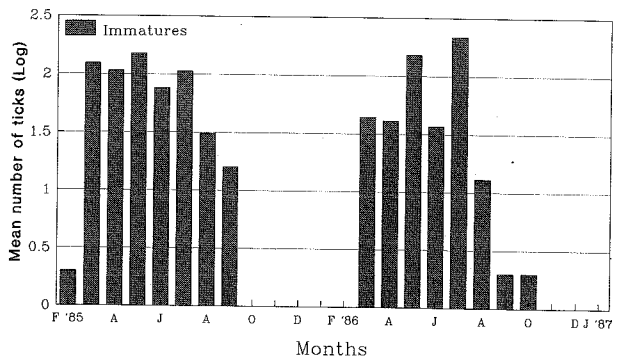

FIG. 4 The seasonal abundance of *Rhipicephalus glabroscutatum* on scrub hares on the farm 'Bucklands" and in the Andries Vosloo Kudu Reserve, eastern Cape Province.

TABLE 6 Ixodid ticks recovered from 11 scrub hares on the farm "Taaiboskraal", north-western Cape Province

Tick species	Total numbers recovered					No. of hares infested
	Larvae	Nymphs	Males	Females	Total	
Hyalomma truncatum	177	174	0	0	351	11
Ixodes rubicundus	0	0	3	2	5	1
Rhipicephalus evertsi evertsi	2	3	0	0	5	3
Rhipicephalus gertrudae	0	20	0	0	20	3
Rhipicephalus sp. (near *R. oculatus*)	0	0	0	1	1	1

TABLE 7 Ixodid ticks recovered from 5 scrub hares on the farm "Sandfontein", northern Cape Province

Tick species	Total numbers recovered					No. of hares infested
	Larvae	Nymphs	Males	Females	Total	
Hyalomma marginatum rufipes	24	26	0	0	50	1
Hyalomma truncatum	232	270	1	0	503	5
Rhipicephalus evertsi evertsi	0	3	0	1	4	2
Rhipicephalus sp. (near *R. oculatus*)	2	0	0	1	3	2

TABLE 8 Ixodid ticks recovered from 50 scrub hares on the farms "Preezfontein" and "Slangfontein", south-western Orange Free State

Tick species	Total numbers recovered					No. of hares infested
	Larvae	Nymphs	Males	Females	Total	
Amblyomma marmoreum	1	3	0	0	4	3
Haemaphysalis leachi/spinulosa	1	0	0	0	1	1
Hyalomma marginatum rufipes	47	347	0	0	394	26
Hyalomma truncatum	39	44	0	0	83	5
Ixodes rubicundus	4	0	0	1 (1)	5	4
Rhipicephalus arnoldi	5	0	2	2	9	3
Rhipicephalus oculatus	0	0	0	1 (1)	1	1
Rhipicephalus punctatus	422	238	349	176 (18)	1 185	46

( ) = Number of maturing female ticks, i.e. idiosoma of *I. rubicundus* > 5,0 mm; *R. arnoldi* > 4,0 mm; *R. oculatus* > 5,0 mm and *R. punctatus* > 5,0 mm in length

although some were recovered during December 1986 and January 1987. The largest numbers of *R. appendiculatus* larvae were recovered from March to June or July and of nymphs from May or June to September or October. The greatest numbers of immatures of the 2-host *R. glabroscutatum* were recovered from March to July. The larvae of *R. oculatus* reached the highest numbers from March to July or August, the nymphs from May to September and the adults from August to December.

Although not illustrated, the larvae of *A. marmoreum* were generally present from February to May and the nymphs from October to December. The adults of the *Rhipicephalus* sp. (near *R. oculatus*) were usually most abundant during August and from November to April.

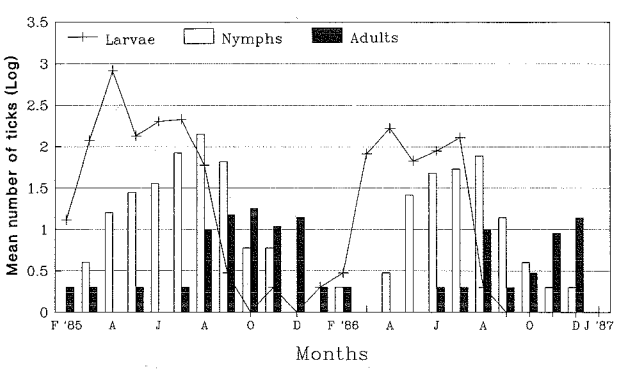

FIG. 5 The seasonal abundance of *Rhipicephalus oculatus* on scrub hares on the farm "Bucklands" and in the Andries Vosloo Kudu Reserve, eastern Cape Province.

The 5 hares examined in the Thomas Baines Nature Reserve were all infested with the immature stages of *A. hebraeum, R. appendiculatus* and *Rhipicephalus evertsi evertsi* (Table 3).

Karoo

The farm "Henham" is located approximately 2 km west of Colesberg (30° 44′ S, 25° 06′ E), in a vegetation zone classified as False Upper Karoo (Acocks, 1988). Three scrub hares were shot on this farm during July 1989.

The hares were all infested with the immature stages of *H. marginatum* (no subspecific identification could be made) (Table 4). One also harboured *Ixodes rubicundus, R. oculatus* and *Rhipicephalus punctatus*.

South-western Cape Province

The physiography of the Bontebok National Park (34° 02′ S, 20° 25′ E), approximately 5 km south of Swellendam, and situated in a vegetation zone described as Coastal Renosterbosveld (Acocks, 1988), has been described by Boomker, Horak & De Vos (1981). One scrub hare was shot in this park during February 1985 and 2 during February 1988 as well as 2 during February 1990.

The 5 hares examined in the park were infested with 7 ixodid tick species of which *R. nitens* was the most abundant and prevalent (Table 5).

North-western Cape Province

The farm "Taaiboskraal" (31° 42′ S, 18° 53′ E) is located approximately 15 km east of Vanrhynsdorp. The vegetation of this region is classified as

TABLE 9 Ixodid ticks recovered from 22 scrub hares on the farm "Bishops Glen", central Orange Free State

Tick species	Total numbers recovered					No. of hares infested
	Larvae	Nymphs	Males	Females	Total	
Amblyomma marmoreum	4	4	0	0	8	3
Boophilus sp.	9	0	0	0	9	2
Haemaphysalis spinulosa	0	1	0	1	2	2
Hyalomma marginatum rufipes	34	31	0	0	65	5
Hyalomma truncatum	637	166	0	0	803	9
Ixodes rubicundus	4	0	1	0	5	2
Rhipicephalus arnoldi	0	1	1	3 (2)	5	2
Rhipicephalus evertsi evertsi	5	6	0	0	11	3
Rhipicephalus punctatus	476	189	125	68 (13)	858	17

( ) = Number of maturing female ticks, i.e. idiosoma of *R. arnoldi* > 4,0 mm and *R. punctatus* > 5,0 mm in length

TABLE 10 Ixodid ticks recovered from 30 Cape hares on the farm "Sandfontein", northern Cape Province

Tick species	Total numbers recovered					No. of hares infested
	Larvae	Nymphs	Males	Females	Total	
Amblyomma marmoreum	15	4	0	0	19	8
Hyalomma marginatum rufipes	115	135	0	0	250	19
Hyalomma truncatum	1 636	1 490	0	0	3 126	24
Rhipicephalus gertrudae	0	1	0	0	1	1
Rhipicephalus oculatus	8	74	20	25 (3)	127	4

( ) = Number of maturing female ticks, i.e. idiosoma of *R. oculatus* > 5,0 mm in length

Succulent Karoo (Acocks, 1988). Eight scrub hares were examined on the farm during November 1988 and 3 during June 1989.

All the hares were infested with the immature stages of *Hyalomma truncatum* (Table 6).

Northern Cape Province

The farm "Sandfontein" (29° 56′ S, 24° 21′ E), lies approximately 43 km south-east of Hopetown. The vegetation of this area is classified as False Arid Karoo (Acocks, 1988). Four scrub hares were shot on the farm during November 1988 and 1 during June 1989.

The 5 hares examined on the farm were all infested with the immature stages of *H. truncatum* (Table 7).

South-western Orange Free State

The farms "Preezfontein" (29° 50′ S, 25° 23′ E) and "Slangfontein" (30° 08′ S, 25° 24′ E) lie approximately 8 and 40 km south-west of Jagersfontein respectively, in a vegetation zone classified as false Upper Karoo (Acocks, 1988). Scrub hares were shot at irregular intervals on both farms during 1985, but 1 to 4 hares were shot each month from December 1985 to December 1986 on "Preezfontein".

The total number of ticks recovered from the 50 hares examined are summarized in Table 8. The seasonal abundances of *H. marginatum rufipes* (combined with that on the Cape hares shot at the same time) and *R. punctatus* are graphically illustrated in Fig. 6 and 7.

The scrub hares were infested with 8 tick species of which *R. punctatus* was the most abundant and prevalent. The largest numbers of immature *H. marginatum rufipes* tended to be present on the hares from about March or April to July or August. No clear pattern of seasonal abundance was evident for *R. punctatus*.

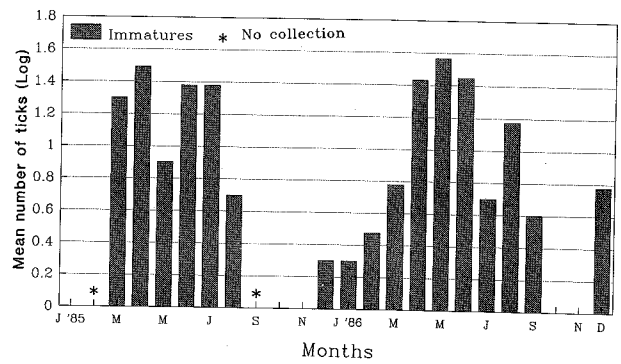

FIG. 6 The seasonal abundance of *Hyalomma marginatum rufipes* on scrub and Cape hares on the farms "Preezfontein" and "Slangfontein", south-western Orange Free State.

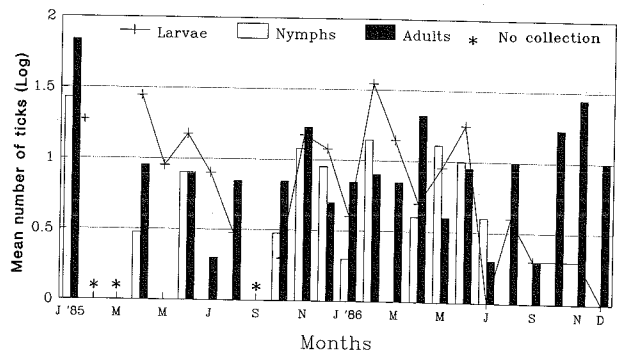

FIG. 7 The seasonal abundance of *Rhipicephalus punctatus* on scrub hares on the farms "Preezfontein" and "Slangfontein", south-western Orange Free State.

Central Orange Free State

The farm "Bishops Glen" (29° 00′ S 26° 21′ E) is situated approximately 17 km north-east of Bloemfontein within a vegetation zone described as Dry Cymbopogon-Themeda Veld (Acocks, 1988). With the exception of April and December 1989 when no hares were obtained and January 1990

TABLE 11 Ixodid ticks recovered from 34 Cape hares on the farms "Preezfontein" and "Slangfontein", south-western Orange Free State

Tick species	Total numbers recovered					No. of hares infested
	Larvae	Nymphs	Males	Females	Total	
Hyalomma marginatum rufipes	63	376	0	0	439	20
Hyalomma truncatum	0	1	0	0	1	1
Ixodes rubicundus	0	0	0	4 (3)	4	2
Rhipicephalus evertsi evertsi	11	0	0	0	11	1
Rhipicephalus oculatus	9	0	16	17	42	8
Rhipicephalus punctatus	27	10	9	6	52	12

( ) = Number of maturing female ticks, i.e. idiosoma of *I. rubicundus* > 5,0 mm in length

TABLE 12 Ixodid ticks recovered from 28 Smith's red rock rabbits on the farms "Preezfontein" and "Slangfontein", south-western Orange Free State

Tick species	Total numbers recovered					No. of hares infested
	Larvae	Nymphs	Males	Females	Total	
Amblyomma marmoreum	24	1	0	0	25	11
Hyalomma marginatum rufipes	1	1	0	0	2	2
Hyalomma truncatum	3	1	0	0	4	3
Ixodes rubicundus	6	0	0	0	6	5
Rhipicephalus arnoldi	15	25	14	12 (1)	66	13
Rhipicephalus evertsi evertsi	1	0	0	0	1	1
Rhipicephalus punctatus	9	2	0	0	11	7

( ) = Number of maturing female ticks, i.e. idiosoma of *R. arnoldi* > 4,0 mm in length

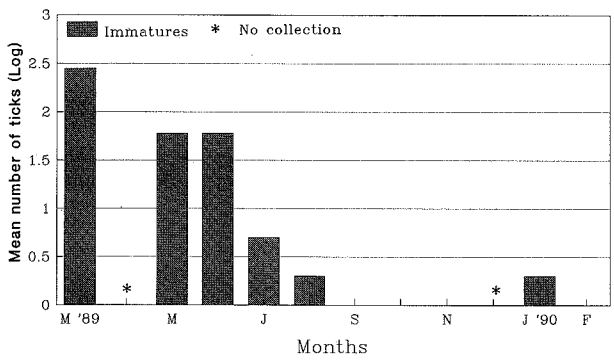

FIG. 8 The seasonal abundance of *Hyalomma truncatum* on scrub hares on the farm "Bishops Glen", central Orange Free State.

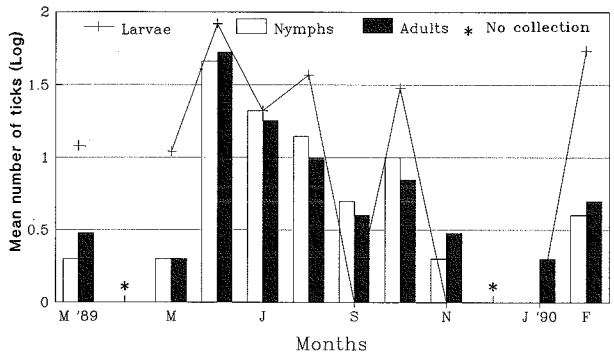

FIG. 9 The seasonal abundance of *Rhipicephalus punctatus* on scrub hares on the farm "Bishops Glen", central Orange Free State.

when 4 were shot, 2 scrub hares were shot on the farm at monthly intervals from March 1989 to February 1990.

The numbers of ticks recovered from the 22 scrub hares examined on this farm are summarized in Table 9, and the seasonal abundances of *H. truncatum* and *R. punctatus* are illustrated in Fig. 8 and 9.

The hares were infested with 9 tick species of which *H. truncatum* and *R. punctatus* were the most abundant and *R. punctatus* the most prevalent. The largest numbers of immature *H. truncatum* were recovered from March to June. The largest numbers of all stages of development of *R. punctatus* were present during June.

Cape hares

Northern Cape Province

With the exception of February and June 1989 when no hares were obtained, 2 to 6 Cape hares were shot on the farm "Sandfontein" each month from December 1988 to December 1989.

The 30 hares examined were infested with 5 tick species (Table 10) and the seasonal abundance of the immature stages of *H. truncatum* is graphically illustrated in Fig. 10.

The largest numbers of *H. truncatum* were recovered from January to May and during November and December 1989. Peak burdens of *H. marginatum rufipes* were present during March and May.

South-western Orange Free State

With the exception of February, July and September when no hares were obtained, 1 or 2 Cape hares

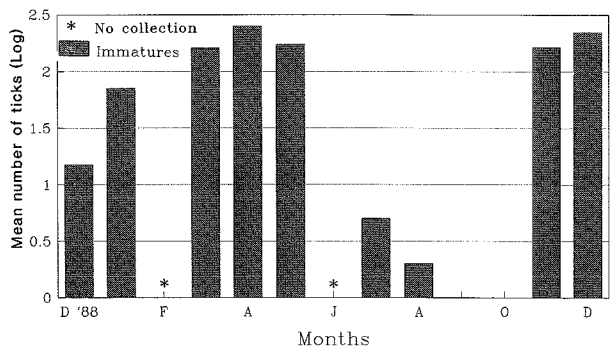

FIG. 10 The seasonal abundance of *Hyalomma truncatum* on Cape hares on the farm "Sandfontein", northern Cape Province.

were shot on the farm "Slangfontein" at monthly intervals during 1985. Except for May, when no hares were collected, 1 or 2 Cape hares were shot each month during 1986 on the farm "Preezfontein".

The total numbers of ticks recovered from the 34 hares shot on the 2 farms are summarized in Table 11.

The hares were infested with 6 tick species of which the immature stages of *H. marginatum rufipes* were the most abundant and prevalent. The seasonal abundance of this tick has been combined with that on the scrub hares shot at the same time (Fig. 6).

Smith's red rock rabbits

South-western Orange Free State

Six red rock rabbits were shot on the farm "Slangfontein" during 1985 and 7 on the farm "Preezfontein". Except for March, August and November when no rabbits were collected, 1 or 2 rabbits were shot on "Preezfontein" each month during 1986. The total numbers of ticks recovered from the 28 red rock rabbits examined are summarized in Table 12.

The red rock rabbits were infested with 7 tick species of which *R. arnoldi* was the most abundant and prevalent.

DISCUSSION

The differences in the ixodid tick fauna of the 2 hare and 1 rabbit species are probably due to 3 chief factors. The first being the habitat preferences of the hosts and the second and third the host and habitat preferences of the ticks. Nevertheless it is still possible to define the host status of the various hare species for some of the tick species recovered. This has been done in Table 13.

TABLE 13 The host status of scrub hares, Cape hares and Smith's red rock rabbits for various tick species that are not just incidental parasites

Host and tick species	Host status	
	Immature stages	Adult ticks
Scrub hares		
Amblyomma hebraeum	Good	N/A
Amblyomma marmoreum	Good	N/A
Hyalomma marginatum rufipes	Preferred	N/A
Hyalomma truncatum	Preferred	N/A
Ixodes pilosus	Good	Good
Rhipicephalus appendiculatus	Good	N/A
Rhipicephalus evertsi evertsi	Good	N/A
Rhipicephalus glabroscutatum	Good	N/A
Rhipicephalus nitens	Good	Preferred
Rhipicephalus oculatus	Definitive	Definitive
Rhipicephalus sp. (near *R. oculatus)*	N/A	Good
Rhipicephalus punctatus	Good	Preferred
Rhipicephalus simus	Good	N/A
Cape hares		
Amblyomma marmoreum	Good	N/A
Hyalomma marginatum rufipes	Preferred	N/A
Hyalomma truncatum	Preferred	N/A
Rhipicephalus oculatus	Definitive	Definitive
Rhipicephalus punctatus	Good	Good
Smith's red rock rabbits		
Amblyomma marmoreum	Good	N/A
*Ixodes rubicundus**	Preferred	N/A
*Rhipicephalus arnoldi**	Good	Definitive

N/A = Not applicable

* Horak, Fourie, Novellie & Williams (1991)

With the exception of *R. arnoldi,* for which Smith's red rock rabbit is the definitive host of the adults, the scrub hare is a good or preferred host of all the ticks occurring on the other 2 lagomorph species, as well as of a number of additional tick species.

Of all the tick species recovered from the hares and rabbits only 2 can be considered definitive parasites of these hosts. These are *R. oculatus* on the scrub and Cape hare and adult *R. arnoldi* on Smith's red rock rabbit. Although the scrub hare is a good or preferred host of all stages of development of 3 other tick species (Table 13), it shares this status with other animals within a particular tick's distribution range as will be discussed later.

Combining the findings of the present survey with those of earlier studies (Horak *et al.,* 1986; Horak, Fourie, Novellie & Williams, 1991) a total of 25 ixodid tick species have recently been recovered from scrub hares. While several of these must be considered accidental infestations, the scrub hare is nevertheless an important host of ixodid ticks in South Africa in which country at least 83 species are known to occur (Walker, 1991).

Amblyomma hebraeum

The geographic distribution of this tick is limited to the northern and eastern parts of South Africa (Howell *et al.,* 1978). Consequently only the scrub hares examined in the Grahamstown area of the eastern Cape Province, a region which falls within the distribution range of the tick, were infested.

Adults of this tick prefer large herbivores, while the immature stages can be found on a variety of bird and mammal species (Theiler, 1962; Horak, MacIvor, Petney & De Vos, 1987; Walker 1991).

The marked differences between the tick burdens of the hares examined on the farm "Bucklands" and those in the adjacent Andries Vosloo Kudu Reserve can be ascribed to the regular acaricidal treatment of domestic stock on the farm (Horak & Knight, 1986; Petney & Horak, 1987). The ratio of larvae to nymphs of 3,1:1 on the hares in the reserve is considerably lower than that on a number of other host species (Horak, MacIvor, Petney & De Vos, 1987). This indicates that scrub hares are better hosts of the nymphs than of the larvae.

No clear pattern of seasonal abundance was obvious but the larvae tended to reach the largest numbers during late summer or autumn and during winter and the nymphs during spring or early summer. Petney & Horak (1987) recovered the largest numbers of larvae from the vegetation of the Andries Vosloo Kudu Reserve during March to June and August or September. Knight & Rechav (1978) recovered the largest numbers of larvae from kudu in the same area during April and of nymphs during April and during November and December.

The scrub hare has been shown by Bezuidenhout (1988) to be a potential reservoir of *Cowdria ruminantium,* the cause of heartwater in cattle, sheep and goats. The presence of large numbers of *A. hebraeum,* the vector of this organism, on scrub hares may thus be significant in the epidemiology of the disease.

Amblyomma marmoreum

This tick is widely distributed in South Africa (Walker, 1991), hence its recovery from hares at nearly every locality. Its absence on the animals

examined at Vanrhynsdorp could be because these animals were not examined during periods of peak seasonal abundance of the tick.

Adult ticks prefer tortoises and the immature stages are present on these animals as well as on various mammals and ground-frequenting birds (Norval, 1975; Horak, MacIvor, Petney & De Vos, 1987; Walker, 1991).

On those properties on which it was possible to determine seasonal abundance the larvae were generally most abundant from late summer to early winter and the nymphs from spring to early summer. This pattern of abundance confirms earlier findings (Norval, 1975; Horak & Williams, 1986; Horak *et al.*, 1986; Rechav *et al.*, 1987).

***Hyalomma* spp.**

The adults are found on large hosts such as eland, zebras and cattle, while the immature stages prefer hares (Horak & MacIvor, 1987; Rechav *et al.*, 1987; Walker, 1991; Horak, Fourie, Novellie & Williams, 1991). The immature stages of *H. marginatum rufipes* may also be found on ground-frequenting birds and those of *H. truncatum* on rodents (Rechav *et al.*, 1987; Horak, Fourie, Novellie & Williams, 1991). The scrub hare and the Cape hare appear to be equally good hosts of these ticks confirming the findings of Rechav *et al.* (1987). In those studies in which it has been possible to make comparisons, birds and rodents appear to harbour only small numbers of ticks (Rechav *et al.*, 1987; Horak, Fourie, Novellie & Williams, 1991). However, because of their own large number their contribution to the total tick population may be significant.

The larvae and nymphs of *H. marginatum rufipes* were generally present in the largest numbers on the hares at some time during the period February to August. This corresponds with the findings of Horak & MacIvor (1987) on scrub hares and Rechav *et al.* (1987) on helmeted guineafowls.

In the northern Cape Province *H. truncatum* was present on Cape hares in the greatest numbers during the period November to May. The summer (November to March) abundance on these animals resembles that observed by Rechav *et al.* (1987). In the central Orange Free State the largest numbers were recovered from scrub hares from March to June.

Ixodes rubicundus

Although only very small numbers were recovered in the present survey, previous studies have indicated that Smith's red rock rabbit is one of the preferred hosts of the immature stages (Stampa, 1959; Horak, Fourie, Novellie & Williams, 1991). The adults prefer mountain reedbuck, eland, caracal and sheep (Stampa, 1959; Fourie, Horak & Marais, 1988b; Horak, Fourie, Novellie & Williams, 1991). Some of the scrub and Cape hares examined in the present study were also infested by adults.

Ixodes pilosus

This tick is found in sourveld regions along the coast from Port Shepstone in the east to Cape Town in the west (Howell *et al.*, 1978). Within this region all stages of development may be found on scrub hares, grey rhebuck, bontebok, caracal and domestic dogs (Horak *et al.*, 1986; Horak, Jacot Guillarmod, Moolman & De Vos, 1987). In the Bontebok National Park the scrub hare is as good a host as the bontebok, but not as good as the grey rhebuck (Horak *et al.*, 1986).

Rhipicephalus appendiculatus

The distribution of this tick in South Africa is similar to that of *A. hebraeum* (Howell *et al.*, 1978). Its recovery from the hares examined in the eastern Cape Province and not from other localities confirms this fact. Clifford *et al.* (1976) recovered the immature stages of *R. appendiculatus* from *Lepus crawshayi* examined in regions with a high rainfall in Kenya and Uganda, but none from *L. capensis* examined in localities in Kenya with a low rainfall. They ascribe these differences as almost certainly being due to tick distribution and habitat requirements rather than host preference.

Contrary to the findings for *A. hebraeum* on "Bucklands" and the Kudu Reserve, acaricidal treatment of livestock on the farm appeared to have no effect on the number of immature *R. appendiculatus* harboured by the 2 groups of hares. The seasonal abundance of the immature stages is similar to that described on kudu examined at the same locality (Knight & Rechav, 1978) and Angora goats on "Bucklands" (Rechav, 1982).

Rhipicephalus arnoldi

Although it appears from the present study that all stages of development prefer Smith's red rock rabbits as hosts, a comparative survey conducted in the Mountain Zebra National Park indicated that rock dassies were the preferred hosts of the immature stages (Horak, Fourie, Novellie & Williams, 1991). The habitats of the red rock rabbits and rock dassies overlap, but the former are nocturnal and the latter diurnal (Smithers, 1983; Fourie, 1983) and this may account for the differences in their burdens of immature ticks.

Too few ticks were recovered in the present study to determine patterns of seasonal abundance. However, Horak, Fourie, Novellie & Williams (1991), who recovered considerably more ticks, were also unable to determine the seasonal abundance of the various developmental stages. They ascribed this to the possible close association between the preferred hosts and the free-living ticks.

Rhipicephalus evertsi evertsi

This tick has a very wide distribution which includes some of the semi-arid areas of South Africa (Howell *et al.*, 1978). Although it also has a wide host range (Hoogstraal, 1956; Theiler, 1962), it hardly ever occurs in large numbers except on eland and zebras (Horak, Fourie, Novellie & Williams, 1991). Hares are good hosts of the immature stages as reported for *L. capensis* and *L. crawshayi* in Kenya by Clifford *et al.* (1976) and *L. saxatilis* in South Africa (Horak & Knight, 1986; Horak, Fourie, Novellie & Williams, 1991).

Rechav *et al.* (1987) observed a definite spring to autumn seasonality in the presence of the immature stages on scrub and Cape hares in the south-western Transvaal. This was not the case with the hares from the eastern Cape Province where the life cycle appeared to be continuous. It has been suggested by Matson & Norval (1977) that this tick may complete several life cycles annually.

Rhipicephalus glabroscutatum

The distribution of this tick in the eastern Cape Province, eastern Karoo and parts of the western Cape Province has been described by MacIvor (1985). The farm "Bucklands", the Andries Vosloo Kudu Reserve and the Bontebok National Park, all

lie within this distribution and ticks have been recovered from scrub hares at these localities and in the Karoo (Horak *et al.* 1986; Horak & Knight, 1986; Horak, Fourie, Novellie & Williams, 1991). The late summer to mid-winter occurrence of the immature stages of this 2-host tick on scrub hares in the eastern Cape Province corresponds to its seasonal abundance on other animals in this region and the Karoo (MacIvor & Horak, 1984; Horak, Fourie, Novellie & Williams, 1991).

Rhipicephalus nitens

According to Morel (1969), *R. nitens* has a geographic distribution limited to the south-western Cape Province. It has, however, been recovered in small numbers from dogs at Grahamstown and large numbers from sheep at Sidbury in the eastern Cape Province (Horak, Jacot Guillarmod, Moolman & De Vos, 1987; Horak, Williams & Van Schalkwyk, 1991). All stages of development feed on scrub hares, grey rhebuck, bontebok and sheep (Horak *et al.* 1986; Horak, Williams & Van Schalkwyk, 1991), hence it is difficult to identify a single preferred host species. Ruminants are, however, beter hosts of the immature stages than are hares (Horak *et al.*, 1986).

Although it was not possible to determine seasonal abundance in the present survey, because of the spacing of the slaughter dates, this has been done in other studies. The larvae are present from late summer to winter, the nymphs during winter and spring and the adults during summer (Horak *et al.*, 1986; Horak, Williams & Van Schalkwyk, 1991).

Rhipicephalus oculatus

This tick was orginally described from a hare, *Lepus timidus* (Neumann, 1901). This hare was probably *L. capensis*, but could possibly have been *L. saxatilis* (Smithers, R.H.N. in a personal cummunication to Walker, 1991). The taxonomic problems that exist between *R. oculatus* and the following species have been discussed by Walker (1991).

Judging by the findings of the present survey and an earlier survey in the eastern Karoo (Horak, Fourie, Novellie & Williams, 1991), *R. oculatus* occurs in the Valley Bushveld regions of the eastern Cape Province, in the Karoo, in the northern Cape Province and in the south-western Orange Free State. It is a definitive parasite of the scrub hare and the Cape hare. Greater numbers were recovered from Cape hares on the farms "Slangfontein" and "Preezfontein" in the south-western Orange Free State than on scrub hares examined on the same farms. This, however, may be due to habitat preferences of the ticks and the hares rather than host preference.

The seasonal abundance of this tick on scrub hares in the eastern Cape Province (Fig. 5) is similar to that on scrub hares in the Mountain Zebra National Park in the Karoo (Horak, Fourie, Novellie & Williams, 1991). It seems likely that only 1 life cycle is possible annually.

***Rhipicephalus* sp. (near *R. oculatus*)**

This tick is fairly common in the Valley Bushveld regions of the eastern Cape Province, where adults may be found on scrub hares, kudu, cattle, sheep and goats (Horak & Knight, 1986). The adults are most abundant during the summer months.

Rhipicephalus punctatus

The taxonomic status of this tick in South Africa has recently been clarified by Walker (1991). It was previously referred to as *Rhipicephalus pravus*-like on Angora goats, *Rhipicephalus* sp. (near *R. pravus*) on Merino sheep, and *Rhipicephalus* sp. (near *R. punctatus*) on cattle (Fourie, Horak & Marais, 1988a, b; Fourie & Horak, 1990). From the present and other published surveys it appears to occur in the northern and north-eastern Transvaal, the northern Karoo and south-western and central Orange Free State (Fourie *et al.*, 1988a, b; Fourie & Horak, 1990; Walker, 1991).

Within this distribution range the tick appears to favour rocky outcrops and hills. The preferred host for the immature stages is the rock elephant shrew which utilizes this terrain as habitat. This probably explains the difference in the tick burdens of the scrub hares and the Cape hares examined on the farms "Slangfontein" and "Preezfontein" in the south-western Orange Free State. Cape hares prefer open, level terrain (Smithers, 1983) and hence would not necessarily come into contract with the ticks.

Although scrub hares are the preferred hosts of adult ticks of this species, these may also attach to several other animals including goats, sheep and cattle (Fourie *et al.*, 1988a, b; Fourie & Horak, 1990). The ticks excrete a toxin while feeding and this can cause paralysis in Angora goat kids (Fourie *et al.*, 1988a).

No clear pattern of seasonal abundance is evident on the hares. This may be due to a close association between the tick and its host with the hare supplying warmth and moisture within its form, thus making continous development of the free-living stages possible. On sheep and cattle adult ticks are most numerous from spring to summer (Fourie *et al.*, 1988b; Fourie & Horak, 1990).

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Parasites of domestic and wild animals in South Africa. XXXII. Ixodid ticks on scrub hares in the Transvaal

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ABSTRACT

HORAK, I.G., SPICKETT, A.M., BRAACK, L.E.O. & PENZHORN, B.L. 1993. Parasites of domestic and wild animals in South Africa. XXXII. Ixodid ticks on scrub hares in the Transvaal. *Onderstepoort Journal of Veterinary Research*, 60:163–174

A total of 264 scrub hares (*Lepus saxatilis*) were examined for ixodid ticks at various localities in the Kruger National Park, eastern Transvaal Lowveld. Thirteen tick species were recovered from these hares. The seasonal abundances of the immature stages of *Amblyomma hebraeum, Amblyomma marmoreum, Hyalomma truncatum, Rhipicephalus appendiculatus, Rhipicephalus evertsi evertsi, Rhipicephalus simus* and *Rhipicephalus zambeziensis* and all stages of a *Rhipicephalus* sp. (near *R. pravus*) were determined.

Three scrub hares, examined in the north-western Transvaal Bushveld, were infested with five ixodid tick species. Ten hares examined in the eastern Transvaal Highveld harboured three species.

A total of 15 ixodid tick species were recovered from the scrub hares examined in the three regions of the Transvaal. No haematozoa were found in blood smears made from the hares examined in the southern region of the Kruger National Park.

INTRODUCTION

The ixodid tick species infesting hares in South Africa have been recorded in several studies (Horak & Knight 1986; Horak, Sheppey, Knight & Beuthin 1986; Rechav 1986; Horak & MacIvor 1987; Rechav, Zeederberg & Zeller 1987; Horak & Fourie 1991; Horak, Fourie, Novellie & Williams 1991a). These surveys indicated that scrub hares (*Lepus saxatilis*) are good hosts of the immature stages of *Amblyomma hebraeum*, *Amblyomma marmoreum*, *Hyalomma marginatum rufipes*, *Hyalomma marginatum turanicum*, *Hyalomma truncatum*, *Rhipicephalus appendiculatus*, *Rhipicephalus evertsi evertsi* and *Rhipicephalus glabroscutatum*. In addition, they are good hosts of all stages of *Ixodes pilosus*, *Rhipicephalus nitens*, *Rhipicephalus oculatus* and *Rhipicephalus punctatus*, as well as the adults of a *Rhipicephalus* sp. (near *R. oculatus*). The seasonal abundances of these ticks on the scrub hares were also determined. With the exception of the survey conducted by Rechav *et al.* (1987), which was carried out in the south-western Transvaal, the other South African studies were done in the Cape Province and in the Orange Free State.

Scrub hares may serve as reservoir hosts of the virus of Crimean-Congo haemorrhagic fever (Hoogstraal 1979; Swanepoel, Struthers, Shepherd, McGillivray, Nel & Jupp 1983). Furthermore, they are the

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preferred hosts of the immature stages of the three *Hyalomma* ticks present in South Africa (Horak & MacIvor 1987; Rechav *et al.* 1987; Horak & Fourie 1991). The virus has been isolated from two of these ticks, namely *H. marginatum rufipes* and *H. truncatum*. *Hyalomma marginatum rufipes* has also been proven to be a vector of the virus (Swanepoel *et al.* 1983). The hares are therefore vitally important in the epidemiology of the disease.

It has recently been shown that scrub hares can be infected experimentally with *Cowdria ruminantium*, the causative organism of heartwater in cattle, sheep and goats, by intravenous injection of infected sheep blood (Bezuidenhout 1988). At the same time it was demonstrated that *A. hebraeum* larvae, placed on one of these hares 7–9 d later, picked up the infection and transmitted it to sheep during the nymphal and adult stage (Bezuidenhout 1988). As scrub hares are good hosts of the immature stages of *A. hebraeum* and *A. marmoreum* (Horak & Fourie 1991)—both of which are proven experimental vectors of *C. ruminantium* (Bezuidenhout 1987)—the hares could potentially play a role in the epidemiology of this important stock disease.

The present paper records the presence and seasonal abundance of ixodid ticks on scrub hares at various localities in the Transvaal, and compares these with the results of surveys conducted elsewhere in South Africa.

MATERIALS AND METHODS

Survey animals

A total of 277 scrub hares were examined—264 from the Kruger National Park (KNP), three from the north-western Transvaal bushveld, and ten from the eastern Transvaal Highveld. They were shot at night, using a spotlight and a single-shot, small-calibre rifle or a .410 shotgun. An attempt was made to shoot only adult animals, but this was not always possible.

Tick recovery

The hares were processed for tick recovery as described by Horak *et al.* (1986) and Horak & Fourie (1991). The ticks were identified and counted under a stereoscopic microscope, and the length of the idiosoma of maturing females was measured. The minimum length assigned to each species is that length which we estimate the maturing female tick would reach 24 h before detaching.

Non-ixodid arthropod parasites recovered from the hares, as well as the helminths recovered from many of the animals and the morphometric measurements of the hares in the south of the KNP, will be reported separately.

Thin blood smears were made from all the hares shot in the south of the KNP. These were fixed in methanol, stained with 10 % Giemsa stain, and examined for haematozoa under oil immersion at 1000 x magnification. At least 50 fields were examined on each smear.

Climate

Monthly mean maximum and minimum temperatures and the total monthly rainfall were recorded at Skukuza, KNP.

SURVEY LOCALITIES AND RESULTS

Kruger National Park (KNP)

This nature reserve, which is about two million ha in extent, is situated in the north-eastern Transvaal Lowveld along the South African border with Mozambique. The localities at which the various surveys were done are listed from north to south.

Pafuri (23°27′S, 31°19′E)

Three scrub hares were shot between February and April 1990 in this region in the far north-east of the KNP. The vegetation here is classified as Mixed Bushveld (Acocks 1988) and the landscape described as Limpopo/Levubu Floodplains by Gertenbach (1983). The species and numbers of ixodid ticks recovered from these hares are summarized in Table 1. They were infested with seven tick species, of which the immature stages of *H. truncatum* were the most numerous.

Shingwedzi (23°07′S, 31°26′E)

The vegetation in this northern section of the KNP is classified as Mopani Veld (Acocks 1988) and the landscape described by Gertenbach (1983) as Alluvial Plains with *Salvadora angustifolia* tree-savanna. A total of 18 scrub hares were shot in groups of three at 2-monthly intervals from June 1989 to April 1990, within a 5-km radius of the Shingwedzi rest camp. The ticks recovered from these hares and the seasonal abundances of *H. truncatum* and a *Rhipicephalus* sp. (near *R. pravus*), are presented in Table 2 and Fig. 1, respectively.

A total of six tick species were recovered from the hares, of which the *Rhipicephalus* sp. (near *R. pravus*) was the most numerous. (We have assumed that the immature stages which we recovered, and which resemble the immature stages of *R. punctatus*, belong to the former tick.) The largest numbers of larvae were recovered during June, and the largest numbers of nymphs during June and August. Adults were always present, but few were recovered in April. *H. truncatum* is a two-host tick, and the greatest numbers of larvae and nymphs

TABLE 1 Ixodid ticks recovered from three scrub hares examined near Pafuri in the far north-east of the Kruger National Park

Tick species	Total numbers recovered					No. of hares infested
	Larvae	Nymphs	Males	Females	Total	
Amblyomma hebraeum	1	3	0	0	4	3
Hyalomma truncatum	178	101	0	0	279	2
Rhipicephalus appendiculatus	0	1	0	0	1	1
Rhipicephalus evertsi evertsi	0	3	0	0	3	2
Rhipicephalus kochi	5	1	4	3	13	2
Rhipicephalus sp. (near *R. pravus*)	4	0	11	5 (1)	20	1
Rhipicephalus zambeziensis	2	1	0	0	3	2

( ) = Number of maturing female ticks, i.e. idiosoma of *R. kochi* and of *Rhipicephalus* sp. (near *R. pravus*) > 5,5 mm in length

TABLE 2 Ixodid ticks recovered from 18 scrub hares from near Shingwedzi in the north of the Kruger National Park

Tick species	Total numbers recovered					No. of hares infested
	Larvae	Nymphs	Males	Females	Total	
Amblyomma hebraeum	3	51	0	0	54	13
Amblyomma marmoreum	0	2	0	0	2	2
Hyalomma truncatum	222	169	0	0	391	15
Rhipicephalus evertsi evertsi	2	6	0	0	8	5
Rhipicephalus sp. (near *R. pravus*)	713	125	163	48 (8)	1 049	18
Rhipicephalus zambeziensis	17	20	0	0	37	6

( ) = Number of maturing female ticks, i.e. idiosoma of *Rhipicephalus* sp. (near *R. pravus*) > 5,5 mm in length

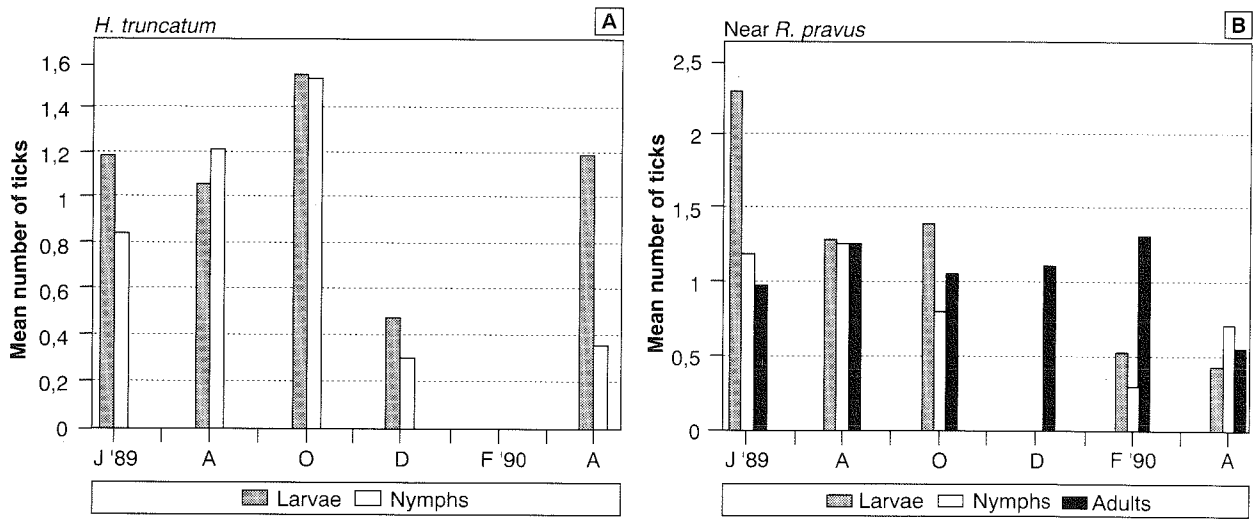

FIG. 1 The seasonal abundance of (A) *Hyalomma truncatum* and (B) *Rhipicephalus* sp. (near *R. pravus*) on scrub hares around Shingwedzi, Kruger National Park

were present from June to October 1989 and during April 1990.

Skukuza (24°58'S, 31°36'E)

This camp is situated in the south of the KNP in a landscape zone described as Thickets of the Sabie and Crocodile Rivers (Gertenbach 1983), and classified as Lowveld by Acocks (1988). At about monthly intervals for a period of 4 years (from August 1988 to July 1992), sets of five scrub hares were shot within a 25-km radius of Skukuza. A total of 240 hares were collected in this way. The species and numbers of ticks collected from these hares are summarized in Table 3.

TABLE 3 Ixodid ticks recovered from 240 scrub hares from near Skukuza in the south of the Kruger National Park

Tick species	Total numbers recovered					No. of hares infested
	Larvae	Nymphs	Males	Females[a]	Total	
Amblyomma hebraeum	2 354	2 497	0	1	4 852	236
Amblyomma marmoreum	522	250	0	0	772	149
Boophilus decoloratus	22	0	3	0	25	10
Haemaphysalis leachi	74	16	1	0	91	21
Haemaphysalis sp.	8	5	0	0	13	2
Hyalomma truncatum	23 421	7 064	0	0	30 485	188
Rhipicephalus appendiculatus	35	76	0	0	111	37
Rhipicephalus evertsi evertsi	2 033	2 003	1	0	4 037	199
Rhipicephalus sp. (near *R. pravus*)	0	3	17	2	22	10
Rhipicephalus simus	342	38	0	0	380	39
Rhipicephalus turanicus	0	0	1	3	4	4
Rhipicephalus zambeziensis	7 864	4 541	3	1	12 409	166

[a] No maturing female ticks were recovered

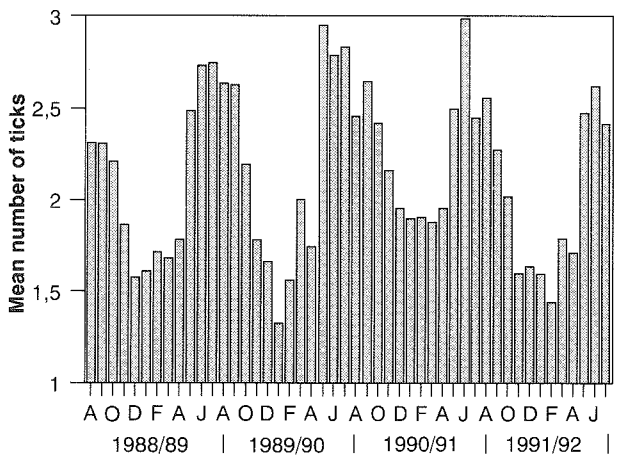

FIG. 2 Mean total numbers of ticks of all species recovered at monthly intervals from scrub hares around Skukuza, Kruger National Park from August 1988 to July 1992

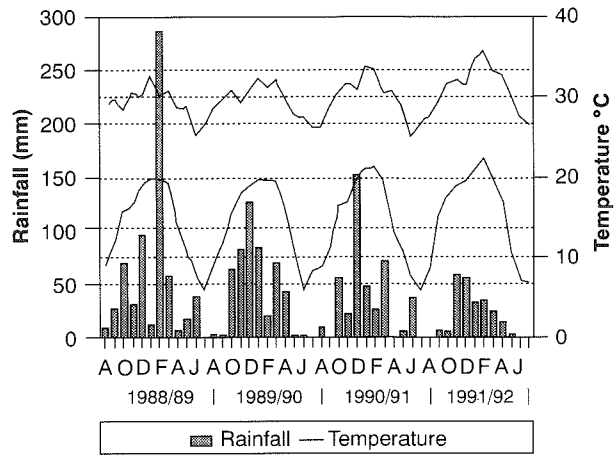

FIG. 3 Mean monthly maximum and minimum atmospheric temperature and total monthly rainfall at Skukuza, Kruger National Park from August 1988 to July 1992

The hares harboured 12 ixodid tick species, of which the immature stages of *H. truncatum* and *Rhipicephalus zambeziensis* were the most abundant, and *A. hebraeum* and *R. evertsi evertsi* the most prevalent.

The mean total numbers of ticks of all species recovered from the hares at monthly intervals during the survey period are shown graphically in Fig. 2. The maximum and minimum atmospheric temperatures and the total monthly rainfall at Skukuza are recorded in Fig. 3.

Significantly fewer ticks were recovered during the period August 1988 to July 1989 than during the corresponding period in 1990/91 (Wilcoxon T = 10; P = 0,05). Significantly more ticks were recovered during these periods in 1989/90 and 1990/91 than during the corresponding period in 1991/92 (t = 0,997; t = 4,391; P = 0,05).

Comment: The low rainfall experienced during the 1991/92 season (Fig. 3) could have been responsible for the lower total numbers of ticks recovered during this period. The highest mean total numbers of ticks were recovered during May and June of each year, corresponding to the peak seasonal abundance of the two main species collected—*H. truncatum* and *R. zambeziensis*. These peaks occurred during periods in which the lowest minimum and maximum temperatures and rainfall were recorded. However, detailed analysis of climatic parameters is beyond the scope of this paper.

The seasonal abundances of *A. hebraeum*, *A. marmoreum*, *H. truncatum*, *R. appendiculatus*, *R. evertsi*

evertsi, *Rhipicephalus simus* and *R. zambeziensis* on the hares are illustrated in Fig. 4 and 5.

No clear pattern of seasonal abundance for *A. hebraeum* or *R. evertsi evertsi*, which is a two-host tick, was evident. The larvae of *A. marmoreum* were generally present from January to July, August or September, while no clear pattern of seasonal abundance was evident for the nymphs. The larvae and nymphs of *H. truncatum* were most numerous from

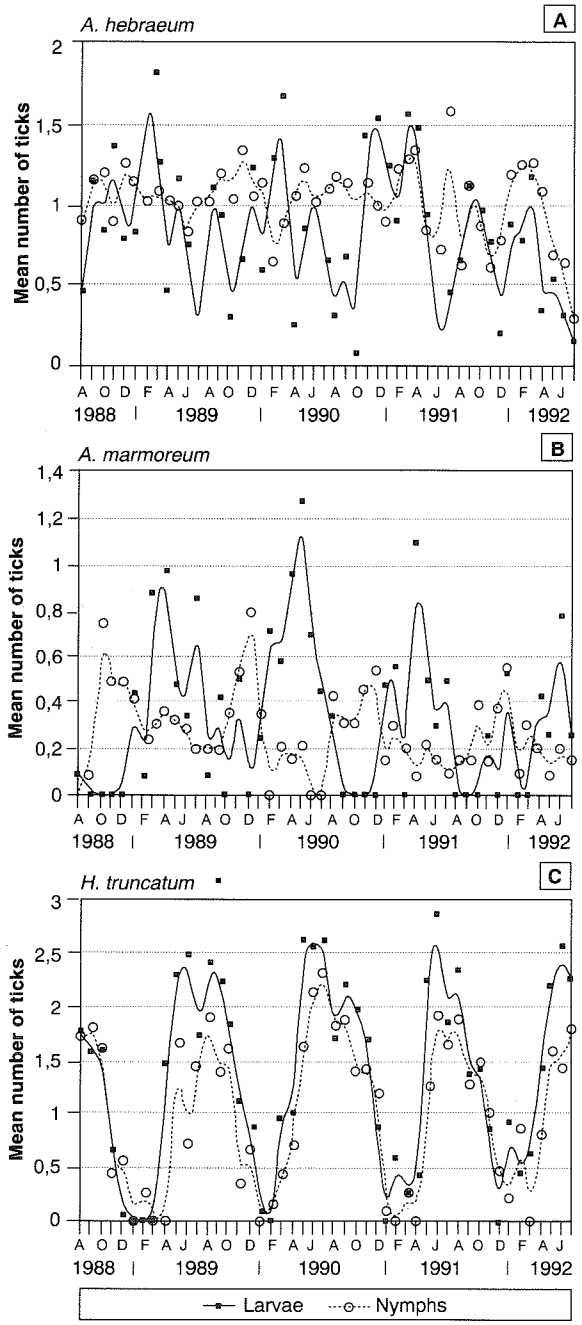

FIG. 4 The seasonal abundance of (A) *Amblyomma hebraeum*, (B) *Amblyomma marmoreum*, and (C) *Hyalomma truncatum* on scrub hares around Skukuza, Kruger National Park

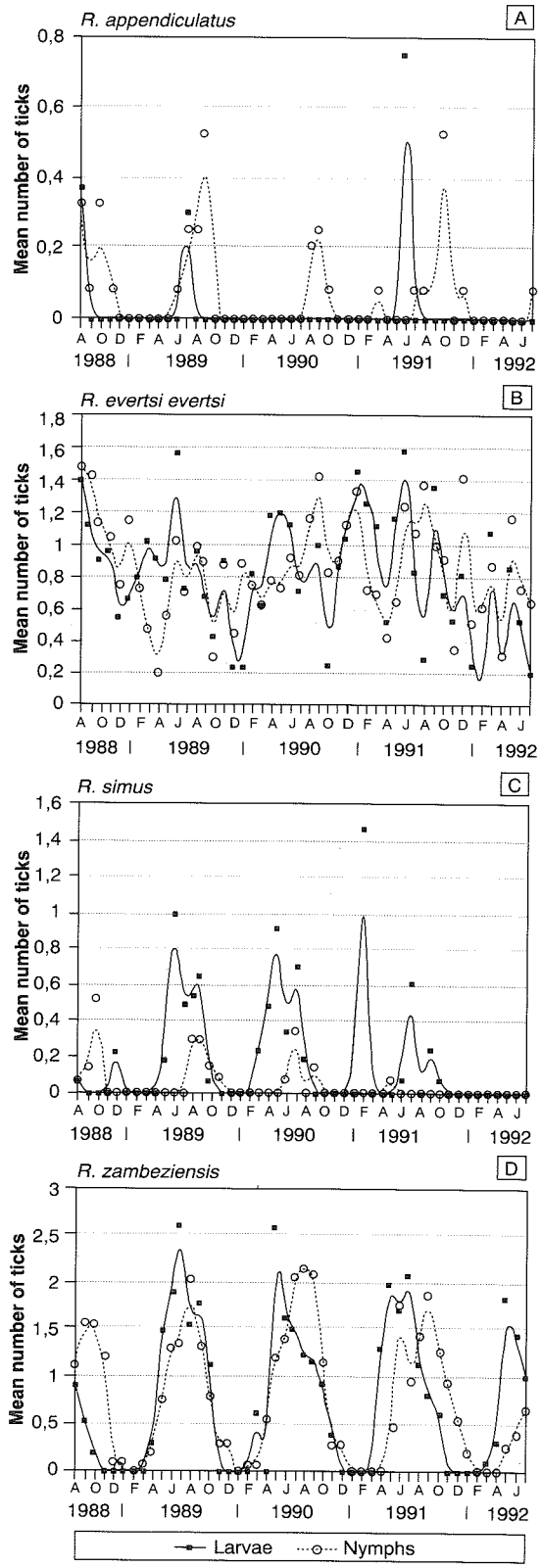

FIG. 5 The seasonal abundance of (A) *Rhipicephalus appendiculatus*, (B) *Rhipicephalus evertsi evertsi*, (C) *Rhipicephalus simus* (D) and *Rhipicephalus zambeziensis* on scrub hares around Skukuza, Kruger National Park

May to October. The nymphs of *R. appendiculatus* were usually present during the period June to September or October. With some exceptions, the larvae of *R. simus* were present during the months March to October, and the nymphs during the months August to October. The greatest numbers of *R. zambeziensis* larvae were recovered during the period May to July, and nymphs during the period August to October.

No haematozoa were found in blood smears from hares collected near Skukuza.

Pretoriuskop (25°10'S, 31°16'E)

The vegetation surrounding this camp, which is located in the south-west of the KNP, is classified as Lowveld Sour Bushveld and Lowveld (Acocks 1988), and the landscape described as Lowveld Sour Bushveld of Pretoriuskop (Gertenbach 1983). During June 1989 three scrub hares were shot within a radius of 6 km of Pretoriuskop. The numbers of ticks recovered from these animals are summarized in Table 4.

Seven tick species were recovered from the hares, of which *R. appendiculatus* was the most numerous.

No haematozoa were found in blood smears from the hares collected at Pretoriuskop.

Eastern Transvaal Highveld

Ermelo (26°32'S, 29°59'E)

Ten scrub hares were shot during June 1989 on three farms to the west of this town. Acocks (1988) has classified the vegetation of this region as Themeda Veld (Turf Highveld). The tick species and numbers harboured by the hares are summarized in Table 5.

A total of three tick species were recovered, of which the immature stages of *R. evertsi evertsi* were the most abundant.

North-western Transvaal

Marken (23°35'S, 28°21'E)

The farm "Mooimeisiesfontein" lies about 10 km to the south of the town Marken. The vegetation is classified as Mixed Bushveld (Acocks 1988). Three scrub hares were shot on the farm during November 1988. The numbers of ticks recovered from these animals are summarized in Table 6.

The hares were infested with five ixodid tick species, of which a *Rhipicephalus* sp. (near *R. pravus*) was the most numerous.

DISCUSSION

Horak & Fourie (1991) listed 13 ixodid ticks for which they considered the scrub hare to be a good, preferred or definitive host. To that list can be added the immature stages of *H. marginatum turanicum*, for which hares in the Mountain Zebra National Park are the preferred hosts (Horak *et al.* 1991a), and the immature stages of *R. zambeziensis*, for which hares in the present study were good hosts. Two of the three hares examined near Pafuri were infested with both immature and adult *Rhipicephalus kochi* (Table 1), and scrub hares may yet prove to be good hosts of this tick. With the exception of the animals at Pretoriuskop and Ermelo, hares at each locality were infested with immature and adult ticks of the *Rhipicephalus* sp. (near *R. pravus*), and appear to be a preferred host of this tick. Although only four hares in the present survey were infested with adults of *R. turanicus* (Table 3), further studies may indicate that they are good hosts of this tick. In their ecological observations on *R. turanicus*, Pegram, Clifford, Walker & Keirans (1987a) record more collections from hares (*Lepus* spp.) than from any other wild hosts.

Horak & Fourie (1991) stated that, in all, 25 ixodid tick species had been recovered from scrub hares in recent surveys in South Africa. The present study has added *Boophilus decoloratus*, the immature stages of an unidentified *Haemaphysalis* sp. and an *Ixodes* sp. which all should be considered accidental infestations, as well as *R. kochi*, *Rhipicephalus* sp. (near *R. pravus)*, *R. turanicus* and *R. zambeziensis.* The number of tick species identified to specific or subspecific level on the scrub hares in these studies now totals 28, with the immature stages of a further four identified only to generic level. However, scrub hares probably serve as hosts of the immature stages of several more of the 83 species of ixodid ticks listed by Walker (1991) as occurring in South Africa. The widespread distribution of the hares and their preference for scrub-type vegetation, combined with their persistence in agriculturally developed areas (Skinner & Smithers 1990), ensure that their habitat overlaps those of most of the ticks occurring on domestic livestock and wild animals in this country.

Although scrub hares may harbour large tick burdens, it would appear that, with the exception of the *Hyalomma* spp., they suffer little irritation from the ticks. At the height of the immature *Hyalomma* spp. infestations, in mid-winter, the necks of hares, where these ticks attach, are frequently nearly hairless, presumably because of continuous scratching.

Amblyomma hebraeum

The distribution area of this tick in the Transvaal lies roughly north and west of the Highveld region of this province (Howell, Walker & Nevill 1978). With the exception of the hares examined near Ermelo in the Highveld, a total of 257 of the 267 animals examined at all the other localities were infested with the immature stages of *A. hebraeum*. One animal

TABLE 4 Ixodid ticks recovered from three scrub hares from near Pretoriuskop in the south-east of the Kruger National Park

Tick species	Total numbers recovered					No. of hares infested
	Larvae	Nymphs	Males	Females	Total	
Amblyomma hebraeum	39	44	0	0	83	3
Amblyomma marmoreum	34	1	0	0	35	2
Hyalomma truncatum	46	11	0	0	57	2
Rhipicephalus appendiculatus	91	32	0	0	123	3
Rhipicephalus evertsi evertsi	8	1	0	0	9	2
Rhipicephalus simus	6	4	0	0	10	2
Rhipicephalus zambeziensis	4	0	0	0	4	1

TABLE 5 Ixodid ticks recovered from ten scrub hares on three farms near Ermelo, eastern Transvaal Highveld

Tick species	Total numbers recovered					No. of hares infested
	Larvae	Nymphs	Males	Females	Total	
Hyalomma marginatum rufipes	1	7	0	0	8	5
Ixodes sp.	4	0	0	0	4	1
Rhipicephalus evertsi evertsi	73	69	0	0	142	9

TABLE 6 Ixodid ticks recovered from three scrub hares on a farm near Marken, north-western Transvaal

Tick species	Total numbers recovered					No. of hares infested
	Larvae	Nymphs	Males	Females	Total	
Amblyomma hebraeum	18	3	0	0	21	2
Hyalomma marginatum rufipes	2	5	0	0	7	2
Hyalomma truncatum	15	47	0	0	62	2
Rhipicephalus evertsi evertsi	4	42	0	0	46	3
Rhipicephalus sp. (near *R. pravus*)	34	10	100	31 (12)	175	3

( ) = Number of maturing female ticks, i.e. idiosoma of *Rhipicephalus* sp. (near *R. pravus*) > 5,5 mm in length

examined near Skukuza was also infested with an adult tick, but this must be considered an accidental infestation. The preferred hosts of the adults are very large herbivores such as cattle, eland, buffaloes, giraffes and rhinoceroses. The immature stages can be found in large numbers on these animals, as well as on a variety of smaller mammal species and helmeted guineafowls (Theiler 1962; Horak, MacIvor, Petney & De Vos 1987a).

The ratio of larvae to nymphs on 42 scrub hares shot at about monthly intervals in the Andries Vosloo Kudu Reserve in the eastern Cape Province was 3,05:1 (Horak & Fourie 1991). The mean burdens of these hares were 46,4 larvae and 15,2 nymphs. In the Skukuza region in the present survey the mean burdens were 9,8 larvae and 10,4 nymphs, with a ratio of 0,94:1. The higher burdens of the hares in the eastern Cape are possibly a reflection of the higher overall stocking density in that reserve than in the Kruger National Park (Horak, Boomker, Spickett & De Vos 1992b). The high ratio of nymphs to larvae compared to that on other animals, indicates that hares are better hosts of the former than the latter stage of development (Horak *et al.* 1987a).

During the same 25 months in which the first 125 scrub hares were examined in the Skukuza region of the KNP, 118 helmeted guineafowls were similarly examined for ticks in the southern part of the KNP (Horak, Spickett, Braack & Williams 1991b). These birds harboured mean burdens of 184,9 larvae and

16,7 nymphs of *A. hebraeum*. This represents a ratio of 11,1:1, indicating a preference of larvae for guineafowls.

No pattern of seasonal abundance could be discerned on the scrub hares in the KNP. This is in agreement with the findings of Horak *et al.* (1991b), Horak *et al.* (1992b) and Spickett, Horak, Van Niekerk & Braack (1992) on helmeted guineafowls, kudus and on the vegetation in the KNP.

Amblyomma marmoreum

This tick is more widely distributed in South Africa than is *A. hebraeum* (Walker 1991). Large numbers of adults and immatures may be found on one of its preferred hosts, the mountain tortoise (Dower, Petney & Horak 1988). Warm-blooded animals are seldom infested with adults, and never harbour the same numbers of immature stages of *A. marmoreum* as they do of *A. hebraeum* where the habitats of the ticks overlap (Horak *et al.* 1987a).

The fact that no hares were infested at some localities included in the present survey, possibly reflects either the small number of animals examined or the seasonality of the immature stages of the tick.

A total of 149 (62,1 %) of the 240 scrub hares examined around Skukuza were infested with *A. marmoreum*. The hares harboured mean burdens of 2,18 larvae and 1,04 nymphs, with a ratio of 2,09:1. Of the 118 helmeted guineafowls examined simultaneously with the first 125 scrub hares, 75,4 % were infested, and the overall mean burdens consisted of 19,4 larvae and 0,9 nymphs, with a ratio of 22,2:1 (Horak *et al.* 1991b). The guineafowls therefore appear to be better hosts of the larvae of this tick than are scrub hares.

The presence of larvae on the hares during the first 7–9 months of each year corresponds with the observations made on guineafowls and on the vegetation in the KNP (Horak *et al.* 1991b; Spickett *et al.* 1992). As in the case of the guineafowls, no pattern of seasonal abundance was evident for the nymphs.

Boophilus decoloratus

Although *Boophilus* sp. larvae have been recovered from scrub hares examined in the eastern and south-western Cape Province and in the central Orange Free State, no specific diagnosis was made (Horak & Fourie 1991). Only *B. decoloratus* has been recovered in the KNP (Walker 1991). The scrub hares in the present survey harboured a total of three males and 22 larvae. No females or nymphs were recovered. We believe that these are accidental infestations and that the larvae would not complete their development on the hares.

Despite the fact that this is a one-host tick, males that have fallen from a host are occasionally collected from the vegetation during drag-sampling (Horak & Spickett, unpublished data 1992). They are possibly questing for a second host. It is probably such males that were recovered from the hares examined around Skukuza, not adults that had matured on the hares from larvae.

Haemaphysalis leachi /spinulosa

We were unable to differentiate between the immature stages of these ticks and hence have considered them together. Both tick species occur widespread in South Africa (Howell *et al.* 1978; Horak, Jacot Guillarmod, Moolman & De Vos 1987b). Present indications are that, provided the climate is not extreme, the existence of a satisfactory rodent and carnivore host complex will ensure the survival of the ticks (Norval 1984).

Adult *H. leachi* prefer carnivores such as domestic dogs and cats and the larger wild canids and felids, while adult *H. spinulosa* prefer the small carnivores (Norval 1984; Horak *et al.* 1987b). However, Clifford, Flux & Hoogstraal (1976) recorded a total of 167 adults of the *Haemaphysalis leachi* group on 397 hares they examined in Kenya.

In South Africa Horak & Fourie (1991) recovered a single female of *H. spinulosa* from 189 scrub hares examined in the Cape Province and the Orange Free State. In the present survey we collected one male *H. leachi* from the 277 hares shot in the Transvaal. The immature stages of these ticks prefer rodents (Norval 1984; Hussein & Mustafa 1985; Fourie, Horak & Van Heerden 1992), but hares may also play a role (Table 3) (Clifford *et al.* 1976; Horak & Fourie 1991).

Hyalomma marginatum rufipes

Except in the north-eastern Lowveld, this tick occurs throughout the Transvaal (Howell *et al.* 1978). Its absence on the hares in the KNP and its presence on those near Ermelo and Marken confirm this distribution pattern.

Scrub hares and Cape hares are the preferred hosts of the immature stages, while ground-frequenting birds, including helmeted guineafowls, may also play a role (Rechav *et al.* 1987; Horak & Fourie 1991). Large animals such as cattle, zebras, eland and giraffes are the preferred hosts of the adults (Horak 1982; Rechav *et al.* 1987; Horak, Anthonissen, Krecek & Boomker 1992a).

Hyalomma truncatum

This tick is found throughout the Transvaal, except for the Highveld, and possibly a small region in the south-west of the province (Howell *et al.* 1978). Its absence on the hares from around Ermelo is in agreement with this distribution pattern. As for *H.*

marginatum rufipes, scrub hares and Cape hares are the preferred hosts of the immature stages (Rechav *et al.* 1987; Horak & Fourie 1991). However, rodents may also be infested (Horak *et al.* 1991a). Large animals such as cattle, eland, zebras and giraffes are the preferred hosts of the adults (Horak 1982; Rechav *et al.* 1987; Horak *et al.* 1991a; Horak *et al.* 1992a).

As this is a two-host tick, the larvae and nymphs are simultaneously present on the host. The 18 scrub hares examined at regular intervals at Shingwedzi in the north of the KNP harboured a total of 222 larvae and 169 nymphs. This represents a ratio of 1,31:1 and a successful translation of larvae to nymphs. The 240 scrub hares shot at monthly intervals in the south of the KNP, where infestation levels were considerably higher, carried a total of 23 421 larvae and 7 064 nymphs. The ratio here was 3,32:1, indicating a considerable loss of nymphs, during or after the moult. The irritation caused by these large numbers of ticks possibly resulted in increased scratching by the hares, causing selectively greater loss of the larger nymphs.

The fairly clearly defined period of maximum seasonal abundance of immatures on the hares from May to October, and their virtual absence from January to March, is an indication that probably only one life cycle per year is completed in the KNP. This differs from the findings of Rechav *et al.* (1987) in the south-western Transvaal and Horak & Fourie (1991) in the northern Cape Province. At both the latter localities the immature stages reached peak abundance during autumn or winter, and again during summer.

Rhipicephalus appendiculatus

The distribution of this tick in the Transvaal was illustrated by Howell *et al.* (1978). To the west of Pretoria it is generally present north of latitude 26°00'S; in the east it is present north and east of the eastern Transvaal Highveld. More recently, this distribution pattern has been modified to exclude the central and northern parts of the KNP, with the exception of a salient of bushveld extending into the northern portion of the Park at Pafuri (Walker 1991).

The preferred hosts of all stages of development, but more particularly of the adults, are the larger members of the Artiodactyla, both domestic and wild (Norval, Walker & Colborne 1982). Although the smaller animals of this group will also harbour adult ticks, they are better hosts of the immature stages (Theiler 1962; Norval *et al.* 1982; Walker 1991). *Lepus crawshayi* in Kenya and *L. saxatilis* in South Africa are efficient hosts of the immature stages (Clifford *et al.* 1976; Horak & Fourie 1991). In the present study those scrub hares examined during the period April or May to October (the time of maximal immature abundance) proved to be an excellent indication of the presence or absence of the tick at a particular locality:

- In the bushveld salient extending into the north of the KNP at Pafuri, *R. appendiculatus* was present (albeit on only one of three hares).
- At Shingwedzi in the north of the KNP, but south of this salient, *R. appendiculatus* was absent.
- At Skukuza in the south, where *R. appendiculatus* occurs in small numbers on the vegetation, but is dominated by *R. zambeziensis* (Horak, Spickett & Braack, unpublished data 1992), an identical pattern was reflected on the scrub hares.
- In the west, at Pretoriuskop, where the converse is true, the burdens of the hares confirmed this.
- No ticks of this species were recovered from the hares examined on the Transvaal Highveld.
- The hares examined in the north-western Transvaal were shot outside the period of maximum abundance.

As mentioned above, the Skukuza region of the KNP is not an ideal habitat for *R. appendiculatus*—a fact reflected by the small numbers of ticks and particularly larvae of this species recovered from the hares examined here. Despite this, the nymphs were most numerous from July or August to September or October. This corresponds to the periods June to October on blue wildebeest, July to October on Burchell's zebras, June to September on warthogs, July to September or November on kudus, and August or September to November or December observed on the vegetation in the KNP (Horak, De Vos & Brown 1983b; Horak, De Vos & De Klerk 1984; Horak, Boomker, De Vos & Potgieter 1988; Horak *et al.* 1992b; Spickett *et al.* 1992). In the eastern Cape Province the largest numbers of nymphs were present on scrub hares from May or June to October (Horak & Fourie 1991).

According to Short & Norval (1981) the pattern of seasonal abundance of *R. appendiculatus* depends mainly on the period of activity of the adults. This in turn is regulated by the combined effects of humidity, temperature and the length of day. Horak *et al.* (1992b) recorded peak adult activity on kudus in the KNP from February to May, while Rechav (1981) and Horak *et al.* (1992a) recovered the largest numbers of adults on cattle and kudus in the eastern Cape Province from December to February. This would probably account for the earlier nymphal activity on scrub hares in the latter region than in the KNP.

Rhipicephalus evertsi evertsi

The biographic distribution of this tick includes the whole of the Transvaal (Howell *et al.* 1978). This pattern was confirmed by the fact that scrub hares examined at each locality in the present survey were infested.

Although scrub hares and other hares never carry very large burdens of immature ticks, they must, because of the high proportion infested, be considered good hosts for these stages of development (Clifford *et al.* 1976; Rechav *et al.* 1987; Horak & Fourie 1991; Horak *et al.* 1991a). The largest number of immature ticks recovered from a single hare in the present survey was 122 larvae and 44 nymphs. Large, wild herbivores such as zebras and eland are the preferred hosts for all stages of development (Horak *et al.* 1984; Horak *et al.* 1991a), while horses, donkeys and cattle probably fulfil this role amongst domestic stock (Norval 1981; Horak 1982).

R. evertsi evertsi is a two-host tick, and the larvae and nymphs occur simultaneously on the host. The 240 hares examined around Skukuza harboured a total of 2 033 larvae and 2 003 nymphs. The larva to nymph ratio of 1,01:1 indicates successful translation with little loss from one stage to the next.

Matson & Norval (1977) have suggested that this tick may complete several life cycles annually, an observation confirmed by the absence of seasonality in the occurrence of the immature stages on the scrub hares examined around Skukuza. Clifford *et al.* (1976) found the percentage of Cape hares (*Lepus capensis*) infested with immature stages to decline on a cattle ranch in Kenya during the season of long rains. In the south-western Transvaal Rechav *et al.* (1987) recorded a clear peak in the abundance of immature stages on Cape and scrub hares from spring to autumn.

Rhipicephalus kochi

In South Africa this tick has as yet been recorded only at Pafuri, while on the rest of the continent it is found south of the Equator in parts of eastern, central and southern Africa (Clifford, Walker & Keirans 1983).

The recorded hosts of the nymphs are four-toed elephant shrews, while those of the nymphs and probably also larvae, are kudus, nyalas and bushbuck (Clifford *et al.* 1983; Horak, Potgieter, Walker, De Vos & Boomker 1983a). Scrub hares may now be added to this list. The adults have been recovered from hares, including scrub hares (Clifford *et al.* 1983) and from numerous artiodactylid hosts.

Rhipicephalus sp. (near *R. pravus*)

Walker (1991), who recently attempted to clarify the taxonomic status of *Rhipicephalus punctatus* in South Africa, included the western, northern and north-eastern Transvaal in its range of distribution. However, it would now appear that the tick occurring in these regions is not *R. punctatus,* but a related *Rhipicephalus* sp. (near *R. pravus*). Further taxonomic studies are, therefore, necessary to clarify this problem. In this connection an observation by Warburton as long ago as 1912, concerning the genus *Rhipicephalus*, seems apposite: "The identification of species of *Rhipicephalus* is likely to give more trouble than that of any other genus of Ixodidae."

One of the hares examined at Pafuri and all the hares from near Marken and around Shingwedzi were infested with this tick. Only a few from around Skukuza harboured ticks of this species, and these were all animals shot to the north of the rest camp.

Adults, including engorging females, were found attached to the ears of the hares examined at the various localities.

Horak & Fourie (1991) could not discern any clear pattern of seasonal abundance for *R. punctatus* on the scrub hares they examined in the central Orange Free State. They suggested that this might be due to the close association between the tick and the hare within the latter's form, where warmth and moisture would be supplied by the hare. In the present study the only hares examined at regular intervals within the distribution range of the *Rhipicephalus* sp. (near *R. pravus*) were those at Shingwedzi. As in the case of *R. punctatus* on the hares in the Orange Free State, larvae were most numerous in June (Horak & Fourie 1991), while most nymphs were recovered in August. Except in April, adult ticks were always present in fairly substantial numbers. Large numbers of adult ticks were recovered from the three scrub hares examined in the north-western Transvaal during November, but as no other hares were shot at this locality, no seasonal comparisons could be made.

Rhipicephalus simus

Theiler (1962) indicated that this species was present in the western, central, north-eastern and eastern Transvaal. Only the hares examined around Skukuza and Pretoriuskop in the south and south-west of the KNP, respectively, were infested.

The preferred hosts of the immature stages are rodents (Norval & Mason 1981; Pegram, Walker, Clifford & Keirans 1987b), but the present results show that hares may also play a minor role. In the KNP large, monogastric animals such as Burchell's zebras, the larger carnivores and warthogs are the preferred hosts of the adults (Horak *et al.* 1984, 1987a, 1988).

The recovery of larvae from the hares, mainly from March to October, and of nymphs, from August to October, is in keeping with the finding that the largest adult burdens on warthogs in the southern KNP were from January to April (Horak *et al.* 1988). This would also seem to indicate that only one life cycle per year is probable at this locality.

Rhipicephalus turanicus

The taxonomic status of this tick and other ticks belonging to the *Rhipicephalus sanguineus* group has been clarified by Pegram *et al.* (1987a). Walker (1991) lists it as being present in scattered localities in the Transvaal. *R. turanicus* has a wide range of hosts, including hares, carnivores, ungulates and ground-feeding birds (Walker 1991). The recovery of the tick from scrub hares at Skukuza, albeit in very low numbers, supports the host status of these animals.

Rhipicephalus zambeziensis

In South Africa this tick has to date been found only in the Transvaal, mainly on farms in the west of the province and in the northern and southern regions of the KNP in the east (Norval *et al.* 1982). Within the southern regions of the KNP there are localities at which the distributions of *R. zambeziensis* and *R. appendiculatus* overlap, and others where one or the other is present nearly exclusively (Horak *et al.* 1992b; Spickett *et al.* 1992). We have been drag-sampling the vegetation around Skukuza for ticks at monthly intervals for the past four years and have recovered virtually only *R. zambeziensis*. The burdens of the hares from Skukuza examined over the same period mirror this finding.

Apparently *R. zambeziensis* has the same host preferences as *R. appendiculatus* (Norval *et al.* 1982; Horak *et al.* 1983b, 1984, 1988, 1992b). Although the Cape hare, *Lepus capensis*, has previously been found to be infested (Norval *et al.* 1982), the scrub hare is a new host record for the immature stages. Judging by the numbers of ticks recovered and the proportion of hares infested, it is an efficient host. The single adults recovered from some of the hares are probably accidental infestations and a reflection of the large numbers of ticks questing from the vegetation.

On kudus examined over a 2-year period in a region of the KNP slightly west and south of Skukuza, in which *R. zambeziensis* and *R. appendiculatus* occur in approximately equal numbers, the largest numbers of *R. zambeziensis* larvae were present from April or May to August or September, and the largest numbers of nymphs from July to November or December (Horak *et al.* 1992b). The seasonal abundances of *R. zambeziensis* larvae and nymphs on the scrub hares fall within these periods.

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Parasites of domestic and wild animals in South Africa. XXXIII. Ixodid ticks on scrub hares in the north-eastern regions of Northern and Eastern Transvaal and of KwaZulu-Natal

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ABSTRACT

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Ixodid ticks were collected from scrub hares (*Lepus saxatilis*) at three localities. Nine tick species were recovered from 24 hares examined at Pafuri, Kruger National Park, Northern Transvaal. The most abundant and prevalent species were *Hyalomma truncatum*, *Rhipicephalus kochi* and a *Rhipicephalus* species (near *R. pravus*). Twelve tick species were collected from 120 scrub hares examined around Skukuza, Kruger National Park, Eastern Transvaal. The immature stages of *Hyalomma truncatum* were most abundant and those of *Amblyomma hebraeum* most prevalent on the hares. No haematozoa were found on blood smears made from these hares.

Thirty-four scrub hares on mixed cattle and game farms near Hluhluwe, north-eastern KwaZulu-Natal harboured 12 tick species. The most abundant and prevalent of these were the immature stages of *Rhipicephalus muehlensi*. Piroplasms, tentatively identified as *Babesia leporis*, were present on blood smears of eight of these hares.

The host status of scrub hares for 18 ixodid tick species or subspecies found in South Africa is tabulated.

Keywords: Ixodid ticks, scrub hares, Transvaal, KwaZulu-Natal, *Hyalomma truncatum, Rhipicephalus kochi, Amblyomma hebraeum, Rhipicephalus muehlensi*

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INTRODUCTION

Several surveys on the ixodid ticks infesting scrub hares (*Lepus saxatilis*) in South Africa have recently been conducted (Horak, Sheppey, Knight & Beuthin 1986; Rechav, Zeederberg & Zeller 1987; Horak & Fourie 1991; Horak, Fourie, Novellie & Williams 1991b; Horak, Spickett, Braack & Penzhorn 1993). These surveys were carried out in the Eastern, Western and Northern Cape Province; the south-western and central Free State; North-West Province; and

Northern and Eastern Transvaal. They indicated that scrub hares are good hosts of the immature and/or adult stages of a large number of ixodid tick species. Some of these ticks are important vectors of disease to animals and man. Not only are scrub hares hosts of the ticks but they may also serve as reservoirs of some of the pathogenic organisms. Most notable of these are the virus that causes Crimean-Congo haemorrhagic fever in humans (Hoogstraal 1979), and *Cowdria ruminantium*, the cause of heartwater in cattle, sheep and goats (Bezuidenhout 1988).

Although several studies on the ticks infesting wild animals in KwaZulu-Natal have been conducted (Baker & Keep 1970; Horak, Potgieter, Walker, De Vos & Boomker 1983; Horak, Keep, Flamand & Boomker 1988; Horak, Keep, Spickett & Boomker 1989; Horak, Boomker & Flamand 1991a), no such investigation involving scrub hares has been done. The present paper records the results of a survey conducted on scrub hares in north-eastern KwaZulu-Natal, and also describes similar surveys on scrub hares in the far north-eastern Northern Transvaal Lowveld as well as in the Eastern Transvaal Lowveld. Hares at the latter locality were the subject of a 4-year survey immediately preceding the present study (Horak *et al.* 1993).

MATERIALS AND METHODS

Survey animals

A total of 183 scrub hares were examined. Twenty-four were from the far north-eastern Northern Transvaal Lowveld and 120 from Eastern Transvaal Lowveld, five from western Northern Transvaal, and 34 from farms in north-eastern KwaZulu-Natal. The hares were shot at night, the hunters using a spotlight and a shotgun.

Tick recovery

The animals were processed for ectoparasite recovery and the ticks counted as described by Horak *et al.* (1986) and Horak & Fourie (1991).

Other parasites

Non-ixodid arthropod parasites collected from the hares, as well as helminths recovered from some of the animals, will be reported separately. Thin blood smears were made from the hares examined around Skukuza, Kruger National Park and in north-eastern KwaZulu-Natal. These were fixed, stained and examined as described by Horak *et al.* (1993).

Climate

Monthly mean maximum and minimum temperatures and total monthly rainfall were recorded at Skukuza.

SURVEY LOCALITIES AND RESULTS

Kruger National Park (KNP)

Pafuri (22°25´S, 31°18´E)

A total of 24 hares were shot at about 2-monthly intervals between March 1992 and April 1993, around this locality in the far north-eastern region of the KNP, Northern Transvaal. The vegetation here is classified as Mixed Bushveld (Acocks 1988) and the landscape described as Limpopo/Levubu Floodplains by Gertenbach (1983). The species and numbers of ixodid ticks recovered from these hares are summarized in Table 1.

Nine tick species were collected, of which *Hyalomma truncatum, Rhipicephalus kochi* and a *Rhipicephalus* sp. (near *R. pravus)* were most abundant and most prevalent. The largest numbers of larvae and nymphs of *H. truncatum*, which is a two-host tick, were present from May to October 1992. The larvae and nymphs of *R. kochi* were recovered from March to October and March to August 1992 respectively, while the adults were present throughout the year. No clear pattern of seasonal abundance was evident for the *Rhipicephalus* sp. (near *R. pravus*).

Skukuza (24°58´S, 31°36´E)

This camp is situated in the southern part of the KNP, Eastern Transvaal, in vegetation classified as Lowveld by Acocks (1988), and a landscape described as Thickets of the Sabie and Crocodile Rivers by Gertenbach (1983). For a period of 2 years (from August 1992 to July 1994), sets of five scrub hares were shot at monthly intervals, within a 25 km radius of Skukuza. A total of 120 hares were collected in this way. The tick burdens of these animals are summarized in Table 2.

The hares harboured 12 ixodid tick species, of which the immature stages of *H. truncatum* and *Rhipicephalus zambeziensis* were the most abundant, and those of *Amblyomma hebraeum* and *H. truncatum*, the most prevalent. The seasonal abundances of *Amblyomma marmoreum, H. truncatum* and *R. zambeziensis* are illustrated in Fig. 1 and the monthly mean maximum and minimum atmospheric temperatures and total monthly rainfall at Skukuza in Fig. 2.

The larvae of *A. marmoreum* were generally present from around March to July, while no clear pattern of seasonal abundance was evident for the nymphs. The immature stages of *H. truncatum* were most numerous from April or May to September. Most *R. zambeziensis* larvae were recovered from April or May to August and nymphs from August or September to October or December. Immature stages of *A. hebraeum* and *Rhipicephalus evertsi evertsi* were present throughout the survey period without exhibiting clear patterns of seasonal abundance.

TABLE 1 Ixodid ticks collected from 24 scrub hares around Pafuri, Kruger National Park

Tick species	Total numbers collected					No. of hares infested
	Larvae	Nymphs	Males	Females	Total	
Amblyomma hebraeum	0	18	0	0	18	7
Amblyomma marmoreum	5	2	0	0	7	3
Boophilus decoloratus	1	0	0	0	1	1
Hyalomma truncatum	336	127	0	0	463	14
Rhipicephalus appendiculatus	0	15	0	0	15	4
Rhipicephalus evertsi evertsi	17	85	0	0	102	9
Rhipicephalus kochi	100	536	93	29(2)	758	17
Rhipicephalus sp. (near *R. pravus*)	192	452	101	24(5)	769	21
Rhipicephalus zambeziensis	13	92	0	0	105	8

( ) = Number of engorging female ticks, i.e. idiosoma of *R. kochi* and *Rhipicephalus* sp. (near *R. pravus*) > 5,5 mm in length

TABLE 2 Ixodid ticks collected from 120 scrub hares around Skukuza, Kruger National Park

Tick species	Total numbers collected					No. of hares infested
	Larvae	Nymphs	Males	Females	Total	
Amblyomma hebraeum	972	759	0	0	1731	114
Amblyomma marmoreum	389	90	0	0	479	65
Aponomma sp.	1	0	0	0	1	1
Boophilus decoloratus	35	0	1	0	36	9
Haemaphysalis leachi	0	3	0	0	3	2
Hyalomma truncatum	13226	2832	0	0	16058	105
Rhipicephalus appendiculatus	0	8	0	0	8	4
Rhipicephalus evertsi evertsi	659	478	1	0	1138	78
Rhipicephalus sp. (near *R. pravus*)	1	0	5	0	6	3
Rhipicephalus simus	0	1	0	0	1	1
Rhipicephalus turanicus	0	0	0	1	1	1
Rhipicephalus zambeziensis	4036	1650	2	1	5689	85

The highest maximum temperatures were recorded during December 1992 and 1993 and the lowest minima during June 1993 and July 1994. Rain fell mainly from November to March and the summer of 1992/93 was considerably wetter than that of 1993/94.

No haematozoa were found on the blood smears made from these hares.

Western Northern Transvaal

Two scrub hares were shot on the farm "Sandspruit" (24°38´S, 27°40´E) during June 1994 and three on the farm "Looplaagte" (24°33´S, 26°50´E) during September 1994. The vegetation in the "Sandspruit" region is classified as Sour Bushveld and Sourish Mixed Bushveld, and in the "Looplaagte" region as Mixed Bushveld (Acocks 1988). Table 3 summarizes the species and number of ixodid ticks collected from these hares.

The hares were infested with nine tick species, of which *H. truncatum* was the most abundant and prevalent.

North-eastern KwaZulu-Natal

Hluhluwe (28°07´S, 32°03´E)

A total of 34 scrub hares were shot at 2-monthly intervals from March 1993 to March 1994 on four mixed cattle and game farms within a 35 km radius of this town. The vegetation of this region is classified as Zululand Thornveld and Lowveld (Acocks 1988). The species and numbers of ixodid ticks recovered from the hares are summarized in Table 4.

The hares were infested with 12 ixodid tick species, of which the immature stages of *Rhipicephalus muehlensi* were the most abundant and prevalent, but they exhibited no pattern of seasonal abundance. The nymphs of *Rhipicephalus appendiculatus* were most abundant and prevalent during September. The larvae of *Rhipicephalus turanicus* were most prevalent from May to July and the adults from January to July.

Piroplasms, tentatively identified as *Babesia leporis*, were present on the blood smears of eight of these

TABLE 3 Ixodid ticks collected from five scrub hares in western Northern Transvaal

Tick species	Total numbers collected					No. of hares infested
	Larvae	Nymphs	Males	Females	Total	
Amblyomma hebraeum	3	6	0	0	9	3
Amblyomma marmoreum	0	2	0	0	2	1
Hyalomma marginatum rufipes	44	132	0	0	176	3
Hyalomma truncatum	99	144	0	0	243	5
Rhipicephalus appendiculatus	3	12	0	0	15	3
Rhipicephalus evertsi evertsi	33	23	0	0	56	2
Rhipicephalus sp. (near *R. pravus)*	1	6	6	0	13	2
Rhipicephalus turanicus	0	0	0	1	1	1
Rhipicephalus zambeziensis	92	8	0	0	100	4

TABLE 4 Ixodid ticks collected from 34 scrub hares around Hluhluwe, north-eastern KwaZulu-Natal

Tick species	Total numbers collected					No. of hares infested
	Larvae	Nymphs	Males	Females	Total	
Amblyomma hebraeum	311	99	0	0	410	25
Amblyomma spp.	201	48	0	0	249	24
Boophilus sp.	1	1	0	0	2	2
Haemaphysalis hoodi	0	0	2	0	2	1
Haemaphysalis leachi	1	1	0	0	2	1
Hyalomma truncatum	5	0	0	0	5	1
Rhipicephalus appendiculatus	92	281	0	0	373	16
Rhipicephalus evertsi evertsi	146	257	0	0	403	15
Rhipicephalus maculatus	0	26	0	0	26	5
Rhipicephalus muehlensi	841	213	0	0	1054	29
Rhipicephalus turanicus	67	1	72	26(2)	166	26
Rhipicephalus sp.	0	0	0	1	1	1

( ) = Number of engorging female ticks, i.e. idiosoma of *R. turanicus* > 5,5 mm in length

TABLE 5 The host status of scrub hares for various ixodid tick species which are not just occasional or accidental parasites

Tick species	Immature stages		Adult ticks	
	Host status	Value[a] (max. 200)	Host status	Value[a] (max. 100)
Amblyomma hebraeum	Good	119	–	–
Amblyomma marmoreum	Fair	55	–	–
Hyalomma marginatum rufipes	Fair	77	–	–
Hyalomma marginatum turanicum	Preferred	165	–	–
Hyalomma truncatum	Preferred	131	–	–
Ixodes sp. (near *I. pilosus*)[b]	Fair	61	Good	47
Rhipicephalus appendiculatus	Fair	72	–	–
Rhipicephalus evertsi evertsi	Fair	77	–	–
Rhipicephalus exophthalmos[c]	–	—	Fair	34
Rhipicephalus glabroscutatum	Fair	68	–	–
Rhipicephalus kochi	Fair	60	Preferred	68
Rhipicephalus muehlensi	Good	116	–	–
Rhipicephalus nitens	Preferred	147	Preferred	100
Rhipicephalus oculatus	Specific		Specific	
Rhipicephalus sp.(near *R. pravus)*	Good	103	Preferred	91
Rhipicephalus sp.(near *R. punctatus*)[d]	Good	91	Preferred	87
Rhipicephalus turanicus	–	23	Preferred	71
Rhipicephalus zambeziensis	Preferred	120	–	–

[a] Sum of prevalence and mean tick burden
[b] McKay (1994) describes this as the "hairless palp" species of the *I. pilosus* complex
[c] Previously referred to as *Rhipicephalus* sp.(near *R. oculatus*) by Horak & Fourie (1991)
[d] Previously referred to as *Rhipicephalus punctatus* by Horak & Fourie (1991)

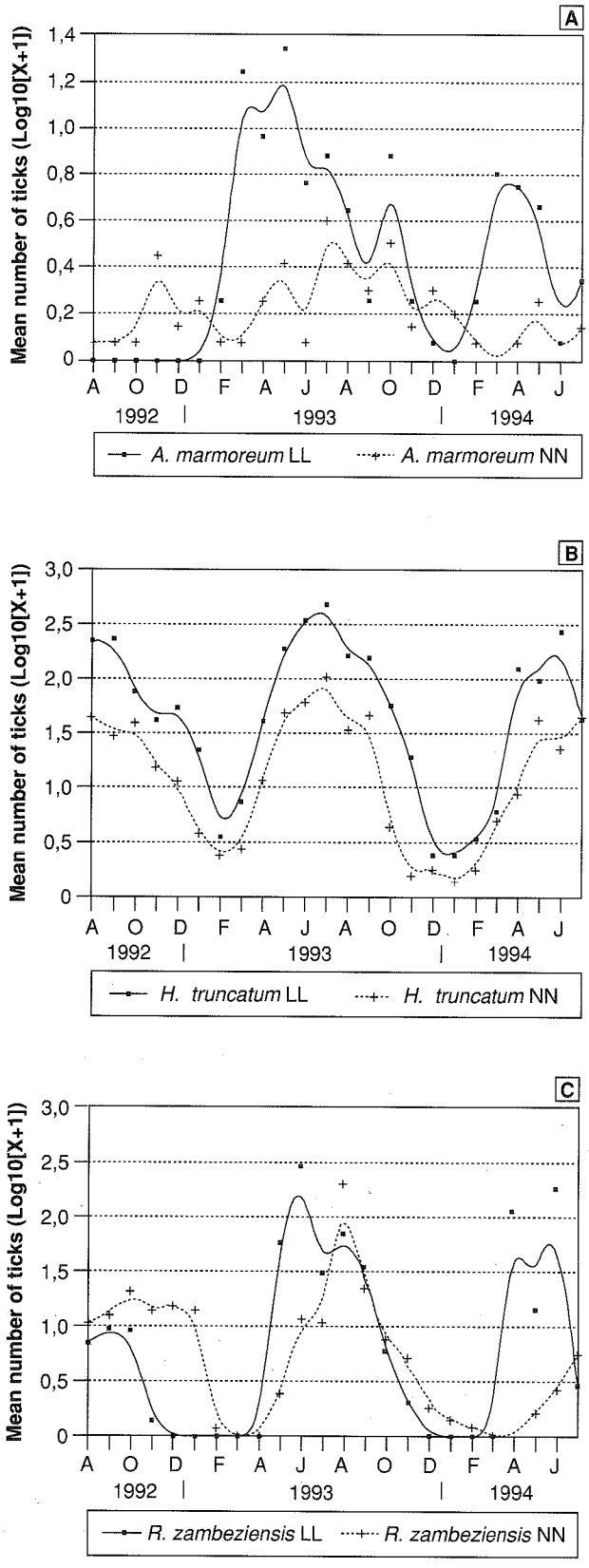

FIG. 1 The seasonal abundance of (A) *Amblyomma marmoreum*, (B) *Hyalomma truncatum* and (C) *Rhipicephalus zambeziensis* on scrub hares around Skukuza, Kruger National Park

hares. A representative blood smear (SM6160) has been deposited in the collection of the Protozoology Division, Onderstepoort Veterinary Institute.

DISCUSSION

Basic data regarding tick abundance, prevalence and seasonality were provided in earlier surveys (Horak *et al.* 1986, 1991b, 1993; Horak & Fourie 1991) and only new findings will be discussed here.

The host status of scrub hares for 13 species or subspecies of ixodid ticks occurring in South Africa was tabulated and discussed by Horak & Fourie (1991). Reassessing their data with the benefit of additional findings from a subsequent survey (Horak *et al.* 1993) and the present study, we have added six tick species or subspecies to their list and removed one. The latest studies have also made it possible to define the host status of scrub hares for some tick species more precisely, and the amended list is presented in Table 5.

For the definition of the host status of scrub hares for a given tick species, we suggest that at least 20 hares should be examined at a particular locality within a specific area, preferably over a period of one year. The percentage of these hares infested, plus their mean tick burden, can then be calculated. Where sets of 20 or more hares have been examined at more than one locality, the values should be calculated for each locality, and the mean used to assign host status.

The values for the various host-status categories for immature ticks are as follows:

Fair	(40–79)
Good	(80–119)
Preferred	(≥ 120)

These values are based on the fact that up to 100% of scrub hares can be infested with the immature stages of a particular tick and that on scrub hares the mean immature burdens of individual species seldom exceed 100 ticks, thus resulting in a potential maximum value of 200.

The values for the various host-status categories for adult ticks are:

Fair	(20–39)
Good	(40–59)
Preferred	(≥ 60)

These values are derived from the fact that because of the tendency towards seasonality in adult ticks, seldom more than 80% of hares are infested and mean burdens on these animals rarely exceed 20 ticks, giving a potential maximum value of 100.

The term, specific host, is applicable when scrub hares (or the closely related Cape hares) are, apart

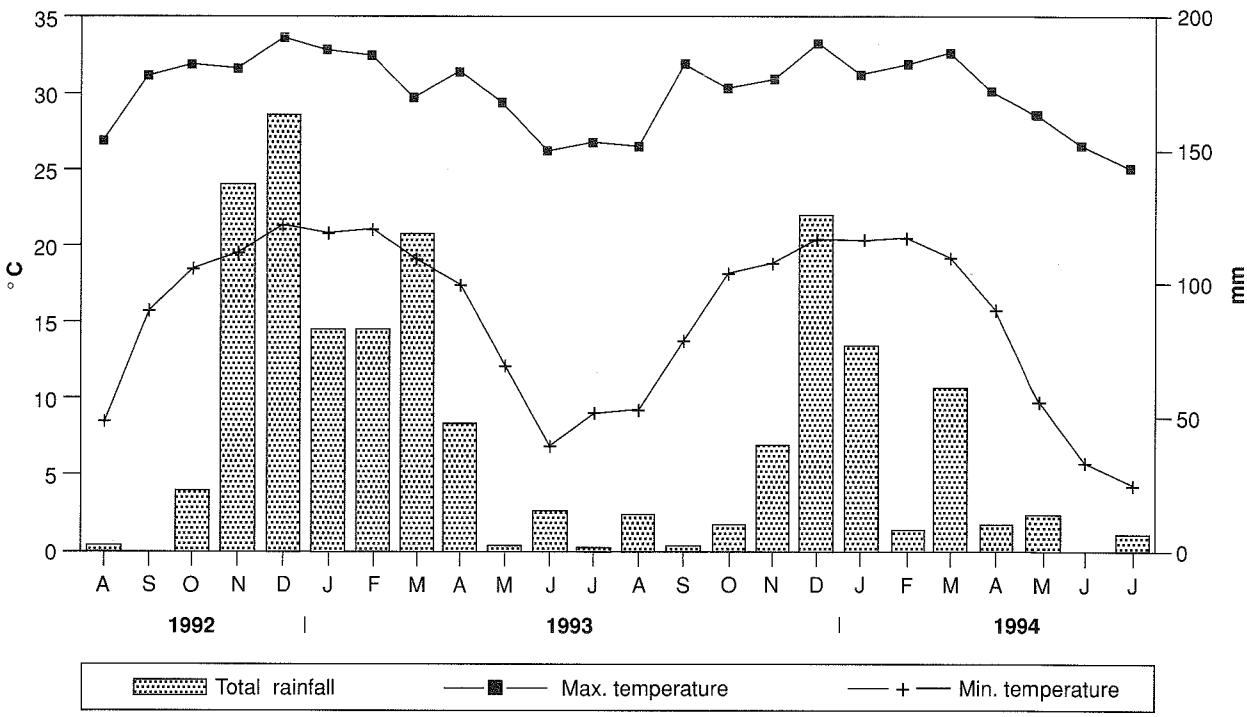

FIG. 2 Mean monthly maximum and minimum atmospheric temperatures and total monthly rainfall at Skukuza, Kruger National Park from August 1992 to July 1994

from accidental infestations on other animals, the only hosts of a particular tick.

Of the 18 tick species or subspecies listed in Table 5, only one can be considered a specific parasite of scrub hares. This is *Rhipicephalus oculatus* (not encountered in the present study) which, with the exception of the Cape hare (*Lepus capensis*), is rarely recovered from any other host species (Keirans, Walker, Horak & Heyne 1993).

When scrub hares or Cape hares are examined within the habitats of the two *Hyalomma* species found in South Africa, both usually carry large burdens of the immature stages of these ticks. However, several rodent species and ground-frequenting birds may also be infested, albeit with lesser numbers of immature *H. truncatum* or of the two subspecies of *Hyalomma marginatum,* respectively, thus denying the hares specific host status for these ticks.

Scrub hares are preferred hosts of the immature stages of four tick species and the adults of five, but they share this status with other animals present within the distribution range of a particular tick. In addition to the 18 ticks listed in Table 5, a further 16 species have been collected from scrub hares in this country during this and other surveys (Horak *et al.* 1986, 1991b, 1993; Horak & Fourie 1991). Most of these ticks are probably accidental infestations reflecting a particular tick's abundance at a specific locality rather than the hare's propensity as a host. Scrub hares may, however, yet prove to be fair or good hosts for the immature stages of four of these ticks, namely *Haemaphysalis leachi, Haemaphysalis silacea, Rhipicephalus maculatus* and *Rhipicephalus simus.* Scrub hares were, in fact, listed as good hosts of the latter tick by Horak & Fourie (1991), but the more recent data cast some doubt on that finding.

Amblyomma spp.

The presence of *A. hebraeum* and *A. marmoreum* on scrub hares has been extensively discussed by Horak & Fourie (1991) and Horak *et al.* (1993). Judging by the small numbers of *A. hebraeum* collected from three scrub hares at Pafuri and 18 examined around Shingwedzi in an earlier survey (Horak *et al.* 1993), and from the 24 hares examined at Pafuri in this study, the north-eastern region of the KNP is not a good habitat for this tick.

In addition to *A. hebraeum* and *A. marmoreum, Amblyomma nuttalli* is present in KwaZulu-Natal where it parasitizes reptiles, particularly tortoises, leguaans and some of the larger snakes (Walker 1991). As we are unable to distinguish the immature stages of this tick from those of *A. marmoreum,* we have listed immature ticks resembling these on the hares in KwaZulu-Natal, as *Amblyomma* spp.

Aponomma sp.

Ticks of this genus generally infest snakes and/or varanid lizards (Walker 1991). The single larva re-

covered from a hare near Skukuza should be regarded as an accidental infestation.

Boophilus sp.

As suggested by Horak *et al.* (1993), ticks of this genus should be considered accidental infestations on scrub hares.

Haemaphysalis spp.

H. hoodi normally infests ground-feeding birds (Walker 1991) and the ticks on a hare from Hluhluwe are probably an accidental infestation. The immature stages of *H. leachi* or *H. spinulosa*, which we are unable to differentiate, are frequently recovered from scrub hares (Horak *et al.* 1986, 1993; Horak & Fourie 1991), and these animals may yet prove to be good hosts for these ticks.

Hyalomma spp.

Scrub hares are the preferred hosts of the immature stages of *H. truncatum* and of *H. marginatum turanicum* (Horak & Fourie 1991; Horak *et al.* 1991b, 1993). They may yet be found to be good or preferred hosts of *H. marginatum rufipes* when more hares have been examined within the distribution zone of this tick. The small number of *H. truncatum* collected from the hares near Hluhluwe, compared to the large numbers on the hares in the Eastern and Northern Transvaal, is probably a consequence of the moist coastal climate of this habitat. These ticks generally prefer the drier regions of South Africa (Howell, Walker & Nevill 1978).

Rhipicephalus spp.

Scrub hares are good hosts of the immature stages of the *Rhipicephalus* sp. (near *R. pravus*) and preferred hosts of its adults and of the immature stages of *R. zambeziensis* (Horak & Fourie 1991; Horak *et al.* 1993; Table 5). They may also harbour small numbers of immature *R. simus* (Horak *et al.* 1993).

R. kochi has been found in South Africa at Pafuri in north-eastern Northern Transvaal (Clifford, Walker & Keirans 1983; Horak *et al.* 1983) and Ndumu in northern KwaZulu-Natal (Walker 1991). The adults and nymphs, and probably also larvae (which at the time were included with other larvae and identified as *Rhipicephalus* spp.), infest bushbuck, nyalas and kudus, and all stages infest scrub hares (Horak *et al.* 1983, 1993). The present study establishes scrub hares as fair hosts for the immature stages and preferred hosts for the adults. In their revision of the taxonomic status of *R. kochi*, Clifford *et al.* (1983) recorded eight collections of adults from hares and one collection of nymphs and an adult from a four-toed elephant shrew (*Petrodromus tetradactylus*).

In South Africa *R. maculatus* is confined to the coastal regions of north-eastern KwaZulu-Natal (Walker 1991). The preferred hosts of the adults are mammals with thick hides such as elephants, black and white rhinoceroses, buffaloes and bushpigs (Baker & Keep 1970; Horak *et al.* 1983, 1991a; Walker 1991). The same authors have also recorded the immature stages on rhinoceroses, buffaloes, some smaller antelope species, bushpigs and scrub hares. The absence of larvae and the relatively low numbers of nymphs on the scrub hares examined near Hluhluwe, are probably more a reflection of the scarcity of large wild hosts for the adults on the farms on which the hares were shot than the suitability of the hares as hosts for the immatures. The examination of scrub hares in close proximity to buffaloes in northern KwaZulu-Natal should establish the host status of the former for the immature stages of *R. maculatus*.

The distribution of *R. muehlensi* in South Africa closely corresponds to that of *R. maculatus* (Walker 1991). In contrast, however, the preferred hosts of the adults, nymphs and probably larvae (which at the time were lumped with other larvae and identified as *Rhipicephalus* spp.) are nyalas and bushbuck (Horak *et al.* 1983, 1988). Nymphs (and larvae that probably belong to this species) have also been collected in large numbers from red duikers (Horak *et al.* 1991a). The large proportion of infested scrub hares and the relatively high numbers of ticks collected from them indicate that these animals are good hosts for the immature stages of this tick.

The recovery of only one *R. turanicus* adult from 120 scrub hares examined around Skukuza confirms the result of the previous survey conducted there when only four adults were collected from 240 scrub hares (Horak *et al.* 1993). The Hluhluwe region of KwaZulu-Natal is apparently a more favourable habitat than Skukuza, as 26 of the 34 scrub hares examined were infested. Furthermore, 67 larvae and a nymph were collected from these animals. According to Walker (1991) the hosts of the immature stages of *R. turanicus* are unknown.

Norval, Daillecourt & Pegram (1983) recorded large infestations of adult *R. turanicus* (referred to by them as *Rhipicephalus* sp.) on the ears of sheep and goats in Zimbabwe. In this survey the preferred site of attachment of the adults was on the ears of the hares. According to Pegram, Clifford & Keirans (1987) the majority of known records of this tick indicate that the adults are active mainly in the late rainy to early dry season. In Zambia for instance, 90% of collections were made between March and July. In Zimbabwe, however, 83,7% of collections of *R. turanicus* were taken in the warm, wet season (November to April) (Norval *et al.* 1983). In KwaZulu-Natal adults were present on the hares throughout the year, the greatest percentage of animals being infested from January to July (warm, wet to cool, dry season).

The collections of *R. turanicus* from hares in western Northern Transvaal, north-eastern Eastern Transvaal

and north-eastern KwaZulu-Natal in the present study, add to the localities at which this tick has been recorded in South Africa (Pegram *et al.* 1987).

The recovery of the immature stages of *R. zambeziensis* from four of the five hares in western Northern Transvaal confirms the presence of this tick in the region as described by Norval, Walker & Colborne (1982).

General

The total number of ticks collected from scrub hares around Skukuza from August of one year to July of the next year generally closely corresponds to total rainfall over the same period (Spickett, Horak, Heyne & Braack 1995). During this period in 1992/93 a total of 14 856 ticks were collected from 60 hares, compared with 10293 ticks from the same number of hares in the considerably drier 12 months of 1993/94. During 1991/92, an even drier year than 1993/94, a total of only 9280 ticks were collected from an equal number of scrub hares (Spickett *et al.* 1995).

Babesia leporis

This species was originally described from European hares, *Lepus europaeus* (Levine 1988). As these animals are closely related to scrub hares (Skinner & Smithers 1990) they may harbour the same *Babesia* species. We suggest that *R. turanicus* could be the vector of this parasite. Only five of the 360 scrub hares examined around Skukuza were infested with this tick (Horak *et al.* 1993; Table 2) and none were infected with *Babesia*. Around Hluhluwe 26 of the 34 scrub hares surveyed harboured the tick and eight of the hares were infected with the *Babesia*.

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Small mammals

Small mammals, and particularly elephant shrews, *Elephantulus* spp., and certain rodent species, are preferred or excellent hosts of the immature stages of a number of tick species. Elephant shrews are the preferred hosts of the immature stages of three ticks that as adults produce toxins capable of inducing paralysis in domestic animals (Fourie, Horak & Van Den Heever 1992; Fourie, Horak, Kok & Van Zyl 2002; Fourie, Horak & Woodall 2005). These ticks are *Ixodes rubicundus*, responsible for paralysis, particularly in sheep, but also in goats, calves and some species of antelope, *Rhipicentor nuttalli*, responsible for paralysis in dogs, and *Rhipicephalus warburtoni*, responsible for paralysis in goats. Certain rodent species are good hosts of the immature stages of *Hyalomma truncatum* (Braack, Horak, Jordaan, Segerman & Louw 1996; Matthee, Horak, Beaucournu, Durden, Ueckermann & McGeoch 2007), of which the adults may cause the toxin-induced condition known as sweating sickness in calves. They are also good hosts of the immature stages of *Haemaphysalis elliptica* (previously referred to as *H. leachi*), the tick responsible for transmitting *Babesia canis* to dogs (Fourie *et al.* 1992; Braack *et al.* 1996; Petney, Horak, Howell & Meyer 2004; Horak, Fourie & Braack 2005; Matthee *et al.* 2007). Rodents, and possibly also elephant shrews are hosts of the immature stages of the rhinoceros tick, *Dermacentor rhinocerinus* (Horak & Cohen 2001).

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The relative host status of rock elephant shrews *Elephantulus myurus* and Namaqua rock mice *Aethomys namaquensis* for economically important ticks

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Several tick species of medical and veterinary importance occur in the southern Orange Free State. The purpose of the present study was to determine the host status of rock elephant shrews (*Elephantulus myurus*) and Namaqua rock mice (*Aethomys namaquensis*) for these ticks. Infestation levels were used as a criterion. The seasonal abundances of the ticks as well as the effects of landscape topography and sex of the host on infestation levels were also investigated. Incidental observations were made on the pouched mouse (*Saccostomys campestris*). No adult ticks were recovered from any of these small mammals. Seven tick species were found on the elephant shrews of which only *Ixodes rubicundus* and *Rhipicephalus punctatus* occurred in high numbers on a large proportion of the animals. Both these ticks cause paralysis in domestic stock. The Namaqua rock mice harboured eight tick species. Only *Haemaphysalis leachi/spinulosa* and *R. punctatus* had a relative abundance exceeding 15%. Three of the 10 pouched mice examined were infested with small numbers of ticks. The 132 rock elephant shrews examined harboured a mean total burden of 121 immature ticks compared to four on each of the 321 Namaqua rock mice. The larvae and nymphs of *I. rubicundus* occurred mainly in the colder months (April to September), while those of *H. leachi/spinulosa* preferred the warmer months (October to March). Large numbers of larvae of *R. punctatus* were present from December to July and nymphs from August to October. Infestation levels of *I. rubicundus* were consistently higher on animals trapped on southern slopes than on those trapped on northern slopes. The sex of the hosts seemed to have little effect on infestation levels.

Verskeie bosluissoorte wat van mediese en veeartsenykundige belang is, kom in die suidelike Oranje Vrystaat voor. Die doel van hierdie studie was om die status van klipklaasneuse (*Elephantulus myurus*) en Namakwa klipmuise (*Aethomys namaquensis*) as gashere van hierdie bosluise te bepaal. Besmettingsvlakke is as maatstaf geneem. Ondersoek is voorts ingestel na die seisoensvoorkoms van die bosluise en die effek van landskaptopografie en gasheergeslag op besmettingsvlakke. Terloopse waarnemings is ook op die wangsakmuis (*Saccostomys campestris*) gemaak. Geen volwasse bosluise is op enige van die diertjies gevind nie. Sewe bosluissoorte is op die klipklaasneuse gevind, maar die resultate dui daarop dat klipklaasneuse goeie gashere vir slegs twee van hierdie bosluise, nl. *Ixodes rubicundus* en *Rhipicephalus punctatus*, is. Beide bosluise kan verlamming onder vee veroorsaak. Agt verskillende bosluise is op Namakwa klipmuise gevind. Slegs twee van hierdie bosluissoorte, nl. *Haemaphysalis leachi/spinulosa* en *R. punctatus* het 'n relatiewe volopheid van meer as 15% getoon. Drie van die 10 wangsakmuise wat ondersoek is, was besmet met enkele bosluise. Klipklaasneuse (n = 132) was oor die studietydperk met 'n gemiddeld van 121 bosluise besmet vergeleke met die vier van Namakwa klipmuise (n = 321). In teenstelling met *H. leachi/spinulosa* was die seisoensvoorkoms van *I. rubicundus* larwes en nimfe hoofsaaklik tot die kouer maande van die jaar (April tot September), beperk. Hoë besmettingsvlakke van *R. punctatus* larwes is op gashere gevind vanaf Desember tot Julie. Nimfgetalle het gepiek vanaf Augustus tot Oktober. In teenstelling met *R. punctatus* en *H. leachi/spinulosa* is daar deurgaans hoër besmettingsvlakke van *I. rubicundus* aangeteken op diere versamel op suidelike hellings, vergeleke met dié versamel op noordelike hellings. Weinig verskille in besmettingsvlakke tussen die gasheergeslagte is gevind.

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Ticks are considered to be the most important biological vectors of micro-organisms which cause disease in man and animals (Balashov 1972). Small mammals may act as reservoir hosts for many of these tick-transmitted diseases (Balashov 1972). In addition, it has been suggested that rodents possibly serve as hosts of more ixodid tick species than any other mammal taxa (Oliver 1989). As ticks are obligate parasites, a major factor influencing population dynamics is the suitability and abundance of hosts (Randolph 1975).

In the south-western region of the Orange Free State, the rock elephant shrew *Elephantulus myurus* occurs sympatrically with the Namaqua rock mouse *Aethomys namaquensis* (Smithers 1983). The latter, followed by the former, are the most abundant of the small mammals confined to rocky terrain (their natural habitat) in the southern parts of the Orange Free State. The elephant shrew has been implicated as an important host of the immature stages of two paralysis-inducing tick species (Stampa 1959; Fourie, Horak & Marais 1988a). Sound quantitative data substantiating this claim are lacking. Furthermore, the relative status of the rock elephant shrew and Namaqua rock mouse as hosts of economically important ticks has not as yet been evaluated.

The objectives of this study were to identify and quantify tick burdens on these small mammals in the south-western Orange Free State, to determine seasonal patterns of abundance of their ticks and to ascertain the effects of topography on tick burdens.

Methods

Study area

Rock elephant shrews and Namaqua rock mice were collected on the farms 'Preezfontein' (29°50'S / 25°23'E) and 'Slangfontein' (30°08'S / 25°24'E) situated approximately 8 km and 40 km respectively from the town of Fauresmith in the south-western Orange Free State. The vegetation in the area has been classified as False Upper Karoo (Acocks 1975) and the climate described as semi-arid with approximately 69% of the annual rainfall occurring during the summer months. Because of the irregular rainfall, mild to severe droughts occur periodically. Air temperatures exhibit major circadian and seasonal fluctuations. The mean maximum temperatures for 1980–1986 range between 32,2°C in January and 17,2°C in June. The mean minimum temperatures varied between 16,4°C in January and 1,3°C in July. Absolute temperatures varied between 39,4 and –6,3°C (Fourie, Petney, Horak & De Jager 1989).

Survey animals

From January to December 1985 an attempt was made to capture at least two specimens of each mammal species on a monthly basis at both sampling localities. From January 1986 to December 1987 animals were captured only at 'Preezfontein'. Box traps similar to Sherman traps were used and baited with a mixture of peanut butter and oatmeal (3:2). The traps were placed on rocky outcrops and checked in the early morning and late afternoon. Trapped specimens were euthanased after which they were preserved in 10% formalin in 250 ml plastic bottles.

In order to determine the relative abundance of the various small mammals, as well as to eliminate experimental topographical trapping preference, two traplines consisting of 50 traps each, were set on northern and on southern slopes from January to December 1987 excluding February. The traps were spaced 7–10 m apart and baited as previously described. Trapping periods varied from 2–4 days during each month. Several of the trapped specimens were killed and processed for tick recovery. However, because of the poor trapping success of elephant shrews, trap lines were abandoned, and traps were placed where the likelihood of catching the shrews seemed greater on northern and southern slopes from January 1988 to December 1988. Because of this bias the latter data were not considered for the determination of relative abundance of the various small mammal species.

Tick recovery

Ticks were recovered by sieving the liquid in each bottle through a 150-µm aperture sieve. This was followed by scrubbing the animals with a tooth brush, washing them in a water-filled container and again pouring the contents of the container through the sieve. The contents of the sieve and the whole animal were then examined under a stereoscopic microscope and the ticks collected and placed in labelled bottles containing 70% ethanol for later identification and counting.

We were unable to differentiate between the immature stages of *Haemaphysalis leachi* and *Haemaphysalis spinulosa* and have designated these as *H. leachi/spinulosa*.

Treatment of data

Seasonal abundance was determined by pooling the numbers of ticks collected from elephant shrews and rock mice in a particular month irrespective of the year during which the hosts were examined. The data were expressed as mean tick burden per animal for the various months. A non-parametric Mann Whitney test was used to test for significant differences in the tick burdens between hosts collected from northern and from southern slopes. To determine whether host sex-related differences occurred in tick burdens, data were transformed to ln (tick count + 1) and an unpaired two-tailed *t* test was performed to compare the means.

Results

A total of 256 *Aethomys namaquensis*, 102 *Elephantulus myurus* and 65 *Saccostomys campestris* were captured on northern and southern slopes during 1987.

The numbers of ticks collected from the three host species are summarized in Tables 1–3. No adult ticks were present on any of the animals. Despite seven tick species being collected from the rock elephant shrews (n = 132), the results suggest that these animals are preferred by only two of these, namely *Ixodes rubicundus* and *Rhipicephalus punctatus*. Eight ixodid tick species parasitized the Namaqua rock mouse (n = 321). Only two of these, *H. leachi/spinulosa* and *R. punctatus*, had a relative abundance in excess of 15%. The mean total tick burden (all species) recorded on elephant shrews during the study period was

Table 1 Ixodid ticks recovered from 132 rock elephant shrews *Elephantulus myurus* on the farms 'Preezfontein' and 'Slangfontein' in the south-western Orange Free State

Tick species	Numbers recovered			Relative abundance %	Percentage of animals infested
	Larvae	Nymphs	Total		
Amblyomma marmoreum	5	0	5	0,03	2,27
Haemaphysalis leachi/spinulosa	26	20	46	0,29	5,30
Hyalomma marginatum rufipes	0	1	1	0,01	0,76
Ixodes rubicundus	2365	1966	4331	27,08	78,79
Rhipicephalus arnoldi	1	3	4	0,02	3,03
Rhipicephalus distinctus	0	3	3	0,02	2,27
Rhipicephalus punctatus	8999	2602	11601	72,55	100,00
Total	11396	4595	15991	100	100

Table 2 Ixodid ticks recovered from 321 Namaqua rock mice *Aethomys namaquensis* on the farms 'Preezfontein' and 'Slangfontein' in the south-western Orange Free State

Tick species	Numbers recovered			Relative abundance %	Percentage of animals infested
	Larvae	Nymphs	Total		
Haemaphysalis leachi / spinulosa	676	360	1036	76,63	49,53
Hyalomma marginatum rufipes	1	0	1	0,07	0,31
Hyalomma truncatum	10	0	10	0,74	0,31
Ixodes rubicundus	17	0	17	1,26	3,74
Rhipicephalus distinctus	8	10	18	1,33	2,80
Rhipicephalus evertsi evertsi	1	0	1	0,07	0,31
Rhipicephalus gertrudae	4	12	16	1,18	1,56
Rhipicephalus punctatus	157	96	253	18,72	19,63
Total	874	478	1352	100	72

Table 3 Ixodid ticks recovered from 10 pouched mice *Saccostomys campestris* on the farms 'Preezfontein' and 'Slangfontein' in the south-western Orange Free State

Tick species	Numbers recovered			Relative abundance %	Percentage of animals infested
	Larvae	Nymphs	Total		
Haemaphysalis leachi / spinulosa	12	6	18	90	20
Ixodes rubicundus	0	1	1	5	10
Rhipicephalus evertsi evertsi	1	0	1	5	10
Total	13	7	20	100	30

121 compared to four on Namaqua rock mice. Only three of the 10 pouched mice examined were infested with ixodid ticks.

No difference in the species composition of ticks collected from animals from the two farms was discernible. In view of the close proximity of these two localities and in order to enlarge the monthly sample sizes for the determination of seasonal activity, results for the two farms and the various years were combined. The immature stages of *I. rubicundus* were active mainly during autumn and winter with discrete peaks during April and August for the larvae and nymphs respectively (Figure 1). Larvae of *R. punctatus* reached high numbers in December and maintained this level until July. Nymphs reached peak levels from August to October (Figure 2). Larval numbers of *H. leachi/spinulosa* increased rapidly in spring (October) followed by an increase in nymphal numbers, both remaining at fairly high levels during summer whereafter larval numbers decreased in May and nymphs in June (Figure 3).

Because of the small monthly sample sizes, comparisons of tick burdens on hosts collected on northern and southern slopes were done for two or four-monthly periods for the three major tick species. Consistently more *I. rubicundus* larvae and nymphs were recorded on elephant shrews collected on southern slopes than on northern slopes (Table 4). These differences were, however, only significant ($p < 0,05$) for the nymphs recovered during the period July to August. Results obtained for *R. punctatus* and *H. leachi/spinulosa* were variable with no conspicuous trends discernible (Tables 5 & 6).

Tick burdens on male and female hosts were significantly

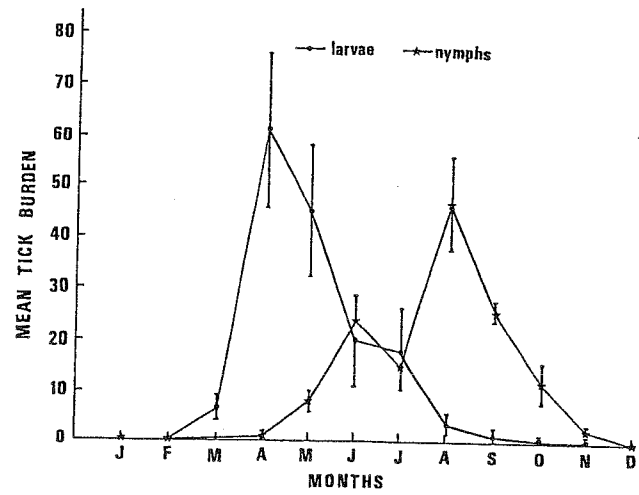

Figure 1 Seasonal abundance of *Ixodes rubicundus* larvae and nymphs on rock elephant shrews (n = 132). Data are expressed as means ± *S.E.*

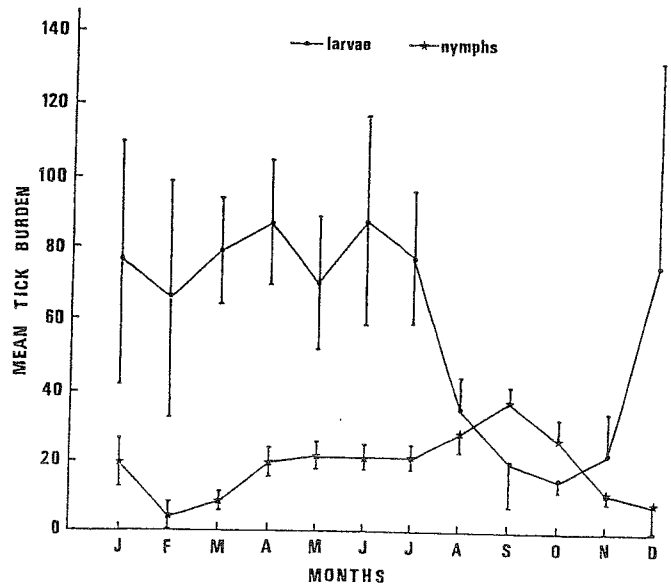

Figure 2 Seasonal abundance of *Rhipicephalus punctatus* larvae and nymphs on rock elephant shrews (n = 132). Data are expressed as means ± *S.E.*

different on only two occasions. Elephant shrew males carried significantly ($p < 0,05$) higher burdens of *I. rubicundus* nymphs during July–August and Namaqua rock mouse males carried significantly higher burdens of *H. leachi/ spinulosa* nymphs during the March–April period than females of the two species.

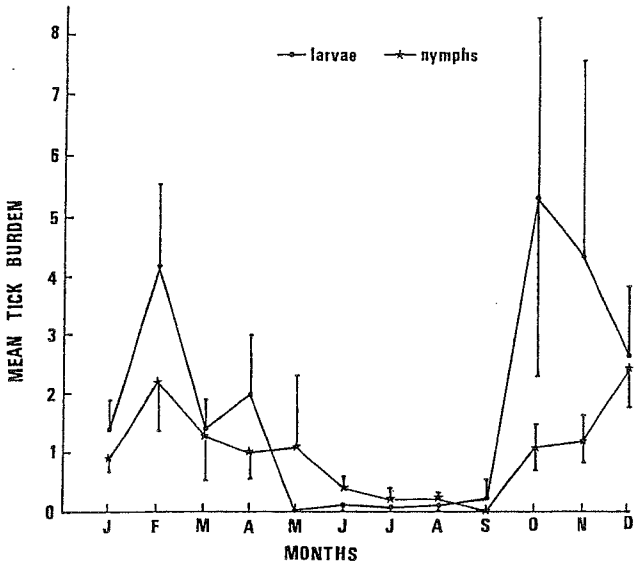

Figure 3 Seasonal abundance of *Haemaphysalis leachi / spinulosa* larvae and nymphs on Namaqua rock mice (n = 321). Data are expressed as means ± *S.E.*

Discussion

The three species of ticks with the highest relative abundance on the rock elephant shrews and Namaqua rock mice are all of economic importance. *I. rubicundus* and *R. punctatus* cause paralysis in domestic stock (Fourie *et al.* 1988a, b; Fourie *et al.* 1989). *H. leachi* is an important vector of *Babesia canis*, the cause of biliary fever in dogs. This tick is also a vector for the organisms causing tick bite fever in humans and Q-fever in humans and animals (Howell, Walker & Nevill 1978).

Recently we have also recovered the immature stages of *Rhipicentor nuttalli* from rock elephant shrews in the central Orange Free State. The hosts of the immature stages were previously unknown (Walker 1991). In its adult stage this tick excretes a toxin which causes paralysis in dogs (Theiler 1962; Norval & Colborne 1985). Three of the paralysis-inducing ticks thus utilize rock elephant shrews as hosts during their immature stages of development and it is tempting to speculate whether this host association has anything to do with toxin production.

Ixodes rubicundus

Three elephant shrew species, which are mainly confined to rocky terrain, occur in South Africa (Smithers 1983) and the distribution of these species to a large extent encompasses that of *I. rubicundus* (Howell *et al.* 1978). The distribution range of this tick appears to be extending (Spickett & Heyne 1988) and it is possible that, provided the bioclimatic requirements of the tick are satisfied, its distribution limits

Table 4 The mean (± *S.E.*) number of *Ixodes rubicundus* recovered from rock elephant shrews on northern and on southern slopes on the farm 'Preezfontein' in the south-western Orange Free State

	Northern slopes					Southern slopes				
	Larvae		Nymphs			Larvae		Nymphs		
Months	$\bar{x}$	*S.E.*	$\bar{x}$	*S.E*	n	$\bar{x}$	*S.E.*	$\bar{x}$	*S.E.*	n
January–February	–	–	–	–	–	–	–	–	–	3
March–April	14,7	4,6	–	–	11	36,4	14,0	–	–	16
May–June	27,0	7,1	8,9	3,6	6	81,6	25,6	26,6	11,9	5
July–August	2,1	0,7	8,5	2,8	8	12,8	8,9	17,7	4,1	9
September–October	–	–	11,0	6,4	3	–	–	13,3	5,4	6
November–December	–	–	2,0	–	1	–	–	4,2	1,7	6

Table 5 The mean (± *S.E*) number of *Rhipicephalus punctatus* recovered from rock elephant shrews on northern and on southern slopes on the farm 'Preezfontein' in the south-western Orange Free State

	Northern slopes					Southern slopes				
	Larvae		Nymphs			Larvae		Nymphs		
Months	$\bar{x}$	*S.E.*	$\bar{x}$	*S.E.*	n	$\bar{x}$	*S.E.*	$\bar{x}$	*S.E.*	n
January–February	–	–	–	–	–	89,0	44,5	12	9,8	3
March–April	65,4	15,4	12,9	5,3	11	106,6	21,8	9,6	1,5	16
May–June	98,3	22,9	35,5	4,3	6	73,6	23,7	14,6	3,9	5
July–August	52,3	21,9	19,0	4,1	8	73,1	16	29,0	4,3	9
September–October	16,7	4,8	19,0	11,1	3	17,5	4,0	30,3	7,2	6
November–December	18	–	7	–	1	7,3	4,4	10,2	3,0	6

Table 6 The mean (± *S.E.*) number of *Haemaphysalis leachi/spinulosa* recovered from Namaqua rock mice on northern and on southern slopes on the farm 'Preezfontein' in the south-western Orange Free State

	Northern slopes					Southern slopes				
	Larvae		Nymphs			Larvae		Nymphs		
Months	$\bar{x}$	*S.E.*	$\bar{x}$	*S.E*	*n*	$\bar{x}$	*S.E.*	$\bar{x}$	*S.E.*	*n*
January–February	1,7	0,8	2,5	1,2	11	3,7	1,8	2,5	1,2	7
March–April	5,2	2,0	4,5	2,2	7	1,0	0,7	0,4	0,5	8
May–August	–	–	0,2	0,3	10	–	–	–	–	19
September–October	0,5	0,6	1,4	0,9	9	0,2	0,3	1,3	0,7	6
November–December	0,5	0,5	2,2	1,1	9	1,0	0,7	0,6	0,6	9

will eventually be similar to those of the elephant shrew species. The rock elephant shrew is a major host of the immature stages of this tick and large numbers have also been collected from *Elephantulus edwardii* (Stampa 1959). Other studies have indicated that Smith's red rock rabbits *Pronolagus rupestris* are also important hosts for immature *I. rubicundus* (Stampa 1959; Horak, Moolman & Fourie 1987). The numbers of ticks collected from red rock rabbits examined concurrently with this study in the same localities, indicate that in terms of tick abundance, these animals are secondary in importance to rock elephant shrews (Horak & Fourie 1991).

The seasonal abundance of immature *I. rubicundus* in this study is very similar to that observed by Stampa (1959) in the New Bethesda area of the Karoo and by Horak *et al.* (1987a) in the Cradock district of the Karoo.

The consistently higher burdens of *I. rubicundus* on rock elephant shrews captured on southern slopes as opposed to northern slopes is indicative of the sensitivity of the tick to adverse environmental conditions (De Jager 1988). Northern slopes are known to be warmer and less densely vegetated than southern slopes. Studies of the spatial distribution of free-living, adult *I. rubicundus* indicate that they are closely associated with trees and shrubs with a dense canopy (Stampa 1959; Fourie, Kok & Van Zyl 1991). Most of these adult ticks were also recovered on the southern more protected sides of the trees. In the northern hemisphere a similar situation pertains to *Rhipicephalus bursa* in Israel, where 66% of the tick population was found on the more densely vegetated northern slopes compared to 20% on the poorly vegetated southern slopes (Yeruham, Hadani, Galker, Rubina & Rosen 1987).

Rhipicephalus punctatus

This tick had previously been referred to as *Rhipicephalus pravus*-like on Angora goats (Fourie *et al.* 1988a), as *Rhipicephalus* sp. (near *R. pravus*) on Merino sheep (Fourie, Horak & Marais 1988b), and *Rhipicephalus* sp. (near *R. punctatus*) on cattle (Fourie & Horak 1990). Its taxonomic status in South Africa as *R. punctatus* has, however, recently been clarified by Walker (1991). It occurs in the northern and north-eastern Transvaal, the northern Karoo and south-western and central Orange Free State (Walker 1991; Horak & Fourie 1991). Within this distribution range it appears to prefer rocky outcrops and hills. All stages of development can be found on scrub hares *Lepus saxatilis* (Horak & Fourie 1991), but the immature stages seem to prefer rock elephant shrews as demonstrated in the present study. All the shrews were infested and their mean burden comprised 88 immature ticks. Small numbers can also be found on Namaqua rock mice. Adults may also be found on sheep, cattle, goats and gemsbok *Oryx gazella* (Fourie *et al.* 1988b; Fourie & Horak 1990, 1991; Fourie, Vrahimis, Horak, Terblanche & Kok 1991).

No clear pattern of seasonal abundance is evident on scrub hares (Horak & Fourie 1991). However, on ruminants the adults appear to prefer the warmer months from spring to summer (Fourie *et al.* 1988b; Fourie & Horak 1990, 1991). Adult *R. punctatus* excrete a toxin while feeding and this has caused paralysis in Angora goat kids (Fourie *et al.* 1988a).

The absence of any clear pattern of utilization by the immature stages of elephant shrews on northern or southern slopes seems to indicate a wider tolerance of climatic conditions than *I. rubicundus*. The larger number of shrews trapped on the northern slopes could, however, mean that a larger total number of immature *R. punctatus* is present on these slopes than on the southern slopes.

Haemaphysalis leachi/spinulosa

H. leachi is distributed throughout the eastern Cape, Natal, eastern and southern Transvaal and scattered in the rest of South Africa (Howell *et al.* 1978). *H. spinulosa* has also been recovered at several of the localities at which *H. leachi* occurs (Horak, Jacot Guillarmod, Moolman & De Vos 1987) and it would appear as if the distributions of these ticks overlap. Adult *H. leachi* prefer dogs, the large wild carnivores and cats, while adult *H. spinulosa* prefer the smaller carnivores (Norval 1984). The preferred hosts of the immature stages are rodents (Hoogstraal 1956; Norval 1984; Hussein & Mustafa 1985). Black-backed jackals *Canis mesomelas* and caracals *Felis caracal*, which occur in the present study region may harbour both adult *H. leachi* and adult *H. spinulosa* (Horak *et al.* 1987b). The immature stages recovered from the shrews and mice are thus also likely to belong to both species.

Although the rock shrews that were infested harboured virtually the same mean burdens of immature *H. leachi/spinulosa* (6,6 ticks) as did infested Namaqua rock mice (6,5 ticks), the greater percentage of the latter animals infested makes them the preferred of these two hosts. Too few pouched mice were examined to determine their host status.

The seasonal abundance of adult *H. leachi* on dogs near Grahamstown in the eastern Cape Province was determined by Horak *et al.* (1987b). Large numbers were generally present from May or June to February with the highest burdens being recorded during the period July to September and the lowest during March and April. If adults follow the same pattern of seasonal abundance in the south-western Orange Free State as recorded in the eastern Cape Province this would complement the present findings. Peak adult burdens would thus follow high nymphal burdens, which occur from mid- to late summer and would precede peak larval burdens present from spring to summer. The prolonged presence of adults would also account for the extended period during which immature ticks were present on the mice.

Amblyomma marmoreum

Tortoises are the preferred hosts of all developmental stages of this tick, but the immature stages have also been recovered from several other hosts (Theiler 1962; Norval 1975). The immature stages, however, seldom feed on rodents (Horak, Sheppey, Knight & Beuthin 1986; Horak, Fourie, Novellie & Williams 1991), and from the present findings the same would seem to apply to rock elephant shrews.

Hyalomma spp.

Scrub hares are the preferred hosts of both immature *H. marginatum rufipes* and *H. truncatum* and fairly large numbers of particularly the former were recovered from hares examined concurrently on the two farms (Horak & Fourie 1991). The adults are found on sheep, cattle and large antelope species (Fourie *et al.* 1988b, 1991b; Fourie & Horak 1990).

Rhipicephalus arnoldi and *R. distinctus*

The immature stages of both ticks prefer rock dassies *Procavia capensis* and Smith's red rock rabbits *Pronolagus rupestris* (Horak & Fourie 1986; 1991). The adults of *R. arnoldi* prefer red rock rabbits (Horak *et al.* 1991) and those of *R. distinctus*, rock dassies (Horak & Fourie 1986). Both these host species are present in the study area.

Rhipicephalus gertrudae

Adult ticks were recovered in small numbers from Angora goats on the farm (Fourie & Horak 1991). Although hosts of the immature stages have apparently not yet been recorded, Walker (1991) suggests that they are likely to be rodents.

Sex-related tick burdens

Several studies have indicated that male mammalian hosts may carry larger tick burdens than females (Seifert 1971; Sonenshine 1975; Keith & Cary 1990). These sex-related differences have been ascribed to differences in the size of home ranges and activity levels of male and female hosts (Sonenshine 1975). In cattle they have been attributed to lower and less stable levels of resistance in male animals (Seifert 1971). Possible reasons for the virtual absence of significant differences in tick burdens between male and female hosts in this study, could be due to small sample sizes or to the overdispersion of ticks within their host population which complicates analysis (Petney, Van Ark & Spickett 1990). The male and female home ranges of those elephant shrew species that have been studied are similar, but specific activity patterns such as foraging, trail cleaning and interspecific aggression may differ (Rathbun 1979). Observations on these aspects for *E. myurus* and *A. namaquensis* are lacking.

Many etho-ecological aspects of small mammal populations are still poorly understood and may prove to be the most important underlying source of variability in the analysis of host population parameters and tick burdens (Zimmerman, McWherter & Bloemer 1987). According to Randolph (1979) variability attributable to these factors may even prove to be greater than that owing to acquired resistance. It is evident that changes in home ranges and sex ratios in a population may influence the host support contribution of that species (Sonenshine 1975). Such changes may have significant implications particularly where ticks act as vectors for pathogens or exert other deleterious effects on their hosts.

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The comparative host status of red veld rats (*Aethomys chrysophilus*) and bushveld gerbils (*Tatera leucogaster*) for epifaunal arthropods in the southern Kruger National Park, South Africa

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ABSTRACT

BRAACK, L.E.O., HORAK, I.G., JORDAAN, LEONORA C., SEGERMAN, JOYCE & LOUW, J.P. 1996. The comparative host status of red veld rats (*Aethomys chrysophilus*) and bushveld gerbils (*Tatera leucogaster*) for epifaunal arthropods in the southern Kruger National Park, South Africa. *Onderstepoort Journal of Veterinary Research*, 63:149–158

Red veld rats (*Aethomys chrysophilus*) and bushveld gerbils (*Tatera leucogaster*) were trapped at monthly intervals, when possible, over a 2-year period, in the southern Kruger National Park, Mpumalanga Province. Forty-six specimens of each species were caught, euthenased and microscopically examined for fleas, lice, ticks and mites. Clear differences existed between the two rodent hosts in infestation intensity and also parasite species. The flea, *Xenopsylla brasiliensis*, commonly and exclusively utilized red veld rats, whereas *Xenopsylla frayi* was common and specific to bushveld gerbils. *T. leucogaster* were commonly infested with the lice *Hoplopleura biseriata* and *Polyplax biseriata*, while only a single *A. chrysophilus* hosted the louse, *Hoplopleura patersoni*. Red veld rats harboured small numbers of the immature stages of *Haemaphysalis leachi/spinulosa* and relatively large numbers of *Rhipicephalus simus*. The larvae of *R. simus* were irregularly collected from February to September and the nymphs from March to November. Bushveld gerbils hosted fewer ticks than did the rats, with a single specimen of *H. leachi/spinulosa* and low numbers of immature *Hyalomma truncatum*, the latter erratically present from June to October. Mites were abundant on both rodent hosts, *A. chrysophilus* hosting 13 species in six families, and *T. leucogaster* hosting 12 species representing seven families, with clear differences in mite assemblages between the two rodents. As the rats and gerbils were collected from the same trap lines at the same times, the differences in species composition and infestation intensity of their parasites, suggest that immunological, behavioural or other segregating mechanisms are in operation to maintain discrete parasite assemblages.

Keywords: *Aethomys chrysophilus*, anthropods, bushveld gerbils, epufaunal, host status, Kruger National Park, red veld rats, *Tatera leucogaster*

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INTRODUCTION

Rodents are hosts of numerous zoonoses such as plague (*Yersinia pestis*), several rickettsial infections, encephalomyocarditis, various haemorrhagic fevers as well as helminth infections (Schnurrenberger & Hubbert 1981). Consequently, knowledge of the ectoparasitic and other epifaunal associations of these animals provides insight not only into potential disease transmission, but also into the role of rodents in the population dynamics of ticks or other parasites affecting wildlife or domestic stock.

It has been suggested that rodents may serve as the hosts of more ixodid tick species than do any other mammal taxa (Oliver 1989). In South Africa, a total of 77 ixodid tick species have been recorded from all host species examined thus far, and 29 of these have been collected from rodents, chiefly in the immature stages of development (Walker 1991). Some of these associations may be accidental and merely a reflection of the very large numbers of immature ticks present within the particular environments of specific rodents. Other associations may be more specific, while some rodents harbour not only the immature stages but also the adults of certain tick species (Walker 1991). A number of species, for which rodents serve as hosts of the immature stages, are important parasites of domestic animals in the adult stage. These are *Haemaphysalis leachi*, a parasite of dogs and cats, *Hyalomma truncatum*, a parasite of cattle, sheep and horses, and *Rhipicephalus simus*, a parasite of cattle and dogs.

Several surveys have already been conducted on the parasites infesting rodents in South Africa. Extensive plague-related surveys initiated in 1926 by the South African Institute for Medical Research, in collaboration with the South African Department of Health, culminated in the substantial reference work on fleas by De Meillon, Davis & Hardy (1961), which formed the basis for Zumpt's (1966) publication. Lice were intensively collected and studied from as early as 1918, by persons such as Bedford, Emerson, Ferris, Hopkins & Paterson, their work forming the basis of the volume on systematics by Ledger (1980). Rodents have been examined for ticks in the Eastern Cape Province by Rechav (1982), Howell, Petney & Horak (1989) and Horak, Fourie, Novellie & Williams (1991); in the Western Cape Province by Horak, Sheppey, Knight & Beuthin (1986); in the Free State by Fourie, Horak & Van Heerden (1992); and in North-West Province by Rechav, Zeederberg & Zeller (1987) and Els (1987). Comparatively little is known regarding mite species utilizing wildlife hosts in southern Africa, with only isolated advances since the major publication edited by Zumpt (1961).

The present study was initiated to determine the species composition and infestation intensity of fleas, lice, ixodid ticks and mites infesting *Aethomys chrysophilus* and *Tatera leucogaster*, two of the most common rodent species in the southern Kruger National Park (KNP), Mpumalanga.

MATERIALS AND METHODS

Thirty-five to 50 hardboard livetraps as described by Willan (1979) were used during the survey. These were baited with a gholfball-sized mixture of rolled oats and peanut butter. Except for August, September and November 1990, traps were placed in Landscape Zone 4 (Thickets of the Sabie and Crocodile Rivers) (Gertenbach 1983), in undisturbed natural environment at least 4 km from the Skukuza rest-camp, KNP, for 4 nights each month from January 1989 to December 1990. The traps were set during the late afternoon, 5 m apart, in a line perpendicular to the road, and collected early the following morning. Traps containing rodents were individually placed in plastic bags, after which a wad of cotton wool soaked with ether was added. After some minutes, the response of each animal was tested, and if quiescent, it was removed, bled by cardiac puncture (Grobler, Raath, Braack, Keet, Gerdes, Barnard, Kriek, Jardine & Swanepoel, 1995), and then returned to the bag until dead. Identification of rodents was based on dentition and skull parameters (Smithers 1983) or spermatozoa (Gordon & Watson 1985).

Each animal was carefully examined under a stereoscopic dissecting microscope, and all ectoparasites were removed and preserved in 70% ethyl alcohol. Because it was not possible to distinguish between the immature stages of *Haemaphysalis leachi* and *Haemaphysalis spinulosa*, the immature ticks resembling them were recorded as *H. leachi/spinulosa*.

RESULTS

Low trap numbers and low trap catch-rates, as well as other factors, meant that samples were consistently small, even absent in some months. Trap catch-rates are presented in Fig. 1. Most (> 96%) rodents captured were either *A. chrysophilus* or *T. leucogaster*. A total of 46 *A. chrysophilus* was captured, varying between zero and six per month, as well as 46 *T. leucogaster*, varying between zero and five per month. Host captures for each month are indicated in Fig. 2–11. The fleas, lice and ixodid ticks recovered from each of the host species are listed in Tables 1 and 2, and the mites in Tables 3 and 4.

Fleas

Fleas differentiated strongly between the two hosts, *Xenopsylla brasiliensis* occurring only on *A. chrysophilus* and *Xenopsylla frayi* only on *T. leucogaster*. Two specimens of *Ctenocephalides felis* were also found as mixed infestations with *X. brasiliensis* on *A.*

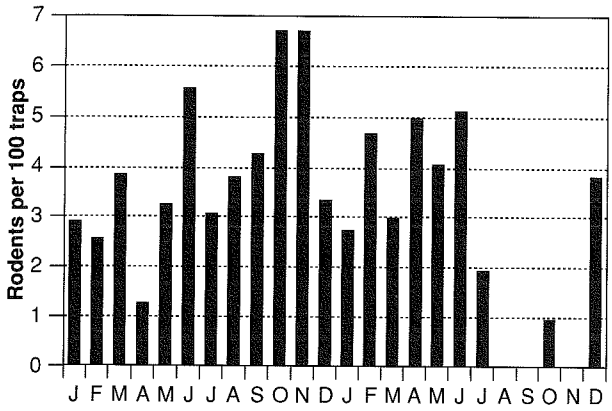

FIG. 1 Rodent-trapping success rate expressed as the total number of all rodent species caught per 100 traps, for each month, January 1989 to December 1990. No trapping was done during August, September or November 1990

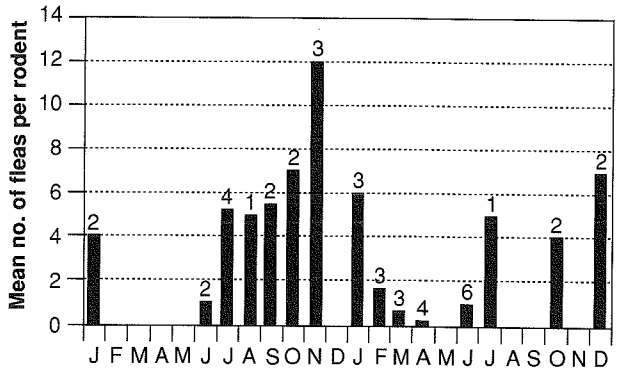

FIG. 2 Mean number of *Xenopsylla brasiliensis* recovered per *Aethomys chrysophilus* for each month, January 1989 to December 1990. No trapping was done during August, September or November 1990. The number of *A. chrysophilus* captured in each month is indicated above each column

TABLE 1 Fleas, lice and ixodid ticks collected from 46 *Aethomys chrysophilus* in the southern Kruger National Park

Arthropod species	Numbers recovered			Total	Number of *Aethomys* infested
	Larvae	Nymphs	Adults		
Fleas					
Xenopsylla brasiliensis	–	–	170	170	31 (67%)
Ctenocephalides felis spp.	–	–	2	2	2 (4%)
Lice					
Hoplopleura patersoni				79	1 (2%)
Ixodid ticks					
Haemaphysalis leachi/ spinulosa	14	30	0	44	16 (35%)
Rhipicephalus simus	537	80	0	617	29 (63%)

TABLE 2 Fleas, lice and ixodid ticks collected from 46 *Tatera leucogaster* in the southern Kruger National Park

Arthropod species	Numbers recovered			Total	Number of *Tatera* infested
	Larvae	Nymphs	Adults		
Fleas					
Xenopsylla frayi	–	–	140	140	23 (50%)
Lice					
Polyplax biseriata / *Hoplopleura biseriata*	–	–	–	568	33 (72%)
Ixodid ticks					
Haemaphysalis leachi/ spinulosa	0	1	0	1	1 (2%)
Hyalomma truncatum	14	25	0	39	9 (20%)

– = not applicable

chrysophilus. A total of 170 *X. brasiliensis* were recovered, fluctuating between zero and 23 per rodent, with the highest numbers occurring between October and December and low numbers between February and June. *T. leucogaster* harboured a total of 140 *X. frayi*, varying between zero and 33 per rodent, but with no clear pattern of seasonality discernible.

TABLE 3 Mites collected from 46 *Aethomys chrysophilus* in the southern Kruger National Park

Taxon	Number collected	Number of *Aethomys* infested
Mesostigmata		
Laelapidae		
Androlaelaps sp.	492	36 (78%)
Laelaps vansomereni		
Laelaps sp.		
Prostigmata		
Trombiculidae		
Gahrliepia (G.) sp.	5053	42 (91%)
Guntherana (?) sp.		
Odontacarus sp.		
Schoutedenichia (?) sp.		
Astigmata		
Myocoptidae		
Myocoptes sp.	219	11 (24%)
Trichoecius sp.		
Listrophoridae		
Afrolistrophorus (?) sp.	3136	33 (72%)
Atopomelidae		
Listrophoroides (Olistrophoroides) (?) sp.		
Glycyphagidae	*c.* 3500	33 (72%)

TABLE 4 Mites collected from 46 *Tatera leucogaster* in the southern Kruger National Park

Taxon	Number collected	Number of *Tatera* infested
Mesostigmata		
Laelapidae		
Androlaelaps sp.	601	36 (78%)
Androlaelaps theseus Zumpt		
Androlaelaps marshalli Berlese		
Laelaps sp.		
Prostigmata		
Cheyletidae		
Cheyletes zumpti Fain		
Trombiculidae	602	19 (41%)
Gahrliepia (G.) sp.		
Uncertain genus (2 spp.)		
Myobiidae	243	15 (33%)
Radfordia (Cryptomyobia) (?) sp.		
Astigmata		
Myocoptidae		
Myocoptes sp.		
Listrophoridae	1 271	36 (78%)
Afrolistrophorus (?) sp.	2 760	20 (43%)
Glycyphagidae		

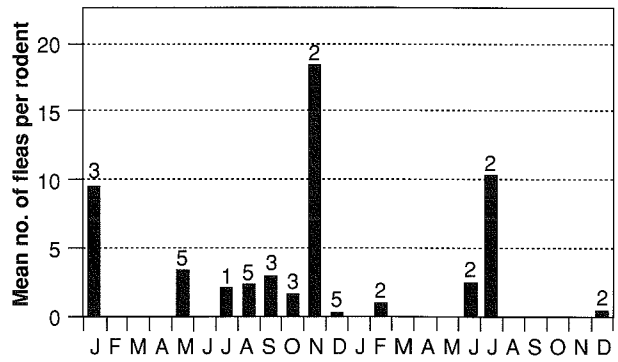

FIG. 3 Mean number of *Xenopsylla frayi* recovered per *Tatera leucogaster* for each month, January 1989 to December 1990. No trapping was done during August, September or November 1990. The number of *T. leucogaster* captured in each month is indicated above each column

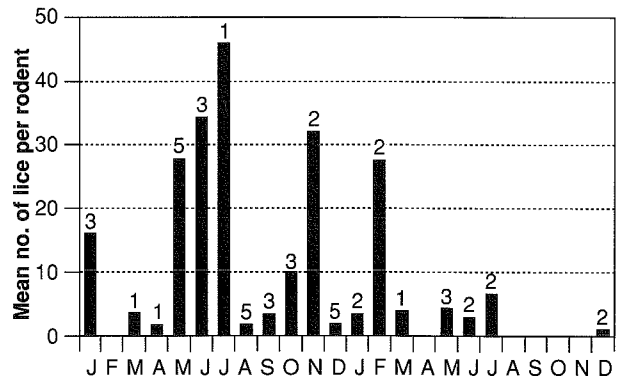

FIG. 4 Mean number of *Hoplopleura patersoni* lice recovered per *Tatera leucogaster* for each month, January 1989 to December 1990. No trapping was done during August, September or November 1990. The number of *T. leucogaster* captured in each month is indicated above each column

Lice

Only one of the 46 *A. chrysophilus* hosted lice—a male which yielded 79 *Hoplopleura patersoni,* but was otherwise not unusually heavily infested with other arthropod parasites. In contrast, most (71,7%) of the *T. leucogaster* had lice, varying between two and 80 per infested host. These were present as mixed populations of two species, *Polyplax biseriata* and *Hoplopleura biseriata.* Lice were counted collectively, with no separate numbers for the two species. However, *P. biseriata* was more prevalent. High numbers were collected from May to July 1989, but few in the corresponding months of 1990. The seasonal pattern is probably confounded by the small host-sample size.

Ticks

Forty-four *H. leachi/spinulosa* (zero to eight per host) and 617 *R. simus* (zero to 114 per host) were recovered from *A. chrysophilus.* The small sample size for *H. leachi/spinulosa* prevented the detection of any seasonality. *R. simus* larvae were most abundant between June and September in 1989 and from February to June in 1990. Nymphs were erratically present from March to November.

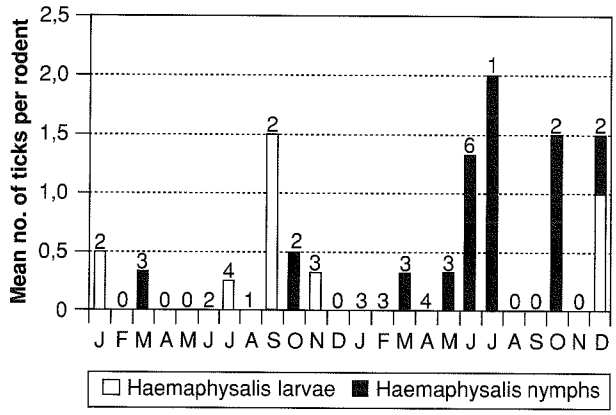

FIG. 5 Mean number of *Haemaphysalis leachi/spinulosa* larvae and nymphs recovered per *Aethomys chrysophilus* for each month, January 1989 to December 1990. No trapping was done during August, September or November 1990. The number of *A. chrysophilus* captured in each month is indicated above each column

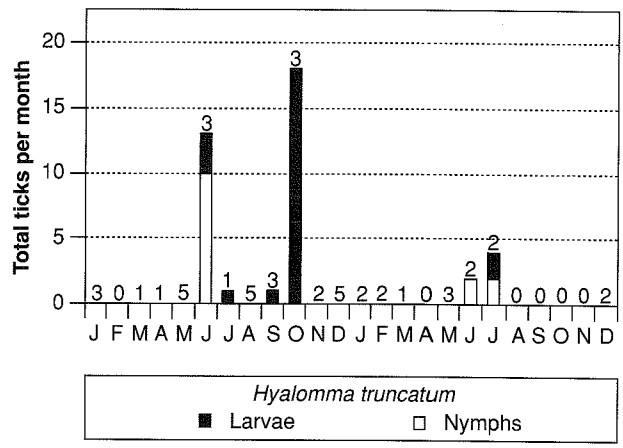

FIG. 7 Total number of *Hyalomma truncatum* recovered from all *Tatera leucogaster* captured in each month, January 1989 to December 1990. No trapping was done during August, September or November 1990. The number of *T. leucogaster* captured in each month is indicated above each column

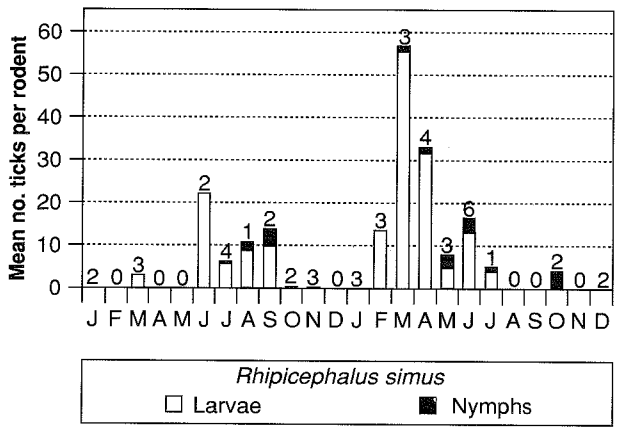

FIG. 6 Mean number of *Rhipicephalus simus* larvae and nymphs recovered per *Aethomys chrysophilus* for each month, January 1989 to December 1990. No trapping was done during August, September or November 1990. The number of *Aethomys chrysophilus* captured in each month is indicated above each column

Few ticks were recovered from *T. leucogaster*, with a total of only one *H. leachi/spinulosa* nymph and 39 immature *H. truncatum*. Larvae of *H. truncatum* were present in June and July, and nymphs from June to October. Despite *R. simus* being commonly recovered from *A. chrysophilus*, not a single individual was found on *T. leucogaster* trapped at the same site.

Mites

All individuals of both host species harboured mites, usually in large numbers. At least 13 species of mites in six families (three suborders) were recovered from *A. chrysophilus*, while *T. leucogaster* yielded 12 species representing seven families (three suborders). These taxa are listed in Tables 4 and 5. In most cases, mites could be identified only to genus level, but there is little doubt that a number of new species are represented in the material collected.

Comment: Because of initial unfamiliarity with the mites, the person (L.E.O.B.) processing the rodents for parasite recovery compiled a rough key to keep track of mite numbers by appearance and habits, thus obaining in collective totals for several species as indicated in Tables 4 and 5. This system of recording unfortunately resulted in species of different families sometimes being counted together, such as members of the Listrophoridae and Atopomelidae being lumped together, as well as Myobiidae and Myocoptidae, based on similarities in appearance and microhabitat.

The most numerous mites on *A. chrysophilus* were Trombiculid larvae, found on 91% of hosts. These mites were typically present in clusters, mouthparts embedded within the skin of the host, usually within the ear or posteriorly near the tail. One species occurred as individual mites partially enclosed in small oedomatous pits on the body. These were usually evenly spaced as a narrow band mid-dorsally, a broadening area laterally, and extending ventrally as a somewhat narrowed band with up to 400 individuals per infested host.

Trombiculids were far less numerous and also less prevalent on *T. leucogaster*. On this host, hypopi (inactive phoretic immatures) of the family glycyphagidae were the most numerous, despite these mites not having as high a general prevalance as some of the other families. This implied that, while fewer rodents hosted glycyphagids, those hosts which did have hypopi carried them in large numbers (50–250 per infested animal). All the glycyphagid mites were recovered from positions buried in the tail skin, and

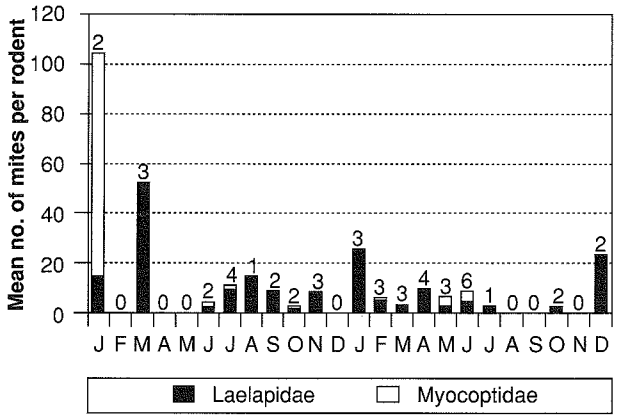

FIG. 8 Mean number of mites (Laelapidae and Myocoptidae) recovered per *Aethomys chrysophilus* for each month, January 1989 to December 1990. No trapping was done during August, September or November 1990. The number of *A. chrysophilus* captured in each month is indicated above each column

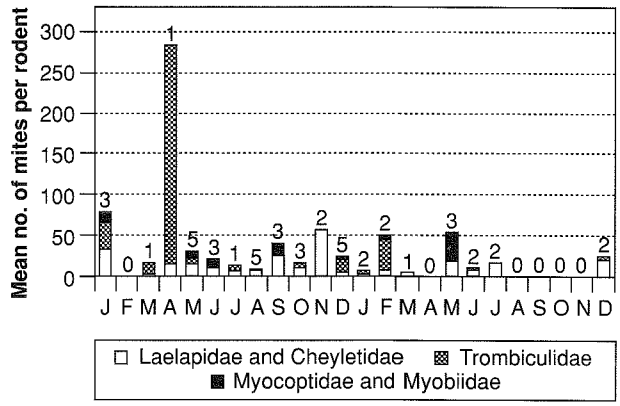

FIG.10 Mean number of mites (Laelapidae and Cheyletidae; Trombiculidae; Myocoptidae and Myobiidae) recovered per *Tatera leucogaster* for each month, January 1989 to December 1990. No trapping was done during August, September or November 1990. The number of *T. leucogaster* captured in each month is indicated above each column

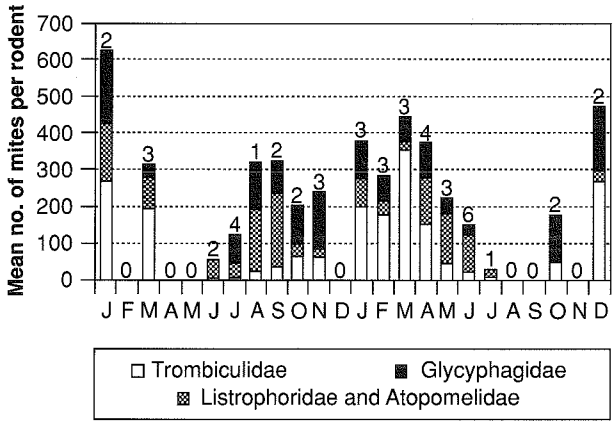

FIG. 9 Mean number of mites (Trombiculidae, Glycyphagidae, Listrophoridae & Atopomelidae) recovered per *Aethomys chrysophilus* for each month, January 1989 to December 1990. No trapping was done during August, September or November 1990. The number of *A. chrysophilus* captured in each month is indicated above each column

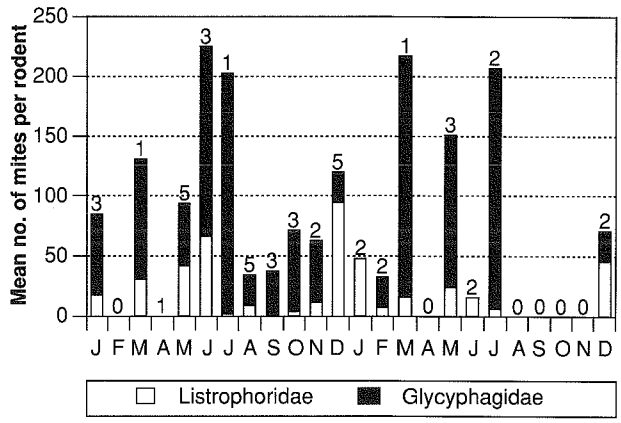

FIG. 11 Mean number of mites (Listrophoridae and Glycyphagidae) recovered per *Tatera leucogaster* for each month, January 1989 to December 1990. No trapping was done during August, September or November 1990. The number of *T. leucogaster* captured in each month is indicated above each column

they were collected by squeezing a section of skin with forceps.

Listrophoridae (*Afrolistrophorus ?*) were abundant on both hosts, and were always found clinging to the hair shafts. The vast majority were concentrated anterodorsally, mainly on the neck. Atopomelid mites were common on *A. chrysophilus*, also attached to hair shafts, but concentrated posterodorsally and sometimes ventrally on the abdomen.

Laelapid mites had a prevalence rate of 78% on both rodent hosts, although the rodents appeared to host different species of these mites. The mites were large and walked around readily, unlike all the other mite groups which tended to be fairly sessile. Up to 65 of these mites were found on each infested host, mostly posterodorsally on the body near the base of the tail.

Myocoptid and myobiid mites were the least numerous and occurred on the skin as isolated individuals, often with mouthparts embedded.

DISCUSSION

Probably the most striking feature of this survey was the marked difference in the species composition of the parasites recovered from *A. chrysophilus* and from *T. leucogaster* captured at the same time and in the same trap lines. This was reflected in specific differences in the fleas and lice and also in clear differentiation

between hosts by three species of ticks. These differences may be due to host-specificity, behavioural differences of the parasites, differences in host behaviour, particular scents exuded by the hosts, a combination of these factors or a number of other reasons.

Fleas

A. chrysophilus was exclusively parasitized by *X. brasiliensis*, whereas *X. frayi* were found only on *T. leucogaster*. *X. brasiliensis* is widely distributed in the Afrotropical Region and has been transported to other parts of the world. It is considered to be an important transmitter of plague in rural environments, and its principal hosts include *Aethomys, Mastomys, Rattus* and *Thallomys* (De Meillon *et al.* 1961; Zumpt 1966). Despite the abundance of *X. brasiliensis* and its hosts within the KNP, plague has never been recorded from this area, and no antibodies against the causative organism could be detected from a sample from several hundred rodents taken in the study area and elsewhere in the KNP between 1982 and 1994 (P.A. Leman, National Institute for Virology, Johannesburg, personal communication 1996).

X. frayi is distributed throughout the savanna bushveld areas from northern Transvaal through Swaziland to Natal, and has never been incriminated in plague transmission. Its principal host is *T. leucogaster*, with only isolated individuals occasionally recovered from other hosts (De Meillon *et al.* 1961).

Regarding host separation, the following statement by De Meillon *et al.* (1961) provides some insight: "A striking feature about the host-association of *brasiliensis* is its rare occurrence in the underground nests and burrows of gerbils (*Tatera* spp.). This is in contrast to its abundance in the nests and lairs of house rats and the above-mentioned group of wild rodents." *A. chrysophilus* and *T. leucogaster* are both nocturnal and terrestrial, often with overlapping habitat, but whereas *T. leucogaster* lives in underground burrows, *A. chrysophilus* appears to prefer to find refuge in piles of vegetation, rocks or other types of cover above ground, although it will also burrow (De Graaff 1981; Smithers 1983). This may contribute to the strong separation in host utilization between the two species of fleas.

Lice

Pronounced differences were evident in lice utilization of the two rodent species. Ledger (1980) records *H. patersoni* as having been collected from *A. chrysophilus* and *A. namaquensis*, and *H. biseriata* from two species of *Tatera*, including *T. leucogaster*, and *P. biseriata* from several species of *Tatera*, again including *T. leucogaster*. Findings in this study support the strict host differentiation displayed by these lice, even in closely sympatric conditions.

Ticks

Clear separation between the two hosts was also found in ixodid ticks, *A. chrysophilus* being the preferred host of the immature stages of *R. simus*, and *T. leucogaster* of the immature stages of *H. truncatum*. The majority (> 80%) of ticks collected off both hosts were attached laterally and dorsally on the head, most of the remainder dorsally on the neck and shoulders, with a few elsewhere on the body. Virtually all the *H. truncatum* were deeply embedded in dermal pits, which would have made removal by host grooming very difficult. *R. simus*, by contrast, did not burrow into the skin.

Fourie *et al.* (1992) collected the immature stages of 11 tick species from Namaqua rock mice, *Aethomys namaquensis*, and rock-elephant shrews, *Elephantulus myurus*, trapped in the same trap lines in the south-western Free State. The mean burdens of immature stages of the dominant species on the 321 rock mice and 132 rock-elephant shrews comprised 3,3 and 0,4 *H. leachi/spinulosa*; 0,1 and 32,8 *Ixodes rubicundus*; and 0,8 and 87,9 *Rhipicephalus punctatus*, respectively. These small mammals thus also differed markedly in their status as hosts for three tick species.

The free-living immature stages of the three tick species collected from the veld rats and bushveld gerbils in the present study, namely *H. leachi/spinulosa, H. truncatum* and *R. simus*, are rarely collected from vegetation in the KNP by drag-sampling with flannel cloth-tails. During 1989, a total of 13 831 immature ticks were collected from the vegetation by monthly drag-sampling in the same landscape zone as that in which the rats and gerbils were trapped, and during 1990, 14 783 immature ticks were collected. Of these, 27 were *H. leachi/spinulosa*, none *H. truncatum* and 44 *R. simus*. Rechav (1982) has also commented on the absence of the immature stages of *R. simus* on grass, while striped mice, *Rhabdomys pumilio*, which he examined in the same region, were infested with this tick. It would thus appear that the immature stages of these ticks seldom migrate onto the vegetation, but rather infest their rodent hosts from the ground.

The combined total number of immature ticks collected from the vegetation by drag-sampling in 1989 and 1990 comprised 28 614 individuals. The larvae of *Amblyomma hebraeum* accounted for 6 221 of these, those of *Boophilus decoloratus* for 8 648 and those of *Rhipicephalus zambeziensis* for 11 962, yet not one of these ticks was recovered from a red veld rat or bushveld gerbil. Howell *et al.* (1989) trapped *R. pumilio* at monthly intervals for 17 months in the Thomas Baines Nature Reserve, Eastern Cape Province, a habitat in which the vegetation is heavily infested with the immature stages of *A. hebraeum* and *Rhipicephalus appendiculatus*. They recovered only

five larvae and one nymph of *A. hebraeum* from the animals examined. Three of the larvae and the nymph did not engorge on the mice and were dead on recovery. The remaining two larvae engorged only partially and did not moult to nymphs. No *R. appendiculatus* were recovered from the mice. Thus there appear to be certain factors militating against rodents becoming infested with immature ticks of species for which they do not serve as natural hosts.

In contrast to the findings on rodents, scrub hares *(Lepus saxatilis)* examined in the Thomas Baines Nature Reserve carried fairly large burdens of immature *A. hebraeum* and very large burdens of immature *R. appendiculatus* (Horak & Fourie 1991). In the KNP, scrub hares examined in the same region and at the same time as the rodents in the present study, carried fairly large burdens of immature *A. hebraeum* and very large burdens of immature *H. truncatum* and of *R. zambeziensis* (Horak, Spickett, Braack & Penzhorn 1993).

Haemaphysalis leachi/spinulosa

The preferred hosts of adult *H. leachi* are large, wild carnivores and domestic dogs, while those of *H. spinulosa* prefer the smaller carnivores (Norval 1984; Hussein & Mustafa 1985). The immature stages of both these ticks prefer rodents (Norval 1984; Hussein & Mustafa 1985; Fourie *et al.* 1992). The small numbers of immature *H. leachi/spinulosa* collected from red veld rats indicate either that they are not very good hosts or that the trap lines were set in a habitat unsuitable for this tick. The single *H. leachispinulosa* nymph collected from a bushveld gerbil probably represents an accidental infestation.

During six years of monthly drag-sampling of the vegetation in two landscape zones in the KNP, a total of 98 adult *H. leachi* and no adult *H. spinulosa* were collected. During the same period, 54 immature *H.leachi/spinulosa* were collected from the vegetation. Forty-seven of the adult *H. leachi* and 30 of the immature *H. leachi/spinulosa* were collected from gully sub-zones, as opposed to open grassland or woodland sub-zones, within each of the landscape zones. As both the adults giving rise to the immatures and the nymphs giving rise to the adults must have detached from carnivores and rodents in the gullies, it would appear as if gullies are important sites of infestation with this tick for both host groups.

Hyalomma truncatum

The preferred hosts of the adults of this tick are large ungulates, particularly giraffes, buffaloes and eland (Norval 1982; Rechav *et al.* 1987; Horak, Anthonissen, Krecek & Boomker 1992). The immature stages prefer Cape and scrub hares (Rechav *et al.* 1987; Horak & Fourie 1991; Horak *et al.* 1993), but may also be found on rodents (Rechav *et al.* 1987; Els 1987). Amongst the rodents, gerbils (*Tatera* spp.) appear to be particularly favoured as hosts (Rechav *et al.* 1987; Els 1987).

The adults of *H. truncatum* are most abundant during the summer months (Horak 1982; Rechav *et al.* 1987). In the southern KNP, large numbers of immature *H. truncatum* are present on scrub hares from May to October, with very few being collected from November to February (Horak *et al.* 1993). The presence of immature ticks on the gerbils during the period June to October in the present study falls within the time of maximum abundance on scrub hares. Although the numbers of immature *H. truncatum* on bushveld gerbils may be small compared with those on scrub hares, the overall abundance of the gerbils themselves may ensure that these small mammals are important hosts of this tick.

Rhipicephalus simus

The preferred hosts of the adults are generally large, monogastric, domestic and wild mammals including dogs, horses, large carnivores, zebras and warthogs, but cattle and buffaloes can also be infested (Norval & Mason 1981; Horak, Jacot-Guillarmod, Moolman & De Vos 1987; Horak, De Vos & De Klerk 1984; Horak, Boomker, De Vos & Potgieter 1988). The immature stages prefer certain rodents (Norval & Mason 1981; Rechav 1982).

In the KNP, adults are present in peak numbers from January to March (Horak *et al.* 1984, 1988), and in the present study, larvae were erratically present from February to September and nymphs from March until November or later.

Eighty-seven of the 136 adult, and 47 of the immature *R. simus* collected by drag-sampling the vegetation in two landscape zones in the KNP at monthly intervals from August 1988 to July 1994, were collected from gully sub-zones as opposed to open grassland and woodland sub-zones. This implies that the hosts of both the adults and the immatures are likely to become infested in this type of habitat.

Mites

In the title of this paper, the term "epifaunal arthropods" was used rather than "ectoparasitic", specifically because many of the mites recovered from their rodent hosts are not parasitic but free-living. As with the other groups of arthropods, clear differences were noticeable in the prevalence rates and infestation intensities of mites on the two host species. Although few groups could be identified to species level, clear differences also existed between the mite taxa associated with the rodents. This reinforces the conclusion that the arthropod assemblages associated with *A. chrysophilus* and *T. leucogaster* are well separated, either in response to host immunological

challenges, host behaviour, or other factors, which would either consistently impact differently upon arthropods to which they are exposed, or consistently tend to expose the hosts to different sets of arthropods.

Although some taxonomic studies have been done on mites associated with southern African rodents (Zumpt 1961), very little appears to have been published on the prevalence rates, infestation intensities, interaction and effects of mites on these hosts. The role of rodent-associated mites in the epidemiology of large mammal diseases appears to be minimal, but some laelapine and other mites have been linked with a variety of viral, bacterial and protozoan pathogens of humans and domestic animals (Domrow 1987).

Many mites of the families Laelapidae and Cheyletidae are predatory on other mites or ectoparasites frequenting the same hosts (Durden 1987), and often show their adaptation to this role by their mouthparts and rapid walking abilities.

Myobiid mites may cause dermatitis in affected rodents, but the numbers of *Radfordia* recovered from *T. leucogaster* in this study were very low, with the exception of one individual which hosted 70 of these mites. Trombiculid larvae, too, are known to occasionally cause itching and dermatitis (Georgi 1985).

ACKNOWLEDGEMENTS

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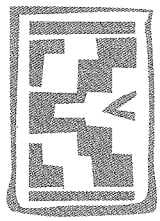

RESEARCH COMMUNICATION

Hosts of the immature stages of the rhinoceros tick, *Dermacentor rhinocerinus* (Acari, Ixodidae)

I.G. HORAK[1] and MARLENE COHEN[2]

ABSTRACT

HORAK, I.G. & COHEN, MARLENE 2001. Hosts of the immature stages of the rhinoceros tick, *Dermacentor rhinocerinus* (Acari, Ixodidae). *Onderstepoort Journal of Veterinary Research*, 68:75–77

The collection of the immature stages of *Dermacentor rhinocerinus* from host animals is described for the first time. These are the bushveld gerbil (*Tatera leucogaster*), from which larvae and nymphs were collected, the red veld rat (*Aethomys crysophilus*), from which a larva was collected, and the Natal multimammate rat (*Mastomys natalensis*), from which a nymph was collected. The rodents were examined in a nature reserve in which there are white rhinoceroses (*Ceratotherium simum*).

Keywords: *Dermacentor rhinocerinus*, Ixodidae, immature stages, rodent hosts

The adults of *Dermacentor rhinocerinus* parasitize both white and black rhinoceroses (*Ceratotherium simum* and *Diceros bicornis*) in Africa from Eritrea, Sudan, Ethiopia and Somalia in the north-east; Kenya, Uganda, the Democratic Republic of Congo, Tanzania, Malawi and Zambia in the eastern and central regions; Angola and Namibia in the west to Zimbabwe, Mozambique and South Africa in the south (Theiler 1962; Keirans 1993). It is, however, doubtful whether rhinoceroses and *D. rhinocerinus* still occur in all these regions. Although nymphs and adults have been collected from rodent nests, implying that these animals may play a role in the tick's life cycle (Clifford & Anastos 1964), neither larvae nor nymphs have been collected from a host animal. In fact the larvae themselves were until recently unknown (Keirans 1993).

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Adult *D. rhinocerinus* quest for hosts from the vegetation, but the immature stages do not appear to do so. With the exception of February 1999 and February and March 2000, when rain made sampling impossible, free-living ticks have been collected since January 1999 by monthly drag-sampling the vegetation of the unfenced Nwaswitshaka experimental burn-plots in the south-west of the Kruger National Park, Mpumalanga Province, South Africa. There are several white rhinoceroses in this region and during spring and summer adult *D. rhinocerinus* can be collected manually from tall, thick grass stems alongside roads and paths (Keirans 1993) and from the shorter grass around rhinoceros middens. Adult ticks have also been collected in the Park from two white rhinoceroses which had died from injuries sustained in fights (Knapp, Krecek, Horak & Penzhorn 1997), one of these approximately 10 km north-east of the burn-plots (Keirans 1993).

Larvae of *D. rhinocerinus* were present in each month's drag-samples during the period November 1999 to June 2000, but whereas a total of 10 086 larvae belonging to several species were collected during this time, only 21 of these were *D. rhinocerinus* (Table1). A similar phenomenon is evident for the larvae of *Haemaphysalis leachi* and *Rhipicephalus simus*. Although adults of both these ticks were

present on the vegetation, no larvae were collected (Table 1). It would thus appear that the larvae, and probably also the nymphs of these three species quest for hosts from the base of grass tufts or from the soil surface. Consequently their collection by drag-sampling would be less likely than that of other species that quest from higher up on the vegetation. Such low questing sites imply that the larvae of these ticks utilize small mammals as hosts, a fact that has been confirmed for both *H. leachi* and *R. simus* (Norval & Mason 1981; Norval 1984).

The Mthethomusha Game Reserve (25°29'S, 31°17'E) is administered and managed for the local community by the Mpumalanga Parks Board. It is approximately 7 200 ha in extent and located immediately south-west of the Kruger National Park in Mpumalanga Province. The two reserves are separated by a railway track that is fenced along either side. Surveys to determine the presence of tuberculosis in this reserve necessitated the killing of a number of animals, and to make the most use of the material available ectoparasites were collected from the carcasses. During March 1999, 38 rodents belonging to seven species were examined in this way, and five were infested with immature *D. rhinocerinus* (Table 2). The common names that we have used for the rodent hosts are based on those suggested by Corbet & Hill (1991), and the scientific nomenclature on that of Wilson & Reeder (1993). We have listed the animals in the same sequence as that given by the latter authors.

Three of the four bushveld gerbils examined were infested and harboured a total of three larvae and two nymphs. A single red veld rat harboured a larva and a Natal multimammate rat a nymph. It would thus appear as if bushveld gerbils are the preferred hosts of the immature stages of *D. rhinocerinus*.

Although we were unable to examine any elephant shrews (*Elephantulus* spp.) we feel that these animals might also prove to be good hosts of the immature stages of *D. rhinocerinus*. This presumption is supported by the collection in north-eastern Democratic Republic of the Congo of a single female tick from a nest inhabited by a macroscelid (Clifford & Anastos 1964), thus implying that the preceding nymph stage had successfully engorged on this ani-

TABLE 1 Ticks collected from the vegetation of the Nwaswitshaka burn-plots, Kruger National Park from November 1999 to June 2000

Tick species	No. of ticks collected				
	Larvae	Nymphs	Males	Females	Total
Amblyomma hebraeum	7 624	5	0	0	7 629
Amblyomma marmoreum	456	1	0	0	457
Boophilus decoloratus	1 227	0	0	0	1 227
Dermacentor rhinocerinus	21	0	0	0	21
Haemaphysalis leachi	0	0	239	261	500
Haemaphysalis zumpti	0	0	1	0	1
Rhipicephalus appendiculatus	291	2	0	0	293
Rhipicephalus evertsi evertsi	230	0	0	0	230
Rhipicephalus simus	0	0	20	21	41
Rhipicephalus zambeziensis	237	4	0	1	242
Total	10 086	12	260	283	10 641

TABLE 2 *Dermacentor rhinocerinus* collected from rodents in the Mthethomusha Game Reseve, Mpumalanga Province

Rodent species	No. examined (No. infested)	No. of ticks collected		
		Larvae	Nymphs	Total
Bushveld gerbil (*Tatera leucogaster*)	4 (3)	3	2	5
Red veld rat (*Aethomys chrysophilus*)	10 (1)	1	0	1
Namaqua rock mouse (*Aethomys namaquensis*)	6 (0)	0	0	0
Single-striped mouse (*Lemniscomys rosalia*)	1 (0)	0	0	0
Multimammate mouse (*Mastomys coucha*)	10 (0)	0	0	0
Natal multimammate rat (*Mastomys natalensis*)	6 (1)	0	1	1
Angoni vlei rat (*Otomys angoniensis*)	1 (0)	0	0	0

mal. In South Africa the rock elephant shrew (*Elephantulus myurus*) is the preferred host of the immature stages of *Ixodes rubicundus*, *Rhipicentor nuttalli* and *Rhipicephalus warburtoni* (Fourie, Horak & Van Den Heever 1992; Du Toit 1993; Walker, Keirans & Horak 2000), and we consider that there is a fair likelihood that it may also be for those of *D. rhinocerinus*.

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The permission of the South African National Parks to collect ticks from the vegetation in the Kruger National Park and the assistance of the Park's staff and that of Mr and Mrs A.M. Spickett of the Onderstepoort Veterinary Institute with the collection of the ticks is greatly appreciated. We express our thanks to Dr Bernd Hey of the Mpumalanga Parks Board, who assisted with the collection of ticks from the rodent hosts, and to Mr Duncan MacFadyan of the National Flagship Institution, who identified the rodents. This research was funded by grants from Bayer Animal Health and the University of Pretoria.

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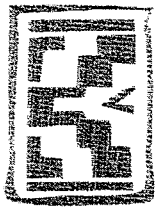

Hosts, seasonal occurrence and life cycle of *Rhipicentor nuttalli* (Acari: Ixodidae)

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ABSTRACT

FOURIE, L.J., HORAK, I.G., KOK, D.J. & VAN ZYL, W. 2002. Hosts, seasonal occurrence and life cycle of *Rhipicentor nuttalli* (Acari: Ixodidae). *Onderstepoort Journal of Veterinary Research*, 69:177–187

There are only two species worldwide within the genus *Rhipicentor*, namely *Rhipicentor bicornis* and *Rhipicentor nuttalli* and both occur only in Africa. *Rhipicentor nuttalli* has a widespread distribution in South Africa and the present investigation was initiated to elucidate its host preference, seasonality and life cycle.

Rock elephant shrews, *Elephantulus myurus* were examined for ticks at four localities in the Free State Province, one in Gauteng Province and two in Limpopo Province, South Africa. Cape elephant shrews, *Elephantulus edwardii* were examined at two places in the Western Cape Province, and a single specimen of the bushveld elephant shrew, *Elephantulus intufi* was examined in central Namibia. Small mammals of other species were also examined at two of these localities.

The majority of *E. myurus* at two sites in the Free State, at the locality in Gauteng and both sites in Limpopo Province were infested with larvae and/or nymphs of *R. nuttalli*, while the single *E. edwardii* examined at one site in the Western Cape Province and the single *E. intufi* examined in Namibia were infested with nymphs of this tick. Not one of the other small animals was infested. Although larvae and nymphs of *R. nuttalli* were present on *E. myurus* throughout the year, the former were generally most numerous during the period March to September, and the latter during May to October. The preferred hosts of the adults are domestic dogs, leopards, *Panthera pardus* and South African hedgehogs, *Atelerix frontalis*. Adult females engorged on *Atelerix frontalis* in 16–32 days and, after a preoviposition period of 2–4 days, produced approximately 17000 eggs during the following 60–70 days. The average incubation period of the eggs was 59 days. Larvae engorged on *E. myurus* in 4–10 days and moulted to nymphs 12–20 days later. Nymphs required 11–15 days to engorge on *E. myurus* and moulted to adults 32–47 days later. Allowing 14 days for the exoskeletons and mouthparts of each of the three parasitic stages to harden before they can attach to a host, the life cycle took approximately 214 days to complete in the laboratory. The length of this period, considered in conjunction with the times of maximum seasonal occurrence of the immature stages, indicates that the life cycle probably takes a year to complete in the field.

Keywords: *Atelerix frontalis*, *Elephantulus myurus*, life cycle, preferred hosts, *Rhipicentor nuttalli*, seasonal occurrence

INTRODUCTION

There are only two species worldwide within the genus *Rhipicentor* and the distribution of both of these is restricted to Africa (Theiler 1961, 1962). *Rhipicentor nuttalli* has been recorded in the Eastern and Western Cape Provinces, and the Free State, Gauteng, North-West and Limpopo Provinces, South Africa (Theiler 1961; Du Toit 1993). In Namibia it occurs north of Windhoek, while it is also

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present in Botswana and Zimbabwe (Theiler 1961; Norval & Colborne 1985). The other species, *Rhipicentor bicornis*, is apparently present only in the northern regions of South Africa, while it has been reported in northern Namibia, in Zimbabwe and Zambia, and is widely distributed in Central Africa (Theiler 1961; Walker 1991).

Adult *R. nuttalli* has been collected from domestic dogs and several wild carnivore species as well as from the South African hedgehog, *Atelerix frontalis* and porcupine *Hystrix africaeaustralis* (Theiler 1961; Walker 1991). However, Norval & Colborne (1985) consider the preferred hosts to be leopards, *Panthera pardus*. The hosts of the immature stages were unknown until Du Toit, Fourie & Horak (cited by Du Toit 1993) collected them from rock elephant shrews, *Elephantulus myurus*.

Adult *R. nuttalli* produces a toxin that can cause paralysis in domestic dogs (Perchman 1976; Norval & Colborne 1985), and the present investigation was conducted to ascertain more about this rare, but potentially important tick.

MATERIALS AND METHODS

Hosts

Immature ticks of all species were collected from rock elephant shrews at various localities in South Africa, from Cape elephant shrews, *Elephantulus edwardii* in the Western Cape Province and from a bushveld elephant shrew, *Elephantulus intufi* in central Namibia, and from other small mammals at two of these localities. For the purposes of this communication only the data pertaining to *R. nuttalli* are presented. Data on the hosts of adult *R. nuttalli* were gleaned from the published records of Theiler (1961, 1962), Perchman (1976), Norval & Colborne (1985), Walker (1991) and Horak, Braack, Fourie & Walker (2000), and have been summarized in tabular form.

Seasonal occurrence

Elephantulus myurus were trapped each month from August 1994 to June 1995 on the farm "Spes Bona" (29°07'S, 26°04'E), in the central Free State Province, They were transported to the laboratory and caged individually at 20 °C to 25 °C and a photoperiod adjusted to that prevailing outside. The cages were placed above collection trays and engorged ticks were collected daily from these trays, and washed in water to remove traces of urine and prevent the growth of fungi. Once all ticks had detached, the rock elephant shrews were returned to their original habitats on the farm "Spes Bona" and released. The following month's trapping commenced a week after this release so that if the same shrews that had just been released were caught again they would have had adequate time to become re-infested with ticks. Despite intensive efforts no elephant shrews were trapped during July 1995. The detached, engorged ticks were maintained at 20 °C and a relative humidity (RH) of approximately 90 % in permanent darkness. Once moulting was complete the various species were identified and counted, and the seasonal occurrence of *R. nuttalli* determined.

Life cycle

Adults

Engorged nymphs were collected from naturally infested elephant shrews and maintained in a cabinet at 20 °C (± 1 °C) and RH > 90 % and a permanently dark photoperiod. The resultant adults were fed on hedgehogs, *A. frontalis*. A male hedgehog was infested with seven male ticks on 17 October 1994 and 2 days later with seven female ticks. This animal was maintained at a constant temperature of 23 (± 0.5 °C) and a photoperiod of 14 h light: 10 h dark. On 19 October 1994 a female hedgehog was infested with seven female ticks, followed 10 days later by seven male ticks. This hedgehog was caged under shelter outdoors where she was exposed to the prevailing climatic conditions. The hedgehogs were kept in cages with mesh floors of which the apertures were large enough to allow detached, engorged female ticks to fall through and thus prevent the hedgehogs from eating them. Double-sided masking tape was applied to the sides of the collection trays positioned below the mesh cage floors to prevent female ticks escaping. The trays were cleaned daily and inspected for ticks.

Engorged female ticks collected from the hedgehogs were placed separately in glass tubes of which both ends were covered with gauze to allow free airflow. One of the four engorged females that laid viable eggs was maintained at 20 °C (± 1 °C), RH > 90 % and a photoperiod of 14 h light: 10 h dark, and the other three at the same temperature and humidity, but in permanent darkness. The ticks were inspected daily to determine the onset of egg-laying, and once this occurred the daily egg production of each female was collected and placed in separate vials. Daily egg production was carefully weighed and converted to eggs per day after the weight of a single egg had been determined. The

conversion efficiency index (CEI) and reproduction efficiency index (REI) of the female ticks were determined (Drummond & Whetstone 1970), where CEI = weight of egg mass (g) / weight of female (g), and REI = number of eggs / weight of female (g).

The eggs were maintained in a cabinet at 20 °C (± 1 °C) and RH > 90% in permanent darkness, and were inspected every second day to determine the length of the incubation period.

Larvae

The larvae that hatched were maintained under the same conditions as the females from which they originated. Three to four weeks after they had hatched the larvae were used to infest rock elephant shrews that were individually kept in plastic cages with wire-mesh lids. During infestation the elephant shrews were placed in a small wire cage and unknown numbers of larvae were placed on their pelage by means of a fine brush. Seven elephant shrews were infested. After infestation the elephant shrews were transferred to plastic cages similar to those they had been held in, but with fine mesh floors so that engorged larvae could fall through into collection trays. Two of the infested elephant shrews were held at 20 °C (± 1 °C) and a photoperiod of 14 h light: 10 h dark, two at the same temperature and a photoperiod of 12 h light: 12 h dark, two at 25 °C (± 1 °C) and a photoperiod of 14 h light: 10 h dark, and one at the same temperature and a photoperiod of 12 h light: 12 h dark. The sides of the collection trays were lined with masking tape to prevent the escape of engorged larvae and the base of the trays with paper towelling to protect the larvae from urine. Detached larvae were collected every 24 h by means of a suction apparatus, and the larvae originating from each elephant shrew were incubated separately at 20 °C (± 1 °C) and RH > 90% in permanent darkness. The larvae were inspected every 24 h to determine the pre-moult and moulting periods.

The percentage of larvae that engorged daily was calculated from the total number of larvae that engorged successfully and not from the total number of larvae used for infestation. The percentage of larvae that moulted daily was calculated from the total number of larvae that moulted and not from the total number of engorged larvae incubated.

Nymphs

Nymphs that had moulted from engorged larvae that had been maintained at 20 °C (± 1 °C) and RH > 90 % in permanent darkness were kept for approximately 21 days to ensure hardening of their mouthparts and exoskeleton before they were used for infestation. An elephant shrew was infested with 50 of these nymphs and housed in a plastic cage with a mesh floor with apertures large enough to allow engorged nymphs to fall through into a collection tray. Engorged nymphs were collected from the tray every 24 h and placed in separate vials maintained at 20 °C (± 1 °C) and RH > 80 % in permanent darkness. Engorged nymphs were also collected from naturally infested elephant shrews and incubated at the same temperature in permanent darkness at RH ± 90 %. The nymphs were inspected daily to determine the length of the pre-moult and moulting periods.

RESULTS

Hosts

The animals and the localities at which they were examined and the numbers of immature *R. nuttalli* collected are summarized in Table 1. Immature ticks were collected from *E. myurus* at two localities in the central Free State Province, the Pretoria district in Gauteng Province, and two localities in the Limpopo Province. Nymphs were collected from the single *E. edwardii* examined in the Clanwilliam District, Western Cape Province and the single *E. intufi* examined near Erongo in central Namibia. None of the other small mammals examined were infested with *R. nuttalli*.

The hosts from which adult *R. nuttalli* has been collected in southern Africa are listed in Table 2. The most frequently infested animals were domestic dogs, hedgehogs and leopards.

Seasonal occurrence

The seasonal occurrence of the immature stages of *R. nuttalli* on rock elephant shrews is graphically illustrated in Fig. 1. With the possible exception of July, when no elephant shrews were captured, larvae and nymphs were present throughout the year. The former life stage was generally most numerous during the period March to September and the latter during May to October.

Life cycle

Adults

Female ticks required 16–32 days to engorge on hedgehogs. All seven females placed on the male

TABLE 1 Hosts of the immature stages of *Rhipicentor nuttalli*

Locality, year of collection and host species	Number examined	No. of *R. nuttalli* collected			Prevalence % (No. infested)
		Larvae	Nymphs	Total	
Free State Province					
"Preezfontein"* (29°50'S, 25°23'E), 1985–1989; "Slangfontein"* (30°08'S, 25°24'E), 1985					
Elephantulus myurus	137	0	0	0	0
Aethomys namaquensis	321	0	0	0	0
Saccostomys campestris	10	0	0	0	0
"Moreson" (28°48'S, 27°13'E), 1992					
Elephantulus myurus	23	147	70	217	95.6 (22)
"Langberg" (29°36'S, 25°28'E), 1992					
Elephantulus myurus	54	0	0	0	0
"Spes Bona" (29°07'S, 26°04'E), 1989/90; 1994/95					
Elephantulus myurus	72	361	261	622	75 (54)
Gauteng Province					
Pretoria District (25°45'S, 28°12'E), 1985					
Elephantulus myurus	11	161	69	230	63.6 (7)
Limpopo Province					
Mapungubwe (22°12'S, 29°21'E), 1985					
Elephantulus myurus	3	1	4	5	100 (3)
Pafuri (23°27'S, 31°19'E), 1984–1987					
Elephantulus myurus	3	14	44	58	100 (3)
Aethomys chrysophilus	8	0	0	0	0
Aethomys namaquensis	2	0	0	0	0
Saccostomys campestris	3	0	0	0	0
Western Cape Province					
Clanwilliam District (32°11'S, 18°54'E), 2001					
Elephantulus edwardii	1	0	7	7	100 (1)
"Gifberg" (31°47'S, 18°40'E), 1989; 1992					
Elephantulus edwardii	66	0	0	0	0
Namibia					
Erongo Wilderness Lodge (21°27'S, 15°52'E), 2001					
Elephantulus intufi	1	0	3	3	100 (1)

* Adapted from Fourie, Horak & Van Heerden (1992)

hedgehog engorged successfully, but only three produced viable eggs. Only two of the seven females on the female hedgehog engorged successfully and only one of these produced viable eggs. The four females that produced viable eggs had required an average of 22.5 days to engorge. Egg laying began 2–4 days after detachment and continued for 58–71 days. It reached a peak 7–17 days after commencement (Fig. 2a) with more than 80 % of eggs produced by day 30. Although the tempo of egg laying was slightly slower when the ticks were kept in permanent darkness it did not differ significantly from that of a tick kept at a photoperiod of 14 h light: 10 h dark (Fig. 2b).

The female kept at 14 h light: 10 h dark laid 16 882 eggs, whereas the average production of the three females kept in permanent darkness was 17 068 eggs.

The CEI varied between 66 % and 69 % and REI between 12 950 and 13 740 eggs per g body weight (Table 3).

TABLE 2 Hosts of adult *Rhipicentor nuttalli*

Hosts	Number of records
Domestic animals	
Dogs	22
Donkeys	1
Cattle	Number not stated
Wild animals	
South African hedgehog, *Atelerix frontalis*	9
Black-backed jackal, *Canis mesomelas*	1
Cheetah, *Acinonyx jubatus*	1
African wild cat, *Felis lybica*	1
"Wild cat"	4
Lion, *Panthera leo*	1
Leopard, *Panthera pardus*	12
Brown hyaena, *Parahyaena brunnea*	4
"Hyaena"	2
"Genet", *Genetta* sp.	1
Eland, *Taurotragus oryx*	1
South African porcupine, *Hystrix africaeaustralis*	3

TABLE 3 Average number of eggs produced, conversion efficiency index and reproduction efficiency index of female *Rhipicentor nuttalli*

Number of females	Temperature	Photoperiod	Average weight of females	Average weight of egg mass	Average number of eggs	CEI	REI
1	20 °C	14 h light: 10 h dark	1.22871 g	0.854245 g	16 882	0.69	13 740
3	20 °C	Permanent darkness	1.31801 g	0.869938 g	17 068	0.66	12 950

CEI = conversion efficiency index (g eggs/g female)
REI = reproduction efficiency index (no. of eggs/g female)

TABLE 4 Length of the life cycle of *Rhipicentor nuttalli* in the laboratory

Activity	Period in days	Average or peak (days)
Female engorgement	16–32	22 (on *A.frontalis*)
Pre-oviposition	2–4	3
Egg laying	58–71	15
Eclosion	59	59
Hardening of exoskeleton	14	14
Larval engorgement	4–10	6 (on *E. myurus*)
Larval moulting	12–20	14
Hardening of exoskeleton	14	14
Nymphal engorgement	11–15	13 (on *E. myurus*)
Nymphal moulting	32–47	40
Hardening of exoskeleton	14	14
Total		214 days

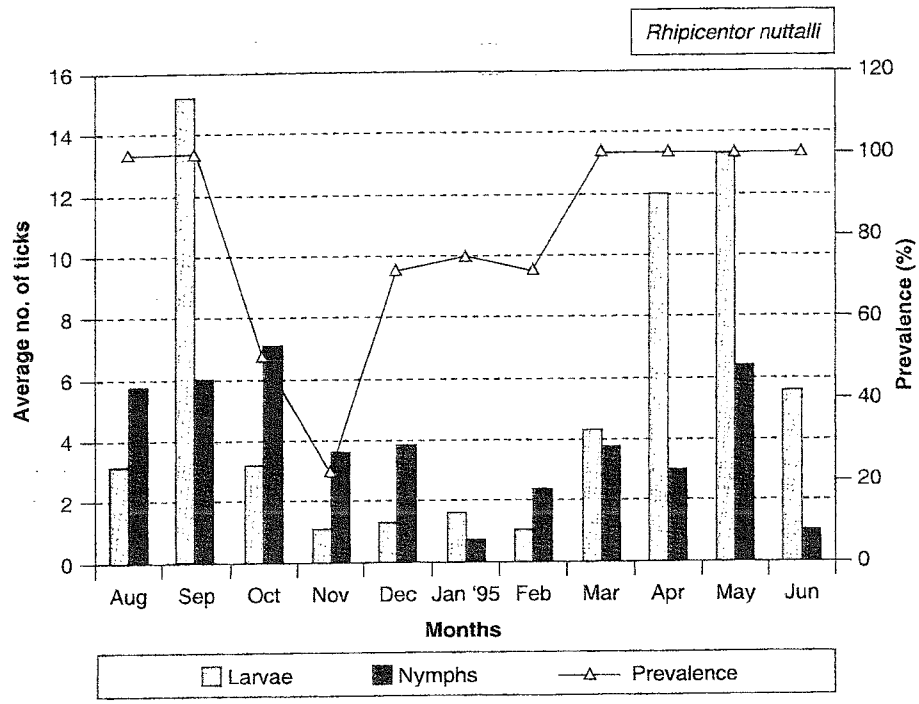

FIG. 1 The seasonal occurrence of the immature stages of *Rhipicentor nuttalli* on rock elephant shrews in the Free State Province

Eggs

Eggs hatched after an average incubation period of 59 days.

Larvae

The larvae used for artificial infestation of the elephant shrews attached mainly around the tail base. The greatest percentage of larvae engorged and detached 5–6 days after infestation irrespective of the photoperiod (Fig. 3).

Most larvae moulted to nymphs between 12 and 19 days after they had detached from elephant shrews (Fig. 4), and 71.5 % of the 225 larvae that had engorged moulted successfully.

Nymphs

Only 17 of the 50 flat nymphs used to infest an elephant shrew engorged successfully, with engorgement and detachment taking place between 11 and 15 days after infestation (Fig. 5). The average weight of an engorged nymph was 0.03188 g.

The 17 engorged nymphs originating from the artificially infested elephant shrew moulted to adults 32–37 days after engorgement, while those detaching from naturally infested elephant shrews and incubated at a slightly higher RH moulted to adults between 37 and 47 days (Fig. 6).

DISCUSSION

Hosts

The large numbers of rock elephant shrews infested with immature ticks confirm the observation of Du Toit, Fourie & Horak (cited by Du Toit 1993) that these animals serve as hosts for these life stages of *R. nuttalli*. The collection of nymphs from both *E. edwardii* and *E. intufi* would seem to indicate that these animals, and possibly other species of *Elephantulus* too, are suitable hosts for immature *R. nuttalli*, particularly in those regions in which *E. myurus* does not occur.

Norval & Colborne (1985) state that although *R. nuttalli* is colloquially known in South Africa as the hedgehog tick, their findings in Zimbabwe indicate that the adults are principally parasites of leopards and that the tick's distribution is restricted to the rocky habitats in which leopards normally occur. It thus seems logical to us that the immature stages, if they do not infest leopards, would infest some other host animal with a preference for rocky habitats. The present results confirm this supposition because both *E. myurus* and *E. edwardii* prefer rocky habitats as signified by the inclusion of the word "rock" in their colloquial names (Skinner & Smithers 1990).

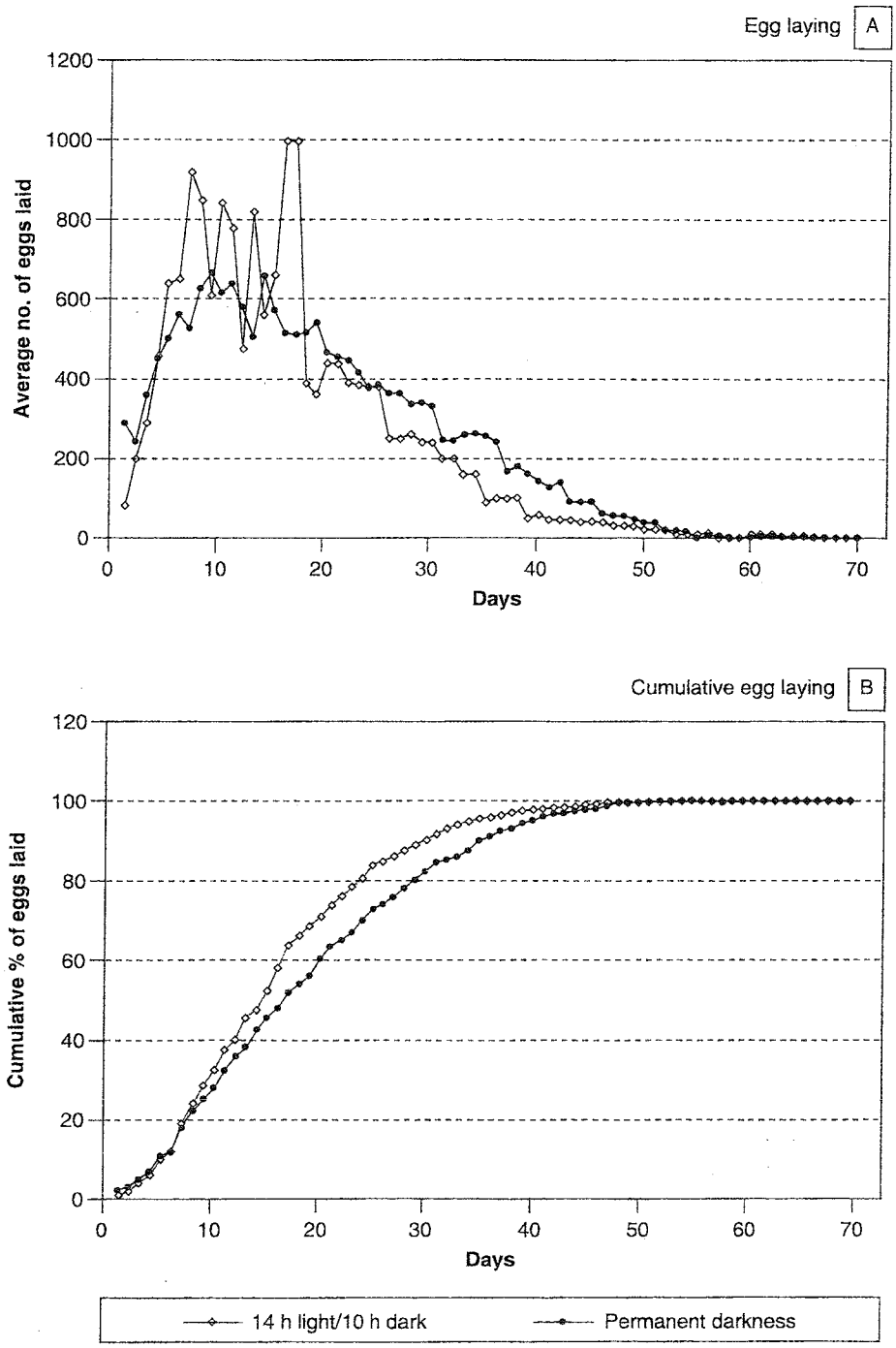

FIG. 2 Egg laying (A) and cumulative egg laying (B) of *Rhipicentor nuttalli* females at 20°C and RH ± 90 %, one female at a photoperiod of 14 h light: 10 h dark and three in permanent darkness

An interesting and perhaps significant finding is that in the Free State *E. myurus* is the host of preference for the immature stages of three ticks capable of inducing paralysis in their adult stage. These are *Ixodes rubicundus*, the Karoo paralysis tick that is responsible for massive annual mortalities of sheep within its distribution region (Spickett & Heyne 1988), *Rhipicephalus warburtoni*, the brown paralysis tick that has been incriminated as inducing paralysis in goat kids in the Free State (Walker, Keirans & Horak 2000), and *R. nuttalli* that can cause paralysis in dogs (Perchman 1976; Norval &

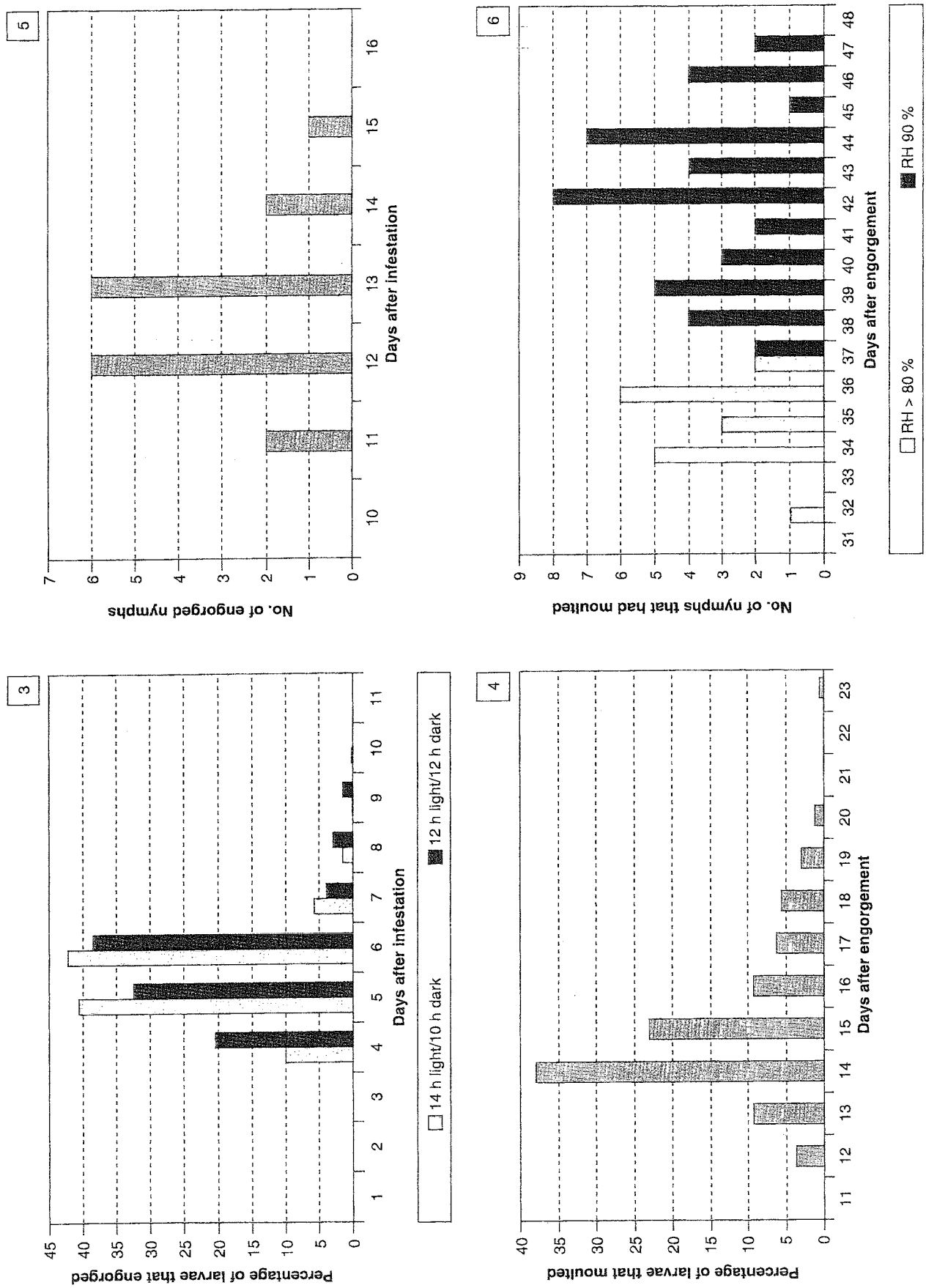
5
No. of engorged nymphs
Days after infestation
6
No. of nymphs that had moulted
Days after engorgement
RH > 80 %
RH 90 %
3
Percentage of larvae that engorged
Days after infestation
14 h light/10 h dark
12 h light/12 h dark
4
Percentage of larvae that moulted
Days after engorgement

FIG. 3 Engorgement of *Rhipicentor nuttalli* larvae on rock elephant shrews kept at 20 °C to 25 °C and a photoperiod of either 14 h light: 10 h dark, or 12 h light: 12 h dark

FIG. 4 Moulting period of *Rhipicentor nuttalli* larvae to nymphs at 20 °C and RH > 90 % in permanent darkness

FIG. 5 Engorgement of *Rhipicentor nuttalli* nymphs on a rock elephant shrew kept at 20 °C and a photoperiod of 14 h light: 12 h dark

FIG. 6 Moulting period of engorged *Rhipicentor nuttalli* nymphs collected from an artificially or from naturally infested rock elephant shrews and kept at 20 °C in permanent darkness at RH > 80 % or RH ± 90 % respectively

Colborne 1985). Within their overall distribution ranges all these ticks prefer rocky habitats.

In addition to the immature stages of *R. nuttalli* and those of the above-mentioned two ticks, the majority of *E. myurus*, examined from September to February on the farm "Spes Bona" in the seasonal occurrence survey, were infested with the immature stages of *Rhipicephalus arnoldi*. The adults of this tick are parasites of Smith's red rock rabbit, *Pronolagus rupestris* (Walker *et al.* 2000). Interspecific competition for attachment sites on the elephant shrews by these four species may have adversely affected the burdens of each.

Seasonal occurrence

Although immature ticks were present on *E. myurus* throughout the year, the majority of larvae were collected from late summer to early spring and nymphs from autumn to spring (Fig. 1). According to Theiler (1962) adult ticks are common on dogs in the Clanwilliam District in the Western Cape Province and in the Omaruru District, Namibia during late summer. In Gauteng and the Free State Provinces adult ticks were collected from a leopard, a brown hyaena and a black-backed jackal in September 1990, October 1993 and December 1994 respectively. In Zimbabwe, however, Norval & Colborne (1985) found that adult ticks were present on hosts during all months of the year.

Life cycle

The length of the life cycle of *R. nuttalli* in the laboratory is summarized in Table 4. Forty-two days have been added to this cycle to accommodate the 14 days each required for the hardening of the exoskeleton and mouthparts of the newly hatched larvae, and newly moulted nymphs and adults respectively to enable each of these life stages to successfully attach to a host.

The total length of the life cycle in the laboratory was 214 days. This length, coupled with the separate peaks of seasonal occurrence of the three developmental stages of the tick on its rock elephant shrew and domestic dog hosts makes it unlikely that more than one life cycle will be completed annually in the field in South Africa.

The engorgement period (16–32 days) of female ticks on artificially infested hedgehogs in this study is considerably longer than that of other ixodid ticks on their preferred mammal hosts. A possible reason for this prolonged period is competition for space. Only a small area dorsal to the tail of the hedgehog was used for attachment, and males, unengorged, and particularly engorged female *R. nuttalli*, are large ticks and hence the number of ticks used to infest the hedgehogs could have been excessive. This attachment site has two advantages for the ticks in that they are protected from the hedgehog's sharp spines and also from predation by the hedgehog. When one of the hedgehogs died approximately 5 months after it had been infested male ticks were still present on it. This phenomenon might be an adaptation to an arid environment in which host-finding and hence mate-finding success is poor. The adult segment of the life cycle should be repeated on domestic dogs or another suitable carnivore host to confirm the duration of engorgement of female ticks and length of attachment of males.

As signified by their weight (> 1.2 g) engorged females are very large and also lay particularly large numbers of eggs, an indication of an adaptation to an unfavourable environment. Another species of which the engorged females are particularly large (> 2.0 g) and egg production exceeds 15 000 is *Amblyomma hebraeum* (Norval 1974a, b). *Amblyomma hebraeum* is a tick that maximises its survival options. The adults have particularly long mouthparts making them difficult to detach and hence unattractive to predation by oxpeckers (*Buphagus* spp.) (Bezuidenhout & Stutterheim 1980). The males can remain attached for months and mate with several females (Norval 1974a), and the

females lay large numbers of eggs within a macro-environment that is generally favourable for their survival, while the resultant larvae possibly have a wider host range than any other ixodid tick in South Africa (Horak, MacIvor, Petney & De Vos 1987). The large number of eggs and larvae produced by *R. nuttalli* are probably a counter to the extremely narrow host preference range of its immature stages and hence the chances of encountering such a host within the rocky environment preferred by rock elephant shrews.

Not only was total egg production high, but so too were the CEI and the REI of the females. The CEI exceeded 0.65 indicating an effective conversion of female body weight to eggs and the REI exceeded 12900, signifying that a particularly large number of eggs were produced per g of female weight. Ticks with a CEI exceeding 0.60 are *A. hebraeum* (Norval 1977), *Amblyomma limbatum* (Chilton & Bull 1993) and *Hyalomma dromedarii* (Hagras & Khalil 1988), while those with a REI exceeding 12 000 are *Hyalomma truncatum* (Linthicum, Logan, Kondig, Gordon & Bailey 1991), *Ixodes rubicundus* (Van der Lingen 1995) and *Ixodes trianguliceps* (Randolph 1975). However, the mean total egg production of *H. trucatum* was only 6 701, that of *I. rubicundus* between 2805 and 3777, and that of *I. trianguliceps* between 1 169 and 1 746, compared to the more than 16 000 eggs produced by *R. nuttalli*.

The pre-oviposition period of 2–4 days and the period of 59 days for eclosion of the larvae are slightly shorter and at least 18 days longer respectively than the pre-oviposition period of 6–8 days and 35–41 days for larvae to hatch recorded for *R. nuttalli* by Theiler (1961).

Only 17 engorged nymphs were harvested from the elephant shrew artificially infested with 50 flat nymphs. This low recovery could have been due to predation of several of the nymphs by the elephant shrew. All these nymphs moulted, however, and the resultant adults all seemed to be viable.

Arthropods are preferred food items for both *A. frontalis* and *E. myurus* (Skinner & Smithers 1990) and hence life cycle studies with ticks or other ectoparasites on these animals must be performed with circumspection lest the parasite itself becomes the victim of predation.

ACKNOWLEDGEMENTS

We gratefully acknowledge the permission given to us by the various land owners to trap elephant shrews on their properties. Dr Peter Woodall collected the ticks from elephant shrews in the Pretoria District, Gauteng Province and at Mapungubwe in Limpopo Province. This project was funded by the University of the Free State and the Foundation for Research Development (now National Research Foundation).

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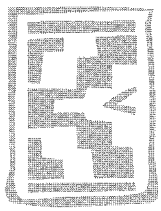

Striped mice, *Rhabdomys pumilio*, and other murid rodents as hosts for immature ixodid ticks in the Eastern Cape Province

T.N. PETNEY[1], I.G. HORAK[2]*, D.J. HOWELL[3] and S. MEYER[2]**

ABSTRACT

PETNEY, T.N., HORAK, I.G., HOWELL, D.J. & MEYER, S. 2004. Striped mice, *Rhabdomys pumilio*, and other murid rodents as hosts for immature ixodid ticks in the Eastern Cape Province. *Onderstepoort Journal of Veterinary Research*, 71:313–318

Striped mice, *Rhabdomys pumilio*, were trapped over a period of 17 months in the Thomas Baines Nature Reserve, and placed in cages, over water, until all the ticks they harboured had detached. The mice were then returned to the reserve. Four ixodid tick species were recovered from the mice of which the larvae and nymphs of *Rhipicephalus follis* and *Rhipicephalus simus* were the most numerous. Most larvae of *R. follis* detached from mice trapped from March to July, and most nymphs in March and from June to September. Most larvae of *R. simus* detached from mice trapped from December to March, and most nymphs from January to March and during May and June. Seven ixodid tick species were collected from striped mice, house rats, *Rattus rattus*, vlei rats, *Otomys* spp. and *Praomys* sp. captured in the vicinity of human dwellings or animal holding facilities in the Grahamstown district. The striped mice captured in the Thomas Baines Reserve harboured considerably larger numbers of ticks than any of the rodent species in the more urbanized localities.

Keywords: Eastern Cape Province, ixodid ticks, *Rhabdomys pumilio*, *Rhipicephalus follis*, *Rhipicephalus simus*, rodents, seasonality, striped mice

INTRODUCTION

Several surveys on the ixodid ticks infesting a variety of rodent species have been conducted in South Africa (Rechav 1982; Horak, Sheppey, Knight & Beuthin 1986; Howell, Petney & Horak 1989; Horak, Fourie, Novellie & Williams 1991; Fourie, Horak & Van Den Heever 1992; Braack, Horak, Jordaan, Segerman & Louw 1996; Horak & Boomker 1998; Horak & Cohen 2001). Some of these rodents are significant, if not preferred, hosts of the immature stages of several tick species of which the adults are important parasites of domestic animals (Norval & Mason 1981; Rechav 1982; Norval 1984; Braack *et al.* 1996). Despite their small size, the potential of rodents for rapid population growth and for maintaining high population levels can contribute significantly to the dynamics of tick species that use them as hosts (Norval 1979; Horak, Spickett & Braack 2000).

In order to assess the significance of tick/rodent host relationships in the epidemiology of tick-borne

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diseases in South Africa, it is essential to know which tick species infest which rodent species and what levels the intensity of infestation can reach. In a previous paper (Howell *et al.* 1989), we suggested that striped mice, *Rhabdomys pumilio*, were of no significance in the epidemiology of heartwater, caused by *Ehrlichia ruminantium*, in domestic ruminants, because they did not represent significant hosts for the immature stages of *Amblyomma hebraeum*, the principal vector of this organism. In this contribution we wish to present data on other tick species that infested the same striped mice, and on the tick burdens of striped mice and other murid rodents in more urbanized habitats.

MATERIALS AND METHODS

The methods employed to collect ticks from the striped mice captured in the Thomas Baines Nature Reserve, Eastern Cape Province (33°23' S, 26°28' E) have been described in detail by Howell *et al.* (1989) and will be repeated only briefly here. Except during September 1987, when no mice were trapped, striped mice were trapped each month from July 1987 to November 1988. These mice were kept in cages over water and once all their ticks had detached the mice were released in the vicinity of the sites at which they had been trapped. The ticks were collected from the water, dried and allowed to moult. When moulting was judged to be complete all the ticks that had moulted and those that had failed to moult were identified and counted. The counts of those that had moulted were converted to the previous life stage and added to those of the larvae or of the nymphs that had detached from the mice, but that had failed to moult.

Murid rodents were also trapped around the stables and dwellings at the field station of the Tick Research Unit, Rhodes University, around an animal shelter situated in a semi-rural environment close to the field station, and around the outbuildings and homestead of the small holding "Faraway", all within a 3 to 10 km radius of the centre of the city of Grahamstown (33°19' S, 26°32' E), Eastern Cape Province. These rodents were killed and processed for the recovery of ticks as described by Horak *et al.* (1986).

RESULTS AND DISCUSSION

Four ixodid tick species were recovered from the mice trapped in the Thomas Baines Nature Reserve (Table 1). Of these the larvae and nymphs of *Rhipicephalus follis* and *Rhipicephalus simus* were the most numerous and the most prevalent. Four of the five *A. hebraeum* larvae and the single nymph recovered from the mice failed to moult to nymphs and to an adult respectively. Howell *et al.* (1989) have discussed the implications of this failure, coupled with the small number of ticks of this species collected from the mice, in relation to the epidemiology of heartwater, in detail. Twenty-four of the 36 larvae, and 11 of the 13 *Haemaphysalis leachi* nymphs recovered from the mice also failed to moult to the next life stage.

Most *R. follis* larvae detached from mice that were trapped from March to July, and most nymphs from those trapped in March and from June to September (Fig. 1). Of these 1 806 larvae and 512 nymphs failed to moult.

Most larvae of *R. simus* detached from mice trapped from December to March, and most nymphs from those trapped from January to March and during May and June (Fig. 2). Of these 803 larvae and 172 nymphs did not moult.

The larvae and nymphs of *R. follis* and *R. simus* are very similar in appearance (Walker, Keirans & Horak 2000) and although we attempted to separate them, it was particularly difficult to do so for the engorged larvae and nymphs that had died before moulting. Accordingly we cannot vouch for the absolute accu-

TABLE 1 Ixodid ticks in 172 collections from striped mice in the Thomas Baines Nature Reserve

Tick species	Number of ticks recovered			No. of collections
	Larvae	Nymphs	Total	
Amblyomma hebraeum	5	1	6	6
Haemaphysalis leachi	36	13	49	18
Rhipicephalus follis	13 313	704	14 017	162
Rhipicephalus simus	2 206	321	2 527	116
Total	15 560	1 039	16 599	169

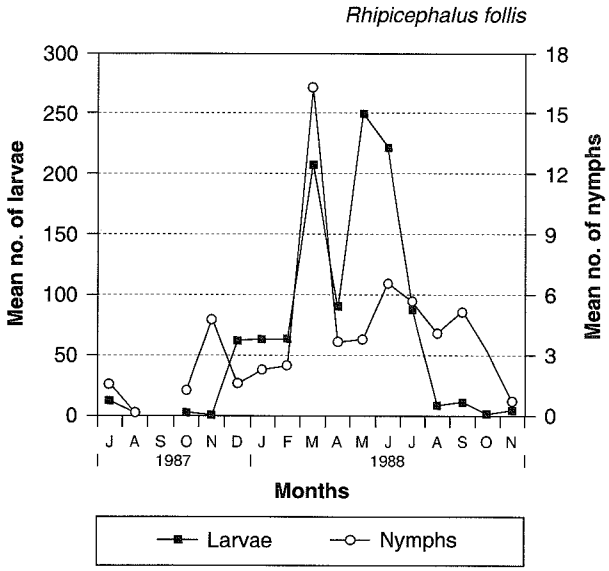

FIG. 1 The seasonal occurrence of the immature stages of *Rhipicephalus follis* on striped mice in the Thomas Baines Nature Reserve, Eastern Cape Province

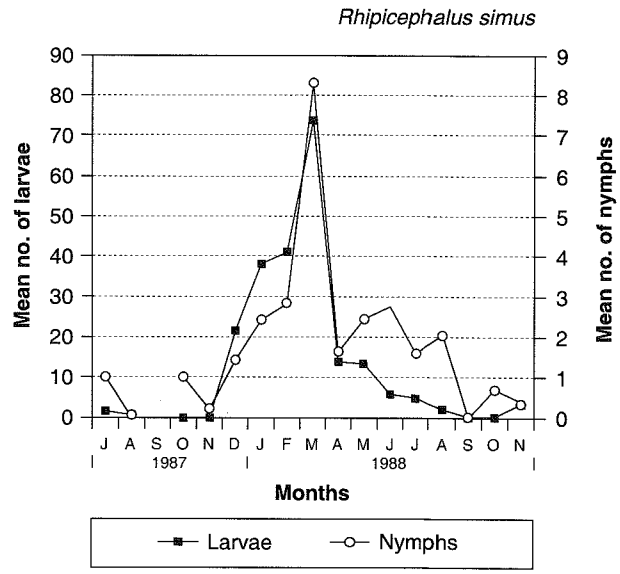

FIG. 2 The seasonal occurrence of the immature stages of *Rhipicephalus simus* on striped mice in the Thomas Baines Nature Reserve, Eastern Cape Province

TABLE 2 Ixodid ticks collected from 14 *Rhabdomys pumilio* in the Grahamstown district

Tick species	Total number of ticks			No. of rodents
	Larvae	Nymphs	Total	infested
Haemaphysalis leachi	42	11	53	6
Ixodes sp.	6	0	6	3
Rhipicephalus (*Boophilus*) sp.	1	0	1	1
Rhipicephalus follis	13	3	16	3
Rhipicephalus simus	37	0	37	6
Rhipicephalus simus group	8	0	8	1
Total	107	14	121	10

racy of the numbers that we have recorded for these species.

Ten of the 14 *R. pumilio* examined in the Grahamstown district were infested with ticks, and five species, of which *H. leachi* and *R. simus* were the most numerous and prevalent, were recovered from them (Table 2). Forty of the 73 *Otomys* spp., five of the 14 *Praomys* sp., and five of the 13 *Rattus rattus* examined in the Grahamstown district were infested and a total of six species were recovered, of which *H. leachi* was amongst the most numerous and prevalent (Tables 3–5).

General

The importance of the availability of rodents for the immature stages of tick species preferring these small mammals as hosts, on the subsequent numbers of adults of the particular species, has been alluded to by Norval (1979) and demonstrated by Horak *et al.* (2000). The latter authors recorded a marked increase in the numbers of adult *R. simus* and *Rhipicephalus turanicus*, both of which use rodents as preferred hosts for their immature stages, on the vegetation of a landscape zone in the Kruger National Park approximately 8 months after a rodent explosion. On the other hand, no such increase in the numbers of adult *Rhipicephalus appendiculatus*, of which the immature stages feed on antelopes or hares, was noted.

The most striking differences between the tick burdens of the mice in the reserve and those of the rodents around human structures in the present study were the intensity of infestation and its prevalence and the species composition of the tick populations. The mean burdens of the various rodent

TABLE 3 Ticks collected from 73 *Otomys* spp. in the Gahamstown district

Tick species	Number of ticks recovered				No. of rodents infested
	Larvae	Nymphs	Females	Total	
Amblyomma hebraeum	1	0	0	1	1
Haemaphysalis leachi	48	9	0	57	15
Ixodes alluaudi	0	0	2	2	2
Ixodes bakeri	0	2	4	6	4
Ixodes spp.	11	0	0	11	6
Rhipicephalus follis	51	8	1	60	12
Rhipicephalus simus	33	18	0	51	18
Rhipicephalus simus group	4	27	0	31	3
Total	148	64	6	218	40

TABLE 4 Ticks collected from 14 *Praomys* sp. in the Gahamstown district

Tick species	Total number of ticks			No. of rodents infested
	Larvae	Nymphs	Total	
Amblyomma hebraeum	0	1	1	1
Haemaphysalis leachi	10	0	10	3
Ixodes bakeri	0	1	1	1
Ixodes sp.	1	0	1	1
Total	11	2	13	5

TABLE 5 Ixodid ticks collected from 13 *Rattus rattus* in the Grahamstown district

Tick species	Total number of ticks			No. of rodents infested
	Larvae	Nymphs	Total	
Haemaphysalis leachi	68	2	70	5
Ixodes sp.	1	0	1	1
Rhipicephalus follis	0	1	1	1
Total	69	3	72	5

species examined close to Grahamstown varied between four ticks on infested *Praomys* sp. and 12 on infested *R. pumilio*, compared to 98 on infested mice in the Thomas Baines Reserve.

Amblyomma hebraeum

The significance of the six immature *A. hebraeum* recovered from the mice in the reserve compared to the abundance of these stages on the large bovids and the vegetation at the same locality has been discussed in an earlier publication (Howell *et al.* 1989). The single larva and nymph collected from the *Otomys* spp. and the *Praomys* sp. respectively examined in the Grahamstown district were not engorging and appeared to be dying, indicating an unsatisfactory host/parasite relationship, further emphasising the unsuitability of murid rodents as hosts for the immature stages of this tick.

Haemaphysalis leachi

The immature stages of *H. leachi*, of which the adults are specific parasites of domestic dogs and cats and the larger wild felids (Norval 1984; Horak Jacot Guillarmod, Moolman & De Vos 1987; Horak, Braack, Fourie & Walker 2000), were proportionally most numerous on the rodents examined close to Grahamstown. This is not surprising as workers at the field station and the owner of "Faraway" kept domestic dogs as pets, and dogs also accounted for a large proportion of the animals housed at the animal shelter. In a survey of the ticks infesting dogs on "Faraway" and on a neighbouring property con-

ducted between August 1983 and July 1986, a total of 6 146 adult *H. leachi* were collected and comprised 71.3 % of all ticks recovered from the dogs (Horak *et al.* 1987). With this number of adult ticks on the dogs at "Faraway" higher burdens could have been expected on the rodents examined there. However, the immature stages do not feed exclusively on rodents, but also on dogs (Horak *et al.* 1987; Jacobs, Fourie & Horak 2004), and this could be a reason for the smaller burdens. The *H. leachi* recovered from the striped mice in the reserve were probably the progeny of adult ticks feeding on wild carnivores there.

Ixodes spp.

All stages of development of *Ixodes alluaudi* and *Ixodes bakeri* infest shrews and rodents, with the latter tick showing a preference for *Otomys* spp. (Walker 1991). The unidentified *Ixodes* larvae collected from some of the rodents probably belonged to one or both of these species.

Rhipicephalus (*Boophilus*) sp.

The single larva collected from a striped mouse at the field station near Grahamstown is a " straggler" originating from ticks on cattle kept on the premises.

Rhipicephalus follis

Eland, *Taurotragus oryx*, examined in the Thomas Baines Nature Reserve during 1982 and 1984, and an African buffalo, *Syncerus caffer*, examined during 1985 harboured adult *R. follis*. It is the ticks on these hosts, and probably also on Burchell's zebras, *Equus burchelli*, in the reserve, which gave rise to the large numbers of immature ticks recovered from the striped mice at this locality.

Large numbers of adult *R. follis* have also been recorded on eland in the Mountain Zebra National Park near Cradock in the Eastern Cape Province (Horak *et al.* 1991) and the greatest intensity of infestation appeared to occur from August to March. Superimposing the seasonality of these adult ticks on that of the large number of larvae detaching from mice trapped in the Thomas Baines Nature Reserve from March to July, and of nymphs detaching during March and from June to September (Fig. 1) indicates that this three-host tick probably only completes one life cycle annually.

The immature stages of *R. follis* collected from the rodents examined close to Grahamstown probably originated from adults infesting cattle at the field station, horses at the animal shelter and dogs on "Faraway". Horses are also good hosts of *R. follis*, which at the time was identified as *Rhipicephalus* sp. (near *R. capensis*) (Horak, Knight & De Vos 1986), as was the single adult tick on a dog at "Faraway" (Horak *et al.* 1987).

Rhipicephalus simus

Adult ticks on the eland, African buffaloes, zebras and carnivores in the reserve were the most likely source of immature *R. simus* on the striped mice at this locality, and on dogs, horses and cattle the source of the immature stages on the rodents examined in the vicinity of Grahamstown. In an earlier survey a total of 1 351 adult *R. simus* was collected from dogs on "Faraway" and on a neighbouring property, and these ticks were most numerous from August to April (Horak *et al.* 1987). Superimposing this pattern of seasonality on that determined for the immature stages on the striped mice in the Thomas Baines Reserve indicates that this tick also only completes one life cycle annually, with most adults present during spring and summer, most larvae from mid to late summer, and most nymphs in late summer, autumn and winter. A similar survey conducted on striped mice in the Andries Vosloo Kudu Reserve, approximately 30 km north-east of Grahamstown, yielded most *R. simus* larvae from March to June and nymphs from June to September (Rechav 1982). Unfortunately Rechav (1982) did not state whether or not he collected the immature stages of other tick species from the mice.

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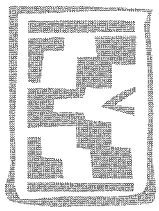

Small mammals as hosts of immature ixodid ticks

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ABSTRACT

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Two hundred and twenty-five small mammals belonging to 16 species were examined for ticks in Free State, Mpumalanga and Limpopo Provinces, South Africa, and 18 ixodid tick species, of which two could only be identified to genus level, were recovered. Scrub hares, *Lepus saxatilis*, and Cape hares, *Lepus capensis*, harboured the largest number of tick species. In Free State Province Namaqua rock mice, *Aethomys namaquensis*, and four-striped grass mice, *Rhabdomys pumilio*, were good hosts of the immature stages of *Haemaphysalis leachi* and *Rhipicephalus gertrudae*, while in Mpumalanga and Limpopo Provinces red veld rats, *Aethomys chrysophilus*, Namaqua rock mice and Natal multimammate mice, *Mastomys natalensis* were good hosts of *H. leachi* and *Rhipicephalus simus*. *Haemaphysalis leachi* was the only tick recovered from animals in all three provinces.

Keywords: Immature ixodid ticks, *Haemaphysalis leachi*, *Rhipicephalus gertrudae*, *Rhipicephalus simus*, small mammals, South Africa

INTRODUCTION

A large number of surveys have focused on the role of small mammals as hosts of the immature stages of ixodid ticks in South Africa. The accent has been mainly on murid rodents (Rechav 1982; Howell, Petney & Horak 1989; Horak, Fourie, Novellie & Williams 1991; Fourie, Horak & Van Den Heever 1992; Braack, Horak, Jordaan, Segerman & Louw 1996; Horak & Boomker 1998; Horak & Cohen 2001; Petney, Horak, Howell & Meyer 2004), but elephant shrews (Stampa 1959; Fourie *et al.* 1992; Fourie, Horak, Kok & Van Zyl 2002), hares and rabbits (Stampa 1959; Horak, Sheppey, Knight & Beuthin 1986; Horak & Fourie 1991; Horak *et al.* 1991; Horak, Spickett, Braack & Penzhorn 1993; Horak, Spickett, Braack, Penzhorn, Bagnall & Uys 1995; MacIvor & Horak 2003), rock dassies (Horak & Fourie 1986; Horak *et al.* 1991), and small carnivores (Horak, Chaparro, Beaucournu & Louw 1999; Horak, Braack, Fourie & Walker 2000) have also been examined.

The adults of some of the tick species that infest these small animals as larvae or nymphs are important vectors of disease or toxins to domestic livestock, whereas others are of little or no economic consequence. Thus murid rodents are among the preferred hosts of the immature stages of *Haemaphysalis leachi*, whose adults parasitize and transmit canine babesiosis to domestic dogs (Lewis, Penzhorn, Lopez-Rebollar & De Waal 1996), and of

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Rhipicephalus simus, whose adults parasitize cattle, horses and domestic dogs and transmit anaplasmosis to cattle and produce a toxin causing paralysis in calves and lambs (Walker, Keirans & Horak 2000). Rock elephant shrews, *Elephantulus myurus*, are the hosts most favoured by the immature stages of *Ixodes rubicundus* and *Rhipicephalus warburtoni*, whose adults cause paralysis in sheep and goats (Stampa 1959; Walker *et al.* 2000), and scrub hares, *Lepus saxatilis*, by the immature stages of *Hyalomma marginatum rufipes* and *Hyalomma truncatum*, whose adults are parasites of domestic cattle, sheep and goats. The former tick transmits anaplasmosis and *Babesia occultans* to cattle, and the latter secretes a toxin that is the cause of sweating sickness in these animals (Walker, Bouattour, Camicas, Estrada-Peña, Horak, Latif, Pegram & Preston 2003). The objective of the present paper is to present recent data on the ixodid ticks that infest small mammals in three of the nine provinces of South Africa, and to supply the geographic coordinates of the localities at which the ticks were collected for future mapping purposes.

MATERIALS AND METHODS

Two hundred and twenty-five small mammals, belonging to 16 species, were collected in Free State, Mpumalanga and Limpopo Provinces, South Africa and processed for tick recovery as described by Horak *et al.* (1986). One hundred and sixty-three of these animals belonging to 10 species were examined in Free State Province and 62 belonging to 11 species were examined in Mpumalanga and Limpopo Provinces (Table 1).

RESULTS AND DISCUSSION

The ticks collected in Free State Province are summarized in Tables 2 and 3, and those from animals in the north-eastern regions of Mpumalanga and Limpopo Provinces in Tables 4 and 5.

Twelve tick species, of which two could be identified only to genus level, were recovered in Free State Province and nine in Mpumalanga and Limpopo Provinces. Only *H. leachi* was collected in all three provinces, while *H. truncatum* and *Rhipicephalus evertsi evertsi* were collected in two, namely Free State and Mpumalanga Provinces.

Scrub hares, *L. saxatilis*, and Cape hares, *Lepus capensis*, were infested with the largest number of tick species. In Free State Province Namaqua rock mice, *Aethomys namaquensis*, and four-striped grass mice, *Rhabdomys pumilio*, were good hosts of the immature stages of *H. leachi* and *Rhipicephalus gertrudae*, while in Mpumalanga and Limpopo Provinces red veld rats, *Aethomys chrysophilus*, Namaqua rock mice and Natal multimammate mice, *Mastomys natalensis*, were good hosts of *H. leachi* and *R. simus*, a tick anagolous to *R. gertrudae*.

Dermacentor rhinocerinus

The hosts of the immature stages of this tick were unknown until Horak & Cohen (2001) collected larvae and nymphs from rodents in Mpumalanga Province. For the sake of completeness we have repeated their findings here because other tick species, recovered from the same hosts, were not listed in the earlier publication. *Dermacentor rhinocerinus* is a host-specific parasite of rhinoceroses (Keirans 1993), of which there are several in the Mthethomusha Reserve, Mpumalanga Province. These animals must have been the source of infestation reflected in the burdens of immature ticks of five of the 38 rodents examined in the reserve (Table 4). There are rhinoceroses in the Willem Pretorius Nature Reserve in Free State Province, but it is not known whether *D. rhinocerinus* is also present.

Haemaphysalis leachi

Domestic dogs and the larger wild felids are the preferred hosts of adult *H. leachi*, while its immature stages occur mainly on murid rodents (Norval 1984; Braack *et al.* 1996; Horak *et al.* 2000). Its widespread distribution in the present survey confirms Norval's (1984) assertion that provided hosts for its adults and immature stages are present, almost any locality in southern Africa can be regarded as suitable. Furthermore the large range of carnivore and rodent species parasitized by its adult and immature stages, respectively (Norval 1984; Horak *et al.* 2000; Tables 2 and 4) and their widespread distribution, ensure that should *H. leachi* be introduced into a region it would readily become established. This assumption is corroborated by its extensive but discontinuous distribution in South Africa (Howell, Walker & Nevill 1978).

Haemaphysalis leachi transmits *Babesia canis*, the cause of canine babesiosis in domestic dogs in South Africa (Lewis *et al.* 1996). Judging by the host preferences of the adult and immature stages of the tick it would seem that transmission mostly takes place via the adults with infection passing transovarially from adult ticks of the previous generation without it being lost when the immature stages feed on rodents.

TABLE 1 Small mammals and the localities at which they were examined for ixodid ticks

Small mammal species			Province, locality and coordinates
Common name	Scientific name	No. examined	
Tree squirrel	*Paraxerus cepapi*	2	Limpopo, Pafuri (23°27′S, 31°19′E) (KNP)
Short-tailed pouched mouse	*Saccostomys campestris*	1 3	Free State, Tussen-die-Riviere NR (30°29′S, 26°15′E) Limpopo, Pafuri (23°27′S, 31°19′E) (KNP)
Bushveld gerbil	*Tatera leucogaster*	5 4 1	Free State, Sandveld NR (27°38′S 25°42′E) Mpumalanga, Mtethomusha NR (25°29′S, 31°17′E) Mpumalanga, Pretoriuskop (25°10′S, 31°16′E) (KNP)
Red veld rat	*Aethomys chrysophilus*	10 1 8	Mpumalanga, Mthethomusha NR (25°29′S, 31°17′E) Mpumalanga, Berg-en-Dal (25°25′S, 31°27′E) (KNP) Limpopo, Pafuri (23°27′S, 31°19′E) (KNP)
Namaqua rock mouse	*Aethomys namaquensis*	17 21 34 5 5 15 6 1 3	Free State, "Preezfontein" (29°50′S, 25°23′E) Free State, Tussen-die-Riviere NR (30°29′S, 26°15′E) Free State, Welbedacht Dam (29°51′S, 26°53′E) Free State, Zandbult (locality unknown) Free State, Wolhuterskop (28°14′S, 28°18′E) Free State, Willem Pretorius NR (28°19′S, 27°15′E) Mpumalanga, Mthethomusha NR (25°29′S, 31°17′E) Limpopo, Tshalungwa (22°33′S, 31°05′E) (KNP) Limpopo, Pafuri (23°27′S, 31°19′E) (KNP)
Single-striped mouse	*Lemniscomys rosalia*	1	Mpumalanga, Mthethomusha NR (25°29′S, 31°17′E)
Multimammate mouse	*Mastomys coucha*	10	Mpumalanga, Mthethomusha NR (25°29′S, 31°17′E)
Natal multimammate mouse	*Mastomys natalensis*	6 1 1 1	Mpumalanga, Mthethomusha NR (25°29′S, 31°17′E) Limpopo, Dube Station (KNP) Limpopo, Mashikiri (22°35′S, 31°11′E) (KNP) Limpopo, Pafuri KNP (23°27′S, 31°19′E)
Pigmy mouse	*Mus minutoides*	2	Free State, Welbedacht Dam (29°51′S, 26°53′E)
Black rat	*Rattus rattus*	1 1	Free State, Sandveld NR (27°38′S 25°42′E) Mpumalanga, Skukuza (24°58′S, 31°36′E) (KNP)
Four-striped grass mouse	*Rhabdomys pumilio*	7 5 4 7 9 4	Free State, Tussen-die-Riviere NR (30°29′S, 26°15′E) Free State, Platberg (28°16′S, 29°10′E) Free State, Welbedacht Dam (29°51′S, 26°53′E) Free State, Zandbult (locality unknown) Free State, Wolhuterskop (28°14′S, 28°18′E) Free State, Golden Gate NP (28°31′S, 28°37′E)
Angoni swamp rat	*Otomys angoniensis*	1	Mpumalanga, Mthethomusha NR (25°29′S, 31°17′E)
Swamp rat	*Otomys irroratus*	1	Free State, Golden Gate NP (28°31′S, 28°37′E)
Spring hare	*Pedetes capensis*	14	Free State, Sandveld NR (29°51′S, 26°53′E)
Cape hare	*Lepus capensis*	1 2	Free State, Tussen-die-Riviere NR (30°29′S, 26°15′E) Free State, Willem Pretorius NR (28°19′S, 27°15′E)
Scrub hare	*Lepus saxatilis*	1 2 1	Free State, Tussen-die-Riviere NR (30°29′S, 26°15′E) Free State, Willem Pretorius NR (28°19′S, 27°15′E) Mpumalanga, Mthethomusha NR (25°29′S, 31°17′E)

KNP= Kruger National Park
NP = National Park
NR = Nature Reserve

TABLE 2 Ticks, other than *Rhipicephalus* species, on small mammals in Free State Province

Tick and host species	No. examined (No. infested)	Number of ticks recovered		
		Larvae	Nymphs	Total
Amblyomma marmoreum				
Lepus saxatilis	3 (1)	4	17	21
Haemaphysalis leachi				
Aethomys namaquensis	97 (38)	63	35	98
Rhabdomys pumilio	36 (9)	72	5	77
Hyalomma marginatum				
Rhabdomys pumilio	36 (1)	1	0	1
Lepus capensis	3 (1)	12	6	18
Lepus saxatilis	3 (2)	4	9	13
Hyalomma truncatum				
Aethomys namaquensis	97 (2)	2	0	2
Rhabdomys pumilio	36 (1)	1	0	1
Tatera leucogaster	5 (1)	4	0	4
Lepus capensis	3 (2)	4	7	11
Lepus saxatilis	3 (2)	33	39	72
Ixodes rubicundus				
Aethomys namaquensis	97 (6)	16	2	18
Lepus saxatilis	3 (1)	0	1	1
***Ixodes* sp.**				
Aethomys namaquensis	97 (8)	2	7	9
Rhabdomys pumilio	36 (2)	1	1	2
Margaropus winthemi				
Rhabdomys pumilio	36 (1)	1	0	1
Lepus saxatilis	3 (1)	4	1	5

TABLE 3 *Rhipicephalus* species on small mammals in Free State Province

Tick and host species	No. examined (No. infested)	Number of ticks recovered		
		Larvae	Nymphs	Total
Rhipicephalus evertsi evertsi				
Aethomys namaquensis	97 (2)	2	0	2
Tatera leucogaster	5 (1)	1	0	1
Lepus capensis	3 (2)	6	17	23
Lepus saxatilis	3 (2)	31	61	92
Rhipicephalus gertrudae				
Aethomys namaquensis	97 (29)	99	48	147
Rhabdomys pumilio	36 (11)	50	6	56
Rhipicephalus lounsburyi				
Rhabdomys pumilio	36 (1)	1	1	2
Rhipicephalus warburtoni				
Aethomys namaquensis	97 (11)	39	0	39
Pedetes capensis	14 (14)	0	34	34
Lepus capensis	3 (1)	6	0	6 + 3 ♂♂
Lepus saxatilis	3 (3)	22	1	23 + 7 ♂♂
***Rhipicephalus* sp.**				
Aethomys namaquensis	97 (2)	1	1	2
Rhabdomys pumilio	36 (1)	1	0	1
Tatera leucogaster	5 (3)	2	12	14

TABLE 4 Ticks, other than *Rhipicephalus* species, on small mammals in north-eastern Mpumalanga and Limpopo Provinces

Tick and host species	No. examined (No. infested)	Number of ticks recovered		
		Larvae	Nymphs	Total
Amblyomma hebraeum				
Mastomys natalensis	9 (1)	1	0	1
Dermacentor rhinocerinus				
Aethomys chrysophilus	19 (1)	1	0	1
Mastomys natalensis	9 (1)	0	1	1
Tatera leucogaster	5 (3)	3	2	5
Haemaphysalis leachi				
Aethomys chrysophilus	19 (11)	17	29	46
Aethomys namaquensis	10 (6)	17	7	24
Mastomys natalensis	9 (2)	0	8	8
Mastomys coucha	10 (2)	3	1	4
Saccostomys campestris	3 (3)	1	4	5
Paraxerus cepapi	2 (1)	2	0	2
Hyalomma truncatum				
Lepus saxatilis	1 (1)	0	14	14
Rhipicephalus (Boophilus) decoloratus				
Aethomys chrysophilus	19 (1)	1	0	1

TABLE 5 *Rhipicephalus* species on small mammals in north-eastern Mpumalanga and Limpopo Provinces

Tick and host species	No. examined (No. infested)	Number of ticks recovered		
		Larvae	Nymphs	Total
Rhipicephalus appendiculatus				
Mastomys natalensis	9 (1)	1	0	1
Lepus saxatilis	1 (1)	0	6	6
Rhipicephalus evertsi evertsi				
Lepus saxatilis	1 (1)	0	5	5
Rhipicephalus simus				
Aethomys chrysophilus	19 (15)	106	48	154
Aethomys namaquensis	10 (10)	112	15	127
Mastomys natalensis	9 (5)	101	9	110
Mastomys coucha	10 (1)	1	0	1
Otomys angoniensis	1 (1)	11	10	21
Lemniscomys rosalia	1 (1)	9	3	12
Saccostomys campestris	3 (1)	1	0	1
Rattus rattus	1 (1)	1	0	1
Tatera leucogaster	5 (2)	2	1	3
Paraxerus cepapi	2 (2)	11	1	12
Rhipicephalus zambeziensis				
Paraxerus cepapi	2 (2)	11	18	29

Hyalomma species

The immature stages of *H. marginatum rufipes* and *H. marginatum turanicum* infest Cape hares, scrub hares and ground frequenting birds, and those of *H. truncatum* hares, gerbils and murid rodents (Rechav, Zeederberg & Zeller 1987; Horak & Fourie 1991; Horak *et al.* 1991; Braack *et al.* 1996). The distributions of *H. marginatum rufipes* and *H. marginatum turanicum* overlap in the southern Free State (Howell *et al.* 1978), and as we are unable to differentiate between their immature stages we have assigned

only the specific epithet *marginatum* to the ticks collected from hares and a four-striped grass mouse examined in this region. Both hare species were infested with the larvae and nymphs of *H. truncatum* and three rodent species with only the larvae of this tick. The immature stages of the three *Hyalomma* ticks are present on their preferred hosts from early autumn to early summer (Horak *et al.* 1991; 1993; Horak & Fourie 1991), and their presence in any study would thus be influenced by the season in which host animals are examined.

Rhipicephalus evertsi evertsi

The small number of rodents infested, and then only with larvae of this two-host tick, indicates that in contrast to hares, on which both larvae and nymphs were present, they are not good hosts. Although a large variety of domestic and wild ruminants are infested with *R. evertsi evertsi*, the preferred hosts of all stages of development are domestic and wild equids (Walker *et al.* 2000).

Rhipicephalus gertrudae

This tick replaces *R. simus* in the winter rainfall regions of south-western Western Cape Province and in the more arid regions of this province and Northern Cape Province as well as in the central and western regions of Free State Province (Walker *et al.* 2000). Its adult and immature stages have much the same host preference as *R. simus*, but in addition, the adults seem to favour primates, including humans (Brain & Bohrmann 1992; Walker *et al.* 2000; Horak, Fourie, Heyne, Walker & Needham 2002). The recovery of its larvae and nymphs only from *A. namaquensis* and *R. pumilio* and not from other small mammals within its distribution range does not necessarily reflect a host preference for these species, but may be influenced by the localities and seasons in which the mice were examined.

Rhipicephalus lounsburyi

The higher mountainous regions of the Eastern Cape Province are one of the preferred habitats of this tick (Walker *et al.* 2000). It has not previously been recorded in Free State Province, but Platberg, the locality at which it was collected from a four-striped grass mouse, forms part of the same mountain range in which it has been collected in the Eastern Cape Province. The adults attach around the feet of their antelope and sheep hosts, while the only known host of its immature stages is a four-striped grass mouse, from which a single nymph was collected (Walker *et al.* 2000).

Rhipicephalus simus

Of all species collected in the two northern provinces, the immature stages of *R. simus* has the largest host range, and judging by the numbers of larvae and the fact that nymphs also were recovered, most of the small mammal species examined could be considered as suitable hosts. Although cattle are frequently infested, the adults are parasites of the larger carnivore species, including domestic dogs, and of large monogastric animals such as zebras, rhinoceroses and warthogs (Horak *et al.* 2000; Walker *et al.* 2000).

Rhipicephalus warburtoni

The distribution of *R. warburtoni* is virtually confined to Free State Province (Walker *et al.* 2000). All stages of development prefer hares as hosts, while the adults are found on domestic and wild ruminants and the immature stages on rock elephant shrews (Walker *et al.* 2000). Its presence on all the spring hares, *Pedetes capensis*, and on some of the Namaqua rock mice examined indicates that these animals may also be suitable hosts. The adults, that at the time were identified as belonging to a species similar to *Rhipicephalus pravus*, produce a toxin causing paralysis in goat kids in the spring and early summer (Fourie, Horak & Marais 1988).

Other species

With the possible exception of those on scrub hares, we consider the remaining species to be accidental parasites or "stragglers" on the small mammals. The immature stages of *Amblyomma hebraeum* and *Amblyomma marmoreum* parasitize scrub hares and small carnivores (Horak *et al.* 1995; Horak *et al.* 2000), but are hardly ever found on rodents (Howell *et al.* 1989; Horak *et al.* 1991; Braack *et al.* 1996; Petney *et al.* 2004). The immature stages of *I. rubicundus* prefer rock elephant shrews and Smith's red rock rabbits, *Pronolagus rupestris* (Stampa 1959; Fourie *et al.* 1992), and the one-host ticks, *Margaropus winthemi* and *Rhipicephalus* (*Boophilus*) *decoloratus*, are parasites of large herbivores (Howell *et al.* 1978).

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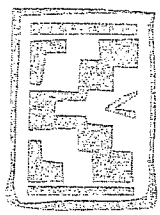

Elephant shrews as hosts of immature ixodid ticks

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ABSTRACT

FOURIE, L.J., HORAK, I.G. & WOODALL, P.F. 2005. Elephant shrews as hosts of immature ixodid ticks. *Onderstepoort Journal of Veterinary Research*, 72:293–301

Two hundred and seventy-three elephant shrews, consisting of 193 *Elephantulus myurus*, 67 *Elephantulus edwardii* and 13 animals belonging to other species, were examined for ixodid ticks at 18 localities in South Africa and Namibia. The immature stages of *Ixodes rubicundus*, *Rhipicentor nuttalli*, *Rhipicephalus warburtoni* and a *Rhipicephalus pravus*-like tick were the most numerous of the 18 tick species recovered. Substantial numbers of immature *Rhipicephalus arnoldi*, *Rhipicephalus distinctus* and *Rhipicephalus exophthalmos* were also collected from elephant shrews at particular localities.

Larvae of *I. rubicundus* were most numerous on *E. myurus* in Free State Province from April to July and nymphs from June to October. Larvae of *R. nuttalli* were most numerous on these animals during April, May, August and September, and nymphs in February and from April to August. The immature stages of *R. warburtoni* were collected from *E. myurus* only in Free State Province, and larvae were generally most numerous from December to August and nymphs from April to October.

Keywords: Elephant shrews, *Ixodes rubicundus*, ixodid ticks, macroscelids, *Rhipicentor nuttalli*, *Rhipicephalus warburtoni*

INTRODUCTION

The ixodid ticks that infest elephant shrews in southern Africa have been recorded by Theiler (1962), who listed 14 species, and reviewed by Fourie, Du Toit, Kok & Horak (1995), who list 22 species. The ticks that infest these small mammals are of more than purely academic interest in that rock elephant shrews, *Elephantulus myurus*, are the preferred hosts of the immature stages of three ticks capable of inducing paralysis in domestic animals (Fourie, Horak & Van Den Heever 1992a; Fourie, Horak, Kok & Van Zyl 2002). These ticks are *Ixodes rubicundus*, responsible for massive annual mortality amongst sheep (Spickett & Heyne 1988), *Rhipicentor nuttalli* that can cause paralysis in dogs (Perchman 1976; Norval & Colborne 1985), and *Rhipicephalus warburtoni* (then referred to as a tick belonging to the *Rhipicephalus pravus* group) that has been incriminated in paralysis in goat kids (Fourie, Horak & Marais 1988a).

The hosts of the immature and adult stages of *I. rubicundus* have been recorded by Stampa (1959) and Horak, Moolman & Fourie (1987a), and the role of *E. myurus* in the life cycle of this tick, colloquially

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known as the Karoo paralysis tick, has been highlighted by Du Toit, Fourie & Horak (1994a, b) and Fourie & Horak (1994). The hosts in Zimbabwe of adult *R. nuttalli* have been listed by Norval & Colborne (1985), while in South Africa the hosts of both adult and immature ticks have been recorded by Fourie *et al.* (2002), who established the details of its life cycle. Walker, Keirans & Horak (2000) have summarized the host records obtained by Fourie and his co-workers for *R. warburtoni* during extensive surveys they conducted in Free State Province between 1985 and 1991. Fourie *et al.* (1992a, 2002) have also documented the seasonal occurrence of the immature stages of the latter three ticks on *E. myurus*.

The economic importance of these ticks and the pivotal role of *E. myurus* in their life cycles prompted further surveys on these animals and on other species of elephant shrews, and the objective of this study was to determine both the species composition and seasonality of ticks that infest them. Fleas were also collected during the surveys and have been recorded by Beaucournu, Horak & Fourie (2003).

MATERIALS AND METHODS

Ticks were collected by one of two methods from elephant shrews. In the first *E. myurus* were trapped in box traps each month from August 1994 to June 1995 on the farm Spes Bona in central Free State Province. They were transported to the laboratory and individually caged above trays from which engorged larvae or nymphs that had detached were collected daily. Once all larvae and nymphs had detached, the elephant shrews were returned to their original habitats on the farm and released. The following month's trapping commenced a week after this release so that if the same shrews were recaptured they would have had adequate time to become re-infested with ticks. Despite intensive efforts no elephant shrews were trapped during July 1995.

TABLE 1 Elephant shrews and the localities at which they were examined for ixodid ticks

Elephant shrew species		Province or locality and coordinates
Common name	Scientific name (no. examined)	
Short-snouted elephant shrew	*Elephantulus brachyrynchus* (4)	Pilanesberg NR (25°15′S, 27°05′E)
Cape elephant shrew	*Elephantulus edwardii* (67)	Gifberg (31°47′S, 18°40′E)
Bushveld elephant shrew	*Elephantulus intufi* (1)	Clanwilliam (32°11′S, 18°54′E) Erongo (21°27′S, 15°52′E) (Namibia)
Rock elephant shrew	*Elephantulus myurus* (193)	Free State Province Môreson (28°48′S, 27°13′E) Spes Bona (29°07′S, 26°04′E) Wolvekop (29°27′S, 26°40′E) Langberg (29°36′S, 25°28′E) Preezfontein (29°50′S, 25°23′E) Welbedacht Dam (29°51′S, 26°53′E) Tussen-die-Riviere NR (30°29′S, 26°15′E) Northern provinces Mapungubwe (22°12′S, 29°21′E) Pafuri (23°27′S, 31°19′E) (KNP) Gustav Kliengbiel NR (25°06′S, 30°31′E) Pilanesberg NR (25°15′S, 27°05′E) Pretoria district (25°45′S, 28°12′E)
Smith's rock elephant shrew	*Elephantulus rupestris* (6)	Avis (22°35′S, 17°07′E) (Namibia) Beaufort West (32°21′S, 22°35′E)
Short-eared elephant shrew	*Macroscelides proboscideus* (1)	Victoria West (31°24′S, 23°07′E)
Four-toed elephant shrew	*Petrodromus tetradactylus* (1)	Pafuri (23°27′S, 31°19′E) (KNP)

NR= Nature Reserve KNP= Kruger National Park

The detached, engorged larvae and nymphs were washed in water to remove traces of urine and prevent the growth of fungi and were maintained at 20 °C and a relative humidity of approximately 90 % in permanent darkness. Once moulting was completed the various species were identified from the newly emerged nymphs or adults and counted. In the second method elephant shrews were captured in box traps, euthanased and their carcasses processed for the recovery of ticks as described by Fourie *et al.* (1992a).

The seasonal occurrence of the immature stages of *I. rubicundus*, *R. nuttalli* and *R. warburtoni* was determined from the average monthly tick burdens of *E. myurus* examined within Free State Province, the only province in which ticks were collected from elephant shrews during every month of the year.

RESULTS AND DISCUSSION

The species of elephant shrews examined, and the localities at which they were trapped are summarized in Table 1.

Tick collections were made at 18 localities from 273 elephant shrews belonging to seven species.

The ticks collected from the elephant shrews are summarized in Tables 2–8.

TABLE 2 Ixodid ticks collected from 66 *Elephantulus edwardii* on the farm Gifberg (31°47′S, 18°40′E) in the Western Cape Province

Tick species	Total number of ticks collected			Number of infested animals
	Larvae	Nymphs	Total	
Haemaphysalis hyracophila	1	2	3	2
Haemaphysalis leachi	1	0	1	1
Ixodes rubicundus	1 962	679	2 641	33
Rhipicephalus arnoldi	0	1	1	1
Rhipicephalus distinctus	15	1	16	11
Rhipicephalus exophthalmos	53	1	54	3
Rhipicephalus gertrudae	6	4	10	5
Rhipicephalus sp.	20	1	21	9

TABLE 3 Ixodid ticks collected from 54 *Elephantulus myurus* on the farm Langberg (29°36′S, 25°28′E) in Free State Province

Tick species	Total number of ticks collected			Number of infested animals
	Larvae	Nymphs	Total	
Amblyomma marmoreum	5	1	6	4
Haemaphysalis hyracophila	0	1	1	1
Hyalomma truncatum	1	0	1	1
Ixodes rubicundus	1 168	353	1 521	42
Rhipicephalus evertsi evertsi	1	1	2	2
Rhipicephalus warburtoni	1 862	672	2 534	54

TABLE 4 Ixodid ticks collected from 86* *Elephantulus myurus* on the farms Spes Bona (29°07′S, 26°04′E) and Wolvekop (29°27′S, 26°40′E) in Free State Province

Tick species	Total number of ticks collected			Number of infested animals
	Larvae	Nymphs	Total	
Haemaphysalis hyracophila	1	0	1	1
*Ixodes rubicundus***	146	538	684	37
Rhipicentor nuttalli	361	75	436	54
Rhipicephalus arnoldi	151	50	201	45
Rhipicephalus distinctus	4	1	5	4
Rhipicephalus warburtoni	2 162	609	2 771	70

* = Although ticks were collected from 86 animals, only those from 72 animals were identified

** = Engorged larvae and nymphs of *I. rubicundus* that detached from 21 heavily infested animals were used for experimental purposes without their numbers being recorded

TABLE 5 Ixodid ticks collected from 24 *Elephantulus myurus* on the farm Môreson (28°48′S, 27°13′E) in Free State Province

Tick species	Total number of ticks collected			Number of infested animals
	Larvae	Nymphs	Total	
Hyalomma marginatum rufipes	1	0	1	1
Ixodes rubicundus	13	87	100	14
Rhipicentor nuttalli	147	70	217	22
Rhipicephalus distinctus	2	0	2	2
Rhipicephalus warburtoni	171	69	240	20

TABLE 6 Ixodid ticks collected from 8 *Elephantulus myurus* at various localities in Free State Province

Tick species	Number of ticks collected			Infested animals	Coordinates of collection localities
	Larvae	Nymphs	Total		
Hyalomma truncatum	0	8	8	1	(30°29′S, 26°15′E)
Ixodes rubicundus	155	117	272	6	(29°50′S, 25°23′E) (29°51′S, 26°53′E) (30°29′S, 26°15′E)
Rhipicephalus evertsi evertsi	1	0	1	1	(29°51′S, 26°53′E)
Rhipicephalus warburtoni	421	47	468	7	(29°50′S, 25°23′E) (29°51′S, 26°53′E) (30°29′S, 26°15′E)

TABLE 7 Ixodid ticks collected from 21 *Elephantulus myurus* in the four northern provinces of South Africa

Tick species	Number of ticks collected			Infested animals	Coordinates of collection localities
	Larvae	Nymphs	Total		
Ixodes bakeri	0	0	1 female	1	(25°06′S, 30°31′E)
Rhipicentor nuttalli	176	117	293	13	(23°27′S, 31°19′E) (25°45′S, 28°12′E)
Rhipicephalus pravus group	679	158	837	13	(23°27′S, 31°19′E) (25°15′S, 27°05′E) (25°45′S, 28°12′E)

Eighteen tick species were recovered and the immature stages of *I. rubicundus*, *R. nuttalli*, *R. warburtoni* and a *Rhipicephalus pravus*-like tick were the most numerous of these. However, substantial numbers of immature *Rhipicephalus arnoldi*, *Rhipicephalus distinctus* and *Rhipicephalus exopthalmos* were also collected from elephant shrews at particular localities.

Ixodes rubicundus

Large numbers of larvae and nymphs of *I. rubicundus* were collected from *E. myurus* in Free State Province and from *Elephantulus edwardii* in Western Cape Province in the present study. Stampa (1959) collected approximately 200 larvae and nymphs from nine *Elephantulus* spp. in the New Bethesda region of the Eastern Cape Province, and more than 2 600 from 76 Smith's red rock rabbits, *Pronolagus rupestris*, at the same locality. On the other hand, Horak & Fourie (1991) recovered only six larvae from 28 red rock rabbits they examined on two farms in south-western Free State Province, whereas 132 rock elephant shrews examined on the same farms harboured 4 331 larvae and nymphs (Fourie *et al.* 1992a). It would thus appear that these small mammals supplant each other as hosts for the immature stages of *I. rubicundus* depending upon locality and environment.

Larvae were most numerous on rock elephant shrews in Free State Province from April to July and

TABLE 8 Ixodid ticks collected from various species of elephant shrews at several localities

Elephant shrew species (no. examined)	Locality	Tick species (no. of infested animals)
Elephantulus brachyrynchus (4)	Pilanesberg, North West Province	*Hyalomma truncatum* 1 larva (1) *Ixodes* sp. 1 nymph (1) *Rhipicephalus pravus* group 48 nymphs (4)
Elephantulus edwardii (1)	Clanwilliam, Western Cape Province	*Ixodes rubicundus* 2 nymphs (1) *Rhipicentor nuttalli* 7 nymphs (1)
Elephantulus intufi (1)	Erongo, Namibia	*Rhipicentor nuttalli* 3 nymphs (1)
Elephantulus rupestris (1)	Beaufort West, Western Cape Province	*Rhipicephalus* sp. 8 larvae, 11 nymphs (1)
Elephantulus rupestris (5)	Avis, Namibia	*Rhipicephalus exophthalmos* 1 larva, 35 nymphs (5) *Rhipicephalus* sp. 1 nymph (1)
Macroscelides proboscideus (1)	Victoria West, Northern Cape Province	*Rhipicephalus exophthalmos* 51 larvae, 15 nymphs (1)
Petrodromus tetradactylus (1)	Pafuri, Limpopo Province	*Haemaphysalis leachi* 2 nymphs (1) *Rhipicephalus kochi* 1 larva, 74 nymphs (1)

nymphs from June to October (Fig. 1A), matching the seasonal occurrence recorded by Fourie *et al.* (1992a) on these animals in south-western Free State Province during 1985. The 4-month difference in peak activity between larvae and nymphs (April to August) agrees with the observations of Stampa (1959) and Fourie *et al.* (1992a) and represents the moulting period of detached larvae and their subsequent attachment to hosts as newly moulted nymphs.

The vast majority of larvae that infest elephant shrews during autumn and early winter originate from eggs deposited by females during the winter of the previous year. These eggs over-summer in a state of diapause and larvae only hatch in autumn (Fourie & Horak 1994). Engorged nymphs that detach from elephant shrews in late winter and spring also over-summer in a state of diapause and only moult to adults during late summer and autumn of the following year (Fourie & Horak 1994). The life cycle thus takes 2 years to complete, with the immature stages present during the cooler months of the first year and the adults during the same months of the second year.

Stampa (1959) collected adult *I. rubicundus* from several wild carnivores in the New Bethesda region, and Horak *et al.* (1987a) have suggested that caracals, *Caracal caracal*, are one of the preferred hosts of this tick. Subsequent collections from wild carnivores as well as from domestic dogs indicate that several species are suitable hosts for adult *I. rubicundus* (Horak, Braack, Fourie & Walker 2000; Jacobs, Fourie, Kok & Horak 2001; Horak & Matthee 2003). Wild bovids that frequent mountain slopes, namely mountain reedbuck, *Redunca fulvorufula*, grey rhebok, *Pelea capreolus*, and eland, *Taurotragus oryx*, as well as domestic sheep on mountainous pastures, also serve as hosts for adult ticks (Stampa 1959; Fourie *et al.* 1988b; Horak, Fourie, Novellie & Williams 1991). Paralysis in sheep and goats is positively correlated with the intensity of infestation of female *I. rubicundus* and is observed during the cooler months of the year (Fourie, Petney, Horak & De Jager 1989; Fourie, Horak & Van Zyl 1992b).

Rhipicentor nuttalli

The genus *Rhipicentor* contains only two species, *Rhipicentor bicornis* and *Rhipicentor nuttalli*, whose distributions are restricted to Africa (Theiler 1961, 1962). *R. nuttalli* has been recorded in the Eastern and Western Cape, Free State, Gauteng, North-West and Limpopo provinces, South Africa (Theiler 1961; Du Toit 1993). In Namibia it occurs north of Windhoek, and it is also present in Botswana and Zimbabwe (Theiler 1961; Norval & Colborne 1985). In this study its immature stages were collected from *E. myurus* in central Free State Province, northern Gauteng Province and in northern and north-eastern Limpopo Province, and from *E. edwardii* in south-western Western Cape Province and *Elephan-*

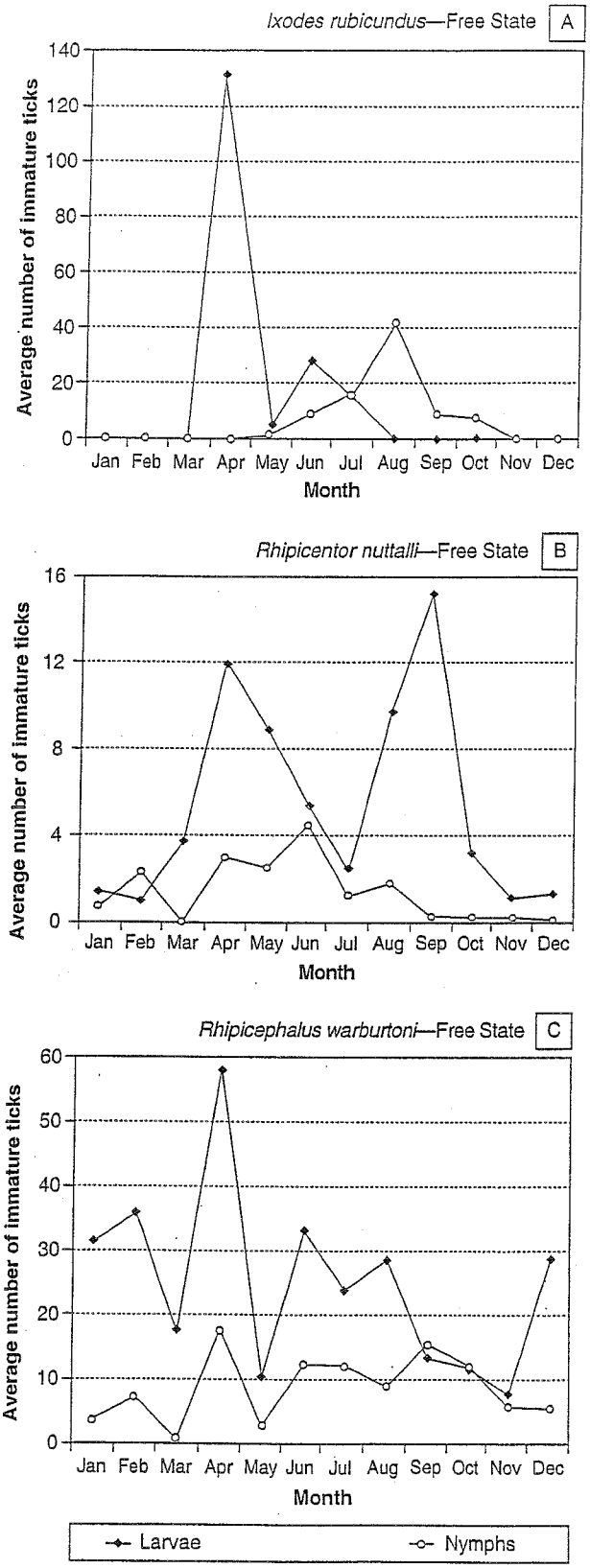

FIG. 1 The seasonal occurrence of the immature stages of (A) *Ixodes rubicundus*, (B) *Rhipicentor nuttalli*, and (C) *Rhipicephalus warburtoni* on rock elephant shrews in Free State Province, South Africa

tulus intufi at Erongo, Namibia. *R. bicornis* occurs in the northern regions of South Africa and in Zimbabwe, northern Namibia and Zambia, and is widely distributed in Central Africa (Theiler 1961; Walker 1991).

The hosts of the immature stages of *R. nuttalli* were unknown until Du Toit (1993) collected larvae and nymphs from *E. myurus* in Free State Province. Adult *R. nuttalli* has been collected from domestic dogs and several wild carnivore species as well as from the South African hedgehog, *Atelerix frontalis* and porcupine, *Hystrix africaeaustralis* (Theiler 1961; Walker 1991; Horak *et al.* 2000). Norval & Colborne (1985) state that whereas *R. nuttalli* is known in South Africa as the hedgehog tick, their findings in Zimbabwe indicate that the adults are principally parasites of leopards, *Panthera pardus*, and that its distribution is restricted to the rocky habitats normally favoured by these animals.

The large number of *E. myurus* infested with *R. nuttalli* in the present study confirms the observation by Du Toit (1993) that they are hosts of the immature stages of this tick. The collection of nymphs from *E. edwardii* and *E. intufi* suggests that these animals, and possibly other species of elephant shrews, are also suitable hosts for the immature stages of this tick, particularly in those regions in which *E. myurus* does not occur.

Although immature ticks were present on *E. myurus* throughout the year, the majority of larvae were collected in April and May and during August and September and nymphs in February and from April to August (Fig. 1B). This differs somewhat from the findings of Fourie *et al.* (2002), also in Free State Province, that larvae were generally most numerous during the period March to September, and nymphs during May to October. Theiler (1962) noted that adult ticks are common on dogs in the Clanwilliam district in the Western Cape Province and in the Omaruru district, Namibia during late summer. In Gauteng and Free State Provinces adult ticks have been collected from wild carnivores in September, October and December (Horak *et al.* 2000). In Zimbabwe, however, Norval & Colborne (1985) found that adult ticks were present throughout the year.

Rhipicephalus arnoldi

This tick utilizes Smith's red rock rabbits as hosts for all its developmental stages (Horak *et al.* 1991; Horak & Fourie 1991), but large numbers of immature ticks have also been collected from rock das-

sies, *Procavia capensis* (Horak & Fourie 1986; Horak *et al.* 1991). It has been suggested by Horak & Fourie (1986) that, even if those on rock dassies are taken into account, the low ratio of immature to adult ticks implies that some other animal could also harbour considerable numbers of immature ticks of this species. It would now appear as if rock elephant shrews might fulfil this role in Free State Province. As their common names imply rock dassies, red rock rabbits and rock elephant shrews inhabit the same rocky habitats (Skinner & Smithers 1990), and since they all have dense pelts it is not surprising that they host some tick species in common. However, whereas rock dassies are also hosts of adult *Haemaphysalis hyracophila* and adult *R. distinctus*, and red rock rabbits of adult *R. arnoldi* (Horak & Fourie 1986, 1991; Horak *et al.* 1991), rock elephant shrews harbour only the immature stages of these species.

Rhipicephalus distinctus

This is a tick of rock dassies (Horak & Fourie 1986; Walker *et al.* 2000), and sympatry between these animals and elephant shrews probably contributed to its presence on 11 *E. edwardii* in the Western Cape Province (Table 2) and on six *E. myurus* in Free State Province (Tables 4 and 5).

Rhipicephalus exophthalmos

Two *E. edwardii* examined in the Western Cape Province were infested with larvae and one with a nymph of *R. exophthalmos* (Table 2). The immature stages of this tick were also present on *Elephantulus rupestris* at Avis, Namibia, and on the single *Macroscelides proboscideus* examined at Victoria West, Northern Cape Province (Table 8). Scrub hares, *Lepus saxatilis*, which incidentally are also hosts of adult *R. exophthalmos*, are the only other animals recorded as hosts for the immature stages of this tick (Walker *et al.* 2000). Theiler (1962) lists nearly all elephant shrew species as hosts of the immature stages of a closely related species, namely *Rhipicephalus oculatus*. It is, however, possible that several of her records refer to *R. exophthalmos*, which has only recently been described (Keirans, Walker, Horak & Heyne 1993).

Rhipicephalus gertrudae

The adults of *R. gertrudae* feed on domestic and wild ruminants and carnivores and its immature stages on murid rodents (Walker *et al.* 2000; Horak & Matthee 2003) and the presence of its immature stages on *E. edwardii* in the Western Cape Province is possibly accidental (Table 2). This tick occurs in the southern, central and western regions of South Africa and in Namibia (Walker *et al.* 2000).

Rhipicephalus kochi

Although widespread elsewhere in East Africa, *R. kochi* has been collected only in the far north-east of Limpopo and KwaZulu-Natal Provinces in South Africa. The preferred hosts of all stages of development are medium-sized and larger antelopes and scrub hares (Walker *et al.* 2000). Judging by the single larva and large number of nymphs collected from the single four-toed elephant shrew examined at Pafuri in north-eastern Limpopo Province (Table 8), these animals appear to be good hosts of the immature stages of *R. kochi*.

Rhipicephalus pravus group

The immature stages of this *R. pravus*-like tick were present on *E. myurus* in northern Gauteng Province and north-eastern Limpopo Province, and its nymphs on *E. myurus* and *Elephantulus brachyrynchus* in North-West Province (Tables 7 and 8). All its parasitic stages have been collected from scrub hares at Shingwedzi and Pafuri in the Kruger National Park in north-eastern Limpopo Province, and on farms in the north-west of this province (Horak, Spickett, Braack & Penzhorn 1993; Horak, Spickett, Braack, Penzhorn, Bagnall & Uys 1995). Walker *et al.* (2000) place *R. arnoldi*, *R. exophthalmos*, *R. kochi*, *R. oculatus*, *R. pravus* and *R. warburtoni* in the *R. pravus* group of ticks on the morphological characters of their immature stages and suggest that these stages favour macroscelids as hosts. The validity of their grouping is supported by the present study in which, with the exception of those of *R. oculatus*, the immature stages of all these ticks were collected from elephant shrews.

Rhipicephalus warburtoni

This tick has only recently been described (Walker *et al.* 2000). It was previously variously referred to as an atypical strain of *Rhipicephalus appendiculatus* (Theiler 1949); as *Rhipicephalus pravus* (Theiler 1962); as an *R. pravus*-like tick (Fourie *et al.* 1988a, b); as an *Rhipicephalus punctatus*-like tick (Fourie & Horak 1990); and as *Rhipicephalus punctatus* in several publications by Fourie & Horak and their co-workers. The preferred hosts of the adults are domestic and wild ruminants and hares, and elephant shrews and hares are the preferred hosts of the immature stages (Fourie *et al.* 1992a; Walker *et al.* 2000). Its distribution is virtually confined to the

central and southern regions of Free State Province (Walker *et al.* 2000), and its presence on 171 of the 182 *E. myurus* examined in this province is thus not unexpected (Tables 3–6).

Larvae were generally most numerous from December to August and nymphs from April to October (Fig. 1C). With the exception of April, when larval numbers were exceptionally high, this pattern of seasonality is fairly similar to that recorded by Fourie *et al.* (1992a). Most adults of this species are present on Angora goats in south-western Free State Province from September or November to February (Fourie & Horak 1991), and it was during this period that paralysis was observed in goat kids (Fourie *et al.* 1988a).

Other species

The immature stages of the remaining tick species should all be considered as "stragglers". Adult *Amblyomma marmoreum* infests tortoises and its immature stages are found on these animals as well as ground-frequenting birds, hares, carnivores and ruminants (Norval 1975; Horak, MacIvor, Petney & De Vos 1987b). Adult and immature *H. hyracophila* are parasites of rock dassies (Horak & Fourie 1986), whereas adults of *Haemaphysalis leachi* are parasites of carnivores and its immature stages of murid rodents (Norval 1984; Fourie *et al.* 1992a). However, the latter may also occur on the same hosts as the adults (Horak & Matthee 2003). Adult *Hyalomma marginatum rufipes* and *Hyalomma truncatum* infest large herbivorous animals and their immature stages infest hares (Norval 1982; Horak & Fourie 1991). All stages of development of *Ixodes bakeri* infest shrews and rodents, with a particular preference for *Otomys* spp. (Walker 1991), while adult *Rhipicephalus evertsi evertsi* feeds on equids and ruminants and its immature stages on these animals and on hares (Walker *et al.* 2000).

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EPIFAUNISTIC ARTHROPOD PARASITES OF THE FOUR-STRIPED MOUSE, *RHABDOMYS PUMILIO*, IN THE WESTERN CAPE PROVINCE, SOUTH AFRICA

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ABSTRACT: Flea, lice, mite, and tick species associated with 510 *Rhabdomys pumilio* were collected at 9 localities in the Western Cape Province, South Africa. The aims of the study were first to quantify the species richness, prevalence, and relative mean intensity of infestation of epifaunistic arthropod species associated with *R. pumilio*, and second to determine temporal variations in the mean abundance of the parasitic arthropods. Each mouse was examined under a stereoscopic microscope and its parasites were removed, identified, and quantified. The epifaunal population was made up of more than 25,000 individuals and included 8 flea, 1 sucking louse, 11 mite, and 13 ixodid tick species. Female-biased sex ratios were noted for 9 (30%) of the ectoparasite species. Three undescribed mite and 1 undescribed tick species were recovered, and new locality records for 2 flea, the louse, and 2 mite species were documented. A phoretic host association between a nonparasitic mite species, *Psylloglyphus uilenbergi kivuensis*, and 3 flea species, *Chiastopsylla rossi*, *Hypsophthalmus temporis*, and *Listropsylla agrippinae*, was recorded. The mean abundance of the parasitic mite and insect species were higher during the cold wet season, whereas ticks were more numerous during the warm dry months. The large number of ectoparasite species on *R. pumilio*, a locally abundant and regionally widespread species, is of medical and veterinary importance particularly in relation to the transmission of pathogens such as *Anaplasma marginale*, *Babesia caballi*, and *Babesia canis* to domestic animals; *Rickettsia conori*; *Yersinia pestis*; and the viral disease Crimean-Congo hemorrhagic fever to humans.

Because of their large numbers, short generation intervals, and their capacity for rapid and maintained population growth, small mammals play an important role in maintaining ecosystems. It is also evident that the ecology of small mammals is partly driven by parasites, which, in some instances, may directly be responsible for natural population fluctuations (Holmes and Price, 1986; Scott, 1987; Hudson et al., 1998; Torchin et al., 2001). The four-striped mouse, *Rhabdomys pumilio*, is a locally abundant and regionally widespread species that occurs endemically throughout southern Africa (De Graaf, 1981). It has successfully adapted from natural to urbanized habitats and may be regarded as a pest species in certain agricultural areas because of frequent population explosions. *Rhabdomys pumilio* is a host for several species of parasites, but few quantitative data are available for its parasite community (Tipton, 1960; Zumpt, 1961; De Meillon et al., 1961; Till, 1963; Ledger, 1980; De Graaf, 1981; Horak et al., 1986, 2005; Howell et al., 1989; Segerman, 1995; Horak and Boomker, 1998; Petney et al., 2004). Some of the parasites that infest *R. pumilio* are of importance in the etiology of zoonotic diseases in humans, and they may be involved in the transmission of diseases of domestic and wild animals (Walker, 1991). In addition, a survey conducted between 1972 and 1981 of rodent species associated with plague in South Africa revealed antibodies to the plague bacterium *Yersinia pestis* in *R. pumilio* and other rodents in the Eastern Cape Province (Shepherd and Leman, 1983).

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Previous parasitological studies conducted on *R. pumilio* recorded the intensities and prevalence of ixodid ticks at several localities throughout South Africa, including 1 locality in the Western Cape (WC) Province (Rechav, 1982; Horak et al., 1986, 2005; Howell et al., 1989; Horak and Boomker, 1998; Petney et al., 2004). Most of these studies were conducted at a single locality and involved monthly or bimonthly sampling of less than 9 mice per mo (Rechav, 1982; Horak et al., 1986; Howell et al., 1989; Petney et al., 2004), whereas 1 study involved a single annual sampling of a total of 25 mice over a 10-yr time period (Horak and Boomker, 1998). Temporal variation in the intensities of infestation of some tick species was recorded in 2 studies conducted in the Eastern Cape Province (Rechav, 1982; Petney et al., 2004). The number of tick species collected during these studies ranged between 1 and 8, and species composition differed among geographic regions (Horak et al., 1986, 2005; Howell et al., 1989; Petney et al., 2004). Between 3 and 6 species were recovered at 1 locality in the WC (Horak et al., 1986; Horak and Boomker, 1998), 4 and 6 species at 2 localities in the Eastern Cape Province (Howell et al., 1989; Petney et al., 2004), and 8 tick species in Free State Province (Horak et al., 2005). However, the accuracy of the species representation for the particular geographic region determined by these studies may be confounded by variations in the sample effort as 25 or fewer mice were examined in most of them (Walther et al., 1995; Poulin and Morand, 2004).

Little is known about the diversity of ectoparasites, especially of fleas, lice, and mites, associated with small mammals in the WC. This region encompasses the Cape Floristic Region (CFR), which, because of its high level of plant diversity and endemism, is a global biodiversity hot spot (Myers et al., 2000). It has been suggested that much of the diversity and endemism associated with this region is due to a heterogeneous topography exposed to cyclic changes during the Pleistocene (Midgley et al., 2005). The rich floral components also support a magnitude of diverse fauna (Picker and Samways, 1996). However, the likelihood of whether the high plant diversity in this region is mirrored by a high invertebrate diversity, particularly of ectoparasites, has received little attention (Picker and Samways, 1996).

TABLE I. Locality information and number of *Rhabdomys pumilio* (n = 510) examined in the Western Cape Province, South Africa, 2003–2004.

Locality	GPS*	No. of sites	Sample size	Sample date
Nature reserves				
Hottentotsholland	34.05308 S, 19.18311 E	5	42	26 Nov. 2003
Jonkershoek	33.98798 S, 18.95541 E	4	41	4 Sept. 2004
Riverlands	33.29272 S, 18.34436 E	4	24	13 Sept. 2004
Helderberg	34.05678 S, 18.86751 E	3	50	8 Dec. 2003
Elandsberg Res	33.44032 S; 19.05064 E	3	98	16 Feb. 2004
			(41, 16, 9, 32)†	1 June 2004
				7 Sept. 2004
				29 Nov. 2004
Agricultural areas				
De Rust	34.17366 S, 19.90833 E	5	51	8 Oct. 2003
Zevenwacht	33.91749 S, 18.73224 E	3	43	3 Nov. 2004
Cordoba	34.03428 S, 18.84764 E	2	57	6 Nov. 2004
Elandsberg Agr	33.44794 S; 19.02741 E	3	104	16 Feb. 2004
			(46, 24, 8, 26)†	1 June 2004
				7 Sept. 2004
				29 Nov. 2004

* GPS = global positioning system.
† Number of *R. pumilio* sampled during February, June, September, and December 2004, respectively.

Using *R. pumilio* as a model entity, the first aim of this study was to quantify the species richness, prevalence, and relative mean intensity of infestation of epifaunistic arthropod species on a small mammal species in the WC. By sampling a large number of host individuals from 9 localities, we hoped to expand the current knowledge of ectoparasites of mammals in the CFR and to provide a comprehensive list of the epifaunistic arthropod fauna occurring on *R. pumilio*. The species list also will supply information on the importance of *R. pumilio* as a host of ectoparasite taxa of veterinary and medical importance. As a second aim, we wanted to provide data on temporal variation in the mean abundance of the ectoparasitic taxa associated with *R. pumilio* in the WC. The latter aim not only will give a better understanding of the dynamics of particular ectoparasite species in this region but also will contribute baseline information toward selecting appropriate sampling periods to address macroecological and parasite community ecology questions.

MATERIALS AND METHODS

The project was approved and permits were issued by the Ethical Committee of the University of Stellenbosch and the Western Cape Nature Conservation Board, respectively. *Rhabdomys pumilio* were trapped at 9 localities in the WC (a winter rainfall region). The localities included 5 pristine lowland Fynbos/Renosterveld regions and 4 bordering agricultural areas (Table I). The localities all lay within a 200-km radius. All were approximately 400 m above sea level, and various antelope and small mammal species were associated with each. Live traps (Sherman-type) with peanut butter and oat bait were used to trap between 24 and 57 mice per locality during October to December (spring and summer months; generally dry and warm conditions) in 2003 and 2004 (Table I). The aim was to trap 40–60 mice in the shortest time possible at each of the localities. Adult mice (mass > 40 g) were mainly sampled during this trapping period. In addition, seasonal trapping of *R. pumilio* was conducted over 8 trap nights (1 trap night equals a 12-hr period) every 3–4 mo (February, June, September, and December) at 2 adjacent localities within proximity to each other (Table I). The traps were checked daily during each trapping period.

Once trapped, the animals were identified and either killed with Fluothane (for *R. pumilio*) or released at the trap site (any nontarget species). Each mouse was individually placed in a premarked plastic bag and frozen for later examination. The entire thawed animal was systematically examined under a stereoscopic microscope by using forceps to remove ectoparasites. All fleas, lice, mites, and ticks were collected; identified to species, where possible; and counted. Adult ticks were collected from vegetation, from clothes of researchers, or from resident domestic dogs at some of the study sites.

The use of the terms prevalence (the number of hosts infected with 1 or more individuals of a particular parasite species divided by the number of hosts examined for that parasite species), relative mean intensity (a standardized comparison of the average intensity of each of the several species in the host sample), and species richness (the number of species present in a collection) follows the definitions as outlined in Bush et al. (1997).

RESULTS

Although the aim was to trap 40 or more *R. pumilio* at each of the 9 localities, this number was unfortunately not possible to achieve at Riverlands, where we only managed to trap 24 mice during a 4-wk trapping period (Table I). *Rhabdomys pumilio* populations are well known to show a strong seasonal fluctuation in the WC (David and Jarvis, 1985). This fluctuation was evident in the host density records for the 2 Elandsberg localities, with the population reaching its trough in September followed by a summer peak (December–February; Table II), in agreement with David and Jarvis (1985). Therefore, the host density fluctuation pattern recorded here is considered to be a seasonal effect and not a consequence of trapping without replacement. In total, 33 ectoparasite species (representing 17 genera) were collected from 510 *R. pumilio* in the WC (Table II). Of these 510 individuals, 317 were reproductively active adults (187 males, 130 females), and 193 were reproductively nonactive adults (98 males, 95 females). The number of tick species recovered represents 39.4% of the total ectoparasite species composition, followed by the mites (33.3%), fleas (24.2%), and the sucking louse (3.1%). Ticks represented 77.7% of the

TABLE II. Epifaunistic arthropod species list for 510 *Rhabdomys pumilio* in the Western Cape Province, South Africa, 2003–2004.

	Order	Suborder	Family/subfamily	Species
Fleas	Siphonaptera		Chimaeropsyllidae	
			Chiastopsyllinae	*Chiastopsylla numae* (Rothschild, 1904)
				C. rossi (Waterston, 1909)
			Chimaeropsyllinae	*Hypsophthalmus temporis* (DeMeillon, 1940)
			Ctenophthalmidae	
			Dinopsyllinae	*Dinopsyllus ellobius* (Rothschild, 1905)
				D. lypusus (Jordan & Rothschild, 1913)
				D. tenax (Jordan, 1930)
			Hystrichopsyllidae	
			Listropsyllinae	*Listropsylla agrippinae* (Rothschild, 1904)
			Pulicidae	
			Xenopsyllinae	*Xenopsylla hirsuta* group
Louse	Phthiraptera	Anoplura	Polyplacidae	*Polyplax arvicanthis* (Bedford, 1919)
Mites	Parasitiformes	Mesostigmata	Laelaptidae	
			Laelaptinae	*Androlaelaps dasymys* (Radford, 1939)
				A. fahrenholzi (Berlese, 1911)
				Androlaelaps sp.
				Laelaps giganteus (Berlese, 1918)
				Laelaps sp. near *tillae* (Taufflieb, 1959)
				Laelaps sp.
				L. paraspinosa (Tipton, 1960)
			Macrochelidae	*Macrocheles* sp.
			Macronyssidae	*Ornithonyssus bacoti* (Hirst, 1913)
			Trombiculidae	Uncertain genus (1 specimen)
	Acariformes	Astigmata	Winterschmidtiidae	*Psylloglyphus uilenbergi kivuensis* (Fain & Beaucournu, 1976)
Ticks	Parasitiformes	Ixodida	Ixodidae	
			Amblyomminae	*Amblyomma sylvaticum* (De Geer, 1778)
			Haemaphysalinae	*Haemaphysalis aciculifer* (Warburton, 1913)
				H. leachi (Audouin, 1827)
			Hyalomminae	*Hyalomma truncatum* (Koch, 1844)
			Ixodinae	*Ixodes alluaudi* (Neumann, 1913)
				I. bakeri (Arthur & Clifford, 1961)
				I. rubicundus (Neumann, 1904)
				Ixodes sp.
			Rhipicephalinae	*Rhipicephalus capensis* (Koch, 1844)
				R. follis (Dönitz, 1910)
				R. gertrudae group
				R. lounsburyi (Walker, 1990)
				R. simus (Koch, 1844)

total number of ectoparasites collected followed by the sucking louse (12.4%), mites (7.4%), and fleas (2.5%) (Table III).

Eight flea species belonging to 5 genera were recovered (Table II). *Chiastopsylla rossi* was the most numerous flea species and was present on 27.5% of the mice. *Listropsylla agrippinae* was the second most numerous flea followed by *Hypsophthalmus temporis*. Female-biased sex ratios were recorded for these 3 species (Table III).

Polyplax arvicanthis was the only louse species recovered and was present on approximately 60.0% of mice (Tables II, III). Nymphs (instars I, II, and III combined) were the most numerous life stage, and the number of female lice exceeded that of the males (Table III).

Eleven mite species representing 6 genera were recovered (Table II). Of these species, *Androlaelaps fahrenholzi* was the most numerous and was present on 50.2% of *R. pumilio*. *Laelaps giganteus* was the second most numerous mite. In addition, 3 undescribed mite species were recorded, *Androlaelaps* sp., *Laelaps* sp. near *tillae*, and a *Laelaps* sp. The latter species was the third most numerous mite. The 3 new species will be described in a separate publication. An unidentified trombiculid (chigger) larva was found on 1 mouse. In addition, chigger larvae also were present on a few mice, specifically anterodorsally on the body near the base of the tail. Unfortunately, the intensity of infestation and prevalence of these mites were not recorded. A nonparasitic predatory mite, *Macrocheles* sp. and a winterschmidtiid mite, *Psylloglyphus uilenbergi kivuensis*, also were present. The mite *P. u. kivuensis* was phoretically associated with 3 flea species (*C. rossi*, *H. temporis*, and *L. agrippinae*) collected from 6 mice. Female-biased sex ratios were recorded for all mite species represented by more than 20 individuals.

Thirteen ixodid tick species, representing 5 genera, were recovered from the mice (Table II). Ticks of the *Rhipicephalus gertrudae* group were the most numerous and prevalent (82.2%; Table III). Similar numbers of *Haemaphysalis leachi*, *Hyalomma truncatum*, and *Ixodes bakeri* were recovered, whereas the prevalence on the rodents of *H. leachi*, *H. truncatum*, and the

TABLE III. Fleas, lice, mites, and ticks recovered from 510 *Rhabdomys pumilio* in the Western Cape Province, South Africa, 2003–2004. Proportions for higher parasite taxa are indicated in bold.

Ectoparasite species	Larvae (%)	Nymphs (%)	Adults (%)	Sex ratio (♂:♀)	Relative mean intensity (%)	Prevalence (%)
Fleas			**100**	**1:1.37**	**2.47**	**46.7**
Chiastopsylla numae			100	1:1	0.01	0.2
Chiastopsylla rossi			100	1:1.27	1.15	27.5
Dinopsyllus ellobius			100	1:1.09	0.09	4.5
Dinopsyllus lypusus			100	1:0.75	0.03	1.0
Dinopsyllus tenax			100	1:0.53	0.11	4.5
Hypsophthalmus temporis			100	1:2.40	0.46	15.5
Listropsylla agrippinae			100	1:1.31	0.62	17.8
Xenopsylla hirsuta spp.			100	0:3	0.01	0.4
Louse						
Polyplax arvicanthis	0	45.30	54.70	1:1.37	12.43	59.2
Mites	**0.05**	**10.63**	**89.32**	**1:12.14**	**7.40**	**68.2**
Androlaelaps dasymys	0	23.08	76.92	1:11	0.3	8.4
Androlaelaps fahrenholzi	0	17.45	82.55	1:8.14	3.75	50.2
Androlaelaps sp.	0	28.57	71.43	1:14	0.08	1.4
Laelaps sp. near *tillae*	0	2.13	97.87	1:22	0.18	5.9
Laelaps giganteus	0	0.15	99.85	1:128.80	2.5	38.4
Laelaps paraspinosa	0	0	100	0:1	0.004	0.2
Laelaps sp.	0	0.96	99.04	1:50.50	0.4	2.6
Ornithonyssus bacoti	0	0	100	0:2	0.01	0.2
Macrocheles sp.	0	0	100	0:1	0.004	0.2
Trombiculidae sp.	100	0	0		0.004	0.2
Psylloglyphus uilenbergi kivuensis	0	100	0		0.01	1.2
Ticks	**91.42**	**8.30**	**0.27**	**1:26.50**	**77.70**	**90**
Amblyomma sylvaticum	100	0	0	0	0.01	0.2
Haemaphysalis aciculifer	97.60	2.40	0	0	0.01	11.0
Haemaphysalis leachi	93.21	6.79	0	0	6.23	31.4
Hyalomma truncatum	80.20	19.80	0	0	6.04	26.5
Ixodes alluaudi	27.27	27.27	45.45	0:5	0.04	1.8
Ixodes bakeri	75.65	20.81	3.54	1:23.50	5.32	43.0
Ixodes rubicundus	100	0	0	0	0.02	0.4
Ixodes sp.	78.45	21.46	0.09	0:1	4.32	32.4
Rhipicephalus gertrudae group	95.24	4.76	0	0	54.45	82.2
Rhipicephalus lounsburyi	0	100	0	0	0.17	4.7

TABLE IV. Adult ticks collected from vegetation, human clothing, dogs, a shrew, and a tortoise at the study sites.

Tick species	No. of adult ticks collected		
	Males	Females	Total
Amblyomma marmoreum	0	1	1
Amblyomma sylvaticum	10	1	11
Haemaphysalis aciculifer	5	1	6
Hemaphysalis leachi	77	129	206
Hyalomma truncatum	0	1	1
Ixodes alluaudi	0	1	1
Ixodes pilosus group	8	52	60
Ixodes rubicundus	5	28	33
Rhipicephalus gertrudae	427	489	916
Rhipicephalus lounsburyi	2	1	3
Total	534	704	1,238

immature stages of an undescribed *Ixodes* species was similar (26.5–32.4%). Larvae were the most numerous of the life stages collected (91.4%), followed by nymphs (8.3%). In total, 1,238 adult ticks belonging to 10 species, were collected from the vegetation, researchers' clothing, domestic dogs, an angulate tortoise, and a shrew at the study sites (Table IV). Of these, ticks of the *R. gertrudae* group, followed by *H. leachi* and ticks of the *Ixodes pilosus* group, were the most numerous.

The seasonal mean abundance and prevalence of 7 fleas (*Chiastopsylla numae*, *C. rossi*, *Dinopsyllus ellobius*, *Dinopsyllus lypusus*, *Dinopsyllus tenax*, *L. agrippinae*, and *Xenopsylla hirsuta* group), the single louse (*P. arvicanthis*), 7 mites (*Androlaelaps dasymys*, *A. fahrenholzi*, *Androlaelaps* sp., *Laelaps* sp near *tillae*, *L. giganteus*, *Laelaps* sp., and *Ornithonyssus bacoti*), and 5 tick species (*Haemaphysalis aciculifer*, *H. leachi*, *H. truncatum*, *I. bakeri*, and *Ixodes rubicundus*) were recorded on *R. pumilio* at 2 of the 9 localities. Because of the proximity (<2 km) and high similarity observed in the patterns of parasite seasonality between the localities, the temporal data for the 2 localities were combined (there were no significant differences, $P > 0.05$, in the mean abundances of 85% of the parasite spe-

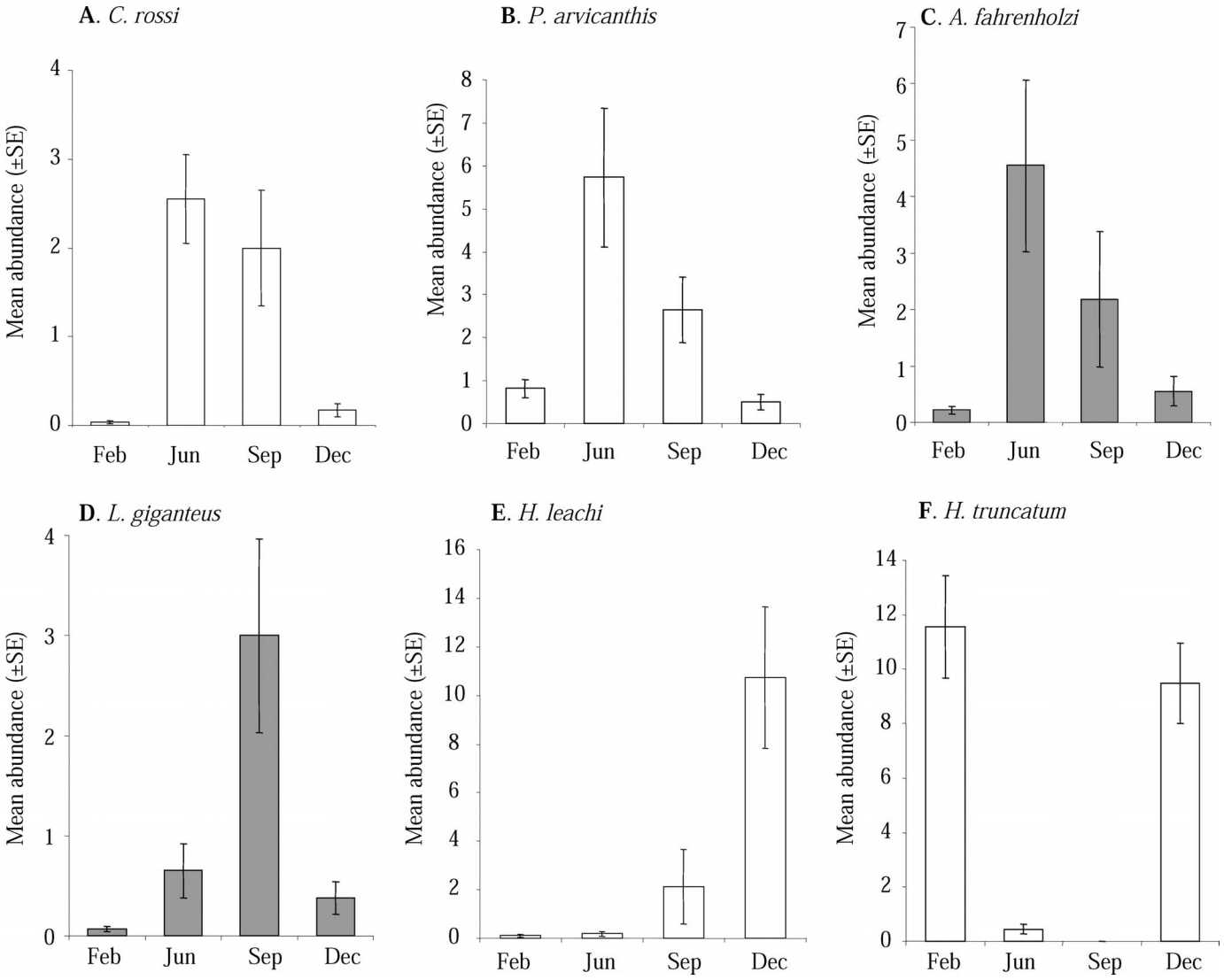

FIGURE 1. Temporal variation of the flea *Chiastopsylla rossi* (**A**); the sucking louse, *Polyplax arvicanthis* (**B**); 2 mites, *Androlaelaps fahrenholzi* (**C**) and *Laelaps giganteus* (**D**); and 2 ticks, *Haemaphysalis leachi* (**E**) and *Hyalomma truncatum* (**F**), collected from *Rhabdomys pumilio* in the Western Cape Province, South Africa, 2003–2004. Data from 2 localities (Elandsberg Reserve and Elandsberg Agriculture) are combined. Mean abundance for each parasite species is expressed as the total number of individuals of a particular parasite species collected in a sampling month divided by the total number of mice recorded for the month (sample sizes for February, June, September, and December were 87, 40, 17, and 58, respectively). Standard errors are included.

cies between localities within seasons). In general, it seems as if infestation with the flea, louse, and mite species was more intense during the cooler and wetter winter and spring months. This relationship was evident for the 2 most numerous flea species, *C. rossi* and *L. agrippinae* (*C. rossi* presented in Fig. 1A), the louse *P. arvicanthis* (Fig. 1B), and the 2 most numerous mite species, *A. fahrenholzi* and *L. giganteus* (Fig. 1C, D). Nymphs of 3 mite species (*A. dasymys*, *A. fahrenholzi*, and *Androlaelaps* sp.) were present during the wet and cooler months and absent during the dry and warmer months. The undescribed species of *Laelaps* was only present during spring (September). The remaining flea and mite species (all present in small numbers) did not show any clear seasonal pattern. In contrast to the above-mentioned taxa, the mean abundance of *H. leachi*, 1 of the 2 most frequently collected tick species, increased in spring and then peaked in early summer (Fig. 1E). High mean abundance was recorded for *H. truncatum* during the early and late summer sampling periods (Fig. 1F).

DISCUSSION

The present study has yielded an extensive list of epifaunistic arthropod species, including obligate ectoparasites and phoretically associated species, on *R. pumilio* in the WC. It is generally accepted that parasite species richness increases with the number of hosts examined (Walther et al., 1995; Feliu et al., 1997; Poulin and Morand, 2004). It, therefore, seems likely that the ectoparasite species richness currently recorded can be attributed to the considerable sampling effort and its intensity (many host individuals at several independent localities within

TABLE V. Checklist of ectoparasite species recorded on *Rhabdomys pumilio* in South Africa. Locality information is provided where available.

Epifaunistic arthropod species	Province	Reference
Fleas		
Chiastopsylla numae†	WC	Present study
Chiastopsylla rossi	WC	Present study
Chiastopsylla capensis	WC	Haeselbarth et al., 1966
Chiastopsylla carus	WC	Haeselbarth et al., 1966
Chiastopsylla coraxis	n.a.*	Segerman, 1995
Chiastopsylla godfreyi	n.a.	Segerman, 1995
Chiastopsylla mulleri	n.a.	Segerman, 1995
Chiastopsylla pitchfordi	n.a.	Segerman, 1995
Ctenocephalides connatus	n.a.	Segerman, 1995
Ctenocephalides craterus	n.a.	Segerman, 1995
Ctenophthalmus calceatus	n.a.	Segerman, 1995
Ctenophthalmus cophurus	n.a.	Segerman, 1995
Ctenophthalmus eumeces	n.a.	Segerman, 1995
Ctenophthalmus singularis	n.a.	Segerman, 1995
Ctenophthalmus stenurus	n.a.	Segerman, 1995
Ctenophthalmus verutus	n.a.	Segerman, 1995
Dinopsyllus abaris	n.a.	Segerman, 1995
Dinopsyllus echinus	n.a.	Segerman, 1995
Dinopsyllus ellobius	WC	Present study
Dinopsyllus longifrons	n.a.	Segerman, 1995
Dinopsyllus lypusus†	WC	Present study
Dinopsyllus tenax	WC	Present study
Epirimia aganippes	n.a.	Segerman, 1995
Echidnophaga gallinacean	n.a.	Segerman, 1995
Hypsophthalmus temporis	WC	Present study
Leptopsylla segnis	n.a.	Segerman, 1995
Listropsylla agrippinae	WC	Present study
Listropsylla basilewskyi	n.a.	Segerman, 1995
Listropsylla cerrita	n.a.	Segerman, 1995
Listropsylla chelura	n.a.	Segerman, 1995
Listropsylla dorippae	n.a.	Segerman, 1995
Listropsylla prominens	n.a.	Segerman, 1995
Nosopsyllus incisus	n.a.	Segerman, 1995
Pulex irritans	n.a.	Segerman, 1995
Xenopsylla brasiliensis	n.a.	Segerman, 1995
Xenopsylla eridos	n.a.	Segerman, 1995
Xenopsylla hirsuta	n.a.	Segerman, 1995
Xenopsylla hirsuta spp.†	WC	Present study
Xenopsylla mulleri	n.a.	Segerman, 1995
Xenopsylla philoxera	n.a.	Segerman, 1995
Xenopsylla piriei	n.a.	Segerman, 1995
Xenopsylla versuta	n.a.	Segerman, 1995
Lice		
Polyplax arvicanthis	WC[1]	[1]Present study; Ledger, 1980
Mites		
Androlaelaps dasymys	WC[1,2]	[1]Zumpt, 1961; [2]Present study
Androlaelaps fahrenholzi	G[1], WC[2]	[1]Zumpt collection‡; [2]Present study
Androlaelaps marshalli	n.a.	Zumpt, 1961
Androlaelaps sp.	WC	Present study
Euschoengastia alticola	KZN	Zumpt 1961
Euschoengastia rhabdomyia	KZN	Zumpt 1961
Haemolaelaps rhabdomys	G	Zumpt 1961
Laelaps sp. near *tillae*	WC	Present study
Laelaps giganteus	EC[1], FS[1], G[1], KZN[1], L[1], M[1], NC[1], NW[1],WC[2]	[1]Zumpt collection‡; [2]Present study
Laelaps lamborni	n.a.	Zumpt 1961
Laelaps muricola	EC, KZN	Zumpt 1961
Laelaps paraspinosa†	WC	Present study
Laelaps peregrinus	M	Zumpt 1961

TABLE V. Continued.

Epifaunistic arthropod species	Province	Reference
Laelaps transvaalensis	EC, M	Zumpt 1961
Laelaps sp.	WC	Present study
Listrophoroides mastomys	KZN	Zumpt 1961
Macronyssus roseinnesi	WC	Zumpt 1961
Ornithonyssus bacoti	WC	Present study
Trichoecius hollidayi	KZN	Zumpt 1961
Trombiculidae sp.	WC	Present study
Ticks		
Amblyomma hebraeum	EC[1,2]	[1]Howell et al., 1989; [2]Petney et al., 2004
Amblyomma sylvaticum†	WC	Present study
Haemaphysalis aciculifer	WC[1,2]	[1]Horak and Boomker, 1998; [2]Present study
Haemaphysalis leachi	EC[1,2], FS[3],WC[4,5,6]	[1]Howell et al., 1989; [2]Petney et al., 2004; [3]Horak et al., 2005; [4]Horak et al., 1986; [5]Horak and Boomker, 1998; [6]Present study;
Hyalomma rufipes†	n.a.	Theiler, 1962
Hyalomma marginatum	FS	Horak et al., 2005
Hyalomma truncatum	FS[1], WC[2,3]	[1]Horak et al., 2005; [2]Horak and Boomker, 1998; [3]Present study
Ixodes alluaudi	WC	Present study
Ixodes bakeri	WC	Present study
Ixodes rubicundus	WC	Present study
Ixodes sp. a	WC	Present study
Ixodes sp. b	FS	Horak et al., 2005
Ixodes sp. n. near *pilosus*	WC	Horak and Boomker, 1998
Margaropus winthemi	FS	Horak et al., 2005
Ornithodorus zumpti	n.a.	Theiler, 1962
Rhipicephalus appendiculatus†	n.a.	Theiler, 1962
Rhipicephalus arnoldi†	n.a.	Theiler, 1962
Rhipicephalus follis	EC[1,2]	[1]Howell et al., 1989; [2]Petney et al., 2004
Rhipicephalus gertrudae group	FS[1], WC[2,3]	[1]Horak et al., 2005; [2]Horak and Boomker, 1998; [3]Present study
Rhipicephalus glabroscutatum	WC	Horak et al., 1986
Rhipicephalus lounsburyi	FS[1], WC[2,3]	[1]Horak et al., 2005; [2]Horak and Boomker, 1998; [3]Present study
Rhipicephalus simus	EC[1,2]	[1]Howell et al., 1989; [2]Petney et al., 2004
Rhipicephalus tricuspis†	n.a.	Theiler, 1962
Rhipicephalus sp. a	FS	Horak et al., 2005
Rhipicephalus sp. b	WC	Horak et al., 1986

EC = Eastern Cape Province, FS = Free State Province, G = Gauteng Province, KZN = KwaZulu-Natal Province, L = Limpopo Province, M = Mpumalanga Province, NC = Northern Cape Province, NW = North-West Province, WC = Western Cape Province.
* The exact locality data for the presence of the ectoparasite species on *R. pumilio* is not available (n.a.).
‡ Information from Zumpt Collection, part of Mite Collection of Plant Protection Research Institute, Pretoria (E.A. Ueckermann, pers. comm.).
† Accidental infestation.

a single geographic region). In addition, the habitat heterogeneity of the WC (Midgley et al., 2005) and the inclusion of both pristine areas and areas bordering agricultural activities may have contributed to species richness. Most of the ectoparasite species that we recovered have previously been reported on *R. pumilio* in the WC and South Africa (Table V) (Tipton, 1960; Zumpt, 1961; De Meillon et al., 1961; Theiler, 1962; Till, 1963; Ledger, 1980; De Graaf, 1981; Horak et al., 1986, 2005; Howell et al., 1989; Segerman, 1995; Horak and Boomker, 1998; Petney et al., 2004). However, this study makes a valuable contribution in terms of 3 undescribed mite species (subfamily Laelapinae) and 1 tick species (*Ixodes* sp.), new locality records for 2 flea species (*C. numae* and *D. lypusus*; Segerman, 1995), for the sucking louse (*P. arvicanthis*), a laelapid mite (*Laelaps paraspinosa* Tipton, 1960), and for the nonparasitic mite *P. u. kivuensis*, for which new phoretic host associations also were recorded (Fain and Beaucournu, 1993).

Several of the more numerous ectoparasite species displayed a strong host–female bias. On-host female-biased sex ratios are common among ectoparasitic insects such as fleas and lice (Askew, 1971; Marshall, 1981). Marshall (1981) noted that female bias occurred in 70 and 78% of collections that included 17 species of Anoplura (sucking lice) and 108 species of Siphonaptera (fleas), respectively. In addition, several studies on small mammals in South Africa have noted a similar pattern for fleas (Horak and Fourie, 1986; Louw et al., 1993, 1995; Beaucournu et al., 2003). It has been suggested that this imbalance is due to the shorter male life span than that of the female, mainly because of a higher level of activity, smaller size, more time spent off the host, and a greater sensitivity of

these male parasites to microclimatic conditions (Marshall, 1981; Krasnov, Burdelova et al., 2002; Krasnov, Khokhlova et al., 2002). Parthenogenetic reproduction and subsequent female bias seems to be common among certain members of another group of ectoparasites, the mammal-infesting ischnoceran lice (Marshall, 1981). Female bias was also present in the mites and in the tick *I. bakeri* in the present study. The female bias in mites seems to be related to the specific genetic reproductive system of the species. Haplodiploidy (males and females that are somatically haploid and diploid, respectively) and arrhenotoky (a haplodiploid system in which males are produced parthenogenetically but females are biparental) seem to be common in laelapid mites, and both these systems are often accompanied by a strong female bias (Norton et al., 1993). The female bias in *I. bakeri* in this study is comparable with that in several other members of this genus, and Fourie and Horak (1994) and Horak and Boomker (1998) have recorded similar patterns for *I. rubicundus* and *Ixodes* sp. (near *I. pilosus*), respectively. Within *Ixodes*, there are nidicolous species that live in or close to caves, burrows, and the nests of their hosts (Sonenshine, 1993). Male nidicolous ticks spend less time on the host, and it seems that, for several of these species, copulation takes place in or near the host nest (Sonenshine, 1993; Kiszewski et al., 2001). It would, however, seem that copulation also takes place off the host in some non-nidicolous species, such as *I. rubicundus* and that few males of such species attach to hosts (Fourie and Horak, 1994).

Eight flea species representing 5 genera were recorded in the present study. These species are largely restricted to South Africa, and 7 of these species have previously been recorded in the WC (Segerman, 1995). Two members of *Chiastopsylla* were present, namely, *C. numae* and *C. rossi*. *Chiastopsylla numae* is host specific to Brants' whistling rat, *Parotomys brantsii*, and its distribution coincides with this rat's distribution (mainly the Karoo area) in South Africa (Segerman, 1995). Its presence on *R. pumilio* represents an accidental infestation. In contrast, *C. rossi* was present in large numbers and on more than 20% of the host population. This flea is a generalist with a broad host preference that includes *R. pumilio*; the vlei rat, *Otomys irroratus*; the bush karoo rat, *Otomys unisulcatus*; and the common highveld gerbil, *Tatera brantsii* (Segerman, 1995). Three species of *Dinopsyllus* were recovered. Two of these species, *D. ellobius* and *D. tenax*, have previously been recorded on *R. pumilio* and in the WC (Segerman, 1995). In addition to parasitizing *R. pumilio*, both fleas infest other small mammals such as gerbils (*Tatera* sp.), vlei rats (*Otomys* sp.), and the Natal multimammate mouse (*Mastomys natalensis*). The third species in this genus, *D. lypusus*, is colloquially known as the tropical flea, mainly because of its preference for the more tropical areas of southern Africa (Segerman, 1995). In South Africa, it is restricted to the northern, more tropical, regions of the country with its most southern distribution recorded as KwaZulu-Natal (Segerman, 1995). This species seems to favor various small mammal species, particularly *M. natalensis* and the red veld rat (*Aethomys chrysophilus*). Its low relative mean intensity of infestation on *R. pumilio* indicates an accidental infestation, but the presence of both male and female fleas at 3 localities (2–3 individuals per locality) in the WC supports a new locality record for the species. The presence of *D. lypusus* in the WC may be due to host switching between sympatric host species (*M. natalensis* and the multimammate mouse, *Mastomys coucha*) followed by a recent south-westward range expansion by *M. coucha* into the WC (Venturi et al., 2004; Avery et al., 2005). *Listropsylla agrippinae* and *H. tempori* were the second and third most numerous flea species, respectively, on *R. pumilio*. In addition to parasitizing *R. pumilio*, both species also infest *Otomys* species (*O. irroratus* by the former, and *O. unisulcatus* by the latter; Segerman, 1995). The presence of 3 female fleas belonging to the *X. hirsuta* group can be seen as an accidental infestation, and it is likely that these females belong to the *hirsuta* subgroup within the *hirsuta* group. The Cape gerbil (*Tatera afra*) has been listed as the only true host of fleas of the *hirsuta* subgroup (Segerman, 1995), which probably explains the low relative mean intensity of infestation and prevalence on *R. pumilio* in the present study. Although the flea species collected in our study do not bite humans, they have the potential to act as enzootic rodent-to-rodent vectors of *Y. pestis*, the bacterium responsible for plague, and they thereby facilitate the survival of foci of plague in nonanthropic areas (De Meillon et al., 1961). Little, if anything, is known of the importance of the flea species recovered in the present study as intermediate hosts of cestodes and filarial worms in South Africa. Certain flea species (e.g., *Ctenocephalides canis*, *Ctenocephalides felis*, *Nosopsyllus fasciatus*, and *X. cheopis*) can, however, act as intermediate hosts for some of the cestodes that infest dogs, cats, and rats (Roberts and Janovy, 2000).

The sucking louse, *P. arvicanthis*, was the only louse species present on *R. pumilio*. It occurred at high intensities of infestation and was present on approximately 60% of mice examined. Ledger (1980) records *R. pumilio* as the preferred host for this louse. Although lice have been collected from *R. pumilio* in the WC and at other localities by Horak et al. (1986, 2005), Horak and Boomker (1998), and Petney et al. (2004), their specific identities were not recorded. The present survey is, therefore, the first empirical study that provides data on the relative mean intensity of infestation, prevalence, and temporal variation of *P. arvicanthis* on *R. pumilio* in the WC.

Studies on the mite species that infest wild hosts in southern Africa are limited and several are mainly taxonomic in nature (Tipton, 1960; Zumpt, 1961; Till, 1963; Louw et al., 1995; Anderson and Kok, 2003). The study by Braack et al. (1996) includes an extensive list of parasitic and phoretic-associated mite species (>13 species) that occur on the red veld rat and the bushveld gerbil (*Tatera leucogaster*) in the northeastern summer rainfall region of South Africa. The results of the latter study and the present study are comparable in that host animals were examined under a stereoscopic dissecting microscope, and all the ectoparasites were collected. In the present study, 11 mite species (including 2 nonparasitic species) were recovered. Although mites were collected from *R. pumilio* examined by Horak et al. (1986), Horak and Boomker (1998), Petney et al. (2004), and Horak et al. (2005), the species recovered were not identified to species.

Most of the mites recovered in the present study (*A. dasymys*, *A. fahrenholzi*, *L. giganteus*, *L. paraspinosa*, and *O. bacoti*) seem to have wide host preferences that include rodents and insectivores, and also wide geographic distributions in southern Africa and Africa or beyond (e.g., *A. fahrenholzi*) (Tipton, 1960; Zumpt, 1961; Till, 1963). In our study, *A. fahrenholzi* was the most numerous mite followed by *L. giganteus*. The

latter species is a large mite (female length 1,274 ± 24.12 μm) and is generally present posterodorsally near the base of the tail (Braack et al., 1996). The collection of a single *L. paraspinosa* is probably due to accidental infestation. Nevertheless, it seems as if this is the first record of this species on *R. pumilio* as well as in the WC. Previous records list the vlei rat as the most common host, and the most southern distribution is noted as the Eastern Cape Province (Tipton, 1960). Three undescribed species also were recovered, namely, *Androlaelaps* sp., *Laelaps* sp. near *tillae*, and a *Laelaps* sp. The tropical rat mite, *O. bacoti*, that was also present, is an intermediate host of filarial worms, *Litomosoides carinii*, in some New World rodents. Under laboratory conditions, it also can transmit *Rickettsia typhi* (murine typhus), *R. akari* (human rickettsial pox), *Coxiella burnetii* (*Q* fever), *Y. pestis* (plague), *Trypanosoma cruzi* (Chagas' disease), and coxsackie virus (Baker, 1999), but it is not known whether this mite is a vector of any of these pathogens in nature. The larvae of trombiculid mites (Trombiculidae) are parasitic and can cause chigger dermatitis, and they act as vectors of the agent of scrub typhus in humans in some Old World tropical areas such as southeastern Asia and the Pacific region (Roberts and Janovy, 2000). A recent case study of chigger dermatitis on dogs and a child in Free State Province seems to be the first formal report in South Africa (Heyne et al., 2001).

Two nonparasitic mite species were collected, *Macrocheles* sp. and *P. u. kivuensis* (Fain and Beaucournu, 1976). The former species is generally associated with decaying matter in soil, humus, forest litter, moss, dung, hay, rotting stumps, and also nests of rodents, birds, mammals, and bumblebees. The mites are often phoretic on insects such as flies, beetles, and bees (Krantz, 1962). Phoresy is a relationship between 2 species in which 1 species attaches itself to the other species, usually for the purpose of transport between hosts or nests (Askew, 1971). Phoretic associations seem to be common between heteromorphic deutonymphs of certain mites and members of the Siphonaptera, and they have been recorded in 76 species of fleas (Fain and Beaucournu, 1993). Hypopial nymphs of *P. u. kivuensis*, which were recovered in the present study, have been associated with various flea species on several small mammal species in 3 African countries, namely, Zaire, Gabon, and Kenya (Fain and Beaucournu, 1993). The present study documents the first record of a phoretic association between *P. u. kivuensis* and several flea species in South Africa. Moreover, it also seems that this is the first record of hypopial nymphs on *C. rossi*, *H. temporis*, and *L. agrippinae*. Interestingly, *P. u. kivuensis* was only recorded at a locality that is generally wetter than the other localities (S. Matthee, unpubl. obs.). The largest proportion of hypopi (50%) was recorded on *C. rossi*, followed by 25% each on *L. agrippinae* and *H. temporis*. Preference for female fleas also was displayed (88% of the hypopi occurred on female fleas). This finding may be attributed to the abdominal segments of female fleas being freer to move than those of males, which could facilitate attachment of the hypopi.

Thirteen ixodid tick species, representing 5 genera, were recovered from *R. pumilio* in the WC. As expected, most of the ticks were larvae (Walker, 1991), which may partly be attributed to grooming by the host or to the height at which the various tick life stages quest for hosts (Gallivan and Horak, 1997). Grooming is more effective in removing the larger adult stages, and allogrooming by *R. pumilio* has been reported (Schradin and Pillay, 2003, 2004). Larval stages of ticks are more susceptible to desiccation than nymphs or adults (Short et al., 1989a; Solomon and Kaaya, 1998), and the larvae of some species therefore may spend more of their time at ground level or in the lower portion of the vegetation compared with the adults (Short et al., 1989b; Mejlon and Jeanson, 1997). This behavior could facilitate a higher frequency of contact between the larvae and small mammal species such as *R. pumilio*. The larvae of some species, however, may have a natural preference for rodents and hence quest for hosts from the soil surface or from vegetation in its proximity.

The single *Amblyomma sylvaticum* larva on *R. pumilio* can be regarded as an accidental infestation. Walker (1991) noted that this tick is commonly associated with reptiles, and specifically with tortoises and lizards. The 11 adult ticks collected at 1 of the study sites (Table IV) were all present on an angulate tortoise (*Chersina angulata*).

Immature stages of *H. aciculifer* have been recorded previously on *R. pumilio* in the WC (Horak and Boomker, 1998), and in the current study they were present in low-to-moderate intensities, supporting the supposition that although *H. aciculifer* is widely distributed, it is never encountered in large numbers (Walker, 1991). Adult *H. aciculifer* parasitize domestic livestock, various antelope, and carnivore species (Walker, 1991). The immature stages of *H. leachi* also have previously been recorded in the WC as well as at other localities in South Africa (Horak and Boomker, 1998; Petney et al., 2004; Horak et al., 2005). Adult *H. leachi* parasitize domestic and wild carnivores (Horak et al., 2000; Horak and Matthee, 2003). *Haemaphysalis leachi* seems to be the only species within the genus that is economically important in the WC and South Africa, in that it is the vector of *Babesia canis*, the causative organism of canine babesiosis in domestic dogs and of *Rickettsia conori*, the cause of human tick-bite fever (also known as boutoneusse fever) (Walker, 1991). It also can harbor *C. burnetii*, the causative agent of *Q* fever in animals and humans (Walker, 1991).

Hyalomma truncatum was present in large numbers (>1,500 individuals) and on most *R. pumilio* at only 2 of the study localities (Elandsberg Reserve and Elandsberg Agriculture). In a previous study on *R. pumilio* in the WC, 4 nymphs were present on 2 of 25 *R. pumilio* examined (Horak and Boomker, 1998), and in the Free State Province a single larva was collected from 1 of 36 striped mice (Horak et al., 2005). Most *H. truncatum* larvae and nymphs were embedded in dermal pits on the anterodorsal part of the body, a finding similar to that made for this species on bushveld gerbils (Braack et al., 1996). The only adult tick collected from a four-striped mouse was from Elandsberg Reserve (Table IV). Certain species of *Hyalomma* are vectors of the virus responsible for Crimean-Congo hemorrhagic fever (CCHF) in humans (Shepherd et al., 1989; Swanepoel, 1998). Since 1982, more than 150 cases of CCHF have been reported in South Africa, of which more than 50% were associated with tick bites (Anonymous, 2000). *Hyalomma truncatum* is a vector of *Babesia caballi*, the causative agent of equine babesiosis, in South Africa (De Waal, 1990). It also produces dermotropic toxins that cause sweating sickness in cattle (Dolan and Newson, 1980) and necrotic lesions around the bites of adult ticks on dogs (Burr, 1983).

Four species of *Ixodes* were recovered. *Ixodes bakeri* and the immature stages of an undescribed *Ixodes* sp. were the 2 most

numerous ticks in this genus. *Ixodes bakeri* was the fourth most numerous tick species and was present on 42.9% of *R. pumilio*. Walker (1991) noted that *I. bakeri* occurs throughout the WC and seems to prefer vlei rats (*Otomys* spp.) and shrews (*Crocidura mariquensis* and *Myosorex varius*) as hosts. As suggested by Walker (1991), both adults and immature stages of this tick parasitize rodents. The immature stages of an undescribed *Ixodes* species were among the most numerous of the ticks collected and were prevalent in approximately one third of the mice. This finding contrasts with their absence on *R. pumilio* in all the previous studies (Horak et al., 1986, 2005; Howell et al., 1989; Horak and Boomker, 1998; Petney et al., 2004). In addition to large numbers of larvae and nymphs of this tick, a single female *Ixodes*, seemingly belonging to an undescribed species, also was recovered. Some of the shared taxonomic characters of the immature *Ixodes* sp. ticks and of this female tick suggest that they may belong to the same species. Both *Ixodes alluaudi* and *I. rubicundus* were present at low intensities. This finding may be explained by the fact that shrews are the preferred hosts of the former tick (Walker 1991), and rock elephant shrews (*Elephantulus myurus*) of the immature stages of the latter tick (Fourie et al., 1992). Both ticks are present at scattered localities in the WC (Walker, 1991). A single adult *I. alluaudi* was recovered from a shrew at the Jonkershoek study site, and 33 adult *I. rubicundus* at the Cordoba and Elandsberg study localities (Table IV). *Ixodes rubicundus* is an economically important tick in that feeding females secrete a toxin that causes paralysis in domestic sheep, goats, and calves as well as in some antelope species (Spickett and Heyne, 1988; Fourie et al., 1991).

Rhipicephalus was represented by larvae and nymphs belonging to the *R. gertrudae* group and nymphs of *R. lounsburyi*. Although the majority of the larvae collected were *R. gertrudae*, other larvae similar in appearance to *R. gertrudae*, namely, *Rhipicephalus capensis*, *Rhipicephalus follis*, *R. lounsburyi*, and *Rhipicephalus simus*, also were present. Because of the large numbers of larvae collected (>13,000 individuals) and the difficulty in distinguishing between the immature stages of the various species (Walker et al., 2000), the larval data for these 5 taxa were pooled. The presence on *R. pumilio* of immature ticks of the *R. gertrudae* group in the present study agrees with previous studies on this mouse in the WC and in Free State Province (Horak and Boomker, 1998; Horak et al., 2005). The immature stages also have been recorded from Namaqua rock mice (*Aethomys namaquensis*) in the Free State Province (Fourie et al., 1992). More than 900 adult *R. gertrudae* were collected at 6 of the 9 study localities (Table IV), implying that a large proportion of the questing immature ticks that infested the mice could have belonged to this species. Because murid rodents are the preferred hosts of the immature stages of *R. gertrudae* (Walker et al., 2000), it is not unreasonable to assume that a large proportion of the immature *Rhipicephalus* spp. collected from *R. pumilio* belonged to this species. Several nymphs of *R. lounsburyi* were recovered from *R. pumilio*. Walker (1991) noted that the preferred hosts of the immature stages of this tick were as yet unknown. Since then, authors of 1 study in the WC (Horak and Boomker, 1998) and another in Free State Province (Horak et al., 2005) have reported immature stages on *R. pumilio*. In both the latter studies, however, the presence of *R. lounsburyi* could be interpreted as due to accidental infestations because of the small numbers recovered (1 nymph and 1 larva, and 1 nymph, respectively). The large numbers of nymphs collected in the present study support the previous findings and indicate the possible importance of *R. pumilio* as a host for the immature stages. Adult *R. lounsburyi* were collected from the environment at 2 of the study sites. *Rhipicephalus simus* is of economic importance and can act as vector for *Anaplasma marginale* and *Anaplasma centrale*, both of which cause anaplasmosis in cattle, sheep, and goats (Potgieter and Van Rensburg, 1987; Walker, 1991). In addition, *R. simus* can secrete toxins that cause paralysis in humans (Walker, 1991).

In general fleas, lice, and mites were more abundant during the cool wet months (predominantly June, followed by September), whereas ticks generally preferred the warm dry months (December and February). High temperatures and low humidity may adversely affect the survival of fleas and lice (Askew, 1971; Cooke, 1984; Cooke and Skewes, 1988). Peaks in intensities during late winter and spring in both summer and winter rainfall regions have been noted for the flea *Ctenocephalides felis damarensis* on scrub hares (*Lepus saxatilis*) at various localities in South Africa (Louw et al., 1993, 1995), and essentially during the same seasons for *Xenopsylla brasiliensis* and *Xenopsylla frayi* on red veld rats and bushveld gerbils, respectively, in Mpumalanga Province, a summer rainfall region (Braack et al., 1996). Because the same pattern was recorded in both summer and winter rainfall regions, these authors suggested that high temperature, rather than low humidity, may be an important climatic factor in determining the intensity of infestation. The predominance of lice in winter followed by spring in the present study is supported by data from a different host species in a previous study in the WC (Horak et al., 1986). In the latter study, both nymphs and adults of the chewing louse *Damalinia pelea* peaked in intensity on grey rhebok (*Pelea capreolus*) during winter (June), and they were almost completely absent during the warm and dry midsummer months (Horak et al., 1986). The same pattern has been observed for lice in studies on several antelope species in the northeastern summer rainfall region of South Africa (Horak et al., 1983, 2003; Matthee et al., 1998). The decline in the relative mean intensity with lice during summer in our study may be related to high temperatures during this period (Horak et al., 2003).

According to Braack et al. (1996) little information is available on the temporal variation of mite species on wild hosts in southern Africa. Recently, Anderson and Kok (2003) provided data on 2 mite species associated with the springhare (*Pedetes capensis*) and noted that the immature stages were prevalent during the cooler yet dry months. This pattern is similar to that noted in the present study in that nymphs of the 3 *Androlaelaps* species were only recorded in June and September. The 2 most numerous mite species, *A. fahrenholzi* and *L. giganteus* in the present study, displayed contrasting seasonal patterns of occurrence during the cooler months. The mean abundance of the former species peaked in June, followed by a decrease in September, whereas the converse was true for the latter species.

The higher mean abundances of tick larvae in the warmer months in the present study are similar to those of several tick species on rock dassies (*Procavia capensis*) in the Eastern Cape Province (Horak and Fourie, 1986). Horak et al. (1986) also noted an increase in the intensities of infestation with larvae on grey rhebok, bontebok (*Damaliscus pygargus dorcas*), and

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scrub hares in the WC during February; but in contrast to the present study, peak intensities of infestation were recorded in April or June. Peak numbers of the immature stages of *H. truncatum* were collected during the dry summer months (December and February) in the present study. In studies on scrub hares, red veld rats, and bushveld gerbils in a summer rainfall region of South Africa, the immature stages were most numerous during the dry winter months from May to October (Horak et al., 1993; Braack et al., 1996). The absence of immature stages of *H. truncatum* on *R. pumilio* during the wet winter months in the present study could be due to a change in the seasonality of this tick, ensuring that all its developmental stages are present during the warm dry summer months.

This study underlines high ectoparasite biodiversity on a small mammal host in the CFR of South Africa. *Rhabdomys pumilio* is a habitat generalist and its consequent success in both pristine natural areas and human-transformed landscapes exposes it to parasitism by a large number of species. The use of a generalist host species as a model organism in addition to a relatively high sampling intensity provides us with an indication of the potential parasite diversity that is present on mammals in the CFR. Based on the sampling approach used in this study, it is evident that a spring-to-early summer sampling period will yield the broadest representation of ectoparasite species in the WC. A distinct on-host temporal pattern was evident between the fleas, lice, and mites on the 1 hand and the ticks on the other hand. This study has highlighted the importance of *R. pumilio* as a host for a number of ectoparasite species because of their high prevalence and large numbers. Several of the ectoparasites that it hosts are of medical and veterinary importance in that they have the potential to act as vectors of various organisms that are pathogenic to animals and humans, such as *A. centrale*, *A. marginale*, *B. caballi*, *B. canis*, *Y. pestis*, and the virus that causes CCHF. In addition, adult *H. truncatum* also produce toxins that cause sweating sickness in calves, and necrosis around their bites on dogs. Therefore, it is suggested that *R. pumilio* can contribute to a risk of disease especially at times of high population numbers and when it is present in proximity to anthropogenic areas.

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Birds

Most birds that alight on the ground are potential hosts of the immature stages of the tortoise tick *Amblyomma marmoreum* and of the bont-legged tick, *Hyalomma marginatum rufipes* (Van Niekerk, Fourie & Horak 2006). The latter tick is the major vector in South Africa of the virus causing Crimean-Congo haemorrhagic fever in people (see Horak, Swanepoel & Gummow 2002c in Chapter 5). In addition helmeted guineafowls, *Numida meleagris*, and crested francolins, *Francolinus sephaena*, are good hosts of the immature stages of *Amblyomma hebraeum* (Horak Spickett, Braack & Williams 1991c; Uys & Horak 2005), the vector of *Rickettsia ruminantium*, the cause of heartwater in cattle sheep and goats.

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PARASITES OF DOMESTIC AND WILD ANIMALS IN SOUTH AFRICA. XXVII. TICKS ON HELMETED GUINEAFOWLS IN THE EASTERN CAPE PROVINCE AND EASTERN TRANSVAAL LOWVELD

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ABSTRACT

HORAK, I. G., SPICKETT, A. M., BRAACK, L. E. O. & WILLIAMS, E. J., 1991. Parasites of domestic and wild animals in South Africa. XXVII. Ticks on helmeted guineafowls in the eastern Cape Province and eastern Transvaal Lowveld. *Onderstepoort Journal of Veterinary Research*, 58, 137–143 (1991)

Seventy-six helmeted guineafowls *(Numida meleagris)* were shot in the Andries Vosloo Kudu Reserve and on an adjacent farm in the eastern Cape Province during the period May 1985 to January 1987 and their tick burdens determined. A total of 10 ixodid tick species were recovered, of which *Amblyomma hebraeum, Amblyomma marmoreum* and *Haemaphysalis silacea* were the most abundant. The seasonal abundances of these 3 species and of *Hyalomma marginatum rufipes* were ascertained. A marked difference between the total number of *A. hebraeum* recovered from the birds in the reserve and those on the farm is ascribed to the treatment of domestic stock on the farm with an acaricide.

The tick burdens of 118 helmeted guineafowls, shot in the southern part of the Kruger National Park, eastern Transvaal Lowveld, from August 1988 to August 1990, were also determined. Ten ixodid tick species and the larvae of an argasid species were recovered. *A. hebraeum, A. marmoreum* and the *Argas* sp. were the most abundant and their seasonal abundances and that of *Rhipicephalus zambeziensis* were determined.

Only 2 of the 54 659 ixodid ticks recovered from the birds at the 3 localities were adults and the presence of these is ascribed to accidental infestations.

INTRODUCTION

The tick species infesting guineafowls have been recorded in a number of studies (Theiler, 1962; Norval, 1974; Fabiyi, 1980; Horak & Williams, 1986; Horak & Knight, 1986; Rechav, Zeederberg & Zeller, 1987; Okaeme, 1988). The actual tick burdens of free-ranging helmeted guineafowls *(Numida meleagris)* were determined in those investigations conducted by Norval (1974), Horak & Williams (1986), Horak & Knight (1986) and Rechav *et al.* (1987). The results of these surveys indicate that guineafowls are good hosts of the immature stages of *Amblyomma hebraeum, Amblyomma marmoreum, Haemaphysalis silacea* and the 2 subspecies of *Hyalomma marginatum* as well as the larvae of *Argas* spp. The seasonal abundances of *A. hebraeum, A. marmoreum, H. silacea* and the 2 subspecies of *H. marginatum* on helmeted guineafowls have also been determined (Horak & Williams, 1986; Rechav *et al.*, 1987).

Recent research has shown that it is possible to infect helmeted guineafowls with *Cowdria ruminantium*, the causative organism of heartwater in cattle, sheep and goats, and that *A. hebraeum* feeding on these birds can acquire infection (Oberem & Bezuidenhout, 1987). The fact that free-living guineafowls are also naturally infested with the immature stages of at least 3 *Amblyomma* species that can act as vectors of *C. ruminantium,* namely *A. hebraeum, A. marmoreum* and *A. variegatum* (Walker & Olwage, 1987; Petney, Horak & Rechav, 1987) indicates that these birds may play a role in the epidemiology of the disease.

The present paper describes surveys in which the tick burdens of free-ranging helmeted guineafowls were determined in the Valley Bushveld of the eastern Cape Province and in the eastern Transvaal Lowveld. In the eastern Cape Province the surveys were conducted on the same properties as those reported by Horak & Williams (1986) and Horak & Knight (1986). The present surveys are a direct extension of that conducted by Horak & Williams (1986) and include in greater detail the tick burdens of 24 guineafowls examined by Horak & Knight (1986).

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METHODS AND RESULTS

Andries Vosloo Kudu Reserve and "Bucklands"

Study site

The Andries Vosloo Kudu Reserve (AVKR) is 6 497 ha in extent and shares a common 11 km boundary with the farm "Bucklands", which is 5 480 ha in extent. The reserve and the farm are located at approximately 33° 07′ S, 26° 40′ E with altitudes ranging from 335–538 m. The vegetation of the region is described as Valley Bushveld (Acocks, 1975). A detailed description of the vegetation on "Bucklands" has been given by Rechav (1982). The reserve contained approximately 54 hartebeest, 450 kudu, 140 eland and 100 buffalo, and the farm 300 Dorper sheep, 4 000 Angora goats, 185 cattle and 300 kudu at the time of the survey. The numbers of helmeted guineafowls on both properties are unknown.

Survey birds

At monthly intervals from May 1985 to January 1987 an attempt was made to shoot 2 helmeted guineafowls in the AVKR and 2 on "Bucklands". This was not always possible and no birds were obtained in the AVKR during July and December 1985, only 1 bird was shot during February and 1 during June 1986 and 3 birds each during March, May and December 1986. On "Bucklands" no birds were obtained during November and December 1985 and only 1 during November 1986.

Necropsy and counting procedures

The guineafowls were processed for tick recovery and the ticks were counted as described by Horak & Williams (1986).

Results

The species and numbers of ticks recovered from the 39 guineafowls examined on the reserve and 37 on the farm are summarized in Table 1 & 2.

TABLE 1 Total numbers of ticks recovered from 39 helmeted guineafowls in the Andries Vosloo Kudu Reserve

Tick species	Total numbers recovered				No. of birds infested
	Larvae	Nymphs	Females*	Total	
Amblyomma hebraeum	22 152	995	0	23 147	39
Amblyomma marmoreum	341	27	0	368	26
Haemaphysalis silacea	1 226	318	0	1 544	33
Hyalomma marginatum rufipes	131	9	0	140	21
Rhipicephalus appendiculatus	18	1	1	20	6
Rhipicephalus evertsi evertsi	3	0	0	3	2
Rhipicephalus glabroscutatum	12	3	0	15	5
Rhipicephalus sp.	1	0	0	1	1
Total	23 884	1 353	1	25 238	

* No males were recovered

TABLE 2 The total numbers of ticks recovered from 37 helmeted guineafowls on the farm "Bucklands"

Tick species	Total numbers recovered			No. of birds infested
	Larvae	Nymphs	Total*	
Amblyomma hebraeum	670	19	689	24
Amblyomma marmoreum	447	33	480	29
Haemaphysalis silacea	1 705	186	1 891	35
Hyalomma marginatum rufipes	51	3	54	12
Ixodes sp.	1	0	1	1
Rhipicephalus appendiculatus	1	1	2	2
Rhipicephalus evertsi evertsi	4	0	4	1
Rhipicephalus glabroscutatum	6	0	6	2
Rhipicephalus oculatus	3	4	7	4
Rhipicephalus sp.	1	0	1	1
Total	2 889	246	3 135	

* No adult ticks were recovered

The birds on the reserve were infested with the immature stages of 8 ixodid tick species and a single adult tick. Of these *Amblyomma hebraeum* followed by *Haemaphysalis silacea* and *Amblyomma marmoreum* were the most abundant and prevalent.

The guineafowls on the farm were infested with the immature stages of 10 ixodid tick species. *H. silacea* followed by *A. hebraeum* and *A. marmoreum* were the most abundant and *H. silacea* followed by *A. marmoreum* the most prevalent.

Comment: Because of the marked difference between the numbers of *A. hebraeum* recovered from the birds in the reserve and on the farm, which will be discussed later, only the burdens of those in the reserve have been graphically illustrated (Fig. 1). The burdens of *A. marmoreum, H. silacea* and *Hyalomma marginatum rufipes* were fairly similar at the 2 localities and these have been combined for each species and graphically illustrated (Fig. 2–4).

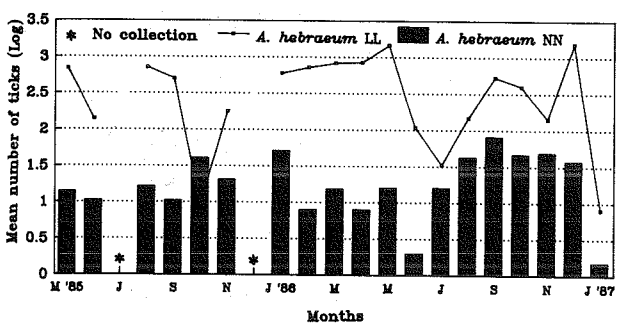

FIG. 1 The seasonal abundance of *Amblyomma hebraeum* on helmeted guineafowls in the Andries Vosloo Kudu Reserve

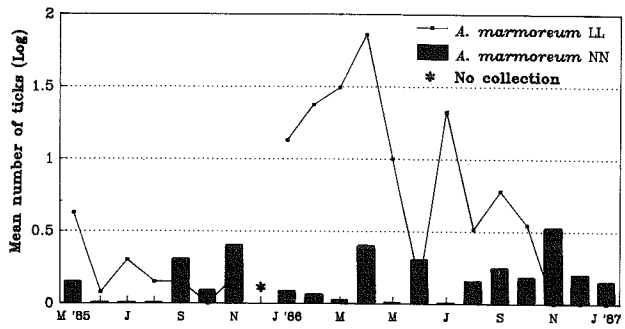

FIG. 2 The seasonal abundance of *Amblyomma marmoreum* on helmeted guineafowls in the Andries Vosloo Kudu Reserve and on the farm "Bucklands"

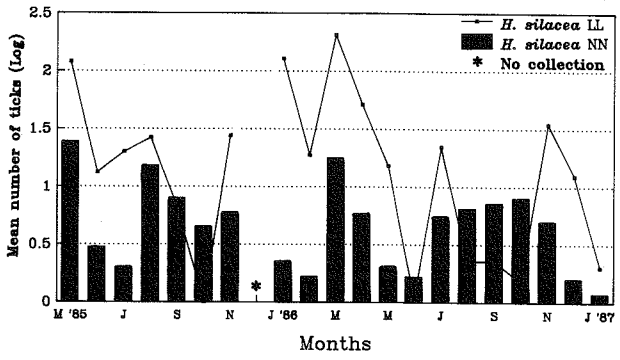

FIG. 3 The seasonal abundance of *Haemaphysalis silacea* on helmeted guineafowls in the Andries Vosloo Kudu Reserve and on the farm "Bucklands"

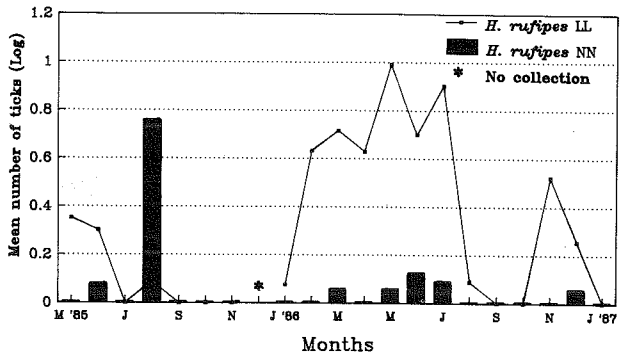

FIG. 4 The seasonal abundance of *Hyalomma marginatum rufipes* on helmeted guineafowls in the Andries Vosloo Kudu Reserve and on the farm "Bucklands"

No clear pattern of seasonal abundance was evident for the immature stages of *A. hebraeum*, and both larvae and nymphs were always present. The largest numbers of *A. marmoreum* larvae were present from January to May and during July 1986,

TABLE 3 The total numbers of ticks recovered from 118 helmeted guineafowls in the Kruger National Park

Tick species	Total numbers recovered				No. of birds infested
	Larvae	Nymphs	Males*	Total	
Ixodid ticks					
Amblyomma hebraeum	21 813	1 965	0	23 778	117
Amblyomma marmoreum	2 284	103	0	2 387	89
Boophilus decoloratus	15	0	0	15	7
Haemaphysalis leachi	3	2	0	5	2
Hyalomma truncatum	9	1	0	10	7
Rhipicephalus appendiculatus	4	0	1	5	3
Rhipicephalus evertsi evertsi	2	0	0	2	2
Rhipicephalus punctatus	0	1	0	1	1
Rhipicephalus simus	11	0	0	11	7
Rhipicephalus zambeziensis	68	4	0	72	15
Total	24 209	2 076	1	26 286	
Argasid ticks					
Argas sp.	1 274	0	0	1 274	26

* No females were recovered

nymphs were present in the largest numbers during November 1985 and 1986. The immature stages of *H. silacea* exhibited no clear pattern of seasonal abundance. Larvae and or nymphs of *H. marginatum rufipes* were present in May, June and August 1985, January to August and during November and December 1986.

Kruger National Park

Study site

The Kruger National Park (KNP) is 1 945 528 ha in extent and is situated in the eastern Transvaal Lowveld. The vegetation of the southern section of the park (South of 24° 50′ S) in which this survey was conducted, is classified as Lowveld with small areas of Lowveld Sour Bushveld and Arid Lowveld (Acocks, 1975). A more detailed description of the vegetation of the various landscape zones that make up this region has been given by Gertenbach (1983). Impala, kudu, Burchell's zebras, blue wildebeest, buffalo and giraffe account for the major portion of the population of large herbivores present in this locality. Small flocks of helmeted guineafowls are scattered throughout the region with several hundred birds concentrated around the Skukuza rest camp, where they feed on the refuse dump. Tortoises, and particularly the mountain tortoise, abound in this part of the park.

Survey birds

Each month, from August 1988 to August 1990, 2 helmeted guineafowls were shot on or near the refuse dump at Skukuza, and 3 were shot at other sites in the southern part of the park. It was not always possible to obtain birds at the latter sites and none were shot during January and February 1990 and only 2 during May 1990. We attempted to shoot only adult birds, but 7 sub-adult birds, approximately 7–10 months old were shot and included in the sample, which comprised 118 birds.

Necropsy and counting procedures

After the guineafowls had been shot, blood was collected from the jugular vein when possible and blood smears were made from each bird. Thereafter the carcasses were placed in sturdy plastic bags, which were securely closed, and transported to the laboratory at Skukuza.

At the laboratory the birds were removed from the plastic bags, mass-measured and various morphometric measurements taken. Each bird was then skinned, the wing-tips and feet being left attached to the skin. The tail including pygostyle and the head with the unfeathered portion of the neck were severed from the skin and placed in a plastic bottle. The remainder of the skin was divided in half lengthwise and 1 half was returned to the plastic bag. Sufficient tick detaching agent[1] was added to the plastic bottle and the plastic bag in order to thoroughly wet the contents and these were left overnight. The following morning formalin was added to the contents of the plastic bottle and bag which were transported to the Faculty of Veterinary Science, Onderstepoort. There the contents of the bottle and bag were separately washed with a strong jet of water over a sieve with 150 µm apertures. The washed head, tail and skin and the fine material retained by the sieve, were collected for microscopic examination.

The head and neck, tail and half portion of skin and all the material retained by the sieve were examined separately under a stereoscopic microscope. Ticks present on or in this material were collected, identified and counted. The number of ticks recovered from the half-portion of skin was doubled and added to the numbers recovered from the remainder of the material in order to calculate the total tick burden of each bird.

Results

The species and numbers of ticks recovered from the 118 guineafowls examined in the park are summarized in Table 3.

The birds were infested with the immature stages of 10 ixodid tick species and a single adult tick. They also harboured the larvae of an *Argas* species. *A. hebraeum* and *A. marmoreum* were the most numerous and prevalent of the ixodid ticks. The guineafowls shot at sites other than the Skukuza refuse dump were infested with significantly more larvae and nymphs of *A. hebraeum* and larvae of *A. marmoreum* than those shot on the refuse dump. Too few nymphs of *A. marmoreum* were recovered for valid comparisons.

The seasonal abundances of *A. hebraeum, A. marmoreum, Rhipicephalus zambeziensis* and the *Argas* sp. are graphically illustrated in Fig. 5–8.

[1] Triatix: Coopers (SA) (Pty) Ltd

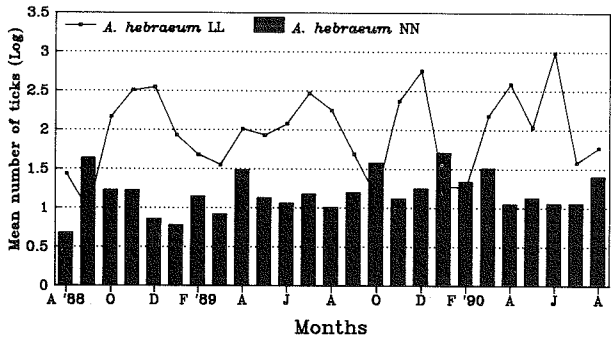

FIG. 5 The seasonal abundance of *Amblyomma hebraeum* on helmeted guineafowls in the Kruger National Park

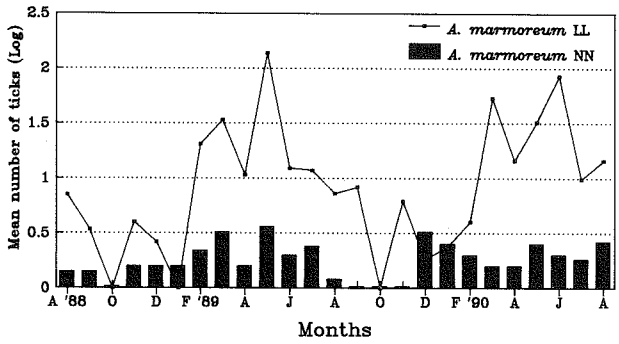

FIG. 6 The seasonal abundance of *Amblyomma marmoreum* on helmeted guineafowls in the Kruger National Park

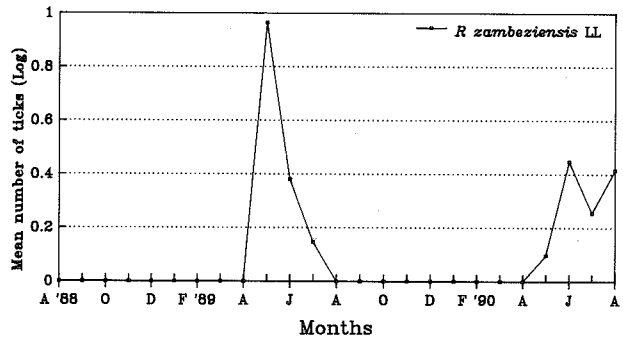

FIG. 7 The seasonal abundance of *Rhipicephalus zambeziensis* on helmeted guineafowls in the Kruger National Park

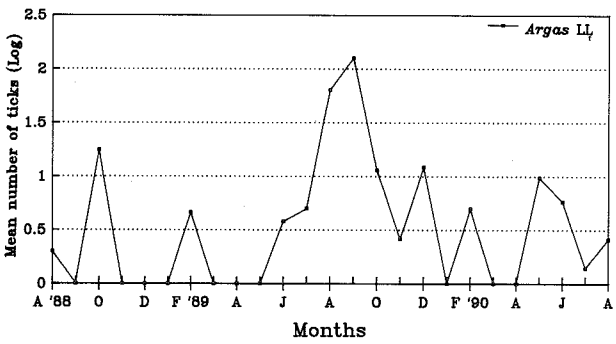

FIG. 8 The seasonal abundance of *Argas* sp. larvae on helmeted guineafowls in the Kruger National Park

No definite pattern of seasonal abundance was evident for *A. hebraeum*, with both larvae and nymphs being present during each month of the survey. The largest numbers of *A. marmoreum* larvae were present from February to September 1989 and March to August 1990. With the exception of October 1988 and September to November 1989, when no nymphs were recovered, these were always present. Larvae of *R. zambeziensis*, which appeared not to have attached, were present on the birds from May to July 1989 and May to August 1990. *Argas* sp. larvae were consistently present from June to December 1989 and May to August 1990.

DISCUSSION

Theiler (1962) lists 13 ixodid tick species that have been recovered from helmeted guineafowls in the Ethiopian region. Although she reported the adults of 3 species as occurring on these birds, Horak & Williams (1986) in discussing her records suggested that the adults of only *Haemaphysalis hoodi* are parasites of guineafowls in South Africa. This tick was not recovered during any of the current surveys.

Horak & Williams (1986) recovered the immature stages of 9 ixodid tick species from helmeted guineafowls they examined in the Mountain Zebra National Park, Cradock district and in the AVKR. Four of these they ascribed to incidental infestations. A total of 16 ixodid species was recovered during the present surveys 12 of which we consider to be incidental infestations. Combining the findings of Theiler (1962) for those species that she listed as occurring in South Africa, and of Horak & Williams (1986) with the present results, 20 ixodid tick species have been found on helmeted guineafowls in this country. Of these we consider only *A. hebraeum, A. marmoreum, H. hoodi, H. silacea, H. marginatum rufipes* and *H. marginatum turanicum* to be true parasites of these birds, the remainder representing incidental infestations.

The majority of attached larval ticks recorded by Horak & Williams (1986) on the guineafowls in the AVKR were recovered from the head and upper necks of the birds and the majority of nymphs from the wings. In the present study in the KNP the majority of larvae and nymphs of *A. hebraeum* were recovered from the heads of the birds and those of *A. marmoreum* from the skins including the lower neck, wings, sides and feathered portions of the legs. These differences in preferred sites of attachment by the 2 species would avoid competition for a limited resource.

A. hebraeum

The marked difference between the burdens of *A. hebraeum* of the guineafowls in the AVKR and those on the farm "Bucklands" can be ascribed to the regular treatment of the domestic stock on the farm with an acaricide[2] containing a synthetic pyrethroid with a residual effect. This resulted in a reduction in the numbers of *A. hebraeum* not only on the guineafowls but also on scrub hares and kudu and on the vegetation on the farm. This has been discussed in greater detail by Horak & Knight (1986) and Petney & Horak (1987).

The smaller tick burdens of the guineafowls shot at the refuse dump at Skukuza, when compared with those shot at other sites in the KNP, are probably due to the dilution of the available number of questing immature ticks amongst the very large flocks of birds concentrated around the dump. The guineafowls do not themselves directly generate larvae as they carry no adult *A. hebraeum*. These are present on the large herbivores in the vicinity and while the

[2] Sumitik, Shell SA (Pty) Ltd

densities of some of these animals are also slightly higher near Skukuza, they are proportionately not nearly as high as that of the guineafowls at this locality.

The immature stages of *A. hebraeum* were the most abundant and prevalent on the guineafowls in both the AVKR and the KNP, and but for 1 bird all the guineafowls examined at these localities were infested. The mean burdens were 568,0 larvae and 25,5 nymphs for birds in the AVKR and 184,9 larvae and 16,7 nymphs for those in the KNP. The ratios of larvae to nymphs were thus 22,3:1 and 11,1:1 respectively for the 2 reserves. The ratio of larvae to nymphs in the AVKR is thus double that in the KNP suggesting a ceiling to the number of nymphs that guineafowls can harbour. However, if individual burdens are considered, the largest number of larvae harboured by a single bird was 1 757 in the AVKR and 2 429 in the KNP and of nymphs 143 and 97 respectively. This seems to negate the possibility of a ceiling to the number of nymphs a guineafowl can carry.

The ratio of larvae to nymphs need not be an accurate reflection of the successful translation of larvae to the nymphal stage. The immature stages of this tick have a very wide host range (Theiler, 1962; Norval, 1974; Horak, MacIvor, Petney & De Vos, 1987) and hence the tick burdens of all host species within a particular region have to be considered in order to assess accurate larval to nymphal ratios. Using the data of Horak *et al.* (1987), larval to nymph ratios of 16,9:1 on guineafowls; 2,3:1 on scrub hares, and 5,1:1 on kudu in the AVKR can be calculated. In the KNP their data would give ratios of 1,3:1 on warthogs; 7,2:1 on impala; 28,8:1 on blue wildebeest; 6,9:1 on kudu, and 6,3:1 on Burchell's zebras. As indicated earlier these species are only some of the hosts that are present in each of the reserves and each of the other host species is likely to have different ratios of larvae to nymphs. The ratios may also differ for the same host species in different localities, as seen with the guineafowls in the AVKR and in the KNP. The latter differences could be due to differences in the diversity and/or density of the host fauna at the 2 localities.

Petney & Horak (1987), during a survey lasting from August 1985 to July 1986, recovered the largest numbers of free-living larvae of *A. hebraeum* from the vegetation of the AVKR during August and September 1985 and from March to June 1986. The larval burdens on the guineafowls slaughtered during the same period in the present survey, were high in August and September 1985 and from January to May 1986. These periods of larval abundance during spring and from late summer to autumn correspond to those observed by Rechav (1982) on cattle on a farm near East London in the eastern Cape Province.

No pattern of abundance was evident for the nymphs on the guineafowls in the AVKR or for the larvae and nymphs on the guineafowls in the KNP.

A. marmoreum

This tick is listed by Hoogstraal & Aeschlimann (1982) as having a strict-total host specificity for tortoises in the Ethiopian region. However, Theiler (1962), Norval (1975b) and Horak *et al.* (1987) have found that several bird and mammal species can serve as hosts for the larvae and nymphs. Although tortoises are the preferred hosts for all stages of development (Theiler, 1962; Norval 1975b; Dower, Petney & Horak, 1988), helmeted guineafowl, caracal, kudu, eland and cattle are all good hosts of the larvae judging by the numbers recovered and the percentage of hosts infested (Horak *et al.*, 1987). With the possible exception of guineafowls, none of these latter animals are good hosts of the nymphs (Horak *et al.*, 1987).

The percentage of guineafowls infested at the 3 localities was AVKR 66,7 %, "Bucklands" 78,4 % and KNP 75,4 %. The mean burdens of infested birds were 13,1; 15,4 and 25,7 larvae and 1,0; 1,1 and 1,2 nymphs respectively. Combining the total burdens of the birds in the AVKR and on "Bucklands", the ratio of larvae to nymphs was 13,1:1 compared with 22,2:1 for the birds in the KNP. These ratios are nearly the exact opposite of those recorded for *A. hebraeum* on the birds at the two localities.

Acaricidal treatment of the domestic stock on "Bucklands" did not have an adverse effect on the *A. marmoreum* burdens of the guineafowls on the farm. This is because the adult ticks are on tortoises and thus unaffected by the acaricide.

The pattern of seasonal abundance in the present surveys differs somewhat from that described by Norval (1975b), Horak, Sheppey, Knight & Beuthin (1986) and Rechav *et al.* (1987). In the eastern Cape Province the larvae appeared to be most numerous on the guineafowls from late summer to spring and the nymphs during early summer. In the KNP larvae were most numerous from late summer to spring and nymphs from spring or mid-summer to the end of winter. Both these patterns of seasonal abundance seem to indicate a 2-year life cycle as suggested by Norval (1975b). This seems quite likely, taking into account the extended time all stages spend on tortoises (Dower *et al.*, 1988).

H. silacea

This tick is found in well-wooded ravines and river valleys in the eastern Cape Province and, to a lesser extent, Natal (Howell, Walker & Nevill, 1978), hence its abundance in the Valley Bushveld regions of both provinces. Theiler (1962), Norval (1975a) and Horak & Williams (1986) have all recorded the helmeted guineafowl as a host of the immature stages. Its abundance on the birds in the eastern Cape Province in the present survey confirms these observations.

Although earlier surveys indicate that the larvae are most numerous from autumn to winter or spring and the nymphs from winter or spring to early summer (Norval, 1975a; Knight & Rechav, 1978; Rechav, 1982; Horak & Williams, 1986), no such pattern was obvious in the present study.

***Hyalomma* spp.**

The immature stages of *H. marginatum rufipes* and *H. truncatum* both prefer hares as hosts (Horak & MacIvor, 1987; Rechav *et al.*, 1987). Those of *H. marginatum rufipes* may also be found on ground-frequenting birds (Horak & Knight, 1986; Rechav *et al.*, 1987), while those of *H. truncatum* prefer rodents as alternate hosts (Horak & MacIvor, 1987). The *H. marginatum rufipes* recovered from the guineafowls in the eastern Cape Province are therefore true parasites of these birds. The small number of *H. truncatum* recovered from the birds in the KNP are incidental parasites and are only a reflection of the considerable number of larvae available in the environment. This is confirmed by the large numbers recovered from scrub hares examined at the same time (Horak, Spickett & Braack, 1990, unpublished data).

The presence of immature *H. marginatum rufipes* on the guinefowls in the eastern Cape Province from January to August 1986 is similar to that on scrub hares at the same locality and on Cape and scrub hares in the S.A. Lombard Nature Reserve, south-western Transvaal (Horak & MacIvor, 1987; Rechav *et al.*, 1987). In the Mountain Zebra National Park, near Cradock, where the winters are colder, the immature stages of *Hyalomma marginatum turanicum* were present on scrub hares in their largest numbers from April to August (Horak & MacIvor, 1987) and on guineafowls only during May and July (Horak & Williams, 1986). Adult ticks of these two subspecies prefer large hosts such as eland and zebras (Horak & MacIvor, 1987; Rechav *et al.*, 1987).

Other ixodid ticks

All the other ixodid ticks recovered from the guinea fowls must be considered incidental parasites and merely a reflection of the seasonal abundance of their free-living stages in the environment.

None of the *R. zambeziensis* larvae recovered appeared to have attached to the birds. Their presence from May to July or August corresponds to that observed for *Rhipicephalus* spp. larvae *(Rhipicephalus appendiculatus* and *R. zambeziensis)* on blue wildebeest and Burchell's zebras in the KNP (Horak, De Vos & Brown, 1983; Horak, De Vos & De Klerk, 1984).

***Argas* sp.**

In northern Nigeria, Fabiyi (1980) recovered the larvae of *Argas persicus* from 30 % of guineafowls he examined, while in southern Guinea savanna, also in Nigeria, Okaeme (1988) recovered the larvae of this tick from 2 % of semi-wild guineafowls and none from wild guinefowls. In the present survey 22 % of the guineafowls from the KNP and none from the estern Cape Province were infested with *Argas* sp. larvae.

Although considerable variation occurred in the presence and numbers of *Argas* sp. larvae on the guineafowls in the KNP, they were recovered consistently from June to December 1989. None were present during January, March and April in both years of the survey. Rechav *et al.* (1987) collected *Argas* sp. larvae from helmeted guineafowls in the S.A. Lombard Nature Reserve throughout the summer, with a peak in October or November.

In Zimbabwe, Norval, Short & Chisholm (1985) recovered variable numbers of *Argas walkerae* larvae throughout the year on domestic fowls kept in a run constructed of poles and thatch. The larvae were most abundant on an artificial perch in the run during early summer. Norval *et al.* (1985) suggested that 2 cohorts of larvae were responsible for this rise, the first in September from overwintering eggs and the second in November from eggs laid by females that had overwintered.

Bloodsmears made from the guineafowls in the KNP revealed the presence of an *Aegyptianella* sp. (Huchzermeyer, Horak & Braack, 1991). Whether the *Argas* sp. collected from the birds play a role in the transmission of this rickettsia could not be determined in the present survey.

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RESEARCH COMMUNICATION

Ticks on crested francolins, *Francolinus sephaena*, and on the vegetation on a farm in Limpopo Province, South Africa

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ABSTRACT

UYS, A.C. & HORAK, I.G. 2005. Ticks on crested francolins, *Francolinus sephaena*, and on the vegetation on a farm in Limpopo Province, South Africa. *Onderstepoort Journal of Veterinary Research*, 72:339–343

Ticks were collected at approximately bi-monthly intervals between June 1996 and June 1997 from crested francolins, *Francolinus sephaena*, and from the vegetation on a mixed cattle and wildlife farm in Limpopo Province, South Africa. The birds were infested with the immature stages of 13 tick species, of which *Amblyomma hebraeum*, *Amblyomma marmoreum* and *Hyalomma marginatum rufipes* were the most numerous and prevalent. Ten ixodid tick species were collected from the vegetation, of which the immature stages of *Rhipicephalus appendiculatus*, *Rhipicephalus* (*Boophilus*) *decoloratus* and *Rhipicephalus evertsi evertsi* were the most numerous. No adult ticks were collected from the birds and only two from the vegetation. The restricted home range of crested francolins implies that they could serve as a source of tick infestation only for other animals within the same habitat as the birds.

Keywords: Crested francolins, *Francolinus sephaena*, free-living ticks, Limpopo Province, parasitic ticks

Birds are hosts of the immature stages of several ixodid tick species (Theiler 1962) and consequently could serve as a source of subsequent adult tick infestation for other hosts. This is particularly so for migrating birds (Hoogstraal, Kaiser, Traylor, Gaber & Guindy 1961), or species such as helmeted guineafowls, *Numida meleagris*, that on occasion can harbour large numbers of immature ticks (Horak & Williams 1986; Horak, Spickett, Braack & Williams 1991). Two species of guineafowls and several species of francolins occur in South Africa and of these the ixodid tick burdens of helmeted guineafowls, Cape francolins, *Francolinus capensis*, and grey-wing francolins, *Francolinus africanus*, have been determined (Horak & Williams 1986; Horak *et al.* 1991; Horak & Boomker 1998). Similar data for crested francolins, *Francolinus sephaena*, or crested guineafowls, *Guttera pucherani*, both of which occur in the northern and north-eastern regions of South Africa, have not been collected.

The objective of the present study was to determine whether crested francolins, which prefer thick cover and matted vegetation, play the same role as helmeted guineafowls, which prefer thorny scrub and savanna veld, as hosts for the immature stages of ticks of veterinary importance. The species spec-

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trum of ticks on the francolins was also compared with that of free-living ticks on the vegetation at the same locality.

The survey was conducted on the farm "Sandspruit" (24°38´S, 27°40´E), comprising 655 ha in the valley of a seasonally flowing river along the southern foothills of the Waterberg mountain range in Limpopo Province. Annual rainfall varies between 550 mm and 600 mm, mean annual temperature is approximately 20 °C, and the vegetation is classified as Sour Bushveld and Sourish Mixed Bushveld (Acocks 1988). A herd of 140 cows and six bulls ran on the farm, and these were hand-sprayed with a synthetic pyrethroid for the control of ticks at weekly intervals during summer and fortnightly during winter. Donkeys and a variety of wild ungulates including warthogs, impalas, greater kudus and grey duikers were also present on the farm.

An attempt was made to shoot six crested francolins every second month from June 1996 to June 1997. This, however, was not always possible because of the very dense vegetation resulting from above average rainfall during the preceding year and during the study period, and a total of only 23 birds were collected. The carcass of each bird was placed in a sturdy plastic bag immediately after it had been shot, and the bag was sealed and transported to a field laboratory. Here the bird was decapitated approximately 1 cm caudad to the junction between the head and the neck, the wings and the tail were severed from the body and the feathered portion of the carcass was skinned. The legs were severed at the tibiotarsal-tarsometatarsal joint, but left attached to the skin. The head, wings, body with legs attached, and tail were placed separately in plastic jars and sufficient tick-detaching agent (Triatix: Hoechst Roussel Vet (Pty) Ltd) was added to cover the material in each jar. Except that the skin and feathers of both wings, both legs and the entire body were examined under a stereoscopic microscope, ticks were otherwise recovered from the material in the jars and identified and counted as described by Horak & Williams (1986).

Free-living ticks were collected from the vegetation using the drag-sampling method described by Petney & Horak (1987), and with the exception of February 1997, when heavy rainfall prevented sampling, this was done every second month from June 1996 to June 1997 in each of four woodland habitats and four open grassland habitats.

The birds were infested with the immature stages of 12 ixodid tick species and the larvae of one argasid tick species (Table 1). The larvae of *A. hebraeum* were the most numerous and prevalent followed by those of *Amblyomma marmoreum* and *Hyalomma marginatum rufipes.*

The immature stages of only four tick species can be regarded as parasites of the francolins, namely *A. hebraeum, A. marmoreum, H. marginatum rufipes* and *Argas* sp. The remaining species should be considered accidental infestations or "stragglers". The highest total burden, comprising 256 larvae and five nymphs, was recorded on a bird examined during April 1997, whereas a bird examined during February 1997 harboured no ticks. The mean tick burdens of the francolins consisted of 88 larvae and three nymphs.

The carcasses of 19 of the 23 francolins were processed in a manner such that the attachment distribution of their ticks could be determined; this is summarized in Table 2. The majority of *A. hebraeum* and *H. marginatum rufipes* larvae were recovered from the heads of the birds, while those of *A. marmoreum* were collected from the body and wings.

Ten ixodid tick species were collected from the vegetation, the larvae of *Rhipicephalus appendiculatus* being the most numerous followed by those of *Rhipicephalus* (*Boophilus*) *decoloratus* and *Rhipicephalus evertsi evertsi* (Table 3). Although ten of the tick species on the francolins were also present on the vegetation, the proportional species representation in the two tick populations differed considerably.

The mean burden of 37 *A. hebraeum* larvae on the francolins is considerably lower than the mean burdens of 184 and 568 larvae on helmeted guineafowls in the Kruger National Park, Mpumulanga Province and the Andries Vosloo Kudu Reserve, Eastern Cape Province respectively (Horak *et al.* 1991). However, four francolins each harboured more than 100 larvae, indicating that these birds are also capable of carrying large numbers of ticks. Horak & Williams (1986) regard helmeted guineafowls as important disseminators of *A. hebraeum* because of their mobility and the large numbers of immature ticks that they harbour. Crested francolins on the other hand with their more restricted home ranges would seem more likely to contribute to the maintenance of localized populations of this tick. This would indeed appear to be the case in that the proportional representation of *A. hebraeum* on the francolins, with their preference for dense vegetation, was considerably greater than that on the vegetation (Tables 1 and 3).

TABLE 1 Ticks collected from 23 crested francolins on the farm "Sandspruit", Limpopo Province

Tick species	Total number of ticks collected			Proportion (%)	No. of birds infested
	Larvae	Nymphs	Total		
Amblyomma hebraeum	853	37	890	40.44	20
Amblyomma marmoreum	582	10	592	26.90	13
Hyalomma marginatum rufipes	507	16	523	23.76	13
Hyalomma truncatum	1	0	1	0.05	1
Ixodes sp.	1	0	1	0.05	1
Rhipicephalus (*Boophilus*) *decoloratus*	4	0	4	0.18	3
Rhipicephalus appendiculatus	7	3	10	0.45	3
Rhipicephalus evertsi evertsi	6	0	6	0.27	3
Rhipicephalus exophthalmos	3	0	3	0.14	2
Rhipicephalus pravus group	8	0	8	0.36	4
Rhipicephalus turanicus	7	0	7	0.32	3
Rhipicephalus zambeziensis	63	3	66	3.00	10
Argas sp.	90	0	90	4.09	4

TABLE 2 The attachment distribution of ticks on 18 crested francolins on the farm "Sandspruit", Limpopo Province

Tick species and life stage	Number of ticks	Relative abundance (%)			
		Head	Body	Wings	Tail
Amblyomma hebraeum					
Larvae	731	84.5	11.9	3.0	0.6
Nymphs	32	46.9	28.1	18.8	6.2
Amblyomma marmoreum					
Larvae	578	13.7	32.7	32.7	20.9
Nymphs	9	44.5	22.2	22.2	11.1
Hyalomma marginatum rufipes					
Larvae	382	91.6	5.8	1.8	0.8
Nymphs	10	90.0	10.0		

TABLE 3 Free-living ticks collected by drag-sampling the vegetation on the farm "Sandspruit", Limpopo Province

Tick species	Total number of ticks collected			Proportion (%)
	Larvae	Nymphs	Total	
Amblyomma hebraeum	111	0	111	7.34
Amblyomma marmoreum	10	0	10	0.66
Hyalomma marginatum rufipes	13	0	13	0.86
Ixodes sp.	2	0	2*	0.13
Rhipicephalus (*Boophilus*) *decoloratus*	363	0	363	24.01
Rhipicephalus appendiculatus	470	86	556**	36.77
Rhipicephalus evertsi evertsi	356	0	356	23.55
Rhipicephalus turanicus	3	0	3	0.20
Rhipicephalus zambeziensis	85	13	98	6.48

* plus 1 male
** plus 1 female

Helmeted guineafowls examined in the Valley Bushveld of the Eastern Cape Province were infested mainly with the larvae of *A. hebraeum* and *Haemaphysalis silacea* and lesser numbers of *A. marmoreum* and small numbers of *H. marginatum rufipes* (Horak & Williams 1986). Of these 86.9 % were

recovered from the heads and upper necks of the guineafowls, a proportion similar to the 84.5 % now recorded for *A. hebraeum* larvae on the heads of the francolins (Table 2).

Tortoises, and particularly the leopard tortoise, *Geochelone pardalis*, are the preferred hosts of all stages of development of *A. marmoreum* (Norval 1975). Helmeted guineafowls are good hosts of the larvae of this tick, and in the Mountain Zebra National Park in the Eastern Cape Province they harboured a mean burden of 86 larvae with a prevalence of 90 %, compared to eight larvae with a prevalence of 66.7 % on birds in the Andries Vosloo Kudu Reserve, and 19 larvae with a prevalence of 75.4 % on guineafowls in the Kruger National Park (Horak & Williams 1986; Horak *et al.* 1991). The mean burden of the crested francolins in the present study was 25 larvae with a prevalence of 56.5 %. Three of the seven Cape francolins examined by Horak & Boomker (1998) in the Bontebok National Park harboured a total of 15 larvae and one nymph of this tick, and four of the seven greywing francolins a total of 129 larvae.

The heads of the crested francolins were the attachment site least favoured by the larvae of *A. marmoreum*, with the body and wings harbouring most. This attachment distribution could be because of competition with the larvae of *A. hebraeum* and of *H. marginatum rufipes*, both of which prefer the head as an attachment site (Table 2). The 26.9 % proportional representation of the immature stages of *A. marmoreum* on the francolins as opposed to the 0.66 % on the vegetation indicates that larvae are attracted to the birds, or that the habitat most favoured by the birds coincides with that most suitable for the survival of the free-living stages of the tick, or that only a small proportion of larvae are collected from the vegetation by drag-sampling, or that the timing of the drag-sampling did not correspond with the periods of peak larval numbers on the vegetation.

The preferred hosts of the immature stages of *H. marginatum rufipes* are hares, *Lepus* spp. and ground-frequenting birds (Rechav, Zeederberg & Zeller 1987; Horak *et al.* 1991). Their presence on the francolins in the present survey is thus not unexpected. As this is a two-host tick the ratio of 31.7 larvae to one nymph on the birds indicates a very poor translation of larvae to nymphs. Forty-four larvae and 132 nymphs of *H. marginatum rufipes* were collected from three of five scrub hares, *Lepus saxatilis*, examined in the same area as the francolins, indicating excellent translation from one life stage to the next on these animals (Horak, Spickett, Braack, Penzhorn, Bagnall & Uys 1995). As with the previous two species there was a considerable difference between the proportional representation of larvae on the francolins (23.76 %) and free-living larvae on the vegetation (0.86 %). The single *H. truncatum* larva recovered from a bird in June 1996 is considered a "straggler". The immature stages of the latter tick prefer hares as hosts, and it was the most numerous of the nine tick species collected from five scrub hares examined in the same region as the francolins (Horak *et al.* 1995).

The larvae of *R.* (*Boophilus*) *decoloratus* were amongst the most numerous of the free-living ticks collected from the vegetation. This tick prefers domestic and wild bovids as hosts (Mason & Norval 1980), and its presence on any bird must be considered accidental and a reflection of the number of free-living ticks in the environment.

The farm on which the present survey was conducted lies in a region of South Africa in which the distributions of *R. appendiculatus* and *Rhipicephalus zambeziensis* overlap (Walker, Keirans & Horak 2000). Although the immature stages of *R. appendiculatus* were considerably more numerous than those of *R. zambeziensis* on the vegetation the converse was true on the birds. A similar pattern of infestation has been observed on helmeted guineafowls in the Kruger National Park, where both ticks also occur (Horak *et al.* 1991). Equids are the preferred hosts of all stages of development of *Rhipicephalus evertsi evertsi,* but cattle are also good hosts (Walker *et al.* 2000). The large number of larvae collected from the vegetation can be ascribed to the presence of cattle and donkeys on the farm, while those on the francolins are accidental infestations.

Most records of *Rhipicephalus exophthalmos* emanate from the southern and western regions of South Africa and from Namibia. Scrub hares are preferred hosts of the adults, and with elephant shrews, *Elephantulus* spp., are the only animals to date from which the immature stages have been recovered (Walker *et al.* 2000). Scrub hares are also preferred hosts of all stages of development of the *Rhipicephalus pravus*-like tick (Horak *et al.* 1995), of which larvae were collected from four of the francolins. An adult of *Rhipicephalus turanicus* has previously been collected from a scrub hare in the study region (Horak *et al.* 1995), and the recovery of larvae from three francolins in the present survey confirms its presence at this locality. Infestation of the birds with the larvae of the aforemen-

tioned three ticks should be considered as accidental.

Four of the 23 birds were infested with the larvae of an *Argas* sp. A similar proportion of 118 helmeted guineafowls examined in the Kruger National Park were also infested with larvae of a tick belonging to this genus (Horak *et al.* 1991).

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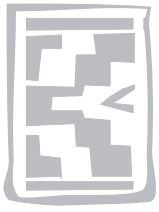

Birds as hosts of immature ixodid ticks in Free State Province, South Africa

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ABSTRACT

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The objective of this study was to determine the species spectrum of ixodid ticks infesting birds in Free State Province, South Africa. To this end a large number of birds belonging to several species were examined for ticks and a total of 180 birds belonging to 39 species at 17 localities were infested, and ticks belonging to eight species were recovered. The immature stages of only two, namely *Amblyomma marmoreum* and *Hyalomma marginatum rufipes*, were sufficiently prevalent and numerous to safely assume that they regularly use birds as hosts. Helmeted guineafowls, Numida meleagris, were the most heavily infested and one harboured a total of 319 larvae and four nymphs. Amongst the other species an eastern clapper lark, Mirafra fasciolata, was infested with 69 larvae and a nymph, but no other bird harboured more than 40 ticks. The larvae and nymphs of H. m. rufipes were most numerous on birds from April to August

Keywords: *Amblyomma marmoreum*, birds, *Hyalomma marginatum rufipes*, ixodid ticks, seasonal occurrence

INTRODUCTION

Despite the small size of most birds their capacity for rapid and maintained population growth can contribute significantly to the demography of those tick species that use them as hosts. Certain species daily fly considerable distances, and may alight in diverse habitats during such flights, thus enhancing their potential for the acquisition, transport and dissemination of ticks. Furthermore, the seasonal migratory species cover considerable distances in a relatively short period of time and can therefore transport ticks from one country or even continent to another (Hoogstraal, Kaiser, Traylor, Gaber & Guindy 1961).

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Few of the migratory birds examined in Egypt by Hoogstraal *et al.* (1961) were infested, and those that were, harboured only small numbers of ticks. In contrast, it would appear as if a large proportion of migratory and non-migratory ground-frequenting birds in rural and wildlife regions of South Africa are infested. The individual burdens of those species commonly referred to as game birds, namely guineafowls, spurfowls and francolins, may be large, often exceeding 100 and sometimes 1 000 immature ticks (Horak, Spickett, Braack & Williams 1991b; Uys & Horak 2005).

In southern Africa, the adults of four tick species, *Haemaphysalis hoodi*, *Ixodes pterodromae*, *Ixodes theilerae* and *Ixodes uriae* prefer birds as hosts (Walker 1991). The adults of two other species, *Hyalomma marginatum rufipes* and *Rhipicephalus*

turanicus, although they usually infest mammals, may infest ostriches, and those of the latter tick, also the larger raptors (Theiler 1962; Norval 1982; Walker, Keirans & Horak 2000). Birds, however, serve as hosts of the immature stages of a number of tick species (Theiler 1962). Helmeted guineafowls, *Numida meleagris*, are good hosts of the immature stages of *Amblyomma hebraeum*, *Amblyomma marmoreum*, *Haemaphysalis silacea*, *H. m. rufipes* and *Hyalomma glabrum* (at the time referred to as *Hyalomma marginatum turanicum*) (Horak & Williams 1986; Rechav, Zeederberg & Zeller 1987; Horak *et al*. 1991b). Crested francolins, *Dendroperdix sephaena*, are good hosts of the immature stages of *A. hebraeum*, *A. marmoreum* and *H. m. rufipes* (Uys & Horak 2005), and Cape francolins, *Pternistis capensis*, are hosts of the immature stages of *Haemaphysalis aciculifer* (Horak & Boomker 1998). Birds of several other species may be infested with the larvae of *A. marmoreum* and the immature stages of *H. m. rufipes* and *H. glabrum* (*H. m. turanicum*) (Norval 1975; Norval 1982; Horak & Boomker 1998; Horak, Fourie, Novellie & Williams 1991a).

Because the adults of *Hyalomma* spp. are often the cause of lameness in small domestic stock (Kok & Fourie 1995), and those of *Ixodes rubicundus* and *Rhipicephalus warburtoni* of toxin-induced paralysis in these animals (Fourie, Horak & Marais 1988; Fourie, Petney, Horak & De Jager 1989), a number of surveys to determine the host spectrum of these ticks in Free State Province, South Africa were conducted. Several birds were examined during these surveys, while other birds were examined for ticks when ringed by one of us (DJVN). This paper presents the findings of these investigations and discusses the role played by birds as hosts of the immature stages of ixodid ticks in South Africa.

MATERIALS AND METHODS

Ticks were collected from birds at various localities in Free State Province, South Africa (Table1). The names of the birds and the sequence in which they are listed follow Maclean (1993), and their common names are those recorded by Hockey, Dean & Ryan (2005). Larger birds were processed for tick recovery as described by Horak & Williams (1986) and smaller birds as described by Horak *et al*. (1991a). When live birds were ringed the head, neck, body, wings and tail were carefully examined with the naked eye and all visible ticks collected. Excluding the ticks from one of the helmeted guineafowls, which was particularly heavily infested, the mean monthly burdens of immature *H. m. rufipes* were calculated irrespective of the year in which the birds were examined.

RESULTS AND DISCUSSION

The species and numbers of birds examined and the species and numbers of ticks they harboured are summarized in Table 2. The immature stages of eight ixodid tick species were recovered from 180 birds belonging to 39 species. Larvae and nymphs of *H. m. rufipes* were the most numerous and prevalent, followed by the larvae of *A. marmoreum*. A single helmeted guineafowl in the Willem Pretorius Nature Reserve harboured the largest infestation of both species, with 209 larvae and a nymph of *A. marmoreum* and 106 larvae and three nymphs of *H. m. rufipes.* In addition it was also infested with three larvae of *Rhipicephalus evertsi evertsi* and a single larva of *Rhipicephalus gertrudae*. With the exception of an eastern clapper lark, *Mirafra fasciolata*, at Glen Agricultural College, which harboured 69 larvae and a nymph of *H. m. rufipes*, and four other birds that each harboured 20 or more larvae and nymphs, no bird was infested with more than 20 ticks.

Amblyomma marmoreum

Infestation with this tick was most prevalent on helmeted guineafowls in the Willem Pretorius Nature Reserve, and four of the six birds examined were infested. Fifteen smaller birds belonging to 11 species were also examined in this reserve, but not one was infested. Of the 170 birds, other than helmeted guineafowls, examined elsewhere in the province, 35 were infested and their individual burdens never exceeded five ticks.

Adult *A. marmoreum*, colloquially known as the South African tortoise tick, infests tortoises, and more particularly the leopard tortoise, *Geochelone pardalis* as hosts (Horak, McKay, Heyne & Spickett 2006). The immature stages infest tortoises, some of the larger reptiles, a large number of bird species, hares, antelopes, carnivores and domestic livestock (Norval 1975; Horak & Fourie 1991; Horak *et al.* 1991a; 2006; Horak, Braack, Fourie & Walker 2000). Helmeted guineafowls appear to be good hosts of the larvae of this tick. In previous surveys several of them harboured more than 50 larvae with 585 being the largest number recovered. However, the number of nymphs rarely exceeded five (Horak & Williams 1986; Horak *et al.* 1991b). Thirteen of 16 helmeted guineafowls examined in an earlier study in the Mountain Zebra National Park, Eastern Cape Prov-

TABLE 1 Localities in Free State Province at which ticks were collected from birds

Tick species	Locality	Coordinates
Amblyomma marmoreum	Bishop's Glen* Salopia* Slangfontein* Wolwespruit*	29°00' S; 26°21' E 29°12' S; 25°58' E 30°08' S; 25°24' E 28°51' S; 25°32' E
Amblyomma marmoreum and *Hyalomma marginatum rufipes*	Willem Pretorius NR Glen Agricultural College Preezfontein* Doornhoek*	28°18' S; 27°15' E 28°54' S; 26°21' E 29°50' S; 25°23' E 28°53' S; 25°43' E
Hyalomma marginatum rufipes	Bloemfontein Morning Star* Floradale* Sandveld NR Wolwekop* Nooitgedacht* Ventersvlei* Soetdoring NR	29°08' S; 26°10' E 28°48' S; 27°14' E 28°57' S; 26°13' E 27°38' S; 25°42' E 29°27' S; 26°40' E 29°13' S; 25°54' E 29°14' S; 25°55' E 28°50' S; 26°04' E
Hyalomma glabrum	Tussen-die-Riviere NR	30°29' S; 26°15' E
Haemaphysalis leachi	Tussen-die-Riviere NR	30°29' S; 26°15' E
Ixodes rubicundus	Bishop's Glen* Tussen-die-Riviere NR Slangfontein*	29°00' S; 26°21' E 30°29' S; 26°15' E 30°08' S; 25°24' E
Rhipicephalus evertsi evertsi	Willem Pretorius NR	28°18' S; 27°15' E
Rhipicephalus gertrudae	Tussen-die-Riviere NR Willem Pretorius NR	30°29' S; 26°15' E 28°18' S; 27°15' E
Rhipicephalus warburtoni	Slangfontein*	30°08' S; 25°24' E

* = Farm
NR = Nature reserve

ince were infested, but not one of 27 smaller birds belonging to five other species (Horak *et al.* 1991a). Other game birds that are regularly infested, and of which individuals may harbour large burdens, are francolins and spurfowls (Horak & Boomker 1998; Uys & Horak 2005).

Smaller birds are either less exposed to the larvae of *A. marmoreum* because of their size, or because they spend less time on the ground, or they may be less susceptible. The larvae of this tick quest for hosts from the vegetation (Horak *et al*. 2006), whereas the activity of many of the smaller birds is confined to the soil surface and hence they may not even come into contact with the larvae. Few nymphs are collected from the vegetation by sampling with flannel strips (Spickett, Horak, Van Niekerk & Braack 1992; Horak *et al.* 2006), indicating that they probably quest for hosts from the soil surface. This may explain the larger number of nymphs collected from small birds than from helmeted guineafowls (Table 2).

Larvae are generally most numerous on the vegetation from late summer to midwinter, and nymphs from spring to midsummer (Norval 1975; Rechav *et al*. 1987; Spickett *et al*. 1992; Horak *et al.* 2006). The presence of this tick on birds could thus also be expected to be seasonal, but because too few ticks were collected from too few birds this could not be verified.

Hyalomma species

Three tick species belonging to the genus *Hyalomma*, namely *H. truncatum*, *H. m. rufipes* and *H. glabrum* (*H. m. turanicum*) are present in South Africa (Walker 1991). Both *H. truncatum* and *H. m. rufipes* are widespread and there is considerable overlap in their distributions (Howell, Walker & Nevill 1978). *Hyalomma glabrum*, which until recently was considered to be identical to Asian *Hyalomma marginatum turanicum* (Apanaskevich & Horak 2006), has a more restricted distribution (Howell *et al.* 1978), and the only region of Free State Province in which there is substantial

TABLE 2 Ixodid ticks collected from birds in Free State Province, South Africa. Bird names and sequence according to Maclean (1993) and Hockey *et al.* (2005)

Bird		Number infested	Number of ticks collected				Other tick species
			Amblyomma marmoreum		*Hyalomma marginatum rufipes*		
Common name	Scientific name		Larvae	Nymphs	Larvae	Nymphs	
Cattle Egret	*Bubulcus ibis*	1					*H. m. rufipes* 1 male
Orange River Francolin	*Scleroptila levaillantoides*	1			8		
Swainson's Spurfowl	*Pternistis swainsonii*	1			1	1	
Helmeted Guineafowl	*Numida meleagris*	10	233	3	139	6	*H. glabrum* 12 LL, 4 NN; *R. e. evertsi* 4 LL; *R. gertrudae* 2 LL
Northern Black Korhaan	*Afrotis afraoides*	3			2	5	
Caspian Plover	*Charadrius asiaticus*	1			1	2	
Crowned Lapwing	*Vanellus coronatus*	3			15	14	
Double-banded Courser	*Rhinoptilus africanus*	1				1	
Namaqua Dove	*Oena capensis*	1			1		
Spotted Eagle Owl	*Bubo africanus*	1			14	10	
Rufous-cheeked Nightjar	*Caprimulgus rufigena*	5		2	1	4	
Melodious Lark	*Mirafra cheniana*	6	1	1	8	13	
Eastern Clapper Lark	*Mirafra fasciolata*	22	2	8	108	8	
Spike-heeled Lark	*Chersomanes albofasciata*	34	7	2	93	7	*I. rubicundus* 3 LL; *R. warburtoni* 5 LL, 15 NN
Red-capped Lark	*Calandrella cinerea*	1			1		
Pink-billed Lark	*Spizocorys conirostris*	1			2	2	
Large-billed Lark	*Galerida magnirostris*	5	12		1	1	
Ashy Tit	*Parus cinerascens*	1				6	
African Red-eyed Bulbul	*Pycnonotus nigricans*	2			1	1	*R. gertrudae* 1 LL
Ant-eating Chat	*Myrmecocichla formicivora*	5			6	2	*H. leachi* 1 N
Cape Robin-Chat	*Cossypha caffra*	4		2	5	12	
Karoo Scrub-Robin	*Cercotrichas coryphoeus*	7	2		15	32	*R. gertrudae* 1 LL
Kalahari Scrub-Robin	*Cercotrichas paena*	1		1			

TABLE 2 *cont.*

Bird		Number infested	Number of ticks collected				Other tick species
			Amblyomma marmoreum		*Hyalomma marginatum rufipes*		
Common name	Scientific name		Larvae	Nymphs	Larvae	Nymphs	
Chestnut-vented Tit-babbler	*Parisoma subcaeruleum*	2			1	1	
Desert Cisticola	*Cisticola aridulus*	1			2		
Cloud Cisticola	*Cisticola textrix*	5		1	6	1	
Blackchested Prinia	*Prinia flavicans*	2	2			1	
Marico Flycatcher	*Bradornis mariquensis*	1				2	
Fiscal Flycatcher	*Sigelus silens*	3			2	7	
Pririt Batis	*Batis pririt*	1	2				
Cape Wagtail	*Motacilla capensis*	1				1	
African Pipit	*Anthus cinnamomeus*	2			3		
Pipit	*Anthus* sp.	2	1		6	4	
Bokmakierie	*Telophorus zeylonus*	1			3	1	
Pied Starling	*Spreo bicolor*	4			8	2	
Wattled Starling	*Creatophora cinerea*	31			59	29	
Cape Weaver	*Ploceus capensis*	1					*I. rubicundus* 2 LL
Red Bishop	*Euplectes orix*	5			3	5	*I. rubicundus* 1 female
Bunting	*Emberiza* sp.	1	1				
Totals		**180**	**263**	**20**	**515**	**181**	

LL = larvae
NN = nymphs

overlap in the geographic distribution of this tick and that of *H. m. rufipes* is the south-west (Howell *et al*. 1978).

These are all two-host ticks and the immature stages of *H. truncatum* and *H. m. rufipes* can readily be differentiated from each other (Arthur 1975a; b), whereas those of the latter tick and *H. glabrum* are somewhat similar in appearance (Apanaskevich & Horak 2006). The only birds examined in the south-west region of the Free State Province were those on the farms "Slangfontein" and "Preezfontein" and in the Tussen-die-Riviere Nature Reserve. Helmeted guineafowls in the reserve were infested with larvae and nymphs of *H. glabrum* (Table 2).

Hyalomma m. rufipes was the most numerous of the ticks recovered and the majority of bird species examined in Free State Province were infested. It was also the most numerous tick collected by Hoogstraal *et al*. (1961) from birds migrating from East Africa to Europe and to Asia via Egypt. All but seven of the 1 025 immature ticks they collected from 340 birds belonged to this species. In the present survey seven of ten helmeted guineafowls examined were infested and one of these birds harboured the highest individual total for a bird of any species, namely 106 larvae and three nymphs. Helmeted guineafowls are not only the largest birds examined in the present survey, but they also spend most of the day on the ground, making them readily accessible to the larvae of *H. m. rufipes*. The bare heads and upper necks of these birds are a favoured attachment site for larvae of several tick species (Horak & Williams 1986), and probably also for those of *H. m. rufipes*. Although the heads and upper necks of crested francolins, *D. sephanea* are not bare, more than 90 % of *H. m. rufipes* larvae have been recovered from here on these birds (Uys & Horak 2005).

The overall ratio of 515 *H. m. rufipes* larvae to 181 nymphs on birds implies a satisfactory translation of one developmental stage to the next and that birds are thus suitable hosts of the tick.

The adults of *H. m. rufipes* attach to large animals such as African buffaloes, *Syncerus caffer*, eland, *Taurotragus oryx*, giraffes, *Giraffa camelopardalis* and domestic cattle (Norval 1982; Rechav *et al*. 1987; Horak, Swanepoel & Gummow 2002). They are most numerous on these animals during the summer months (Londt, Horak & de Villiers 1979; Rechav *et al*. 1987; Fourie, Kok & Heyne 1996; Dreyer, Fourie & Kok 1998). The immature stages use birds, Cape hares, *Lepus capensis* and scrub hares, *Lepus saxatilis* as hosts (Norval 1982; Rechav *et al.* 1987; Horak & Fourie 1991), and are most numerous on helmeted guineafowls and hares from late summer to late winter (Rechav *et al*. 1987; Horak & Fourie 1991). In the present survey most immature ticks were collected from birds between April and August with a peak in May (Fig. 1). The discrete separate periods of seasonal occurrence of the adults and the immature stages imply that a single life cycle is completed annually.

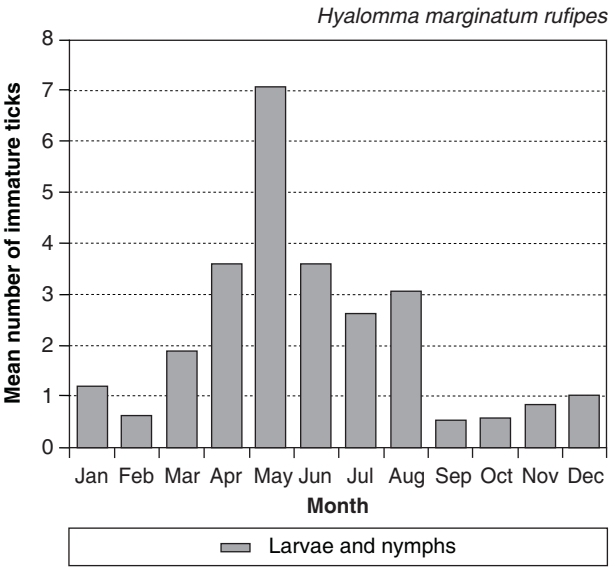

FIG. 1 Seasonal occurrence of the immature stages of *Hyalomma marginatum rufipes* on birds in Free State Province, South Africa

Hyalomma m. rufipes is probably the principal vector in South Africa of the virus causing Crimean Congo haemorrhagic fever (Horak *et al.* 2002; Swanepoel & Burt 2004). Although certain bird species would seem to be susceptible to experimental infection with the virus and can then transmit it to *H. m. rufipes* (Zeller, Cornet & Camicas 1994), according to Swanepoel & Burt (2004) it seems unlikely that this would occur naturally. The larvae and nymphs require 22 days to complete feeding on experimentally infested rabbits (Knight, Norval & Rechav 1978), and if they require the same length of time to feed on birds, their long-distance translocation is a distinct possibility, particularly on migratory species.

The hosts and seasonal occurrence of adult and immature *H. glabrum* [at the time considered to be *H. m. turanicum* by Horak *et al*. (1991a)] are similar to those of *H. m. rufipes*. Its host spectrum is, however, curtailed by the limits of its own distribution in South Africa. The immature stages of *H. truncatum* infest scrub hares and rodents (Horak *et al*. 1991a). If they are found on birds it can safely be assumed that they

are 'stragglers' from a heavily contaminated environment.

Other ticks

The remaining five tick species must be considered 'stragglers' and their presence on the birds reflecting local or seasonal abundance rather than host preference. The immature stages of *Haemaphysalis leachi* and *R. gertrudae* parasitize murid rodents (Norval 1984; Walker *et al*. 2000), and those of *I. rubicundus* and *R. warburtoni* parasitize rock elephant shrews, *Elephantulus myurus* (Fourie, Horak & Van Den Heever 1992; Walker *et al*. 2000). However, an engorged female *I. rubicundus* was recovered from a red bishop, *Euplectes orix*. The immature stages of *R. e. evertsi* prefer domestic and wild equids as hosts, but may also be found on a large variety of other animals, and occasionally also on birds (Walker *et al*. 2000).

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Reptiles

Of necessity the ticks that infest reptiles require long mouthparts to ensure their attachment to hosts that in all respects appear to be inhospitable. Ticks of the genus *Amblyomma* meet this requirement and *Amblyomma marmoreum*, *Amblyomma nuttalli* and *Amblyomma sylvaticum* use tortoises as hosts, while *Amblyomma exornatum* infests varanid lizards and *Amblyomma latum* snakes (Horak, McKay, Heyne & Spickett 2006a; Horak, McKay, Henen, Heyne, Hofmeyr & De Villiers 2006d). The largest of these ticks, and possibly of all ticks in southern Africa, is *A. marmoreum*. Its nymphs and adults prefer leopard tortoises, *Geochelone pardalis*, as hosts, while the larvae may be found on tortoises as well as a variety of warm-blooded hosts, including birds (Horak *et al*. 2006a, d). All stages of development of *A. sylvaticum* prefer angulate tortoises, *Chersina angulata*, as hosts (Horak *et al*. 2006d).

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Hosts, seasonality and geographic distribution of the South African tortoise tick, *Amblyomma marmoreum*

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ABSTRACT

HORAK, I.G., MCKAY, I.J., HEYNE, HELOISE & SPICKETT, A.M. 2006. Hosts, seasonality and geographic distribution of the South African tortoise tick, *Amblyomma marmoreum*. *Onderstepoort Journal of Veterinary Research*, 74:13–25

The tortoise tick *Amblyomma marmoreum* was collected from large numbers of reptiles and other animals during the course of numerous surveys conducted in South Africa. A total of 1 229 ticks, of which 550 were adults, were recovered from 309 reptiles belonging to 13 species, with leopard tortoises, *Geochelone pardalis* being the most heavily infested. The 269 birds sampled harboured 4 901 larvae, 217 nymphs and no adult ticks, and the prevalence of infestation was greatest on helmeted guineafowls, *Numida meleagris*. Only two larvae were recovered from 610 rodents, including 31 spring hares, *Pedetes capensis*, whereas 1 144 other small mammals yielded 1 835 immature ticks, of which 1 655 were collected from 623 scrub hares, *Lepus saxatilis*. The 213 carnivores examined harboured 2 459 ticks of which none were adult. A single adult tick and 6 684 larvae and 62 nymphs were recovered from 656 large herbivores, and a total of 4 081 immature ticks and three adults were collected from 1 543 domestic animals and 194 humans.

Adult male and female *A. marmoreum* were most numerous on reptiles during January and February, and larvae during March. The largest numbers of larvae were present on domestic cattle and helmeted guineafowls in the Eastern Cape Province during March or April respectively, whereas larvae were most numerous on helmeted guineafowls, scrub hares and the vegetation in north-eastern Mpumalanga Province during May. In both provinces nymphs were most numerous between October and December. *Amblyomma marmoreum* appears to be most prevalent in the western regions of the Western and Eastern Cape and Free State provinces, and the north-eastern regions of the Northern Cape, KwaZulu-Natal, Mpumulanga and Limpopo provinces.

Keywords: *Amblyomma marmoreum*, birds, carnivores, domestic animals, geographic distribution, large herbivores, reptiles, seasonality, small mammals, vegetation

INTRODUCTION

The majority of ticks that have been collected from tortoises in South Africa belong to the genus *Amblyomma* and of these *Amblyomma marmoreum*, colloquially known as the South African tortoise tick, is probably the most prevalent (Theiler & Salisbury 1959). Although records of ticks on tortoises in South Africa date back to the 18th and 19th centuries (Theiler 1943; Walker & Schulz 1984), it was not until Theiler & Salisbury (1959) and Norval (1975) published their descriptions of ticks in the "*Amblyomma marmoreum* group" and on the ecology of *A. marmoreum*, respectively, that the taxonomy and biology of the latter tick was comprehensively addressed. In their paper, Theiler & Salisbury (1959) illustrated and described all stages of development of *A. marmoreum*

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and mapped its distribution and supplied a brief host list, while Norval (1975) described its ecology, life cycle and seasonality in the Eastern Cape Province and provided a more comprehensive list of hosts. Some years later Walker & Schulz (1984) recorded the burdens of *A. marmoreum* on tortoises in the Addo Elephant National Park in the Eastern Cape Province, while Norval (1983) listed its hosts and mapped its distribution in Zimbabwe.

Interest in *A. marmoreum* gained momentum with the unpublished discovery by Bezuidenhout & Olivier in 1985 and Bezuidenhout in 1986 (cited by Bezuidenhout 1987, and Oberem & Bezuidenhout 1987) that it could both acquire and transmit *Ehrlichia* (*Cowdria*) *ruminantium*, the causative organism of heartwater in domestic and wild ruminants. In addition, Bezuidenhout (1988) demonstrated that the leopard tortoise, a preferred host of all stages of development of the tick, could be infected with *E.* (*Cowdria*) *ruminantium* and that the tick could acquire infection from an infected tortoise. He also demonstrated that two hosts of the immature stages, namely helmeted guineafowls and scrub hares could act as subclinical reservoirs of *E.* (*Cowdria*) *ruminantium*.

Walker & Olwage (1987) have published colour illustrations of a male and female tick and have mapped the distribution of *A. marmoreum* in Africa. Horak, MacIvor, Petney & De Vos (1987a) have provided host lists as well as the mean intensity and prevalence of infestation on these hosts, while Dower, Petney & Horak (1988) determined the tick burdens, and the detachment periods and weights of the various life stages of *A. marmoreum* on naturally infested tortoises in the Eastern Cape Province. The presence, and occasionally also the seasonality, of the immature stages of *A. marmoreum* on a large number of host species have been recorded by Horak and his co-workers in several published and unpublished surveys of parasites of domestic and wild animals conducted in South Africa (Horak & Fourie 1986; Horak, Jacot Guillarmod, Moolman & De Vos 1987b; Dower *et al.* 1988; Fourie & Horak 1990; Horak, Williams & Van Schalkwyk 1991a; Horak, Fourie, Novellie & Williams 1991b; Horak, Spickett, Braack & Williams 1991c; Horak, Knight & Williams 1991d; Horak & Fourie 1991; Horak, Boomker, Spickett & De Vos 1992; Horak, Spickett, Braack & Penzhorn 1993; Boomker, Horak & Ramsay 1994; Horak & Boomker 1998; Horak 1999; Horak, Braack, Fourie & Walker 2000; Horak, MacIvor & Greeff 2001; Horak, Gallivan, Braack, Boomker & De Vos 2003; Horak & Matthee 2003; Uys & Horak 2005).

Fielden, Magano & Rechav (1992) have compared the length of the life cycle of *A. marmoreum* on tortoises and on guinea pigs in the laboratory, and Fielden & Rechav (1994) and Rechav & Fielden (1995) have determined its attachment sites and seasonal abundance on leopard tortoises. Burridge (2001) and Burridge & Simmons (2003) have described its introduction as well as that of other ticks into the United States of America on imported reptiles and Allan, Simmons & Burridge (1998) have reported its establishment on a reptile-breeding facility in Florida. Peter, Burridge & Mahan (2000) have demonstrated the competence of *A. marmoreum* as a potential effective vector of *E.* (*Cowdria*) *ruminantium* in that country.

The present paper is based on the findings pertinent to *A. marmoreum* in the numerous surveys conducted in South Africa as well as on a large number of tick collections made from reptiles, particularly tortoises that have not previously been published. Its purpose is to record the presence and the seasonality of adult and immature *A. marmoreum* on tortoises, and that of its larvae and nymphs on mammals and birds as well as of its free-living larvae on vegetation. Furthermore the coordinates of the localities at which the abovementioned collections were made have been used to up-date Theiler & Salisbury's (1959) map of the tick's distribution in South Africa.

MATERIALS AND METHODS

Ticks were collected manually from several live reptiles, chiefly tortoises, and preserved in 70% ethyl alcohol for subsequent identification and counting. Ticks were also collected from domestic and wild animals in various regions of the country, as well as from the vegetation within the Kruger National Park in north-eastern Mpumalanga Province. The techniques used to collect ticks in the various surveys have been described by Horak *et al.* (1987b; 1991c; 1992), Dower *et al.* (1988) and Spickett, Horak, Van Niekerk & Braack (1992), and are not repeated here. The findings presented pertain only to *A. marmoreum* and not to the other ticks collected during the various surveys.

The animal species sampled have been divided into six groupings, namely reptiles, birds, small mammals, carnivores, large herbivores, and domestic animals and humans, and the numbers of *A. marmoreum* collected from each host species within each of the groupings have been summarized in tabular format. The scientific names of the animals

examined are included in the tables and are not repeated in the text.

The monthly mean adult and immature tick burdens of all tortoises examined over a period 6 years, irrespective of species and the year in which they were sampled, have been used to construct a pattern of annual seasonality for *A. marmoreum*. A similar process has been followed with the immature tick burdens of helmeted guineafowls and of cattle examined at monthly intervals over a period of 2 years in the Eastern Cape Province, and of helmeted guineafowls and scrub hares examined at monthly intervals over periods of 2 and 6 years, respectively in north-eastern Mpumalanga Province. The seasonality of free-living larvae on the vegetation was determined from the means of consecutive monthly collections made over a period of 13 years and 8 months in a landscape zone within the southern Kruger National Park.

The geographic coordinates of the localities at which the various collections were made have been added to those of Theiler & Salisbury (1959), and have been used to redefine the distribution of *A. marmoreum* within the borders of South Africa.

RESULTS AND DISCUSSION

Hosts

A total of 309 reptiles belonging to 13 species were examined and with the exception of the Karoo padloper, of which only two specimens were sampled, all tortoise species were infested with adult *A. marmoreum* (Table 1). The largest numbers of adult and immature ticks were recovered from leopard tortoises. Comparisons between reptile species are, however, not possible because of differences in the sampling techniques. Most collections were done manually and focused on the more visible and hence detachable ticks, but 14 leopard tortoises were kept in cages over water until all the ticks present on most of them had detached (Dower *et al.* 1988). The prevalence of infestation on the various species of reptiles can also not be deduced from the available data as the majority of collections were made from live animals and no records were kept of the number of reptiles on which no ticks were seen.

Whereas other animals harbour only the immature stages of *A. marmoreum*, reptiles, and more particularly tortoises, harbour all stages of development. This pattern of host preference dictates that the tick's life cycle can be completed only in those localities where tortoises and certain other large reptile species are present. In the present study the ratio of larvae to nymphs to adults on tortoises and other reptiles was 2.7:1.0:3.0, indicating that the number of immature ticks would have been unable to maintain the adult population. However, as most of the collections made from these animals were not designed to be total recoveries, and focused mainly on the more visible adult ticks, these ratios are not surprising. In a more detailed study on the seasonal occurrence of *A. marmoreum*, leopard tortoises in a large, fenced enclosure containing natural savanna-type vegetation in the National Zoological Gardens, Pretoria, were examined for ticks at monthly intervals (Rechav & Fielden 1995). Over a period of a year the ratio of larvae to nymphs to adults on these animals was 5.7:2.7:1.0, indicating an adequate number of immature ticks to maintain the adult burdens on the tortoises.

Five bird species, comprising 269 individuals, were examined for ticks (Table 2). These examinations were thorough as they were conducted on dead birds and hence both the prevalence and intensity of infestation recorded are more reliable than they would have been had they been based on manual collections of ticks from live birds. A large proportion of helmeted guineafowls and francolins were infested and many larvae were collected from these birds. The largest number of ticks recovered from a single guineafowl consisted of 585 larvae and one nymph collected from a bird examined during February 1984 in the Mountain Zebra National Park in the Eastern Cape Province. Helmeted guineafowls and francolins are not only large birds, but also spend most of their lives on the ground, factors that both probably contribute to their success as hosts of the immature stages of *A. marmoreum*.

Ticks were collected from a total of 1754 small mammals belonging to 11 species, the majority of which were killed for survey purposes (Table 3). Amongst these there were 579 murid rodents and 31 springhares, a very large rodent, all of which were sampled in localities in which tortoises, or other animals harboured *A. marmoreum*, and yet only two bush Karoo rats were infested, each with a single larva. This supports the contention of Petney, Horak, Howell & Meyer (2004) that rodents are not good hosts of *Amblyomma* spp. They arrived at this conclusion after recovering only five unhealthy-looking larvae and a nymph of *Amblyomma hebraeum* from just six of 169 collections made from striped grass mice in a habitat heavily contaminated with

TABLE 1 *Amblyomma marmoreum* collected from reptiles

Host species	Number examined	Number infested	Number of ticks collected				
			Larvae	Nymphs	Males	Females	Total
Leopard tortoise, *Geochelone pardalis*	59	56	336	92	301	83	812
Geometric tortoise, *Psammobates geometricus*	64	54	9	7	52	12	80
Karoo tortoise, *Psammobates oculifer*	11	11	0	1	9	4	14
Tent tortoise, *Psammobates tentorius tentorius*	24	11	8	8	14	2	32
Tent tortoise, *Psammobates tentorius trimeni*	5	1	0	0	1	0	1
Angulate tortoise, *Chersina angulata*	52	6	0	5	12	1	18
Areolate padloper, *Homopus areolatus*	73	68	58	63	32	20	173
Speckled padloper, *Homopus signatus*	11	2	81	0	1	0	82
Greater padloper, *Homopus femoralis*	4	4	0	1	4	0	5
Karoo padloper, *Homopus boulengeri*	2	2	2	5	0	0	7
White-throated monitor, *Varanus exanthematicus*	1	1	0	1	1	0	2
Puff adder, *Bitis arietans*	2	1	0	0	1	0	1
Gaboon adder, *Bitis gabonica*	1	0	2	0	0	0	2
Total	**309**	**217**	**496**	**183**	**428**	**122**	**1 229**

TABLE 2 *Amblyomma marmoreum* collected from birds

Host species	Number examined	Number infested	Number of ticks collected				
			Larvae	Nymphs	Males	Females	Total
Helmeted guineafowl, *Numida meleagris*	231	177	4 175	206	0	0	4 381
Greywing francolin, *Francolinus africanus*	7	4	129	0	0	0	129
Cape francolin, *Francolinus capensis*	7	3	15	1	0	0	16
Crested francolin, *Francolinus sephaena*	23	13	582	10	0	0	592
Swainson's francolin, *Francolinus swainsonii*	1	0	0	0	0	0	0
Total	**269**	**197**	**4 901**	**217**	**0**	**0**	**5 118**

TABLE 3 *Amblyomma marmoreum* collected from small mammals

Host species	Number examined	Number infested	Number of ticks collected				
			Larvae	Nymphs	Males	Females	Total
Pouched mouse, *Saccostomys campestris*	14	0	0	0	0	0	0
Namaqua rock mouse, *Aethomys namaquensis*	425	0	0	0	0	0	0
Striped grass mouse, *Rhabdomys pumilio*	91	0	0	0	0	0	0
Swamp rat, *Otomys irroratus*	2	0	0	0	0	0	0
Bush Karoo rat, *Otomys unisulcatus*	47	2	2	0	0	0	2
Spring hare, *Pedetes capensis*	31	0	0	0	0	0	0
Rock dassie, *Procavia capensis*	102	21	108	3	0	0	111
Rock elephant shrew, *Elephantulus myurus*	296	7	10	1	0	0	11
Cape hare, *Lepus capensis*	67	8	15	4	0	0	19
Scrub hare, *Lepus saxatilis*	623	272	1 260	395	0	0	1 655
Smith's red rock rabbit, *Pronolagus rupestris*	56	17	36	3	0	0	39
Total	**1 754**	**327**	**1 431**	**406**	**0**	**0**	**1 837**

larvae of this tick. With the exception of scrub hares, of which 43.6% were infested with *A. marmoreum*, and which collectively also harboured surprisingly large numbers of nymphs, other small mammals also appeared not to be suitable hosts of this parasite.

Fifteen carnivore species, comprising 213 individuals that were killed for survey and other purposes, were examined. The prevalence of infestation was highest on black-backed jackals (Table 4).

The average prevalence of infestation on the 656 herbivores, all of which had been killed for survey purposes, was 28.2% and varied between 2.4% on 41 warthogs to 72.7% on 11 elands (Table 5). The only black wildebeest infested was a very old animal, which harboured a burden of 146 larvae and two nymphs, while 34 infested greater kudus had mean burdens of 92 larvae. With the exception of a single male tick on a bontebok ram examined during December 1979 in the Bontebok National Park in the Western Cape Province (Horak, Brown, Boomker, De Vos & Van Zyl 1982), no large herbivorous animal was infested with adult ticks.

The ticks from domestic cats and dogs were collected either by the staff at veterinary clinics when the animals were brought in for treatment, or by their owners and hence cannot be regarded as complete collections or as a true indication of the prevalence of infestation on these animals. Those collected from horses, cattle, sheep and goats were recovered from animals that had been slaughtered for survey purposes and had thus been thoroughly processed for the recovery of external and internal parasites. The ticks recorded on humans were collected as part of an on-going survey to identify those species that bite people in South Africa (Horak, Fourie, Heyne, Walker & Needham 2002).

The incomplete nature of the collections made from dogs and cats is endorsed by the fact that larger numbers of nymphs than larvae were recovered, whereas on the other domestic animals, for which

TABLE 4 *Amblyomma marmoreum* collected from carnivores

Host species	Number examined	Number infested	Number of ticks collected				
			Larvae	Nymphs	Males	Females	Total
Black-backed jackal, *Canis mesomelas*	8	8	243	27	0	0	270
Hunting dog, *Lycaon pictus*	8	1	0	16	0	0	16
Bat-eared fox, *Otocyon megalotis*	2	1	1	0	0	0	1
Cheetah, *Acinonyx jubatus*	3	2	26	18	0	0	44
Caracal, *Caracal caracal*	51	35	1 360	15	0	0	1 375
African wild cat, *Felis lybica*	1	1	1	0	0	0	1
Lion, *Panthera leo*	24	17	159	203	0	0	362
Leopard, *Panthera pardus*	6	5	43	202	0	0	245
Yellow mongoose, *Cynictis penicillata*	80	3	11	0	0	0	11
White-tailed mongoose, *Ichneumia albicauda*	2	2	7	0	0	0	7
Banded mongoose, *Mungos mungo*	2	1	7	0	0	0	7
Spotted hyaena, *Crocuta crocuta*	10	2	0	15	0	0	15
Aardwolf, *Proteles cristatus*	1	1	27	0	0	0	27
Civet cat, *Civettictis civetta*	7	6	16	46	0	0	62
Large-spotted genet, *Genetta tigrina*	8	6	13	3	0	0	16
Total	**213**	**91**	**1 914**	**545**	**0**	**0**	**2 459**

the collection procedures had been more thorough, the converse was true (Table 6). The two horses that were examined had both been used as trails horses in the Mountain Zebra National Park, where four of 14 Cape mountain zebras and eight of 11 elands examined during the same period were infested. The cattle were examined on farms in Valley Bushveld in the Eastern Cape Province (Horak 1999) and in False Upper Karoo in south-western Free State Province (Fourie & Horak 1990), the sheep on farms in Valley Bushveld and Eastern Province Thornveld (Horak *et al.* 1991a), and the goats in Valley Bushveld and in Noorsveld in the Eastern Cape Province (Horak *et al.* 1991d; 2001) and in Mixed Bushveld in Limpopo Province (Boomker *et al.* 1994). The prevalence and intensity of infestation was greater on cattle and sheep than on goats, while the intensity of infestation was greater on cattle than on sheep (Table 6).

Horak *et al.* (2002) noted that the comparatively small total number of only 194 collections of ticks taken from humans over four decades reflects the tendency in South Africa for individuals and health-care personnel to discard attached specimens, and more particularly larvae, once they have been removed.

In addition, a large proportion of persons living or working in rural environments in the eastern, north-eastern and northern regions of the country regard

TABLE 5 *Amblyomma marmoreum* collected from large herbivores

Host species	Number examined	Number infested	Number of ticks collected				
			Larvae	Nymphs	Males	Females	Total
Cape mountain zebra, *Equus zebra zebra*	14	4	180	1	0	0	181
Warthog, *Phacochoerus africanus*	41	1	2	0	0	0	2
Giraffe, *Giraffa camelopardalis*	6	1	0	2	0	0	2
Impala, *Aepyceros melampus*	229	67	2 227	23	0	0	2 250
Black wildebeest, *Connochaetes gnou*	13	1	146	2	0	0	148
Bontebok, *Damaliscus pygargus dorcas*	47	14	90	4	1	0	95
Springbok, *Antidorcas marsupialis*	22	2	4	0	0	0	4
African buffalo, *Syncerus caffer*	1	1	8	1	0	0	9
Eland, *Taurotragus oryx*	11	8	167	0	0	0	167
Greater kudu, *Tragelaphus strepsiceros*	120	34	3 131	2	0	0	3 133
Red forest duiker, *Cephalophus natalensis*	23	12	40	8	0	0	48
Gemsbok, *Oryx gazella*	26	15	457	13	0	0	470
Grey rhebok, *Pelea capreolus*	62	20	210	4	0	0	214
Reedbuck, *Redunca arundinum*	21	2	12	0	0	0	12
Mountain reedbuck, *Redunca fulvorufula*	20	3	10	2	0	0	12
Total	**656**	**185**	**6 684**	**62**	**1**	**0**	**6 747**

tick-bite as a normal occurrence and would seldom consider retaining specimens. Thus, the eight instances of bites by *A. marmoreum* are likely to represent only a small proportion of bites on humans due to this species.

The large numbers of *A. marmoreum* larvae collected from the vegetation by drag-sampling with flannel strips implies that they quest for hosts from this vantage point. This would seem to be an unnecessary strategy if tortoises and other land-bound reptiles are their only hosts. By questing from the vegetation the larvae are unlikely to be particularly host-specific and will attach to a variety of animals, an observation supported by the present findings.

Norval (1975) stated that adult ticks attach in greater numbers around the bases of the hind-legs of tortoises, and nymphs around those of the forelegs as well as on the head and neck, while larvae are evenly distributed between the two sites. Fielden & Rechav (1994) and Burridge, Simmons & Allan (2000) report most adults on the upper soft-skinned parts of the hind-legs and in the hollows in front of these legs, as well as around the base and on the ventral surface of the tail. Larvae and nymphs attach mainly in soft skinned localities that are protected by the carapace, particularly the neck and upper legs (Fielden & Rechav 1994). Uys & Horak (2005) collected equal numbers of *A. marmoreum* larvae from the bodies and from the wings of crest-

TABLE 6 *Amblyomma marmoreum* collected from domestic animals and from humans

Host species	Number examined	Number infested	Number of ticks collected				
			Larvae	Nymphs	Males	Females	Total
Dogs	915	8	2	13	0	0	15
Cats	20	1	0	2	0	0	2
Horses	2	2	14	0	0	0	14
Cattle	58	32	1 942	17	0	0	1 959
Sheep	175	81	1 132	30	0	0	1 162
Goats	373	82	851	73	0	0	924
Humans	194	7	2	3	3	0	8
Total	**1 737**	**213**	**3 943**	**138**	**3**	**0**	**4 084**

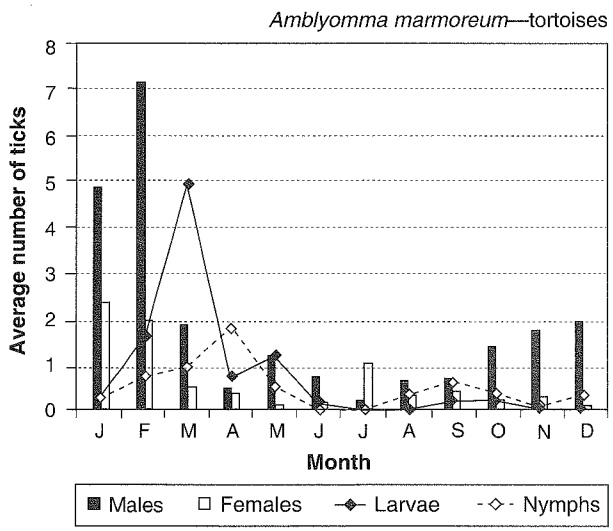

FIG. 1 The seasonal occurrence of *Amblyomma marmoreum* on tortoises in South Africa

ed francolins, fewer from their tails and the least from their heads and upper necks. They suggest that this attachment pattern might be a strategy to avoid competition with the larvae of *A. hebraeum* and *Hyalomma marginatum rufipes*, of which more than 84% attach to the heads and upper necks of the birds.

Seasonality

The countrywide seasonality of all stages of development of *A. marmoreum* on tortoises is graphically illustrated in Fig. 1.

Male and female ticks were most numerous on tortoises during January and February. Thereafter, with the exception of July, the only month during which female ticks outnumbered males, the numbers of female ticks remained low even when the numbers of males started to increase on tortoises from October to December. Norval (1975) recorded the largest numbers of adult ticks on leopard tortoises on a farm in the Eastern Cape Province from January to March, whereas Rechav & Fielden (1995) recorded the largest numbers of adults on these animals in the National Zoological Gardens, Pretoria from October to January, with males most numerous from October to May and females from September to December.

Female ticks can take up to 60 days (Norval 1975) to 91 days (Fielden *et al.* 1992) to complete feeding on artificially infested tortoises, and Dower *et al.* (1988) recorded a period as long as 73 days before all females and 111 days before all males had detached from tortoises that they had collected in the field. The January and February peak in adult tick numbers may therefore reflect an accumulation of ticks that had attached a month or two earlier. The longer period of attachment of male ticks may in part explain the preponderance of male compared to female ticks on tortoises.

Larvae were most numerous on tortoises, irrespective of the localities in which they had been sampled, during March (Fig. 1), and on helmeted guineafowls and cattle in inland Valley Bushveld in the Eastern Cape Province from February to April with an April peak on the guineafowls and a March peak on the cattle (Fig. 2A and B). Larvae were most numerous on helmeted guineafowls, scrub hares and the vegetation in the Lowveld of north-eastern

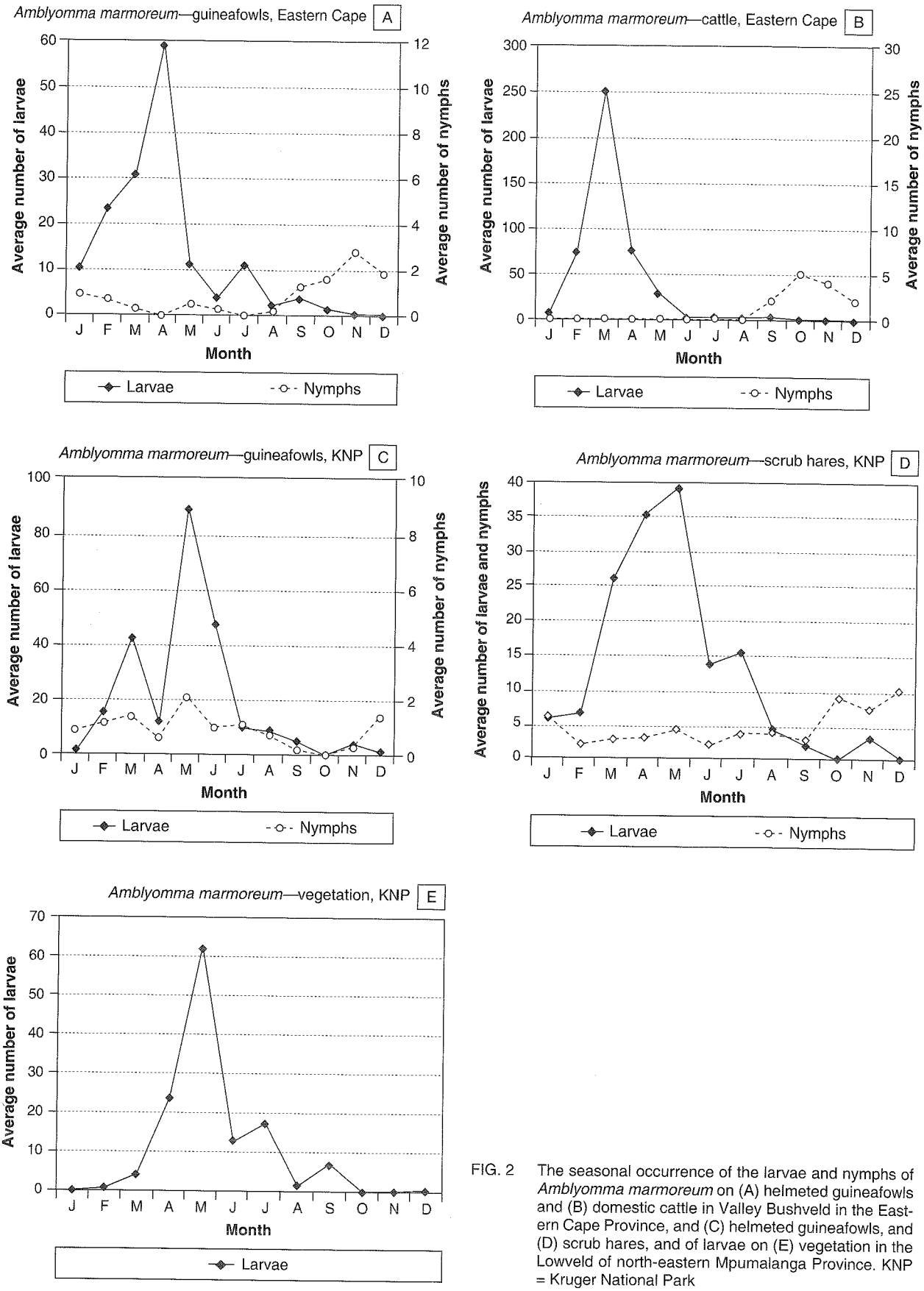

FIG. 2 The seasonal occurrence of the larvae and nymphs of *Amblyomma marmoreum* on (A) helmeted guineafowls and (B) domestic cattle in Valley Bushveld in the Eastern Cape Province, and (C) helmeted guineafowls, and (D) scrub hares, and of larvae on (E) vegetation in the Lowveld of north-eastern Mpumalanga Province. KNP = Kruger National Park

Mpumalanga Province from March or April to June or July, with peaks in May (Fig. 2C–E). Very few if any larvae were present from October to December or January in either of the provinces. Norval (1975) collected most larvae from a naturally infested leopard tortoise during April and from the vegetation on a farm in the Eastern Cape Province from February to June with a peak in May. Rechav & Fielden (1995) recorded the largest numbers of larvae on tortoises in the National Zoological Gardens, Pretoria from January to May with a peak in February and March.

Nymphs were most numerous on tortoises, irrespective of the localities in which they had been examined, during April (late summer) and during September (spring) (Fig. 1). Nymphs were most numerous on helmeted guineafowls and on cattle in inland Valley Bushveld from September to December (Fig. 2A and B), and on scrub hares in the Lowveld from October to December (Fig. 2D). However, nymphs were most numerous on guineafowls in the latter habitat from December to August (Fig. 2C). The largest numbers of nymphs were present on tortoises in the National Zoological Gardens, Pretoria from May to October with a peak in June and July (Rechav & Fielden 1995).

Compared to 1 604 larvae, only six nymphs were collected during nearly 14 years of monthly drag-sampling the vegetation in the Lowveld. These nymphs have not been incorporated in Fig. 2E. On the other hand, Norval (1975) collected 449 larvae and 27 nymphs from the vegetation by this sampling method and the latter were most numerous from October to January. The present results indicate that the seasonal pattern of occurrence of the immature stages of *A. marmoreum* in the north-east of the country is similar to that in the south-east.

Norval (1975) thought that hosts other than tortoises did not play a significant role in the life cycle or seasonality of *A. marmoreum* because of the small number of ticks he encountered on these hosts. However, the substantial numbers presently recorded on some host species, other than tortoises, as well as the proportion of these animals that are infested, imply that they may well play an important role in the tick's life cycle. In his experiments on the life cycle of *A. marmoreum* Norval (1975) found that larvae required up to 30 days to complete feeding on tortoises and nymphs up to 51 days, whereas larvae he fed on the ears of sheep engorged in 6–12 days and nymphs in 8–20 days. Dower *et al.* (1988) recorded a mean of 35 days and a range of 8–104 days for larvae, and a mean of 21 days and range of 4–47 days for nymphs to detach from tortoises collected in the field. As there was no way of knowing exactly how many days before capture these ticks attached to the latter tortoises, all these periods are probably considerably longer.

Fielden *et al.* (1992) compared the length of the life cycle of *A. marmoreum* on tortoises and on guinea pigs in the laboratory. On tortoises the period between larval attachment and the emergence of adults varied between 69 and 172 days, whereas on guinea pigs it varied between 63 and 95 days. Domestic chickens, and hence presumably guineafowls, have higher body temperatures than those of mammals, and larvae of *A. hebraeum* fed on chickens engorged and detached in 4–8 days compared to 5–10 days on rabbits infested at the same time (Holley & Petney 1988). If a similar phenomenon occurs when the immature stages of *A. marmoreum* feed on guineafowls as opposed to sheep, the length of the life cycle could be reduced even further.

According to Norval (1975) the life cycle of *A. marmoreum* in the Eastern Cape Province can be completed in either 1 or 2 years. He proposed that for it to be completed in 1 year, it was necessary for larvae to feed on tortoises in late summer and the resultant nymphs and subsequent adults to feed on tortoises in spring and in early summer respectively. Fielden *et al.* (1992) suggest that host selection by the immature stages could be important in determining whether the life cycle is completed in 1 or in 2 years, an opinion with which we concur. Provided the larvae and the nymphs feed on mammals or birds in late summer and in spring respectively and the adults on tortoises in early summer the life cycle can be completed in 1 year.

Geographic distribution

Theiler & Salisbury (1959) mapped the distribution of *A. marmoreum* in South Africa from the geographic coordinates of 49 localities at which collections were made. We have now added more than 100 localities to their map (Fig. 3).

Most collections have been made in the western regions of the Western and Eastern Cape and Free State provinces, and in the north-eastern regions of the Northern Cape, KwaZulu-Natal, Mpumalanga and Limpopo provinces. The seemingly large number of localities at which *A. marmoreum* was present in north-eastern Mpumalanga and Limpopo provinces are a reflection of the numerous surveys conducted in these regions by Horak and his co-workers over a period of 25 years. The several collections made in other regions imply that these are also suitable hab-

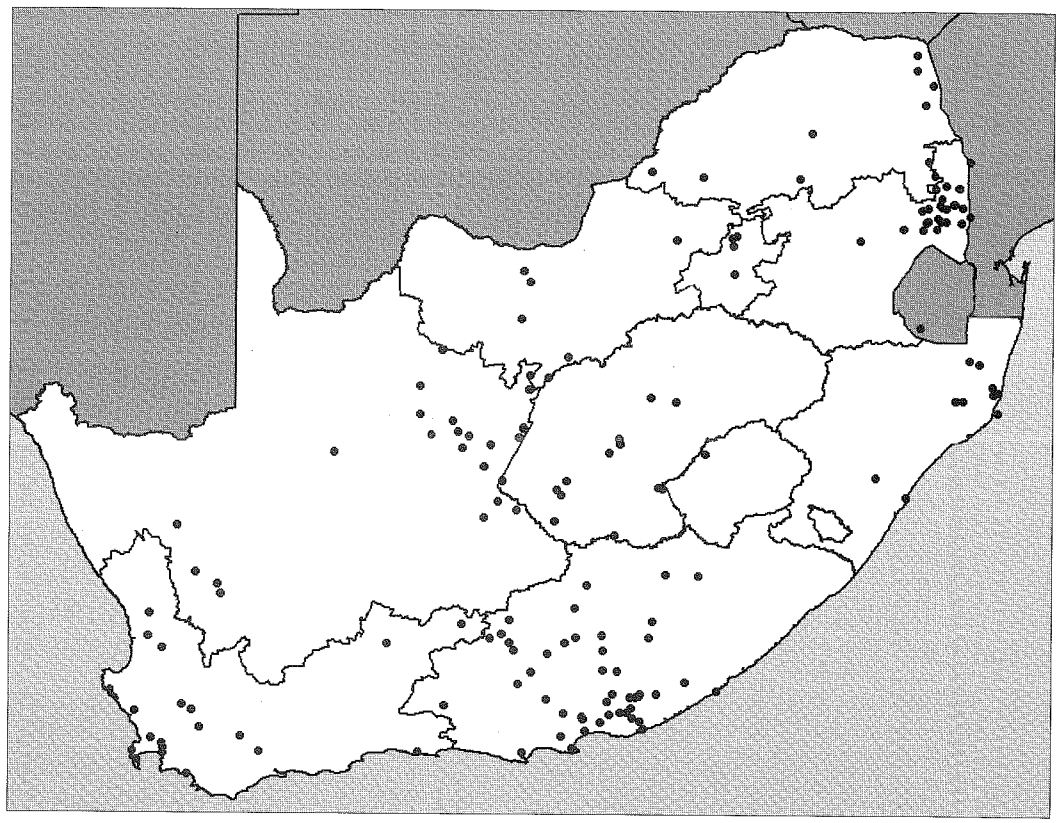

FIG. 3 The geographic distribution of *Amblyomma marmoreum* within the borders of South Africa

itats for the tick. Very few collections of *A. marmoreum* have been made in the eastern Highveld regions of the Eastern Cape, Free State and Mpumalanga provinces and inland mountainous regions of KwaZulu-Natal. We are, however, convinced that future collections will indicate an even wider distribution for *A. marmoreum* in South Africa than that now proposed.

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Parasites of domestic and wild animals in South Africa. XLVII. Ticks of tortoises and other reptiles

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ABSTRACT

HORAK, I.G., MCKAY, I.J., HENEN, B.T., HEYNE, HELOISE, HOFMEYR, MARGARETHA D. & DE VILLIERS, A.L. 2006. Parasites of domestic and wild animals in South Africa. XLVII. Ticks of tortoises and other reptiles. *Onderstepoort Journal of Veterinary Research*, 73:215–227

A total of 586 reptiles, belonging to 35 species and five subspecies, were examined in surveys aimed at determining the species spectrum and geographic distribution of ticks that infest them. Of these reptiles 509 were tortoises, 28 monitor or other lizards, and 49 snakes. Nine ixodid tick species, of which seven belonged to the genus *Amblyomma*, and one argasid tick, *Ornithodoros compactus* were recovered. Seven of the ten tick species are parasites of reptiles. Amongst these seven species *Amblyomma marmoreum* was most prevalent and numerous on leopard tortoises, *Geochelone pardalis*; *Amblyomma nuttalli* was present only on Bell's hinged tortoises, *Kinixys belliana*; and most *Amblyomma sylvaticum* were collected from angulate tortoises, *Chersina angulata*. *Amblyomma exornatum* (formerly *Aponomma exornatum*) was only recovered from monitor lizards, *Varanus* spp.; most *Amblyomma latum* (formerly *Aponomma latum*) were from snakes; and a single nymph of *Amblyomma transversale* (formerly *Aponomma transversale*) was collected from a southern African python, *Python natalensis*. All 30 Namaqualand speckled padloper tortoises, *Homopus signatus signatus*, examined were infested with *O. compactus*.

The seasonal occurrence of *A. sylvaticum* and the geographic distribution of this tick and of *A. marmoreum*, *A. nuttalli*, *A. exornatum*, *A. latum* and *O. compactus* are illustrated.

Keywords: *Amblyomma* spp., argasid tick, geographic distribution, ixodid ticks, *Ornithodoros compactus*, reptiles, seasonality, snakes, tortoises, varanid lizards

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INTRODUCTION

Reptiles in southern Africa are hosts of several species of ixodid ticks (Theiler 1962). The majority of these ticks belong to the genus *Amblyomma*, of which nine species, including three species that belonged to the former genus *Aponomma* (now *Amblyomma*), occur in South Africa (Walker 1991). Theiler (1943, 1945a, b) has published illustrations of *Amblyomma sylvaticum* and of the ornate and inornate *Aponommas*. The latter ticks have recently been placed in the genus *Amblyomma* and are now designated *Amblyomma exornatum*, *Amblyomma latum* and *Amblyomma transversale* (Klompen, Dobson & Barker 2002). Theiler & Salisbury (1959) have illus-

trated ticks of 'the *Amblyomma marmoreum* group', and colour illustrations of *Amblyomma hebraeum* and *A. marmoreum* have been published by Walker & Olwage (1987). A single argasid species, *Ornithodoros compactus* infests tortoises in southern Africa, and has been illustrated by Walton (1962).

Theiler (1962) has listed the reptile species and the localities in sub-Saharan Africa from which ticks of the genera *Amblyomma* and *Aponomma* (now *Amblyomma*) have been collected. Norval (1983, 1985) has recorded the hosts and mapped the localities at which *Amblyomma nuttalli*, *A. marmoreum*, *A. exornatum*, *A. latum* and *A. transversale* have been collected in Zimbabwe. Walker & Schulz (1984) have recorded the numbers of *A. hebraeum* and *A. marmoreum* collected from tortoises in the Addo Elephant National Park, Eastern Cape Province, and Dower, Petney & Horak (1988) those collected from leopard tortoises in the Andries Vosloo Kudu Reserve and in the Thomas Baines Nature Reserve, Eastern Cape Province. The seasonality of *A. marmoreum* on leopard tortoises in the National Zoological Gardens, Pretoria, Gauteng Province has been determined by Rechav & Fielden (1995), and the hosts, seasonality and geographic distribution of the latter tick in South Africa have been recorded and illustrated by Horak, McKay, Heyne & Spickett (2006). Walton (1962) has listed the tortoise species from which *O. compactus* has been collected.

With the exception of *A. hebraeum* and *O. compactus*, the above-mentioned ticks have all been recorded on reptiles imported into the United States of America (USA) from Africa (Burridge, Simmons & Allan 2000; Burridge 2001; Burridge & Simmons 2003). This illustrates not only the close association between the ticks and their hosts, but their prolonged periods of attachment, which exceed the length of time from the capture of the reptile in Africa, its translocation to a foreign country and its legal or illegal importation into that country. *Amblyomma marmoreum* has in fact adapted to its new habitat and become established at a reptile breeding facility in Florida in the USA (Allan, Simmons & Burridge 1998). According to Walton (1962) the *O. compactus* recorded in European zoological gardens, probably arrived there as first stage nymphs on imported tortoises.

The purpose of this paper is to record the species spectrum of ticks that infest tortoises and various other reptiles in South Africa, and to illustrate the seasonality and geographic distributions of those species for which sufficient data exist.

MATERIALS AND METHODS

The data for this communication are derived from four surveys of ticks parasitizing tortoises and other reptiles.

Firstly a study conducted specifically on tortoises, chiefly in the southern provinces of South Africa, between 1975 and 1981, during which all visible ticks were collected, but no record was kept of the number of tortoises that were not infested. Secondly ticks were collected from tortoises in the Western and Northern Cape Provinces between 2000 and 2003 as part of a larger investigation on the biology and conservation of these animals. Again no record was kept of the number of tortoises that were not infested. Thirdly from casual collections between 1981 and 2005 from tortoises and other reptiles, and finally studies on 23 leopard tortoises conducted by Dower *et al.* (1988) and Horak & Boomker (1998) have been included for completeness' sake. The vast majority of collections were made from free-living reptiles, with a few made from captive animals. With the exception of the study by Dower *et al.* (1988), in which ticks were recovered after detaching from caged, naturally infested tortoises, ticks were collected manually, or by means of pincers, and preserved in 70% ethyl alcohol for subsequent identification and counting. The collections made by Dower *et al.* (1988) were exhaustive, while the others concentrated on collecting only the visible and hence more easily accessible ticks. The parasite host tables that follow list the total number of tortoises and other reptiles of each species that were infested irrespective of the tick species and the numbers of animals that were infested with particular species. The localities at which ticks were collected were recorded and their geographic coordinates determined and plotted.

The results of the collections pertaining to *A. marmoreum* have been reported separately (Horak *et al.* 2006) and, with the exception of the tick-host table and geographic distribution map, to which new data have been added, they are not repeated here. Large numbers of all stages of development of *A. sylvaticum* were collected from angulate tortoises during the course of the surveys, and the mean numbers recovered each month, irrespective of the year, have been used to determine the seasonal occurrence of this tick on these animals. The maps illustrating the geographic distributions of the various tick species have been compiled from the coordinates of localities listed by Theiler (1962), as well as from those at which ticks were collected in the surveys reported here.

We have used Branch (1998) as our primary source of reference for the specific and common names of the tortoise and other reptile species examined. These have been listed in the tables and the scientific names will not be repeated in the text. Whenever we have been uncertain of the sub-specific identity of a particular tortoise we have used the geographic distribution maps plotted by Branch (1998), or the habitat preferences of the various sub-species of tent tortoises (Branch 1989), and the field experience of B.T.H. and M.D.H. to arrive at an acceptable solution. When this has not been possible we have used only the specific name of the tortoise. In some cases the animals were identified only as 'tortoise' or 'monitor lizard' by the collectors and are listed as such in the tables.

RESULTS AND DISCUSSION

Amblyomma hebraeum

The hosts of adult *A. hebraeum* are large herbivorous mammals, whereas the larvae and nymphs can be found on a variety of large and small mammals and on ground-frequenting birds, and the nymphs also on reptiles (Norval 1983; Horak, MacIvor, Petney & De Vos 1987; Dower *et al.* 1988). Consequently, despite the fact that *A. hebraeum* adults were

TABLE 1 Ticks collected from various reptile species

Tick and host species	Number infested with ticks	Number infested with species listed	Number of ticks collected				
			Larvae	Nymphs	Males	Females	Total
Amblyomma hebraeum							
Leopard tortoise, *Geochelone pardalis*	31*	19	0	686	20	13	719
Rock monitor, *Varanus albigularis albigularis*	4*	2	0	33	0	0	33
Amblyomma nuttalli							
Bell's hinged tortoise, *Kinixys belliana*	7	5	0	0	9	0	9
Amblyomma exornatum							
Rock monitor, *V. a. albigularis*	7	7	0	112	191	116	419
Water monitor, *Varanus niloticus*	12	12	0	53	104	75	232
"Monitor", *Varanus* spp.	3	3	0	3	17	2	22
Amblyomma transversale							
Southern African python, *Python natalensis*	3	1	0	1	0	0	1
Hyalomma truncatum							
Leopard tortoise, *G. pardalis*	82	3	0	0	1	3	4
Geometric tortoise, *Psammobates geometricus*	86	1	0	0	1	0	1
Rhipicephalus gertrudae							
Geometric tortoise, *P. geometricus*	86	1	0	0	0	1	1
"Tortoise"	9	1	0	0	2	0	2

* = Number of animals examined within the distribution range of *A. hebraeum*

TABLE 2 *Amblyomma marmoreum* collected from reptiles

Host species	Number infested with ticks	Number infested with *A. marmoreum*	Number of ticks collected				
			Larvae	Nymphs	Males	Females	Total
Leopard tortoise, *G. pardalis*	82	80	336	105	545	217	1 203
Bell's hinged tortoise, *K. belliana*	7	2	0	0	5	3	8
Geometric tortoise, *P. geometricus*	86	68	28	9	64	14	115
Serrated tortoise, *Psammobates oculiferus*	11	11	0	1	9	4	14
Tent tortoise, *Psammobates tentorius tentorius*	23	22	0	8	21	11	40
Namaqualand tent tortoise, *Psammobates tentorius trimeni*	5	1	0	0	1	0	1
Bushmanland tent tortoise, *Psammobates tentorius verroxii*	11	2	0	0	4	0	4
Tent tortoise, *Psammobates tentorius*	5	1	1	0	0	0	1
Angulate tortoise, *Chersina angulata*	138	9	0	6	17	2	25
Common padloper, *Homopus areolatus*	87	75	68	65	33	21	187
Karoo padloper, *Homopus boulengeri*	2	2	2	5	0	0	7
Greater padloper, *Homopus femoralis*	4	4	0	1	4	0	5
Southern speckled padloper, *Homopus signatus cafer*	8	2	81	0	1	0	82
Namaqualand speckled padloper, *Homopus signatus signatus*	30	0	0	0	0	0	0
"Tortoise"	10	8	7	21	23	10	61
Rock monitor, *V. a. albigularis*	7	3	0	7	1	0	8
"Monitor", *Varanus* spp.	3	1	0	2	2	0	4
Southern African python, *P. natalensis*	3	3	0	11	0	0	11
"Python"	1	1	0	0	0	1	1
Puff adder, *Bitis arietans*	3	2	0	2	2	0	4
Gaboon adder, *Bitis gabonica*	1	1	2	0	0	0	2
Common egg eater, *Dasypeltis scabra*	1	1	0	1	0	0	1
Boomslang, *Dispholidus typus*	1	1	0	2	0	0	2
Total	**529**	**300**	**525**	**246**	**732**	**283**	**1 786**

present on a number of leopard tortoises examined within the tick's distribution range (Table 1), these infestations must be considered opportune, possibly triggered by *A. hebraeum* or *A. marmoreum* males already present on the tortoises. Attached, engorging *A. hebraeum* males produce pheromones that, with the carbon dioxide exhaled by their hosts, attract con-specific females, other males and nymphs (Norval, Yunker & Butler 1987). The life stage spectrum of the ticks attached to the 19 infested leopard tortoises seems to indicate that male *A. marmoreum* may also produce pheromones that can be detected by con-specific ticks as well as by *A. hebraeum* nymphs and adults.

Howell, Walker & Nevill (1978) have illustrated the geographic distribution of *A. hebraeum* within the boundaries of South Africa, and the present records from tortoises all fall within this range.

Amblyomma marmoreum

This tick, colloquially known as the South African tortoise tick, is probably the species most frequently encountered on tortoises throughout South Africa (Theiler & Salisbury 1959; Horak *et al.* 2006). It is the largest ixodid tick in South Africa, and engorged females may exceed 25 mm in length. With the exception of angulate and Namaqualand speckled padloper tortoises (the latter the smallest tortoise species in the world), a large percentage of individuals within each tortoise species were infested (Table 2). It would seem that the larger the species the greater the number of adult ticks it is likely to harbour, and leopard tortoises, the largest of the South African species, carried most adult ticks. Amongst the latter was a tortoise infested with 63 male and 105 female ticks. The immature stages, particularly larvae, infest not only reptiles, but also a large variety of mammals and birds (Horak *et al.* 2006).

The comparatively small total number of immature ticks collected from the various tortoise species could not sustain the large number of adult ticks collected from these animals. Because complete collections were not always made, large numbers of immature ticks were probably overlooked. Furthermore, the large number of larvae and fewer nymphs that attach to a variety of warm-blooded hosts, both avian and mammalian (Horak *et al.* 2006), could serve to augment the apparently insufficient numbers of immature ticks collected.

Theiler & Salisbury (1959) mapped the distribution of *A. marmoreum* in South Africa from the geographic coordinates of 49 localities at which collections had been made. Horak *et al.* (2006) added more than 100 localities to that map and we have now added approximately 70 more sites (Fig. 1). Most collections have been made in the south-western

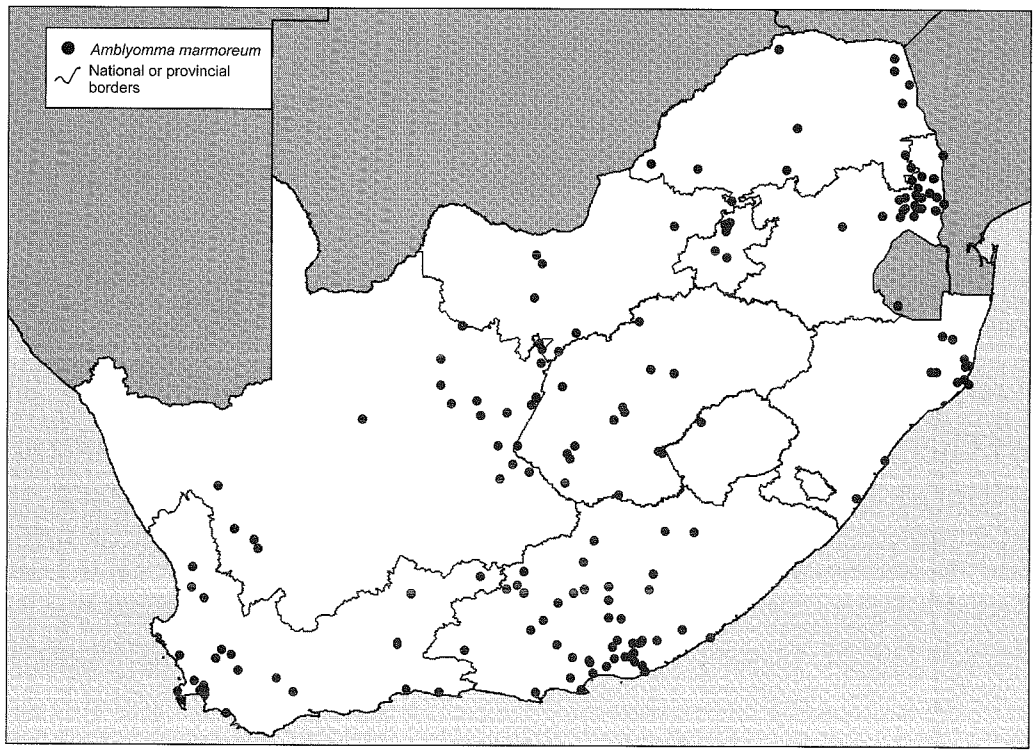

FIG. 1 Geographic distribution of *Amblyomma marmoreum* in South Africa

Western Cape Province, the western half of the Eastern Cape and Free State Provinces, the eastern regions of the Northern Cape Province, and the north-eastern regions of KwaZulu-Natal and Mpumulanga Provinces. This distribution closely corresponds to that of several of the tick's most favoured host species, namely common padloper tortoises in south-western Western and Eastern Cape Provinces, geometric tortoises in south-western Western Cape Province, tent tortoises in western Western and Northern Cape Provinces, serrated tortoises in eastern Northern Cape Province, and leopard tortoises in the central, northern and north-eastern regions of South Africa (Branch 1998).

Amblyomma nuttalli

The difficulty in distinguishing between *A. nuttalli* and other ticks of the *A. marmoreum* group has been discussed by Theiler & Salisbury (1959). One of the hosts frequently infested by adult *A. nuttalli* is Bell's hinged tortoise, *Kinixys belliana* (Hoogstraal 1956; Table 1), but other tortoises, monitor lizards and snakes may also be infested (Theiler & Salisbury 1959; Burridge *et al.* 2000). The immature stages infest the same hosts as the adults, but are also found on birds and mammals (Theiler 1962). The tick is widespread in the Afrotropical region, but in South Africa almost all collections have been made in north-eastern KwaZulu-Natal (Theiler 1962; Walker 1991; Fig. 2).

Amblyomma sylvaticum

Theiler (1962) describes *A. sylvaticum* as "this somewhat rare Cape tortoise tick", an observation refuted by the present surveys, during which, after *A. marmoreum*, *A. sylvaticum* was the tick most frequently collected. Theiler lists adult ticks on the angulate tortoise, tent tortoise and common padloper as well as on a mole snake, *Pseudaspis cana*. In contrast to *A. marmoreum*, which infests a wide spectrum of tortoise species, all stages of development of *A. sylvaticum* would seem to infest angulate tortoises by preference (Table 3). The number of immature ticks collected from these tortoises could clearly not sustain their adult burdens, and incomplete collections can in part be responsible for this. Although we have examined numerous birds and mammals, we have not collected larvae or nymphs of *A. sylvaticum* from any of them, and it would thus appear as if infestations on other tortoise species and reptiles augment the population of immature ticks (Table 3).

The considerable differences in the numbers of angulate tortoises examined in the different months of

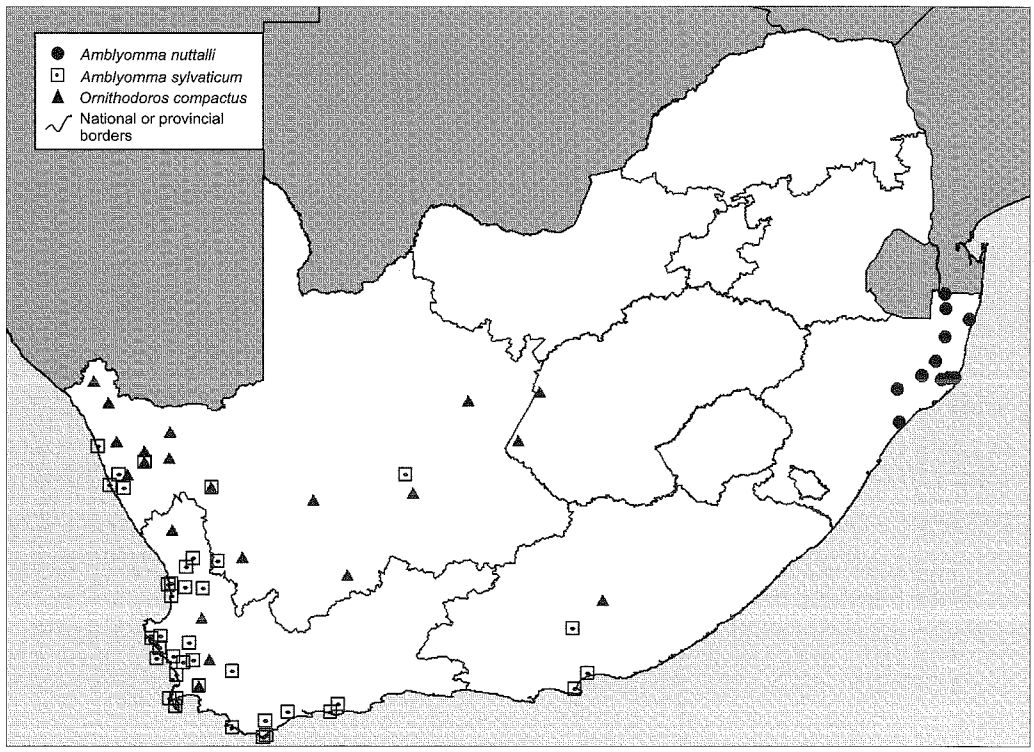

FIG. 2 Geographic distributions of *Amblyomma nuttalli*, *Amblyomma sylvaticum* and *Ornithodoros compactus* in South Africa

TABLE 3 *Amblyomma sylvaticum* collected from various reptile hosts

Host species	Number infested with ticks	Number infested with *A. sylvaticum*	Number of ticks collected				
			Larvae	Nymphs	Males	Females	Total
Geometric tortoise, *P. geometricus*	86	14	2	3	0	14	19
Tent tortoise, *P. t. tentorius*	23	1	0	0	1	0	1
Namaqualand tent tortoise, *P. t. trimeni*	5	0	0	0	0	0	0
Bushmanland tent tortoise, *P. t. verroxii*	11	1	0	0	2	0	2
Tent tortoise, *P. tentorius*	5	1	3	0	0	0	3
Angulate tortoise, *C. angulata*	138	124	736	249	277	159	1 421
Common padloper, *H. areolatus*	87	4	0	14	2	3	19
Southern speckled padloper, *H. s. cafer*	8	5	0	0	4	1	5
Namaqualand speckled padloper, *H. s. signatus*	30	0	0	0	0	0	0
Knox's desert lizard, *Meroles knoxi*	3	3	62	0	0	0	62
Southern spiny agama, *Agama hispida*	1	1	5	0	0	0	5
Total	**397**	**154**	**808**	**266**	**286**	**177**	**1 537**

the year as well as in the tick burdens of individual animals make it difficult to obtain a clear pattern of seasonality for *A. sylvaticum*. Five or fewer tortoises were examined per month in January, March (none examined), June, August and November, and six or more in the other months, with 36 examined during May. To compensate for these inequalities, 3-month running means have been used to illustrate seasonality. With this in mind, most larvae were present from May to November, most nymphs during the period August to January, and most adults from August to February (Fig. 3). This pattern of seasonality agrees with the sizes of ticks observed on angulate tortoises during January, May, July and September by B.T.H. and M.D.H. If this indeed were the pattern of seasonality, it would imply that female ticks deposit eggs in summer and that most larvae hatch from early winter to early summer. These larvae would feed and moult to nymphs from midwinter to midsummer, and once the latter had fed and moulted they would

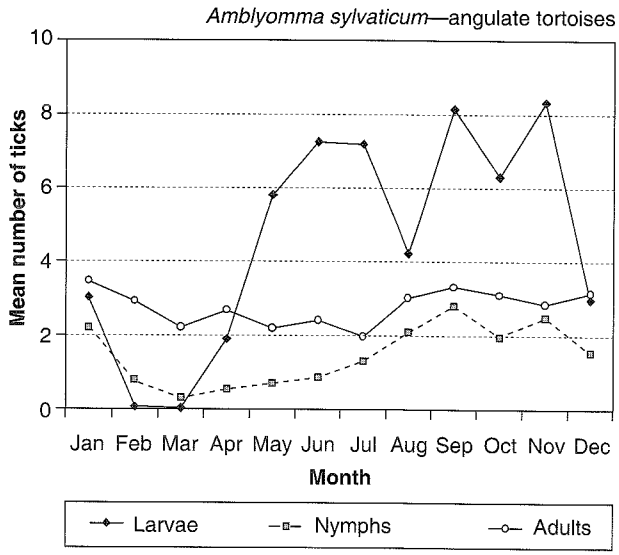

FIG. 3 Seasonal occurrence of *Amblyomma sylvaticum* on angulate tortoises in South Africa (3-month running means)

maintain the numbers of adult ticks during summer. From the available data we are, however, unable to determine whether the life cycle requires 1 or 2 years to complete, or whether diapause occurs during any particular stage of development.

According to Theiler (1962), who based her findings on collections made at 12 localities, the distribution of *A. sylvaticum* is confined to the Eastern and Western Cape Provinces and to parts of Little Namaqualand. We were unable to trace two of Theiler's 12 collection sites, but have now plotted a further 33 localities. From these it is apparent that *A. sylvaticum* is a strictly South African species, predominantly present in the western regions of the Northern and Western Cape Provinces as well as in the southwestern regions of the latter province and of the Eastern Cape Province, with a single outlying record from a tent tortoise in the centre of the Northern Cape Province (Fig. 2).

Infestation was most prevalent on angulate tortoises, southern speckled padloper tortoises and on Knox's desert lizards. Angulate tortoises and the desert lizards have a strong association with sandy soils. Although southern speckled padloper tortoises occur in rocky terrain, they can be sympatric with angulate tortoises (M.D.H. and B.T.H.) and have sandy soil in their habitat. It is possible that these soils and the micro-environment associated with them provide essential elements for the survival of the free-living stages of *A. sylvaticum*.

This tick and its angulate tortoise hosts are both common in the West Coast National Park and nearly all tortoises examined by two of us (B.T.H. and M.D.H.) were infested. However, despite examining large numbers of angulate tortoises on Dassen island, an island about 10 km southwest of the park, only one tick has been collected from these reptiles. The absence of ticks on this small island might be due to its very salty environment and ephemeral and mostly exotic vegetation. *Amblyomma sylvaticum* has been recorded in the United States on a tortoise imported from South Africa (Burridge & Simmons 2003).

Amblyomma exornatum

No *A. exornatum* larvae were recovered, but 168 nymphs and 505 adult ticks were collected from 22 monitor lizards (Table 1). According to Theiler (1945a), Hoogstraal (1956) and Norval (1985) these large lizards are its preferred hosts. A single rock monitor examined during the present surveys in the National Zoological Gardens, Pretoria, harboured 79 nymphs, 150 males and 94 female ticks. Although no adult ticks were collected during October, 14 of

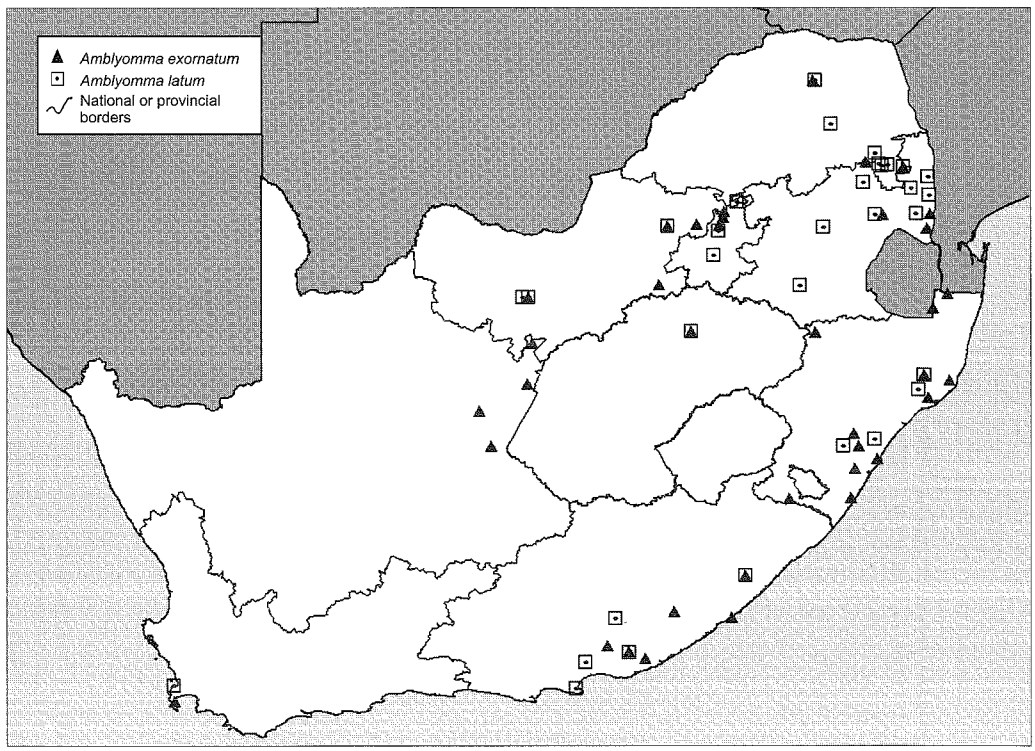

FIG. 4 Geographic distributions of *Amblyomma exornatum* and *Amblyomma latum* in South Africa

the 21 collections of adult ticks were made during the period September to December (spring to mid-summer).

Thirty-one of the 37 localities at which we have recovered *A. exornatum* are in the eastern and south-eastern half of the country (Fig. 4). According to Theiler (1962) and Norval (1985) it is widespread in South Africa and Zimbabwe, and Theiler suggests that it is probably present across the range of its varanid hosts in these countries. The single record from Simonstown in south-west Western Cape Province originates from a monitor lizard that had probably been translocated, as this region lies outside the geographic distribution of these lizards (Branch 1998).

Amblyomma latum

This tick, aptly named the snake tick by Hoogstraal, infests snakes, and more particularly the larger species (Theiler 1945b, 1962; Hoogstraal 1956; Norval 1985). According to Walker (1991) the occasional records from lizards and even from some mammals, represent incidental infestations. The single female collected from a leopard tortoise in the present study would thus seem to be unusual (Table 4). *Amblyomma latum* has, however, been collected from two captive yellow-footed tortoises, *Geochelone denticulata*, in the USA. The latter tortoise is native to South America, where this tick does not occur, and the tortoises probably acquired infestation while in captivity (Burridge 2001; Burridge & Simmons 2003).

The 32 males, two females, eight nymphs and 76 larvae collected from a black mamba near Hectorspruit, in the Lowveld of Mpumalanga Province, appear to be one of the largest recorded collections of *A. latum* taken from a single snake. Many of the adult ticks in this collection were attached under scales in and adjacent to a large superficial dorsal wound just posterior to the snake's head. Whether the ticks had caused the lesion, or had attached there because of it, could not be ascertained. According to Burridge (2001), adult ticks attach under dorsal and lateral scales on all parts of the body of snakes, with the head being the most common site.

In Zimbabwe, Norval (1985) recovered all developmental stages of *A. latum* throughout the year, but collected most samples in the warm months when snakes are most active. During the present surveys 28 collections of adult ticks were made during the period October to February (summer) and only 11 from March to September (late summer to spring).

The distribution of *A. latum* in South Africa, based on Theiler's (1962) records, to which we have added several localities, is illustrated in Fig. 4. Most records of this tick emanate from the eastern half of the country, with a single collection in the far south-west from a reptile in a snake park in Cape Town.

Amblyomma transversale

A single nymph of this tick was collected from a southern African python (Table 1), which incidentally was also infested with nymphs of *A. marmoreum* and an adult *A. latum*. Pythons are apparently the only host species recorded for *A. transversale* in southern Africa (Norval 1985; Walker 1991).

Hyalomma truncatum

Despite our examination of large numbers of tortoises in regions in which *H. truncatum* is present (Howell *et al.* 1978), only three leopard tortoises and one geometric tortoise were infested with this tick (Table 1). These ticks should be considered 'stragglers' from a heavily infested environment. The hosts of adult *H. truncatum* are large herbivorous mammals (Norval 1982; Horak, Swanepoel & Gummow 2002), to which they attach in the axillary and perianal regions and in the tail brush.

Rhipicephalus gertrudae

This tick is particularly prevalent in the Western Cape Province, and its adults infest herbivores and carnivores (Walker, Keirans & Horak 2000; Horak & Matthee 2003). The ticks on two tortoises examined during June and August respectively (Table 1), must be considered 'stragglers' reflecting the tick's abundance in the Western Cape Province at this time of the year (Horak & Fourie 1992).

Ornithodoros compactus

This tick has been recorded on the tortoises, *Testudo oculifera* (*Psammobates oculiferus*), *Testudo verreauxi* (*Psammobates tentorius verroxii*), *Testudo shonlandi* (*Psammobates tentorius verroxii*) and *Homopus femoralis* in southern Africa (Walton 1962), and tortoises would appear to be its only hosts. In the current surveys ticks were collected from six tortoise species, and infestation was most prevalent on Namaqualand speckled padloper tortoises. The larvae of *O. compactus* are not parasitic, but 450 nymphs and 57 adults (70 adults if the 13 unsexed adult ticks are included) were collected from 58 tortoises (Table 5).

TABLE 4 *Amblyomma latum* collected from various reptile hosts

Host species	Number infested with ticks	Number infested with *A. latum*	Number of ticks collected				
			Larvae	Nymphs	Males	Females	Total
Leopard tortoise, *G. pardalis*	82	1	0	0	0	1	1
Aurora house snake, *Lamprophis aurora*	1	1	0	0	1	0	1
Brown house snake, *Lamprophis fuliginosus*	4	4	0	1	3	2	6
Black mamba, *Dendroaspis polylepis*	5	5	76	8	81	28	193
Snouted cobra, *Naja annulifera annulifera*	5	5	2	1	30	3	36
Mozambique spitting cobra, *Naja mossambica*	5	5	0	1	15	0	16
Cape (Yellow) cobra, *Naja nivea*	1	1	0	0	2	3	5
Rinkhals, *Hemachatus haemachatus*	1	1	0	0	7	0	7
Puff adder, *B. arietans*	3	2	0	0	1	1	2
Snouted night adder, *Causus defilippii*	2	2	4	2	0	2	8
Common night adder, *Causus rhombeatus*	1	1	0	0	0	2	2
Cape file snake, *Mehelya capensis*	6	6	1	16	49	9	75
Black file snake, *Mehelya nyassae*	1	1	0	3	0	0	3
Herald snake, *Crotaphopeltis hotamboeia*	1	1	0	2	0	0	2
Shield-nose snake, *Aspidelaps scutatus*	3	3	0	0	7	0	7
Southern African python, *P. natalensis*	3	2	0	0	5	14	19
Olive grass snake, *Psammophis mossambicus*	3	3	8	2	4	0	14
Striped skink, *Mabuya striata*	1	1	6	0	0	0	6
Variable skink, *Mabuya varia*	1	1	3	0	0	0	3
Total	**129**	**46**	**100**	**36**	**205**	**65**	**406**

Unlike other *Ornithodoros* species, of which the nymphs and adults spend most of their time in the dwellings or burrows of their hosts, or under the surface of the soil, it would seem as if those of *O. compactus* live on their tortoise hosts. Namaqualand speckled padloper tortoises, all of which were infested, prefer rocky terrain, but also have sand in their habitat. These tortoises often rest among the debris and soil under shrubs or between boulders and it is possibly here that they acquire infestation

TABLE 5 *Ornithodoros compactus* collected from various reptile hosts

Host species	Number infested with ticks	Number infested with *O. compactus*	Number of ticks collected				
			Larvae	Nymphs	Males	Females	Total
Leopard tortoise, *G. pardalis*	51*	2	0	3	0	0	3
Geometric tortoise, *P. geometricus*	86	2	0	26	2	0	28
Tent tortoise, *P. t. tentorius*	23	0	0	0	0	0	0
Namaqualand tent tortoise, *P. t. trimeni*	5	5	0	30	0	0	30
Bushmanland tent tortoise, *P. t. verroxii*	11	8	0	79	2	0	81
Tent tortoise, *P. tentorius*	5	3	0	27	0	0	27
Angulate tortoise, *C. angulata*	138	3	0	9	0	0	9
Common padloper, *H. areolatus*	87	5	0	18	0	0	18
Southern speckled padloper, *H. s. cafer*	8	0	0	0	0	0	0
Namaqualand speckled padloper, *H. s. signatus*	30	30	0	258	12	41	311**
Total	**444**	**58**	**0**	**450**	**16**	**41**	**507****

* Number of tortoises examined within the apparent distribution range of *O. compactus*
** Plus 13 unsexed adults

via newly moulted first stage nymphs. These nymphs would have moulted from non-parasitic larvae that had hatched from eggs that had dropped off or were deposited in these protected localities. Walton (1962) has suggested that the axillary and perineal skin folds are probably the most suitable sites for the ticks to survive on tortoises. Loehr, Henen & Hofmeyr (2006) found that the ticks tend to use the hind limbs of Namaqualand speckled padloper tortoises more frequently than the fore limbs and cervical region, and many move when the tortoises are handled. Like other *Ornithodoros* spp. feeding appears to be occasional, and only one male and two female ticks of the 57 adults that we collected appeared to have recently engorged.

The distribution of *O. compactus* is apparently restricted to southern Africa south of the Zambezi River (Walton 1962). In the present surveys most collections were made from tortoises in the semi-arid Northern Cape Province (Fig. 2).

General

Only 26 of the 591 reptiles examined harboured mixed infestations of two tick species, and only two hosted three species. One of the latter was a rock monitor, which was infested with nymphs of *A. hebraeum* and of *A. marmoreum* and nymphs and adults of *A. exornatum*, and the other a southern African python that harboured nymphs of *A. marmoreum*, a single *A. transversale* nymph, and a male *A. latum*. Eighteen leopard tortoises were infested with both *A. hebraeum* and *A. marmoreum*, three with *A. marmoreum* and *H. truncatum*, and one with *A. marmoreum* and a nymph of *O. compactus*. A geometric tortoise harboured *A. marmoreum* and a female *R. gertrudae*, and a Namaqualand tent tortoise was infested with one male *A. marmoreum* and 20 *O. compactus* nymphs. Two rock monitors were infested with *A. marmoreum* and *A. exornatum*. It would thus seem that, with the exception of *A. hebraeum* and *A. marmoreum*, the ticks infesting reptiles have

evolved fairly distinct preferences for individual host species or for hosts belonging to the same genus or grouping.

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Sympatric wildlife

Although practically all the studies on wildlife listed above involve sympatric wildlife species, each of them usually only highlights the ticks of a single or closely related host species. The studies listed in this section all encompass at least two sympatric species of wildlife and their ticks. Thus sympatric bushbuck, *Tragelaphus scriptus*, and common duikers, *Sylvicapra grimmia* (Horak, Keep, Spickett & Boomker 1989), and red duikers, *Cephalophus natalensis*, and bush pigs, *Potamochoerus porcus* (Horak, Boomker & Flamand 1991e), were examined in KwaZulu-Natal. The bushbuck and the common duikers were infested mainly with all stages of development of ticks of the *Ixodes pilosus* group, and also harboured adult *Haemaphysalis aciculifer*. The red duikers harboured all stages of development of the rather rare tick *Haemaphysalis parmata* and the bush pigs were infested with all stages of development of *Rhipicephalus maculatus* and with the adults of the fairly rare *Rhipicephalus zumpti*.

When possible, eight sympatric host species were examined in the Bontebok National Park in the Western Cape Province during February of ten consecutive years (Horak, Fourie & Boomker 1997; Horak & Boomker 1998). With the exception of four-striped mice, *Rhabdomys pumilio*, all host species were infested with the larvae of *Amblyomma marmoreum*, and leopard tortoises, *Geochelone pardalis*, also with the adults of the latter tick. Bontebok, *Damaliscus pygargus dorcas*, grey rhebok, *Pelea capreolus*, and scrub hares, *Lepus saxatilis*, were infested with all stages of development of ticks of the *I. pilosus* group and *Rhipicephalus nitens*.

Varying numbers of six species of ground frequenting birds and 15 species of small and large mammals were examined at irregular intervals over a period of nearly 3 years in the Mountain Zebra National Park in the Eastern Cape Province (Horak, Fourie, Novellie & Williams 1991b), and a total of 16 tick species were recovered. Because of the large number of host species examined simultaneously certain tick/host preferences became apparent, namely all stages of development of *Haemaphysalis hyrocaphila* and *Rhipicephalus distinctus* for rock dassies, *Procavia capensis*, adult *Hyalomma* spp. and *Rhipicephalus follis* for eland, *Taurotragus oryx*, all stages of development of *Ixodes*

rubicundus for caracal, *Caracal caracal*, and the immature stages of the latter tick as well as all stages of development of *Rhipicephalus arnoldi* for Smith's red rock rabbits, *Pronolagus rupestris*, the one-host tick, *Margaropus winthemi*, for Cape mountain zebras, *Equus zebra zebra*, and all stages of development of *Rhipicephalus oculatus* for scrub hares. It was also obvious that black wildebeest, *Connochaetes gnou* are innately resistant to infestation with ticks. A similar phenomenon has been reported in blue wildebeest, *Connochaetes taurinus* (Horak, De Vos & Brown 1983).

Six host species were examined in the Etosha Nature Reserve in the north of Namibia, and two in the Hardap Nature Reserve in the south of that country (Horak, Anthonissen, Krecek & Boomker 1992a), and a total of seven ixodid tick species was recovered. Giraffes, *Giraffa camelopardalis*, in the Etosha Nature Reserve proved to be excellent hosts of the adults of *Hyalomma marginatum rufipes* and *Hyalomma truncatum*, while large numbers of adult *Rhipicephalus exophthalmos* [referred to as *Rhipicephalus* sp. (near *R. oculatus* in the publication)] were collected from gemsbok, *Oryx gazella*, in the Hardap Nature Reserve. The majority of Burchell's zebras, *Equus burchelli*, Hartmann's mountain zebras, *Equus zebra hartmannae*, giraffes and greater kudus, *Tragelaphus strepsiceros* examined in the Etosha Nature Reserve were infested with *Rhipicephalus evertsi mimeticus*.

Ticks were collected at irregular intervals over a period of one year from two species of ground-nesting birds and 20 species of small and large mammals on a game ranch in Central Province, Zambia (Zieger, Horak, Cauldwell & Uys 1998b), and 13 species were recovered. Of these *Amblyomma variegatum*, *Boophilus decoloratus*, and particularly *Rhipicephalus appendiculatus*, accounted for the largest proportion collected. The biggest burdens of adult *A. variegatum* were encountered on Burchell's zebras, a Lichtenstein's hartebeest, *Sigmoceros lichtensteinii*, and on eland, and the greatest numbers of adult *R. appendiculatus* were recorded on eland, greater kudus, and defassa waterbuck, *Kobus ellipsiprymnus defassa*. The largest numbers of all stages of development of *Boophilus decoloratus* were collected from eland, greater kudus and a sable antelope, *Hippotragus niger*.

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PARASITES OF DOMESTIC AND WILD ANIMALS IN SOUTH AFRICA. XXIV. ARTHROPOD PARASITES OF BUSHBUCK AND COMMON DUIKER IN THE WEZA STATE FOREST, NATAL

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ABSTRACT

HORAK, I. G., KEEP, M. E., SPICKETT, A. M. & BOOMKER, J., 1989. Parasites of domestic and wild animals in South Africa. XXIV. Arthropod parasites of bushbuck and common duiker in the Weza State Forest, Natal. *Onderstepoort Journal of Veterinary Research*, 56, 63–66 (1989)

One bushbuck, *Tragelaphus scriptus*, and 1 common duiker, *Sylvicapra grimmia*, were shot each month from May 1983 to May 1984 in the Weza State Forest, Natal, i.e. a total of 13 animals of each species. The bushbuck were infested with 8 ixodid tick species, 2 louse species and a louse-fly species. The common duiker harboured 7 tick species and 2 louse species.

Ticks of the genus *Ixodes* were the most numerous and prevalent on both antelope species, but no pattern of seasonal abundance was evident. Although only small numbers were recovered, adult *Haemaphysalis aciculifer* were present from September to February, nymphs of *Rhipicephalus appendiculatus* from May to September, and adult *Rhipicephalus lunulatus* from December to March. The louse-fly, *Lipoptena paradoxa*, was recovered from some of the bushbuck from October to May.

INTRODUCTION

The distribution, habitats, habits and food preferences of bushbuck, *Tragelaphus scriptus*, and of common duiker, *Sylvicapra grimmia*, have been summarized and commented upon by Boomker, Keep & Horak (1987) and Boomker, Du Plessis & Boomker (1983) respectively.

The ixodid ticks of these animals in countries outside the Republic of South Africa have been recorded by Theiler (1962), Yeoman & Walker (1967) and Walker (1974). Those occurring in South Africa are listed by Theiler (1962) and Baker & Keep (1970), while Horak, Potgieter, Walker, De Vos & Boomker (1983) and Boomker *et al.* (1983) have determined the actual tick burdens of both species in the Transvaal.

The lice recovered from bushbuck and common duiker have been listed by Ledger (1980) and the flies by Haeselbarth, Segerman & Zumpt (1966). The louse and louse-fly burdens of common duiker have been determined by Boomker *et al.* (1983).

Allen-Rowlandson (1986) required freshly-killed bushbuck and common duiker for his study of these species within the Weza forestry areas of Natal. During the later part of his project, material for parasitological investigation was collected and the present paper records the arthropod parasite burdens of 13 animals of each species. The helminth burdens of these animals have been reported in a separate paper (Boomker *et al.*, 1987).

MATERIALS AND METHODS

Study site

The physiography of the Weza State Forest (30° 35′ S; 24° 45′ E), Alfred District of Natal, in which the animals were collected, has been described by Boomker *et al.* (1987).

Survey animals

One bushbuck and 1 common duiker were shot at night each month for 13 consecutive months from May 1983 to May 1984. Eleven adults and 2 sub-adults of each species were shot. These comprised 7 male and 6 female bushbuck and 8 male and 5 female duiker.

Parasite recovery

Immediately after slaughter the skins of the animals were processed for arthropod parasite recovery as described by Horak, Meltzer & De Vos (1982). The ectoparasite burdens of the animals were determined as described by Horak *et al.* (1983).

RESULTS

Bushbuck

The total numbers of arthropod parasites recovered from the 13 animals examined are summarized in Table 1.

The bushbuck were infested with 8 ixodid tick species, 2 louse species and a louse-fly species. Small numbers of adult *Haemaphysalis aciculifer* were recovered from each animal examined from September 1983 to February 1984. Ticks of the genus *Ixodes* were the most numerous and all animals were infested, but no pattern of seasonal abundance was evident. Three of the 5 antelope examined between December 1983 and April 1984 each harboured 2 adult *Rhipicephalus follis*, while the 3 animals examined between December and February were each infested with adult *Rhipicephalus lunulatus*. Six of the 8 antelope examined between October 1983 and May 1984 harboured the louse-fly *Lipoptena paradoxa*

Common Duiker

Table 2 summarizes the total numbers of arthropod parasites recovered from the 13 antelope examined.

The duiker harboured 7 ixodid tick species and 2 species of lice. The 3 animals examined between November 1983 and January 1984 were each infested with adult *H. aciculifer*. Although ticks of the genus *Ixodes* were the most numerous no pattern of seasonal abundance was evident. Each of the animals examined from May to September 1983 was infested with 2–4 nymphs of *Rhipicephalus appendiculatus*. Only the animal shot during March 1984 was infested with adult *R. lunulatus*.

DISCUSSION

Ixodid ticks

The bushbuck harboured more ticks of each species than did the duikers. In total they carried approximately 8 times more larvae, twice as many nymphs and 10 times

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TABLE 1 Arthropod parasites recovered from 13 bushbuck from the Weza State Forest, Natal

Arthropod species	Total numbers of arthropods recovered					Number of animals infested
Ixodid ticks	Larvae	Nymphs	♂♂	♀♀	Total	
Boophilus decoloratus	70	0	2	0	72	4
Haemaphysalis aciculifer	0	0	58	16	74	6
Ixodes spp.	42 502	4 568	—	—	47 070	13
Ixodes pilosus	—	—	212	978	1 190	13
Ixodes sp. (near *I. pilosus*)	—	—	64	930	994	12
Rhipicephalus appendiculatus	26	4	0	0	30	2
Rhipicephalus evertsi evertsi	788	120	0	0	908	9
Rhipicephalus follis	0	0	4	2	6	3
Rhipicephalus lunulatus	0	0	18	14	32	3
Total	43 386	4 692	358	1 940	50 376	
Lice	Nymphs		Adults		Total	
Damalinia natalensis	150		112		262	6
Linognathus panamensis	216		142		358	10
Total	382		258		640	
Flies	Adults				Total	
Lipoptena paradoxa	156				156	6

TABLE 2 Arthropod parasites recovered from 13 common duiker from the Weza State Forest, Natal

Arthropod species	Total numbers of arthropods recovered					Number of animals infested
Ixodid ticks	Larvae	Nymphs	♂♂	♀♀	Total	
Boophilus sp.	12	2	0	0	14	4
Haemaphysalis aciculifer	0	2	6	4	12	4
Ixodes spp.	5 370	2 140	—	—	7 510	13
Ixodes pilosus	—	—	21	124	145	12
Ixodes sp. (near *I. pilosus*)	—	—	15	58	73	10
Rhipicephalus appendiculatus	6	14	0	0	20	6
Rhipicephalus evertsi evertsi	92	20	0	0	112	9
Rhipicephalus lunulatus	0	0	2	0	2	1
Total	5 480	2 178	44	186	7 888	
Lice	Nymphs		Adults		Total	
Damalinia sp.	22		26		48	2
Linognathus breviceps-complex	30		50		80	8
Total	52		76		128	

more adults. MacLeod, Colbo, Madbouly & Mwanaumo (1977) have stated that the larger the host the more adult ticks it seems likely to carry. This is confirmed by the observations of Horak & Knight (1986) and Horak, Sheppey, Knight & Beuthin (1986). They determined the total tick burdens of various sympatric host species and found that, with some exceptions, the larger the animal species the better host it is, particularly for the adults.

Boophilus decoloratus

Horak *et al.* (1983) found that in habitats in which *B. decoloratus* abounds, such as the Kruger National Park, bushbuck are good hosts of this tick. The small number of ticks recovered from these animals in the present survey therefore probably indicates an unfavourable habitat. *B. decoloratus* prefers open grassland or savanna with an annual rainfall above 380 mm (Howell, Walker & Nevill, 1978), whereas the study area comprises mountain grassland (27 %), indigenous forest (19 %) and plantations of exotic trees (54 %) (Boomker *et al.*, 1987). The bushbuck and duiker examined in this study were shot in forested regions with variable grass cover depending upon the size of the trees. However, as only small numbers of *B. decoloratus* have been recovered from common duiker examined in a habitat suitable for the blue tick (Boomker *et al.*, 1983), duiker are in any event probably not good hosts for this species.

Haemaphysalis aciculifer

Hoogstraal & El Kammah (1972) have recorded bushbuck as a host of this tick in Uganda, Kenya and Tanzania and common duiker in Kenya. Walker (1974) also lists bushbuck and common duiker as hosts in Kenya. Its recovery from these animals in the Weza State Forest confirms the observation of Horak *et al.* (1986) that it has a wider distribution in South Africa than is given by Theiler (1962). Norval (1985) notes that the 7 collections made in Zimbabwe were all from animals in woodland or wooded grassland habitats on the high rainfall, highveld plateau. These collections, which consisted only of adults, were all made from November to January. In the south-western Cape Province Horak *et al.* (1986) recovered small numbers of adult ticks from grey rhebuck (*Pelea capreolus*) and bontebok (*Damaliscus dorcas dorcas*) from August to February. In the present survey adults were recovered from September to February.

Ixodes pilosus

We have assumed that the immature stages of this tick and those of the other *Ixodes* species recovered are indistinguishable, hence they are lumped under *Ixodes* spp. in the tables. *I. pilosus* is found in sourveld areas along the coast from Port Shepstone in Natal to Cape Town in the western Cape Province (Howell *et al.*, 1978). A total of 29 males and 102 females (a ratio of

1:3,5) were recovered by Norval (1974) from bushbuck and duiker in the eastern Cape Province. Horak, Jacot Guillarmod, Moolman & De Vos (1987) recovered 38 males and 130 females (a ratio of 1:3,4) from dogs and only 1 male and 39 females from caracals (*Felis caracal*) in the same region, while Horak *et al.* (1986) recovered 63 males and 205 females (a ratio of 1:3,3) from bontebok, grey rhebuck and scrub hares (*Lepus saxatilis*) in the south-western Cape Province. The animals from the Weza forest harboured a total of 233 males and 1 102 females (a ratio of 1:4,7). Norval (1974) suggests that these ratios indicate that mating may occur either on the host or on the ground.

Although no pattern of seasonal abundance was obvious in the present survey, Horak *et al.* (1986, 1987) found that in the south-western and eastern Cape Province the larvae peak in June and the nymphs in August, while the adults may peak from October to December or January to May. They suggested that only one life cycle was completed annually.

Ixodes sp.

These ticks resemble *I. pilosus*, but show definite palpal, coxal and setal differences and they probably represent a new species. One of us (A.M.S.) examined the *Ixodes* sp. collected from 2 blue duikers (*Cephalophus monticola*) during the National Tick Survey in Zimbabwe (Norval, Spickett & Clifford, 1987) and considers them to be identical to those collected in the present survey. No pattern of seasonal abundance is evident and the ratio of males to females is 1:12,5.

Rhipicephalus appendiculatus

Horak *et al.* (1983) and Boomker *et al.* (1983) recovered fair numbers of larvae and nymphs, but few adults, from bushbuck and common duiker examined in the Transvaal. None of those bushbuck were examined during late summer, the season of peak adult abundance, while some of the duiker were. The infestation at Weza was possibly maintained by cattle and goats which occasionally stray into the forest from surrounding farms (Boomker *et al.*, 1987). The period during which the nymphs were present (May–September) was slightly shorter than that of the peak nymphal abundance (April–October) observed by Knight & Rechav (1978) and Rechav (1982) on kudu (*Tragelaphus strepsiceros*), goats and cattle in the eastern Cape Province.

Rhipicephalus evertsi evertsi

Although no adult ticks were recovered this species was probably maintained by the mules and horses used as transport animals in the forest (Boomker *et al.*, 1987). Equids are the preferred hosts of this tick (Hoogstraal, 1956; Norval, 1981).

Rhipicephalus follis

The description of the male of *R. follis* by Theiler (1947) and the original illustrations by Dönitz (1910) were used to identify this species. The descriptions given under this name by Theiler & Robinson (1953) and the accompanying illustrations by D. Pringle are now thought to refer to another species. Theiler (1947) suggests that domestic stock are hosts of this tick. Although only very small numbers of adult ticks were recovered from the bushbuck these were present from December to April.

Rhipicephalus lunulatus

There has been considerable confusion in the past between this species and *Rhipicephalus tricuspis* (Walker, Keirans, Pegram & Clifford, 1988), but these authors have recently published redescriptions of both species, listed their host associations and illustrated their geographic distributions.

Norval & Tebele (1983) state that *R. lunulatus* is widely distributed in Zimbabwe in woodland or woodland/savanna habitats which receive 550–1 200 mm of rain per annum. Amongst the collections of adult ticks in that country, the majority of which were made from November to January, there is one from a common duiker. Colborne (1985) recovered adults from cattle in Zimbabwe from November to May. The preferred sites of attachment were the legs and tail. In the present study adult ticks were present from December to March and all but 2 were recovered from the lower legs of the bushbuck or duiker.

Lice

Both *Damalinia natalensis* and *Linognathus panamensis* are specific parasites of bushbuck (Ledger, 1980). The *Damalinia* sp. on the duiker could not be specifically identified, while the *Linognathus* sp. on this host belonged to the *Linognathus breviceps*-complex as discussed by Ferris (1932). Boomker *et al.* (1983) have recovered small numbers of *Damalinia lerouxi*, *L. breviceps* and *Linognathus zumpti zumpti* from common duikers in the central Transvaal. The lice burdens were never large on either of the antelope species and no patterns of seasonal abundance could be ascertained.

Flies

The louse-fly, *L. paradoxa*, has a wide host range among the antelope and many species that browse are infested (Haeselbarth *et al.*, 1966). Although some of the bushbuck in the present survey were infested none of the duikers were. This contrasts with the findings of Boomker *et al.* (1983), who recovered *L. paradoxa* from 12 of the 16 duikers they examined. In the present survey the flies were only recovered from October to May and then not from all the bushbuck examined during this period.

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PARASITES OF DOMESTIC AND WILD ANIMALS IN SOUTH AFRICA. XXVI. THE MOSAIC OF IXODID TICK INFESTATIONS ON BIRDS AND MAMMALS IN THE MOUNTAIN ZEBRA NATIONAL PARK

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ABSTRACT

HORAK, I. G., FOURIE, L. J., NOVELLIE, P. A. & WILLIAMS, E. J., 1991. Parasites of domestic and wild animals in South Africa. XXVI. The mosaic of ixodid tick infestations on birds and mammals in the Mountain Zebra National Park. *Onderstepoort Journal of Veterinary Research,* 58, 125–136 (1991).

Sixteen species of ixodid ticks were collected over varying periods of time from 6 species of ground-frequenting birds and 15 species of small and large mammals in the Mountain Zebra National Park, Karoo, Cape Province. *Margaropus winthemi* followed by *Rhipicephalus glabroscutatum* and *Rhipicephalus evertsi evertsi* were the most abundant species. The host preferences of 14 tick species and the seasonal abundances of 13 species were determined.

Small numbers of immature stages of only a few tick species were generally recovered from ground-frequenting birds, mice and rats. Amongst the slightly larger animals the smallest number of ticks and species were recovered from springhares and the largest numbers from scrub hares. Amongst the larger mammals, very few ticks were harboured by springbuck and black wildebeest, while heavy infestations of several species were encountered on Cape mountain zebras and eland.

INTRODUCTION

Studies on the ecology of ixodid ticks may involve a single tick species on a single host species (Sutherst, Wharton, Cook, Sutherland & Bourne, 1979), or on a variety of hosts (Randolph, 1975a, b; Doube, 1974). These studies could also encompass several tick species on a single host species (Baker & Ducasse, 1967; Londt, Horak & De Villiers, 1979; Knight & Rechav, 1978; Horak, De Vos & Brown, 1983), or on a number of host species in the same habitat (Rechav, 1982; Horak, Sheppey, Knight & Beuthin, 1986; Rechav, Zeederberg & Zeller, 1987). The latter approach makes it possible to determine the preferred hosts of the ticks as well as the contribution made by each host species towards the total tick population.

Numerous tick species are found within the Mountain Zebra National Park (Young, Zumpt, Boomker, Penzhorn & Erasmus, 1973; Horak, Potgieter, Walker, De Vos & Boomker, 1983). This park also contains large numbers of bird and mammal species (Fourie, 1983). Several studies on the abundance and seasonality of a number of these tick species have already been published (Horak & Williams, 1986; Horak & Fourie, 1986; Horak, Knight & De Vos, 1986; Horak, Moolman & Fourie, 1987; Horak & MacIvor, 1987; MacIvor & Horak, 1987).

Some of the results presented in the latter publications will be repeated to give a more complete picture of the pattern of tick infestation in the park. This paper describes the abundance of 16 ixodid tick species on 6 species of ground-frequenting birds and 15 mammal species in the park.

MATERIALS AND METHODS

Study locality

The Mountain Zebra National Park (32° 15′ S; 25° 27′ E; alt. 1 200–1 957 m) comprises an area of 6 536 ha in extent situated 20 km south-west of Cradock in the Cape Province, Republic of South Africa. The physiography and climate of this park have been described in detail by Fourie (1983). It contains approximately 190 bird species (Skead, 1965; Penzhorn & Bronkhorst, 1976; Penzhorn, 1977; Grobler & Bronkhorst, 1981) and 33 small mammal species (De Graaf & Nel, 1970; Nel & Pretorius, 1971). Of these the rock dassie (*Procavia capensis*), estimated to number 12 700 in 1983, is one of the numerically dominant species. The numbers of large animals, counted in February 1983 during a National Parks Board ground count census, have been summarized by Horak & Fourie (1986).

Survey period

The main survey ran from February 1983 to December 1985 with Smith's red hares (referred to in previous publications as red rock rabbits), scrub hares, rock dassies, mountain reedbuck, springbuck, black wildebeest and eland being shot and examined at approximately 3-monthly intervals during this period. The other animals were generally killed within this period but 2 red hares had already been examined during November 1982.

Survey animals

The bird and mammal species examined, their numbers and the periods over which they were collected are summarized in Table 1.

A total of 6 species of ground-frequenting birds and 15 mammal species were examined. The birds and larger mammals were shot, while the rats and mice were trapped and killed.

Tick recovery

The helmeted guineafowls were processed as described by Horak & Williams (1986), while whole body searches were made under the stereoscopic microscope for ticks on the smaller birds. The ticks on the lagomorphs, rodents and dassies were recovered and counted as described by Horak, Sheppey, Knight & Beuthin (1986), and those on the larger mammals as described by Horak, Meltzer & De Vos (1982) and Horak, Potgieter, Walker, De Vos & Boomker (1983). The length of the idiosoma of maturing female ticks of all species was measured to the nearest 0,5 mm under a stereoscopic microscope to determine the number of ticks engorging successfully on each host species.

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TABLE 1 Birds and mammals examined for ixodid ticks in the Mountain Zebra National Park

Species	Common name	No. Examined	Dates collected
Birds			
Numida meleagris	Helmeted guineafowl	16	Feb. 84–Dec. 85
Galerida magnirostris	Thick-billed lark	4	Feb.–May 1985
Chersomanes albofasciata	Spike-heeled lark	3	Feb. 85
Certhilauda curvirostris	Long-billed lark	10	Mar. 84–Feb. 85
Cercomela familiaris	Familiar chat	5	June and July 84
Anthus similis	Nicholson's pipit	5	June 84–May 85
Mammals			
Lepus saxatilis	Scrub hare	26	Feb. 83–Dec. 85
Pronolagus rupestris	Smith's red hare	28	Nov. 82–Dec. 85
Pedetes capensis	Springhare	17	Feb. 83–Dec. 85
Otomys irroratus	Vlei rat	2	May and June 84
Otomys unisulcatus	Bush Karroo rat	38	Mar. 84–Dec. 85
Rhabdomys pumilio	Striped mouse	30	Mar. 84–Dec. 85
Aethomys namaquensis	Namaqua rock mouse	6	Mar.–Dec. 84
Saccostomys campestris	Pouched mouse	3	May and June 84
Felis caracal	Caracal	3	May 84–Mar. 85
Procavia capensis	Rock dassie	25	May 83–Dec. 85
Equus zebra zebra	Cape mountain zebra	14	Feb. 83–Dec. 84
Connochaetes gnou	Black wildebeest	9	May 83–Dec. 85
Antidorcas marsupialis	Springbuck	18	Nov. 83–Dec. 85
Taurotragus oryx	Eland	11	May 83–Dec. 85
Redunca fulvorufula	Mountain reedbuck	18	Nov. 83–Dec. 85

Results and Discussion

Sixteen ixodid tick species were recovered during the course of this survey (Table 2). The minimum estimated length of the idiosoma of maturing female ticks of each species approximately 24 h before detaching is also supplied in the table.

Two species of *Rhipicephalus*, both of which have been described previously as *Rhipicephalus oculatus*, were recovered. According to C. M. Clifford & J. E. Keirans (personal communication to J. B. Walker) their examination of the syntype and of *R. oculatus* described by Neumann (1901) from "Damaraland, D.S.W. Afrika" revealed that these ticks do not belong to the same species as the series described under this name by Theiler & Robinson (1953). We accept the ticks described by Neumann (1901) as *R. oculatus sensu stricto*, and have listed those described by Theiler & Robinson (1953) as *Rhipicephalus* sp. (near *R. oculatus*).

TABLE 2 The ixodid tick species recovered from animals in the Mountain Zebra National Park and the minimum lengths of the idiosoma of maturing female ticks*

Tick species	Minimum length in mm of idiosoma of maturing females
Amblyomma marmoreum	9,0
Haemaphysalis hyracophila	4,0
Haemaphysalis spinulosa	4,0
Hyalomma marginatum turanicum	7,5
Hyalomma truncatum	7,5
Ixodes rubicundus	5,0
Ixodes sp.	5,0
Magaropus winthemi	4,5
Rhipicephalus arnoldi	4,0
Rhipicephalus distinctus	4,0
Rhipicephalus evertsi everstsi	6,0
Rhipicephalus follis	6,0
Rhipicephalus glabroscutatum	4,5
Rhipicephalus lounsburyi	5,0
Rhipicephalus oculatus	5,0
Rhipicephalus sp. (near *R. oculatus*)	5,0

* These ticks sould detach within the next 24 h

The host records for each of the tick species within the park, and the seasonal abundances of those species of which sufficient numbers were recovered, are summarized in Tables 3–13 and Fig. 1–11. The seasonal abundances are based on accumulated monthly mean numbers of ticks recovered from the various host species irrespective of the year in which the hosts were examined.

Considering the semi-arid climate, cold winters and hot summers of the region in which the survey was conducted (Fourie, 1983), a surprisingly large number of tick species were recovered. Some of these ticks, notably *A. marmoreum, H. spinulosa, R. follis* and *R. evertsi evertsi*, have widespread distributions and can also be found in moister regions (Theiler, 1962; Howell, Walker & Nevill, 1978; Walker & Olwage, 1987; Horak, Jacot Guillarmod, Moolman & De Vos, 1987; Horak, Keep, Spickett & Boomker, 1989). Others, such as *H. hyracophila, R. arnoldi, R. distinctus* and *R. oculatus*, are host specific and are only found where their hosts are present and the climate is suitable (Theiler, 1962).

TABLE 3 Host records of *Amblyomma marmoreum* in the Mountain Zebra National Park

Host species	No. examined	No. infested	Numbers of ticks recovered				
			Larvae	Nymphs	Males	Females	Total
Birds							
Helmeted guineafowl	16	13	884	14	0	0	898
Mammals							
Scrub hare	26	13	78	9	0	0	87
Smith's red hare	28	6	12	2	0	0	14
Bush Karroo rat	38	2	2	0	0	0	2
Caracal	3	2	108	0	0	0	108
Rock dassie	25	4	3	1	0	0	4
Cape mountain zebra	14	4	180	1	0	0	181
Eland	11	8	167	0	0	0	167
Mountain reedbuck	18	3	10	2	0	0	12

TABLE 4 Host records of various ixodid tick species in the Mountain Zebra National Park

Tick and host species	No. examined	No. infested	Numbers of ticks recovered				
			Larvae	Nymphs	Males	Females	Total
Haemaphysalis hyracophila							
Smith's red hare	28	2	1	1	0	0	2
Rock dassie	25	15	18	3	20	7(2)	48
Ixodes sp.							
Cape mountain zebra	14	1	32	0	0	0	32
Black wildebeest	9	1	2	0	0	0	2
Springbuck	18	1	4	2	0	0	6
Eland	11	1	0	0	1	1	2
Rhipicephalus arnoldi							
Scrub hare	26	3	1	0	2	2(2)	5
Smith's red hare	28	24	77	10	78	41	206
Rock dassie	25	18	186	148	0	0	334
Cape mountain zebra	14	1	0	0	2	0	2
Rhipicephalus lounsburyi							
Caracal	3	1	0	0	0	1	1
Black wildebeest	9	1	0	0	2	0	2
Eland	11	2	0	0	3	0	3
Mountain reedbuck	18	4	0	0	19	10(1)	29
Rhipicephalus oculatus							
Scrub hare	26	19	957	306	21	23(4)	1 307
Smith's red hare	28	1	0	0	2	1	3
Springhare	17	2	2	0	0	0	2
Mountain reedbuck	18	1	4	0	0	0	4
Rhipicephalus sp. (near *R. oculatus*)							
Eland	11	1	0	0	0	2	2
Rhipicephalus spp.							
Scrub hare	26	2	2	0	0	0	2
Smith's red hare	28	1	1	0	0	0	1
Vlei rat	2	2	111	7	0	0	118
Bush Karroo rat	38	10	40	3	0	0	43
Striped rouse	30	11	95	7	0	0	102
Namaqua rock mouse	6	6	188	16	0	0	204
Pouched mouse	3	2	48	3	0	0	51
Rock dassie	25	2	4	0	0	0	4

( ) = Number of maturing females

Generally the ground-frequenting birds and the rodents were each infested with only 1 or a few tick species, and then only the immature stages. The lagomorphs, caracals and rock dassies harboured fairly similar mean total burdens of approximately 50–100 ticks, comprising several species. Although immature ticks predominated, each of these animals harboured some adult ticks, particularly of those species of which they are considered the preferred hosts.

Of the small to medium-sized antelope the springbuck harboured the smallest numbers of ticks and the black wildebeest the fewest species. With the exception of *R. glabroscutatum* on the mountain reedbuck, none of these hosts harboured large numbers of adult ticks. In contrast the mountain zebras and eland were infested with large numbers of the immatures and adults of many tick species.

These findings confirm the observations of Horak, Potgieter, Walker, De Vos & Boomker (1983) and Horak (1987), who suggest that the larger the host species the more likely it is to carry large numbers of adult ticks, while the really small hosts are likely to carry only immature ticks. There may be several reasons for this, such as the greater surface area exposed, larger volumes of CO_2 exhaled or less efficient grooming by the larger animals.

Amblyomma marmoreum (Table 3; Fig. 1)

No adult ticks were recovered, but of the animals examined guineafowls were the preferred hosts of larvae and nymphs. Tortoises are the preferred hosts of all developmental stages of this tick, but the immature stages have also been recovered from a variety of other hosts (Theiler & Salisbury, 1959; Norval, 1975; Horak, MacIvor, Petney & De Vos, 1987). Tortoises are plentiful in the park, consequently the presence of immature ticks on a number of host species is not surprising. Considerably more larvae than nymphs were recovered from the various hosts (1 444 larvae, 29 nymphs), confirming similar observations by Horak, MacIvor, Petney & De Vos (1987). It must therefore be assumed that the nymphs also prefer tortoises to other host species.

In this study only 2 bush Karroo rats were infested out of a total of 96 rodents (including 17 springhares) examined. In the Bontebok National Park no larvae of *A. marmoreum* were recovered from the 28 rodents examined, whereas more than 35 % of the

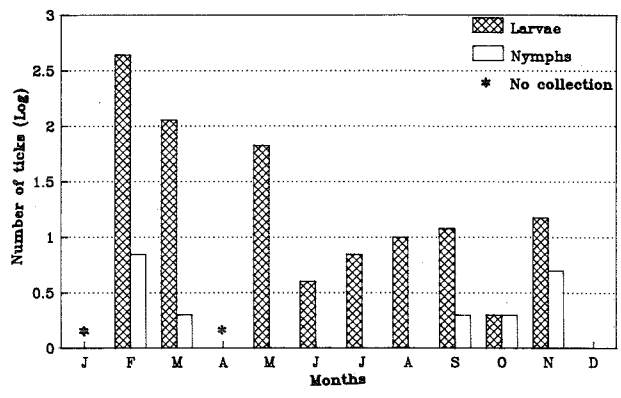

FIG. 1 The seasonal abundance of *Amblyomma marmoreum* on guineafowls, scrub hares, mountain zebras and eland in the Mountain Zebra National Park

TABLE 5 Host records of *Haemaphysalis leachi/spinulosa* in the Mountain Zebra National Park

Host species	No. examined	No. infested	Numbers of ticks recovered				
			Larvae	Nymphs	Males	Females	Total
Birds							
Long-billed lark	10	2	2	0	0	0	2
Mammals							
Springhare	17	2	1	4	0	0	5
Bush Karroo rat	38	2	40	9	0	0	49
Namaqua rock mouse	6	3	1	8	0	0	9
Caracal	3	1	0	0	0	1* (1)	1

* *H. spinulosa* ( ) = Number of maturing females

TABLE 6 Host records of *Hyalomma marginatum turanicum* in the Mountain Zebra National Park

Host species	No. examined	No. infested	Numbers of ticks recovered				
			Larvae	Nymphs	Males	Females	Total
Birds							
Helmeted guineafowl	16	5	19	3	0	0	22
Thick-billed lark	4	3	20	6	0	0	26
Long-billed lark	10	7	67	17	0	0	84
Familiar chat	5	3	5	12	0	0	17
Nicholson's pipit	5	3	6	4	0	0	10
Mammals							
Scrub hare	26	16	996	1 672	0	0	2 668
Smith's red hare	28	6	325	0	0	0	325
Springhare	17	4	13	1	0	0	14
Rock dassie	25	1	0	1	0	0	1
Cape mountain zebra	14	14	0	0	201	44 (10)	245
Springbuck	18	1	0	0	2	0	2
Eland	11	11	0	0	955	191 (57)	1 146

( ) = Number of maturing females

scrub hares, grey rhebuck and bontebok were infested (Horak, Sheppey, Knight & Beuthin, 1986). Howell, Petney & Horak (1989) recovered a total of only 5 larvae and 1 nymph of *Amblyomma hebraeum* from 159 collections from striped mice in a region abounding with this tick. It is thus apparent that the larvae of *A. marmoreum* and also of *A. hebraeum* do not readily infest rodents, but prefer some larger animal.

Larvae of *A. marmoreum* feeding on naturaly infested tortoises take approximately 35 days or more to engorge and detach (Dower, Petney & Horak, 1988). It seemed reasonable to assume that larvae feeding on warm-blooded animals would engorge more rapidly. In this case the length of the life cycle and the seasonal abundance of this tick could be affected by the hosts on which it feeds during its immature stages of development. However, the seasonal abundance does not seem to be influenced by this possibility as most larvae are recovered in autumn and most nymphs in spring (Norval, 1975; Horak & Williams, 1986; Horak, Sheppey, Knight & Beuthin, 1986; Rechav *et al.*, 1987). This pattern also applies to the larvae in the present study.

Haemaphysalis hyracophila (Table 4)

We have assumed that the immature *Haemaphysalis* ticks recovered from the rock dassies and Smith's red hares are *H. hyracophila*, particularly as they differ morphologically from those of *H. leachi/spinulosa*. Although only small numbers were recovered, rock dassies are the preferred hosts of all stages of development.

Horak & Fourie (1986) commented on the small number of immature ticks compared to the total numbers of adults they recovered from 77 dassies in the park. A similar situation exists in the present study. Although a large variety of hosts were examined only 2 of 28 Smith's red hares in addition to the dassies were infested with immature ticks of this species, and these 2 carried only 1 tick each. Possibly the collection technique is not sensitive enough to collect all the immature stages.

In their earlier study, Horak & Fourie (1986) recovered adult ticks from April–December. In this survey no animals were examined during April, and adult ticks were present from May–December.

Haemaphysalis leachi/spinulosa (Table 5)

Because we have difficulty in differentiating the immature stages of these ticks we are discussing the 2 species together. Rodents are the preferred hosts of the immature stages of both, while adult *H. leachi* prefer the larger carnivores and wild cats, and *H. spinulosa* the smaller carnivores (Norval, 1984; Hussein & Mustafa, 1985; Horak, Jacot Guillarmod, Moolman & De Vos, 1987). Although we recovered only small numbers of ticks these host preferences were still apparent. Unless more collections are made from long-billed larks in future, the presence of a larva on 2 of these birds must be viewed as accidental infestations.

Hyalomma spp. (Tables 6, 7; Fig. 2, 3)

The findings relating to *H. marginatum turanicum* and *H. truncatum* have previously been discussed by Horak & MacIvor (1987). It is now clear that scrub hares are the preferred hosts of the immature stages and mountain zebras and eland the preferred hosts of the adults of both species of *Hyalomma* occurring in the park.

TABLE 7 Host records of *Hyalomma truncatum* in the Mountain Zebra National Park

Host species	No. examined	No. infested	Numbers of ticks recovered				
			Larvae	Nymphs	Males	Females	Total
Mammals							
Scrub hare	26	15	273	604	0	0	877
Smith's red hare	28	5	35	8	0	0	43
Bush Karroo rat	38	2	4	0	0	0	4
Striped mouse	30	2	20	4	0	0	24
Namaqua rock mouse	6	2	6	0	0	0	6
Cape mountain zebra	14	13	0	0	174	31 (1)	205
Springbuck	18	1	0	0	2	0	2
Eland	11	11	0	0	350	51 (15)	401
Mountain reedbuck	18	1	0	0	2	0	2

( ) = Number of maturing females

TABLE 8 Host records of *Ixodes rubicundus* in the Mountain Zebra National Park

Host species	No. examined	No. infested	Numbers of ticks recovered				
			Larvae	Nymphs	Males	Females	Total
Mammals							
Scrub hare	26	11	8	27	0	0	35
Smith's red hare	28	20	105	585	0	0	690
Vlei rat	2	1	2	0	0	0	2
Bush Karroo rat	38	1	1	0	0	0	1
Namaqua rock mouse	6	2	5	0	0	0	5
Pouched mouse	3	1	4	0	0	0	4
Caracal	3	3	26	1	43	44 (16)	114
Eland	11	7	0	0	34	81 (7)	115
Mountain reedbuck	18	7	16	0	20	29 (6)	65

( ) = Number of maturing females

With the possible exception of the springhare, which is a very large rodent, the immature stages of *H. marginatum turanicum* preferred ground-frequenting birds to rodents as hosts. Although the Smith's red hares carried a fairly large number of larvae of *H. marginatum turanicum* no nymphs were recovered. Possibly the immature stages of the latter tick cannot complete their life cycle on this host species.

The absence of any seasonal overlap between the immature and adult stages of *H. marginatum turanicum* indicates that only a single life cycle can be completed annually in the Mountain Zebra Park. Rechav *et al.* (1987) found that the seasonal activity pattern for *Hyalomma marginatum rufipes* at Bloemfhof in the south-western Transvaal is similar to that determined for *H. marginatum turanicum* in the present survey.

In addition to scrub hares the immature stage of *H. truncatum* preferred rodents to ground-frequenting birds as hosts. As some overlap in the seasonal abundance of immature and adult *H. truncatum* does occur, the possibility of more than 1 annual life cycle exists. Rechav *et al.* (1987) also recorded 2 peaks of activity for the immature stages of *H. truncatum*, 1 in winter and the other in early, rather than late, summer.

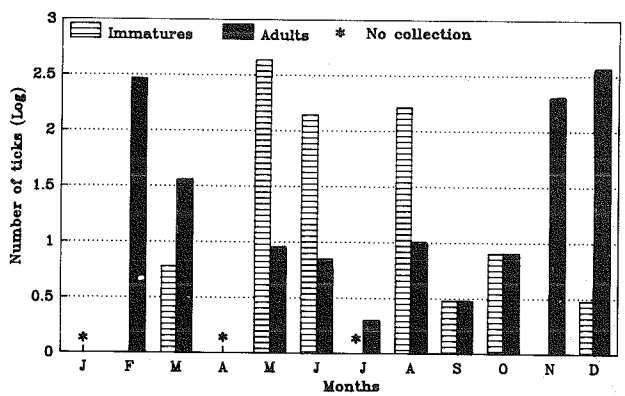

FIG. 2 The seasonal abundance of immature *Hyalomma marginatum turanicum* on guineafowls and scrub hares and adults on mountain zebras and eland in the Mountain Zebra National Park

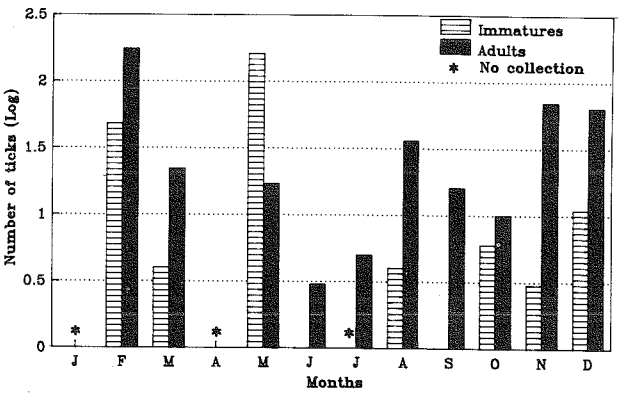

FIG. 3 The seasonal abundance of immature *Hyalomma truncatum* on scrub hares and adults on mountain zebras and eland in the Mountain Zebra National Park

Ixodes rubicundus (Table 8; Fig. 4)

These findings have previously been discussed by Horak, Moolman & Fourie (1987). In summary the immature stages prefer Smith's red hares and the

TABLE 9 Host records of *Margaropus winthemi* in the Mountain Zebra National Park

Host species	No. examined	No. infested	Numbers of ticks recovered				
			Larvae	Nymphs	Males	Females	Total
Birds							
Helmeted guineafowl	16	2	2	0	0	0	2
Mammals							
Scrub hare	26	2	4	0	0	0	4
Smith's red hare	28	3	3	0	0	0	3
Springhare	17	2	6	2	0	0	8
Striped mouse	30	1	1	0	0	0	1
Caracal	3	1	11	2	0	0	13
Rock dassie	25	4	6	0	0	0	6
Cape mountain zebra	14	14	56 816	27 737	13 353	4 353 (640)	102 259
Black wildebeest	9	1	892	8	4	4	908
Springbuck	18	1	2	0	0	0	2
Eland	11	9	12 792	6 874	1 915	893 (109)	22 474
Mountain reedbuck	18	3	6	2	0	0	8

( ) = Number of maturing females

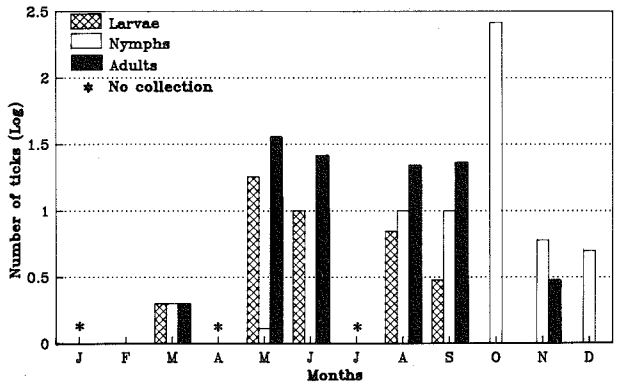

FIG. 4 The seasonal abundance of immature *Ixodes rubicundus* on Smith's red hares and adults on eland and mountain reedbuck in the Mountain Zebra National Park

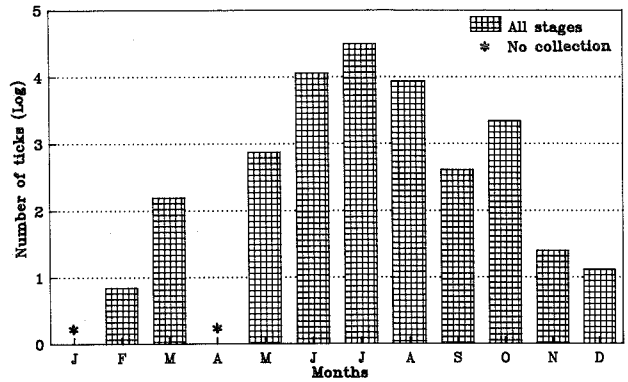

FIG. 5 The seasonal abundance of *Margaropus winthemi* on mountain zebras and eland in the Mountain Zebra National Park

adults eland and mountain reedbuck, while caracal harbour all stages of development. The rock elephant shrew, *Elephantulus myurus,* is, however, probably the prime host of the immature stages (Stampa, 1959). Unfortunately we did not examine any shrews and our data for the park are thus incomplete in this respect. With the exception of eland, which roam on the plateaux and hills, all the aforementioned hosts prefer mountainous terrain, which is also the preferred habitat of the tick (Theiler, 1950; Stampa, 1959).

Although the periods of seasonal abundance of the immature and adult ticks appear to overlap (Fig. 4), it must be remembered that the life cycle takes 2 years to complete (Howell *et al.*, 1978). The larvae and nymphs are present from autumn to spring of the first year and the adults during the same period of the second year.

Margaropus winthemi (Table 9; Fig. 5)

This is by far the most numerous tick recovered from Cape mountain zebras (Horak, Knight & De Vos, 1986). Theiler & Salisbury (1958) and Howell *et al.* (1978) state that it is most commonly found on horses, but that it also attacks cattle. Young *et al.* (1973) have recorded large infestations on zebras in the park and Horak, Potgieter, Walker, De Vos & Boomker (1983) have recovered small numbers from gemsbok in the park in early summer. The gemsbok have subsequently all been removed from the park.

The large numbers recovered from eland in the present survey and the high proportion of engorging females indicate that these large antelope must also be considered preferred hosts. With the exception of black wildebeest, which may harbour moderate numbers of *M. winthemi* (Table 9), the presence of small numbers on other animals in the present survey must be regarded as evidence of the superabundance of free-living larvae during the winter months. The absence of adults indicates that the parasitic life cycle can probably not be completed on these accidental hosts.

The ratio of larvae to nymphs to adults (3,4:1,7:1,0) based on the combined burdens of the zebras, wildebeest and eland is not unlike that of the1-host tick *Boophilus decoloratus* (3,0:1,1:1,0) on Burchell's zebras, *Equus burchelli,* in the Kruger National Park (Horak, De Vos & De Klerk, 1984). The major losses between the larval and nymphal, and nymphal and adult stages probably occur just prior to, during, and just after moulting.

The addition of the monthly burdens of the eland to those of the mountain zebras further confirms the winter abundance of this tick noted by Theiler & Salisbury (1958), Howell *et al.* (1978) and Horak, Knight & De Vos (1986). It has been suggested by Penzhorn & Horak, (1989) that pale-winged starlings, *Onychognathus nabouroup,* exploit the large numbers of *M. winthemi* present on zebras in the park as a food source during winter. The virtual absence of ticks from November–March suggests that oversummering must occur as detached engorged females or more probably as eggs.

TABLE 10 Host records of *Rhipicephalus distinctus* in the Mountain Zebra National Park

Host species	No. examined	No. infested	Numbers of ticks recovered				
			Larvae	Nymphs	Males	Females	Total
Mammals							
Scrub hare	26	9	41	3	1	0	45
Smith's red hare	28	4	10	0	0	0	10
Springhare	17	1	1	0	0	0	1
Vlei rat	2	1	1	0	0	0	1
Bush Karroo rat	38	1	1	0	0	0	1
Namaqua rock mouse	6	1	1	0	0	0	1
Caracal	3	1	2	0	0	0	2
Rock dassie	25	23	747	132	208	73 (4)	1 160

( ) = Number of maturing females

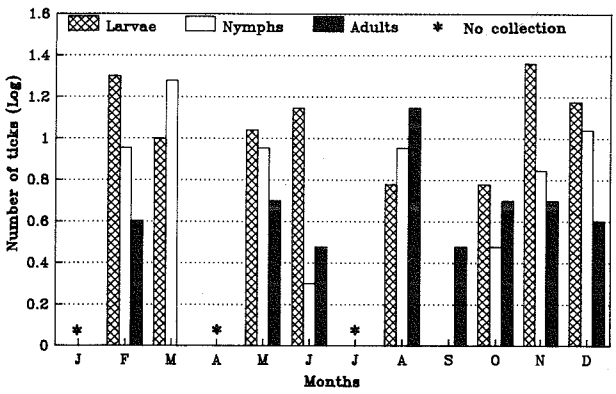

FIG. 6 The seasonal abundance of immature *Rhipicephalus arnoldi* on Smith's red hares and rock dassies and adults on Smith's red hares in the Mountain Zebra National Park

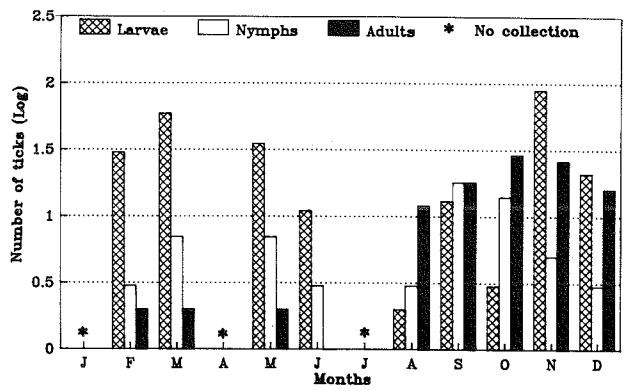

FIG. 7 The seasonal abundance of *Rhipicephalus distinctus* on rock dassies in the Mountain Zebra National Park

***Rhipicephalus arnoldi* (Table 4; Fig. 6)**

The adults of this tick prefer Smith's red hares (Norval, 1985), but as evidenced by the present and a previous survey (Horak & Fourie, 1986), the immature stages prefer rock dassies. The habitats of the latter animals and those of Smith's red hares largely overlap. The hares are, however, nocturnal, while the dassies are strictly diurnal (Smithers, 1983; Fourie, 1983). The 2 adult ticks recovered from a mountain zebra must be regarded as an accidental infestation. The ratio of larvae to nymphs and nymphs to adults (2,1:1,3:1,0) based on the combined burdens of scrub hares, Smith's red hares and rock dassies in the present survey are exceptionally close. This suggests that some other animals, not examined in the present survey, may have harboured large numbers of immature ticks. It is, however, also possible that the rocky shelters and refuges occupied by the hares and dassies respectively afford excellent protection for the free-living ticks. This would ensure their efficient translation through the various life cycle stages with minimal loss. The lack of a clear pattern of seasonal abundance for any of the life stages further supports the latter theory. The heat and moisture originating from the host while in its form or refuge provides an ideal microhabitat for the year-round development of the ticks.

***Rhipicephalus distinctus* (Table 10; Fig. 7)**

Theiler (1947) recorded this tick as preferring rock dassies as hosts, and the present study confirms that fact. In an earlier survey of the ectoparasites of rock dassies in the Mountain Zebra Park, Horak & Fourie (1986) commented on the apparent paucity of nymphs in comparison with the number of adults recovered. The current study supports that observation and, although several larvae and only a few nymphs were recovered from scrub hares and some larvae from Smith's red hares, it is still possible that these animals do play a role as hosts of the immature stages.

In the previous survey the largest numbers of larvae were present from December–May and adults from August–January. The activity periods recorded now correspond almost exactly with those previously observed. In that survey nymphal burdens peaked during January and March compared with September and October currently. These fluctuations possibly reflect variations in the small nymphal burdens rather than shifts in nymphal activity.

***Rhipicephalus evertsi evertsi* (Table 11; Fig. 8)**

Equids, and possibly more particularly zebras, are the preferred hosts of this tick (Norval, 1981; Horak, De Vos & De Klerk, 1984). The large numbers of immature ticks recovered from the external ear canals of zebras and eland certainly indicates that they are excellent hosts of these developmental stages. The scrub hares in this study and in surveys at other localities, also proved to be efficient hosts of the immature stages (Horak & Knight, 1986; Rechav *et al.*, 1987). The large numbers of adults recovered from the eland in the present survey implies that they may be more efficient hosts of this stage of development than the mountain zebras.

Although all stages of development were present in variable numbes throughout the year, suggesting that the life cycle can be continuous, some seasonality was apparent, with the largest numbers of immatures present from February–May and of adults from December–February.

TABLE 11 Host records of *Rhipicephalus evertsi evertsi* in the Mountain Zebra National Park

Host species	No. examined	No. infested	Number of ticks recovered				
			Larvae	Nymphs	Males	Females	Total
Birds							
Helmeted guineafowl	16	2	3	0	0	0	3
Mammals							
Scrub hare	26	22	268	272	0	0	540
Smith's red hare	28	8	16	6	0	0	22
Springhare	17	4	6	1	0	0	7
Caracal	3	3	34	1	0	0	35
Rock dassie	25	1	4	0	0	0	4
Cape mountain zebra	14	14	6 384	4 797	619	201 (35)	12 001
Black wildebeest	9	9	180	24	18	8	230
Springbuck	18	15	400	10	0	0	410
Eland	11	11	2 196	1 161	1 123	267 (38)	4 747
Mountain reedbuck	18	12	116	14	0	1	131

( ) = Number of maturing females

TABLE 12 Host records of *Rhipicephalus follis* in the Mountain Zebra National Park

Host species	No. examined	No. infested	Number of ticks recovered				
			Larvae	Nymphs	Males	Females	Total
Mammals							
Cape mountain zebra	14	7	0	0	19	7	26
Black wildebeest	9	1	0	0	2	0	2
Springbuck	18	1	0	0	2	0	2
Eland	11	10	0	0	971	446 (50)	1 417

( ) = Number of maturing females

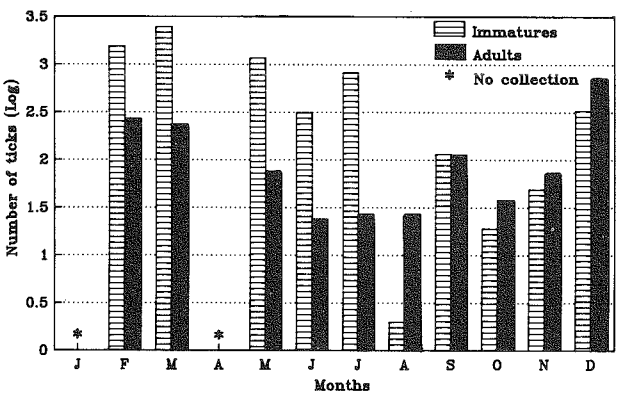

FIG. 8 The seasonal abundance of *Rhipicephalus evertsi evertsi* on mountain zebras and eland in the Mountain Zebra National Park

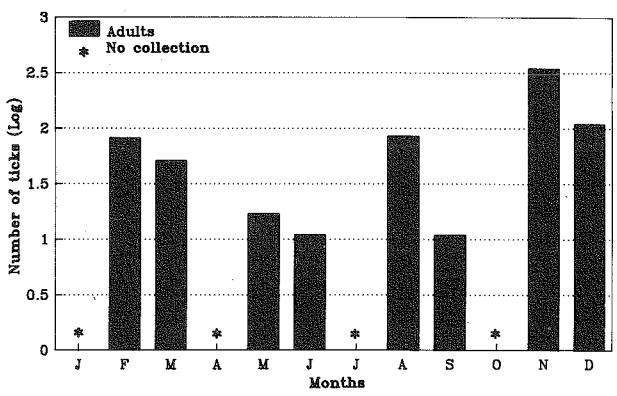

FIG. 9 The seasonal abundance of adult *Rhipicephalus follis* on eland in the Mountain Zebra National Park

Rhipicephalus follis (Table 12; Fig. 9)

The problems encountered in establishing the correct identity of this tick have been mentioned by Walker (1989) cited by Horak *et al.* (1989). There are no published descriptions of the immature stages, but we have reared larvae and nymphs and these were used as aids in identifying these stages in the present survey. Unfortunately the immature stages of other ticks are similar in appearance to those of *R. follis* and this has complicated specific identification. The immature stages of all these ticks have been combined as *Rhipicephalus* spp. in Table 4 and all apparently prefer rodents as hosts. Eland are the preferred hosts of the adults.

Horak *et al.* (1989) recovered adult *R. follis* from bushbuck in the Weza State Forest, Natal, from December to April. Most adults were recovered from eland in the present survey during November and December.

Rhipicephalus glabroscutatum (Table 13; Fig. 10)

The geographic distribution of this 2-host tick in the Valley Bushveld regions of the eastern Cape Province and in the eastern Karoo has been described by MacIvor (1985). In the Valley Bushveld, kudu, common duikers, cattle and goats are the preferred hosts (Knight & Rechav, 1978; Horak & Knight, 1986; MacIvor & Horak, 1987). In the present survey in the eastern Karoo, eland and mountain reedbuck were preferred hosts, while in the Bontebok National Park in the south-western Cape Province, bontebok fill this niche (Horak, Sheppey, Knight & Beuthin, 1986).

With the exception of scrub hares, on which the sites of attachment are unknown, both immature and adult ticks occur on the lower legs and around the feet of their preferred hosts (Horak & Knight, 1986). The translation of larvae to nymphs is good

TABLE 13 Host records of *Rhipicephalus glabroscutatum* in the Mountain Zebra National Park

Host species	No. examined	No. infested	Numbers of ticks recovered				
			Larvae	Nymphs	Males	Females	Total
Birds							
Helmeted guineafowl	16	1	3	0	0	0	3
Mammals							
Scrub hare	26	13	329	212	1	0	542
Smith's red hare	28	6	7	1	0	0	8
Springhare	17	2	1	1	0	0	2
Caracal	3	1	23	1	0	0	24
Rock dassie	25	2	2	0	1	0	3
Cape mountain zebra	14	14	1 419	271	133	103 (8)	1 926
Black wildebeest	9	7	222	10	18	16 (4)	266
Springbuck	18	13	30	4	94	60	188
Eland	11	11	5 628	2 683	668	331 (34)	9 310
Mountain reedbuck	18	18	19 544	4 249	548	247 (16)	24 588

( ) = Number of maturing females

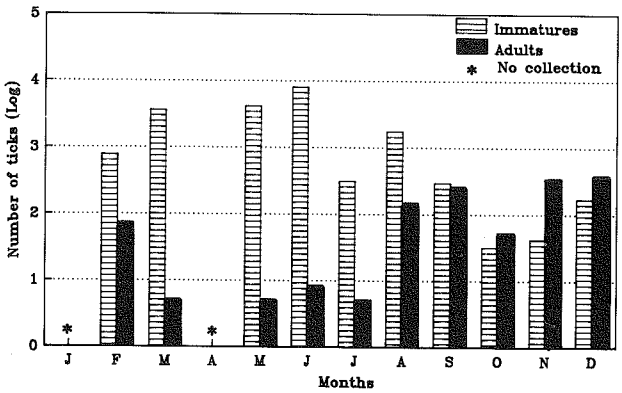

FIG. 10 The seasonal abundance of *Rhipicephalus glabroscutatum* on scrub hares, mountain zebras, black wildebeest, springbuck, eland and mountain reedbuck in the Mountain Zebra National Park

on scrub hares and eland, while it is poor on mountain zebras and black wildebeest. On mountain reedbuck, which harbour the largest numbers of larvae, less than 1 in 4 of these will develop to the nymphal stage (Table 13).

The presence of the immature stages from March–June and the adults from August–February is similar to that described on kudu, common duikers goats and cattle in the eastern Cape Province (Knight & Rechav, 1978; MacIvor & Horak, 1984, 1987) and bontebok in the south-western Cape Province (Horak, Sheppey, Knight & Beuthin, 1986). Although this tick is associated with foot abscess in goats in the eastern Cape Province (MacIvor & Horak, 1987) no evidence of abscessation was seen in any of the wild hosts.

Rhipicephalus lounsburyi (Table 4)

This recently-named tick has been collected in the north-eastern, south-western and west coast regions of the Cape Province (Walker, 1990). The adults have been recovered from sheep, grey rhebuck and bontebok (Walker, 1990) and black wildebeest, eland and particularly mountain reedbuck in the present survey. The single tick recovered from the caracal must be considered an accidental infestation. The hosts of the immature stages are unknown (Walker, 1990).

In the Mountain Zebra Park it was most abundant during August when it was recovered from black wildebeest, eland and mountain reedbuck.

Rhipicephalus oculatus (Table 4; Fig. 11)

All stages of development of this tick prefer hares as hosts (Horak & Knight, 1986). Most of the scrub hares in the present survey, but only 1 of the Smith's red hares were infested. The larvae recovered from 2 springhares and a mountain reedbuck are probably accidental infestations.

The ticks exhibited a clear pattern of seasonal abundance on the scrub hares with larvae reaching the highest numbers from March–August, nymphs from June–October and the adults from August–November. It would thus appear that all stages avoided the really hot summer months from December-February.

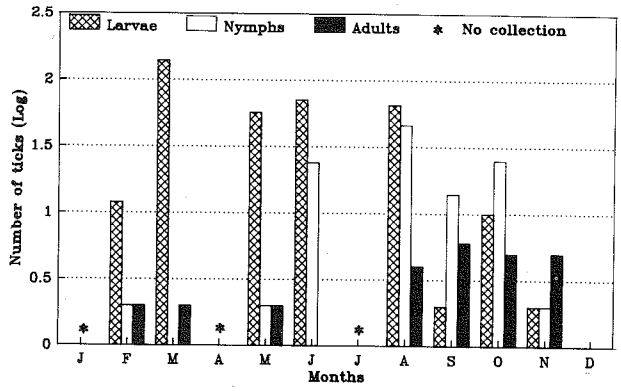

FIG. 11 The seasonal abundance of *Rhipicephalus oculatus* on scrub hares in the Mountain Zebra National Park

Rhipicephalus sp. (near *R. oculatus)* (Table 4)

Two ticks only were recovered, both from 1 eland. It seems therefore that the Cradock district lies at the edge of one of the distributional boundaries of this tick. On a farm and nature reserve near Grahamstown, eastern Cape Province, scrub hares, kudu, cattle, sheep and goats were infested with small numbers of adult ticks, suggesting a fairly wide host range (Horak & Knight, 1986).

HOST/PARASITE LIST

The ticks recorded below were recovered from animals in the Mountain Zebra National Park only during this survey (Table 14). The host preferences of the ticks are also indicated. Preferred hosts are those animals which, within the distribution range of a particular tick, will nearly always be infested with the largest numbers of that tick. Where adult ticks

TABLE 14 Host/parasite list for ixodid ticks collected from birds and mammals in the Mountain Zebra National Park from November 1982—December 1985. The ticks whose names are given in bold type prefer the host(s) under which they are listed. (Im=immature, Ad=adult ticks)

PART 1: BIRDS

Numida meleagris Helmeted guineafowl
- ***Amblyomma marmoreum* (Im)**
- *Hyalomma marginatum turanicum* (Im)
- *Margaropus winthemi* (Im)
- *Rhipicephalus evertsi evertsi* (Im)
- *Rhipicephalus glabroscutatum* (Im)

Galerida magnirostris Thick-billed lark
- *Hyalomma marginatum turanicum* (Im)

Certhilauda curvirostris Long-billed lark
- *Haemaphysalis leachi/spinulosa* (Im)
- *Hyalomma marginatum turanicum* (Im)

Cercomela familiaris Familiar chat
- *Hyalomma marginatum turanicum* (Im)

Anthus similis Nicholson's pipit
- *Hyalomma marginatum turanicum* (Im)

PART 2: MAMMALS

Lepus saxatilis Scrub hare
- *Ambloyomma marmoreum* (Im)
- ***Hyalomma marginatum turanicum* (Im)**
- ***Hyalomma truncatum* (Im)**
- *Ixodes rubicundus* (Im)
- *Margaropus winthemi* (Im)
- *Rhipicephalus arnoldi* (Im, Ad)
- *Rhipicephalus distinctus* (Im, Ad)
- *Rhipicephalus evertsi evertsi* (Im)
- *Rhipicephalus glabroscutatum* (Im, Ad)
- ***Rhipicephalus oculatus*** (Im, Ad)
- *Rhipicephalus* sp. (Im)

Pronolagus rupestris Smith's red hare
- *Amblyomma marmoreum* (Im)
- *Haemaphysalis hyracophila* (Im)
- *Hyalomma marginatum turanicum* (Im)
- *Hyalomma truncatum* (Im)
- ***Ixodes rubicundus* (Im)**
- *Margaropus winthemi* (Im)
- ***Rhipicephalus arnoldi* (Im, Ad)**
- *Rhipicephalus distinctus* (Im)
- *Rhipicephalus evertsi evertsi* (Im)
- *Rhipicephalus glabroscutatum* (Im)
- *Rhipicephalus oculatus* (Ad)
- *Rhipicephalus* sp. (Im)

Pedetes capensis Springhare
- *Haemaphysalis leachi/spinulosa* (Im)
- *Hyalomma marginatum turanicum* (Im)
- *Margaropus winthemi* (Im)
- *Rhipicephalus distinctus* (Im)
- *Rhipicephalus evertsi evertsi* (Im)
- *Rhipicephalus glabroscutatum* (Im)
- *Rhipicephalus oculatus* (Im)

Otomys irroratus Vlei rat
- *Ixodes rubicundus* (Im)
- *Rhipicephalus distinctus* (Im)
- *Rhipicephalus* sp. (Im)

Otomys unisulcatus Bush Karroo rat
- *Amblyomma marmoreum* (Im)
- ***Haemaphysalis leachi/spinulosa* (Im)**
- *Hyalomma truncatum* (Im)
- *Ixodes rubicundus* (Im)
- *Rhipicephalus distinctus* (Im)
- *Rhipicephalus* sp. (Im)

Rhabdomys pumilio Striped mouse
- *Hyalomma truncatum* (Im)
- *Margaropus winthemi* (Im)
- *Rhipicephalus* sp. (Im)

Aethomys namaquensis Namaqua rock mouse
- *Haemaphysalis leachi/spinulosa* (Im)
- *Hyalomma truncatum* (Im)
- *Ixodes rubicundus* (Im)
- *Rhipicephalus distinctus* (Im)
- *Rhipicephalus* sp. (Im)

Saccostomys campestris Pouched mouse
- *Ixodes rubicundus* (Im)
- *Rhipicephalus* sp. (Im)

Felis caracal Caracal
- *Amblyomma marmoreum* (Im)
- ***Haemaphysalis spinulosa* (Ad)**
- ***Ixodes rubicundus* (Im, Ad)**
- *Margaropus winthemi* (Im)
- *Rhipicephalus distinctus* (Im)
- *Rhipicephalus evertsi evertsi* (Im)
- *Rhipicephalus glabroscutatum* (Im)
- *Rhipicephalus lounsburyi* (Ad)

Procavia capensis Rock dassie
- *Amblyomma marmoreum* (Im)
- ***Haemaphysalis hyracophila* (Im, Ad)**
- *Hyalomma marginatum turanicum* (Im)
- *Margaropus winthemi* (Im)
- ***Rhipicephalus arnoldi* (Im)**
- ***Rhipicephalus distinctus* (Im, Ad)**
- *Rhipicephalus evertsi evertsi* (Im)
- *Rhipicephalus glabroscutatum* (Im)
- *Rhipicephalus* sp. (Im)

Equus zebra zebra Cape mountain zebra
- *Amblyomma marmoreum* (Im)
- ***Hyalomma marginatum turanicum* (Ad)**
- ***Hyalomma truncatum* (Ad)**
- *Ixodes* sp. (Im)
- ***Margaropus winthemi* (Im, Ad)**
- *Rhipicephalus arnoldi* (Ad)
- *Rhipicephalus follis* (Ad)
- ***Rhipicephalus evertsi evertsi* (Im, Ad)**
- *Rhipicephalus glabroscutatum* (Im, Ad)

Connochaetes gnou Black wildebeest
- *Ixodes* sp. (Im)
- *Margaropus winthemi* (Im, Ad)
- *Rhipicephalus evertsi evertsi* (Im, Ad)
- *Rhipicephalus follis* (Ad)
- *Rhipicephalus glabroscutatum* (Im, Ad)
- *Rhipicephalus lounsburyi* (Ad)

Antidorcas marsupialis Springbuck
- *Hyalomma marginatum turanicum* (Ad)
- *Hyalomma truncatum* (Ad)
- *Ixodes* sp. (Im)
- *Margaropus winthemi* (Im)
- *Rhipicephalus evertsi evertsi* (Im)
- *Rhipicephalus follis* (Ad)
- *Rhipicephalus glabroscutatum* (Im, Ad)

Taurotragus oryx Eland
- *Amblyomma marmoreum* (Im)
- ***Hyalomma marginatum turanicum* (Ad)**
- ***Hyalomma truncatum* (Ad)**
- ***Ixodes rubicundus* (Ad)**
- *Ixodes* sp. (Ad)
- ***Margaropus winthemi* (Im, Ad)**
- ***Rhipicephalus evertsi evertsi* (Im, Ad)**
- ***Rhipicephalus follis* (Ad)**
- ***Rhipicephalus glabroscutatum* (Im, Ad)**
- *Rhipicephalus lounsburyi* (Ad)
- *Rhipicephalus* sp. (near *R. oculatus*) (Ad)

Redunca fulvorufula Mountain reedbuck
- *Amblyomma marmoreum* (Im)
- *Hyalomma truncatum* (Ad)
- *Ixodes rubicundus* (Im, Ad)
- *Margaropus winthemi* (Im)
- *Rhipicephalus evertsi evertsi* (Im, Ad)
- ***Rhipicephalus glabroscutatum* (Im, Ad)**
- *Rhipicephalus oculatus* (Im)
- ***Rhipicephalus lounsburyi* (Ad)**

are involved, they will permit these to engorge successfully. Several host species can act as preferred hosts of a single tick species.

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IXODID TICKS AND LICE INFESTING RED DUIKERS AND BUSHPIGS IN NORTH-EASTERN NATAL

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ABSTRACT

HORAK, I. G., BOOMKER, J. & FLAMAND, J. R. B., 1991. Ixodid ticks and lice infesting red duikers and bushpigs in north-eastern Natal. *Onderstepoort Journal of Veterinary Research*, 58, 281–284 (1991)

Eighteen red duikers, *Cephalophus natalensis*, from the Charters Creek Nature Reserve and 2 from Fanies Island Nature Reserve were processed for arthropod parasite recovery. They harboured 8 species of ixodid ticks and 2 lice species. All were infested with *Haemaphysalis parmata* and the nymphs of *Rhipicephalus muehlensi*.

Two bushpigs, *Potamochoerus porcus*, from the Ndumu Nature Reserve, 5 from the Eastern Shores Nature Reserve and 1 from Cape Vidal were examined for ectoparasites. They were infested with 8 ixodid tick species, of which *Rhipicephalus maculatus* was the most abundant, and with 1 louse species.

INTRODUCTION

Red duikers, *Cephalophus natalensis*, are small antelope that are limited to the thick scrub and evergreen forests of the eastern parts of Natal and a small area on the southern slopes of the Soutpansberg in the northern Transvaal (Smithers, 1983). They are considered rare and their status is precarious because of the rapid destruction of their natural habitat (Smithers, 1983). Very little is known about their ecology, but Pienaar (1963) and Heinichen (1972) state that they occur either singly or in temporary pairs, or a female may be accompanied by her offspring. These shy, secretive browsers are found near permanent surface water.

Bushpigs, *Potamochoerus porcus*, are chiefly nocturnal animals that occur in groups, or sounders, of up to 40 individuals. Sounders consist of a dominant board and sow, other sows, juveniles and piglets. They are usually associated with dense vegetation growth, such as forests, thickets, reed beds or heavy cover of tall grass. Like warthogs, bushpigs wallow in mud, probably as a means of temperature regulation and as protection against biting insects. They root in the same way as warthogs, generally making less use of hard ground. In areas where they are hunted, feeding will not commence before late at night but where they are afforded protection, they may be seen in the late afternoon and early morning. They consume a wide variety of plant matter, including fruits, *Acacia* pods and roots, and are known to be attracted to carrion (Smithers, 1983).

The ticks infesting red duikers and bushpigs have been listed by Theiler (1962) and Baker & Keep (1970) and the lice by Ledger (1980). Total tick collections have been made from 3 red duikers in the Charters Creek Nature Reserve (Horak, Keep, Flamand & Boomker, 1988). Two studies on the total numbers of arthropod parasites harboured by warthogs, *Phacochoerus aethiopicus*, have been conducted in southern Africa (Horak, Biggs, Hanssen & Hanssen, 1983; Horak, Boomker, De Vos & Potgieter, 1988), but no such work exists for bushpigs.

The present paper describes the total tick and lice burdens of red duikers and bushpigs examined in the north-eastern Natal nature reserves.

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MATERIALS AND METHODS

Survey localities

Charters Creek (28° 14′ S, 32° 25′ E, altitude 0–100 m) and Fanies Island (28° 07′ S, 32° 27′ E, altitude 0–100 m) are nature reserves situated on the western shores of Lake St Lucia. The Eastern Shores Nature Reserve (27° 51′–28° 25′ S, 32° 20′–32° 40′ E, altitude 0–30 m) occupies an area of approximately 250 km^2 at the southern end of the Mozambique coastal plain, between the Indian Ocean to the east and Lake St Lucia to the west. Cape Vidal (28° 08′ S, 32° 33′ E) is a camp situated on the sea shore in the Eastern Shores Nature Reserve, almost opposite Fanies Island.

All these localities form part of the greater St Lucia Nature Reserve, the vegetation of which is classified as the Zululand Palm Veld subdivision of Coastal Thornveld and Coastal communities (Acocks, 1988). The annual rainfall varies between 650 and 1 000 mm, most of which falls in summer. Summers are hot and humid and winters are mild. Frost seldom occurs.

Ndumu Game Reserve (26° 50′–26° 56′ S, 32° 09′–32° 21′ E, altitude 30–100 m) is situated in the extreme north of Natal and comprises an area approximately 11 000 ha in extent. It falls within the Lowveld subtype of Tropical Bush and Savannah (Acocks, 1988). The rainfall varies from 500 to 750 mm *per annum* and falls mostly in summer. Summers are hot and humid and winters are mild. Frost does not occur.

Survey animals

Eighteen red duikers were shot in the Charters Creek Nature Reserve and 2 in the Fanies Island Nature Reserve. Two bushpigs were shot in the Ndumu Nature Reserve, 5 in the Eastern Shores Nature Reserve and 1 at Cape Vidal.

Parasite recovery

The animals were all processed for ectoparasite recovery as described by Horak, Meltzer & De Vos (1982). All the material collected was examined under a stereoscopic microscope and the arthropods collected, identified and counted. The red duikers were also processed for the recovery of helminths and these have been recorded separately (Boomker, Horak & Flamand, 1991).

TABLE 1 Arthropod parasites recovered from 20 red duikers in 2 north-eastern Natal nature reserves

Arthropod species	Total number of arthropods recovered					Number of animals infested
Ixodid ticks	Larvae	Nymphs	Males	Females	Total	
Ambyomma marmoreum	38	8	0	0	46	11
Haemaphysalis leachi	2	0	0	0	2	1
Haemaphysalis parmata	1 388	608	476	116(10)	2 588	20
**Rhipicephalus* spp.	15 194	—	—	—	15 194	20
Rhipicephalus appendiculatus	—	2	2	0	4	2
Rhipicephalus maculatus	—	226	0	0	226	11
Rhipicephalus muehlensi	—	3 246	2	0	3 248	20
Rhipicephalus evertsi evertsi	42	22	0	0	64	2
Rhipicephalus sp. (near *R. oculatus*)	0	0	2	0	2	1
Lice		Nymphs		Adults	Total	
Damalinia sp.		894		398	1 292	9
Linognathus sp.		2 676		1 016	3 692	14

* Undifferentiated larvae of *R. appendiculatus, R. maculatus* and *R. muehlensi,* which are almost indistinguishable when partially engorged

( ) = Number of maturing female ticks that should detach within 24 h, i.e. idiosoma of *H. parmata* > 2,5 mm in length

TABLE 2 Arthropod parasites recovered from 8 bushpigs in 3 north-eastern Natal nature reserves

Arthropod species	Total number of arthropods recovered					Number of animals infested
Ixodid ticks	Larvae	Nymphs	Males	Females	Total	
Amblyomma hebraeum	2	2	6	2	12	3
Haemaphysalis parmata	6	2	0	0	8	1
Rhipicephalus appendiculatus	0	3	2	2	7	2
Rhipicephalus follis	0	0	2	12	14	1
Rhipicephalus maculatus	329	386	2 273	988(54)	3 976	8
Rhipicephalus muehlensi	0	43	0	2	45	3
Rhipicephalus simus	0	0	2	0	2	1
Rhipicephalus zumpti	0	0	81	58(8)	139	6
Lice		Nymphs		Adults	Total	
Haematopinus latus		186		114	300	4

( ) = Number of maturing female ticks that should detach within 24 h, i.e. idiosoma of *R. maculatus* and *R. zumpti* > 6,0 mm in length. The other female ticks had not yet reached this stage of maturation

RESULTS

Red duikers

The animals from the 2 reserves harboured the same parasite species in similar numbers and their burdens have been combined in Table 1.

The red duikers were infested with 8 ixodid tick species of which *Rhipicephalus* spp. larvae (*Rhipicephalus appendiculatus, Rhipicephalus maculatus* and *Rhipicephalus muehlensi*) were the most abundant and, together with all stages of development of *Haemaphysalis parmata* and the nymphs of *R. muehlensi* the most prevalent. No patterns of seasonal abundance could be established because the animals were not shot at regular intervals. Two lice species were also recovered.

Bushpigs

The parasite burdens of the bushpigs from the various localities have been combined and summarized in Table 2.

Eight species of ixodid ticks were recovered. Of these *R. maculatus* was the most abundant and prevalent. Four animals were infested with the louse *Haematopinus latus*.

DISCUSSION

The small size of red duikers and their habitat preference make them ideal hosts for the immature stages of many tick species. Their size also precludes them as hosts for adult ticks of many species as these appear to prefer larger animals (Horak, Potgieter, Walker, De Vos & Boomker, 1983). In contrast bushpigs, like warthogs, carry few immature ticks and are mainly infested by adults (Horak, Boomker, De Vos & Potgieter, 1988). This could be due to host preference or the thickness of their hides or their grooming habits or a combination of all 3 factors.

With the exception of *Amblyomma hebraeum, R. appendiculatus* and *Rhipicephalus simus*, the tick species recovered from the bushpigs differed from those recovered from warthogs in the eastern Transvaal Lowveld (Horak, Boomker, De Vos & Potgieter, 1988). This, however, is related to the geographic distributions of the ticks rather than host preference.

Amblyomma hebraeum: The immature stages of this tick have a particularly wide host range (Theiler, 1962; Horak, MacIvor, Petney & De Vos, 1987). Their virtual absence in the present survey and on common reedbuck, *Redunca arundinum,* examined in the same region (Horak, Keep, Flamand & Boomker, 1988) indicates that these reserves lie on the edge of this tick's distribution in this particular region.

Amblyomma marmoreum: The adults feed almost exclusively on tortoises, while the immature stages can be found on many host species (Theiler, 1962; Norval, 1975; Horak, MacIvor, Petney & De Vos, 1987). The small numbers on the red duikers are thus not unexpected.

Haemaphysalis parmata: The immature stages are not easily distinguishable from those of *Haemaphysalis silacea,* which also occurs in this region (Horak, Keep, Flamand & Boomker, 1988). Because we recovered the adults of only *H. parmata* in the present survey we have assigned the immature stages to this species as well.

Theiler (1962) states that *H. parmata* is a central and west African tick that ranges into the forested highlands of eastern Africa. She questions whether the only record for South Africa that she lists from Durban may not be due to a recent introduction. Horak, Keep, Flamand & Boomker (1988) surmised that it was more widespread than Theiler had thought and the present results confirm this. They felt that the bushbuck was a favoured host of this species, and red duikers must now also fall within this category.

Rhipicephalus appendiculatus: Very few ticks of this species were recovered from common reedbuck in the Eastern Shores Nature Reserves, but fairly large numbers were present on these animals in the Charters Creek Reserve (Horak, Keep, Flamand & Boomker, 1988). Their virtual absence on the red duikers and bushpigs in the present survey could be due either to host preference or to the very dense vegetation both species prefer as habitat.

Rhipicephalus follis: Although this tick is fairly widespread in the eastern half of the country (Horak, Keep, Spickett & Boomker, 1989; Horak, Fourie, Novellie & Williams, 1991), with the possible exception of eland, it is never encountered in large numbers (Horak *et al.*, 1991). Only 1 of the bushpigs was infested.

Rhipicephalus maculatus: Buffaloes appear to be the preferred hosts of all stages of development (Horak *et al.*, 1983). The immature stages may also be found on red duikers, nyala, *Tragelaphus angasi,* and bushpigs (Baker & Keep, 1970; Horak, Potgieter, Walker, De Vos & Boomker, 1983). Judging by the present findings, the latter animals are also excellent hosts of the adults.

Rhipicephalus muehlensi: Nyala are the preferred hosts of all stages of development (Horak, Potgieter, Walker, De Vos & Boomker, 1983). Red duikers, probably because they share the nyalas' habitat, may harbour large numbers of immatures. Even though bushpigs share the same habitat they harbour few specimens of this species.

Rhipicephalus simus prefers monogastric animals such as zebras, carnivores and warthogs (Horak, De Vos & De Klerk, 1984; Horak, Jacot Guillarmod, Moolman & De Vos, 1987; Horak, Boomker, De Vos & Potgieter, 1988). The small number recovered from only 1 of the bushpigs is probably more a reflection of the tick's geographic distribution than host preference.

Rhipicephalus zumpti: Baker & Keep (1970) have recorded this tick from black rhinoceros in Natal. According to them it is prevalent in Mozambique, but rare in Zululand. However, Clifford & Anastos (1962) have synonymized *R. zumpti* with *Rhipicephalus reichenowi*, which in turn has been synonymized with *Rhipicephalus planus* (Morel, 1980). Nevertheless it may yet prove to be a valid species. The presence of *R. zumpti* on 6 of the 8 bushpigs not only indicates that they are preferred hosts, but that the tick might not be rare in the north-eastern regions of Natal and Zululand.

No specific identifications of the lice on the red duikers were made. *Damalinia* species have not previously been recorded from this host (Ledger, 1980). The *Linognathus* species recovered seemed to belong to the *L. breviceps* group, but there is controversy concerning the identities of lice belonging to this group (Ledger, 1980). *Haematopinus latus,* recovered from the bushpigs, fairly closely resembles *Haematopinus phacochoeri* which parasitizes warthogs (Ledger, 1980).

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ARTHROPOD PARASITES OF SPRINGBOK, GEMSBOK, KUDUS, GIRAFFES AND BURCHELL'S AND HARTMANN'S ZEBRAS IN THE ETOSHA AND HARDAP NATURE RESERVES, NAMIBIA

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ABSTRACT

HORAK, I. G., ANTHONISSEN, M., KRECEK, R. C. & BOOMKER, J., 1992. Arthropod parasites of springbok, gemsbok, kudus, giraffes and Burchell's and Hartmann's zebras in the Etosha and Hardap Nature Reserves, Namibia. *Onderstepoort Journal of Veterinary Research*, 59, 253–257 (1992)

A total of 48 springbok, 48 gemsbok, 23 kudus and 6 giraffes were examined for ticks and lice, while 9 Burchell's zebras and 6 Hartmann's mountain zebras were examined only for ticks. Springbok and gemsbok were shot in both the Etosha National Park in the north and the Hardap Nature Reserve in the south of Namibia. All the other animals were shot in the Etosha National Park.

A total of 7 ixodid tick species and 8 lice species were recovered. The springbok carried few ticks. The adults of a *Rhipicephalus* sp. (near *R. oculatus*) were most numerous on the gemsbok, especially during November. The kudus were the only animals harbouring *Rhipicephalus zambeziensis*. Adult *Hyalomma truncatum*, followed by adult *Hyalomma marginatum rufipes*, were most abundant on the giraffes and adult *Rhipicephalus evertsi mimeticus* were commonest on the zebras.

INTRODUCTION

The ixodid ticks found in Namibia have been listed by Theiler (1962). Her records were compiled after the identification of ticks that had generally been collected by stock inspectors, veterinarians, zoologists and other interested parties. These did not represent total collections of ticks from the animals examined.

In recent times more thorough collections of ticks have been made by examining animals of a particular species at regular intervals for periods of at least 1 year. Warthogs (*Phacochoerus aethiopicus*), Hartmann's mountain zebras (*Equus zebra hartmannae*) and cattle have been examined in Namibia in this way and 9 ixodid tick species recovered (Horak, Biggs, Hanssen & Hanssen, 1983; Horak, Biggs & Reinecke, 1984; Biggs & Langenhoven, 1984). In a recent review of ticks occurring in southern Africa, Walker (1991) lists 30 species from Namibia.

A number of animals of various species were to be shot in the Etosha National Park and the Hardap Nature Reserve, Namibia, for reproductive and biological studies, while others were to be killed for helminth recovery. This presented the opportunity to obtain ticks also from these animals and collections were made from springbok (*Antidorcas marsupialis*), gemsbok (*Oryx gazella*), kudus (*Tragelaphus strepsiceros*), giraffes (*Giraffa camelopardalis angolensis*), Burchell's zebras (*Equus burchelli antiqorum*) and Hartmann's mountain zebras. This paper records the ixodid tick burdens of these animals, and the lice burdens of the springbok, gemsbok and kudus. The helminths from the zebras, kudus and giraffes have been reported elsewhere (Krecek, Reinecke & Malan, 1987; Boomker, Anthonissen & Horak, 1988; Krecek, Boomker, Penzhorn & Scheepers, 1990).

MATERIALS AND METHODS

Study sites

The localities at which the animals were shot are summarized in Table 1.

Survey animals

Springbok and gemsbok were shot in the Hardap Nature Reserve at approximately 2-monthly intervals from May 1983 to June 1984. Springbok were also shot near Okaukuejo and gemsbok from near Otjovasandu in the Etosha National Park from June 1983 until April 1984 and February 1984 respectively. In addition 4 gemsbok were shot near Okaukuejo towards the end of April and beginning of May 1984. Kudus were shot at 2-monthly intervals near Namutoni, Etosha National Park, from June 1983 until April 1984. Nine Burchell's zebras and 6 Hartmann's mountain zebras were shot near Okaukuejo and Otjovasandu respectively in the Etosha National Park.

Two giraffes were shot near Okaukuejo in November 1985, 2 in March 1986 and 2 in July 1986. These months fall within the 3 seasons described for Etosha by Berry (1980); these are hot and wet (January to April); cold and dry (May to August), and hot and dry (September to December).

Parasite recovery

The springbok, gemsbok, kudus and giraffes were processed for ectoparasite recovery as described by Horak, Boomker, Spickett & De Vos (1992). Ticks were recovered from the zebras by making whole body searches; this meant that few immature ticks and no lice were collected. The ectoparasites from all the animals were identified and counted under a stereoscopic microscope.

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TABLE 1 Localities at which various herbivores were shot in Namibia for the recovery of arthropod parasites

Locality	Co-ordinates	Vegetation type (Van der Merwe, 1983)
Otjovasandu, Etosha National Park	19° 15′ S, 14° 30′ E	Mopane savanna
Okaukuejo, Etosha National Park	19° 11′ S, 15° 55′ E	Mopane savanna
Namutoni, Etosha National Park	18° 49′ S, 16° 56′ E	Saline desert with dwarf shrub savanna fringe surrounded by Mopane savanna and Forest savanna and woodland
Hardap Nature Reserve	24° 30′ S, 17° 45′ E	Dwarf shrub savanna

TABLE 2 Ixodid ticks recovered from various wild herbivores in Namibia

Tick and host species	Locality	No. examined	No. infested	No. of ticks recovered				
				Larvae	Nymphs	Males	Females	Total
Hyalomma marginatum rufipes								
Gemsbok	Otjovasandu	18	1	0	0	1	0	1
	Okaukuejo	4	2	0	0	9	1	10
	Hardap	26	1	0	0	4	0	4
Giraffe	Okaukuejo	6	6	0	0	372	75	447
Burchell's zebra	Okaukuejo	9	3	0	0	8	1	9
Hartmann's mountain zebra	Otjovasandu	6	3	0	0	10	5	15
Hyalomma truncatum								
Gemsbok	Otjovasandu	18	5	0	0	6	1	7
	Okaukuejo	4	2	0	0	12	8	20
	Hardap	26	1	0	0	2	0	2
Giraffe	Okaukuejo	6	6	0	0	1550	584	2134
Burchell's zebra	Okaukuejo	9	1	0	0	2	0	2
Hartmann's mountain zebra	Otjovasandu	6	5	0	0	27	1	28
Rhipicephalus evertsi mimeticus								
Springbok	Okaukuejo	21	1	1	0	0	0	1
	Hardap	27	1	6	0	0	0	6
Gemsbok	Otjovasandu	18	2	0	3	2	0	5
Kudu	Namutoni	23	18	4835	1057	23	23	5938
Giraffe	Okaukuejo	6	5	0	0	14	5	19
Burchell's zebra	Okaukuejo	9	6	5	4	34	9	52
Hartmann's mountain zebra	Otjovasandu	6	5	13	9	46	13	81
Rhipicephalus longiceps								
Giraffe	Okaukuejo	6	1	0	0	1	0	1
Rhipicephalus turanicus								
Burchell's zebra	Okaukuejo	9	1	0	0	0	1	1
***Rhipicephalus sp.* (near *R. oculatus*)**								
Springbok	Hardap	27	4	0	0	3	1	4
Gemsbok	Otjovasandu	18	1	0	0	1	0	1
	Hardap	26	17	0	0	220	130	350
Kudu	Namutoni	23	6	0	0	10	4	14
Rhipicephalus zambeziensis								
Kudu	Namutoni	23	7	2	0	10	8	20

RESULTS AND DISCUSSION

Ixodid ticks

The tick species recovered, the hosts from which they were collected and the localities at which the hosts were examined are summarized in Table 2.

A total of 7 ixodid tick species were recovered. With the exception of the *Rhipicephalus* sp. (near *R. oculatus*), the Etosha National Park seemed to be a more favourable habitat for all species than the Hardap Nature Reserve. As noted in previous surveys, springbok had very low tick burdens (Horak, Meltzer & De Vos, 1982; De Villiers, Liversidge & Reinecke, 1985; Horak, Fourie, Novellie & Williams, 1991). Whether this was due to natural immunity, or host preference, or habitat preference, or behaviour of the antelope could not be determined in either this or the other surveys.

Hyalomma spp.

Both *Hyalomma marginatum rufipes* and *Hyalomma truncatum* prefer the drier western regions of southern Africa (Theiler, 1962; Howell, Walker & Nevill, 1978; Walker, 1991). Judging by the present results the Okaukuejo region of the Etosha National Park is a better habitat for *H. truncatum* than for *H. marginatum rufipes*. The preferred hosts of the adults are large animals such as cattle (Horak, 1982; Biggs & Langenhoven, 1984), horses (Horak, Biggs & Reinecke, 1984; Horak, Knight & De Vos, 1986), zebras and eland (Rechav, Zeederberg & Zeller, 1987; Horak *et al.*, 1991). The present results indicate that giraffes probably rank above all the other animals mentioned above as the host of choice. Each of the 6 giraffes examined harboured more than 200 adult *Hyalomma* and 1 of them more than 850 ticks.

Kudus are definitely not good hosts of adult *H. truncatum* (Horak *et al.,* 1992), while gemsbok should only be considered fair hosts of both species (Fourie, Vrahimis, Horak, Terblanche & Kok, 1991). Warthogs examined in the northern bushveld region of Namibia harboured more *H. truncatum* than *H. marginatum rufipes* (Horak *et al.,* 1983), while the converse was true for mountain zebras and horses examined in the central region west of Windhoek, and cattle examined east of Windhoek (Horak *et al.,* 1984; Biggs & Langenhoven, 1984). The preferred hosts of the immature stages of both species are scrub hares (Rechav *et al.,* 1987; Horak *et al.,* 1991; Horak & Fourie, 1991).

As only 2 giraffes were examined on each occasion, and then at 4-monthly intervals, it is virtually impossible to determine a pattern of seasonal abundance for these ticks. The total counts of *H. marginatum rufipes* were 206, 189 and 52, and those of *H. truncatum* 497, 602 and 1035, for both animals examined during November 1985 and March and July 1986 respectively.

Both these ticks have long mouthparts and these can cause considerable tissue damage, which may lead to secondary bacterial infection (Howell *et al.*, 1978). *H. marginatum rufipes* is a vector of *Anaplasma marginale*, the cause of gallsickness in cattle (Potgieter, 1981), and *H. truncatum* transmits a toxin causing sweating sickness in the latter animals (Howell *et al.*, 1978).

Rhipicephalus evertsi mimeticus

We are unable to differentiate the immature stages of this tick from those of *Rhipicephalus evertsi evertsi*. However, as the adults of only *R. evertsi mimeticus* were recovered we have assigned all the immatures to this subspecies. This tick prefers the arid regions of Namibia and western Botswana (Howell *et al.*, 1978).

In the case of *R. evertsi evertsi* equids are among the preferred hosts of all stages of development (Norval, 1981; Horak *et al.*, 1986). *R. evertsi mimeticus* appears also to favour these hosts (Horak *et al.*, 1984). The collection methods employed on the zebras in the present survey virtually precluded the recovery of immature ticks, which are found in the outer ear canals, and the numbers of adult ticks recovered were also small. Nevertheless their mean burdens of adult ticks were slightly higher than those of the other host species. The vast majority of the immature ticks recorded from the kudus at Namutoni were found on a single animal, which carried 4 172 larvae and 952 nymphs. Kudus are considered to be poor hosts of the closely related *R. evertsi evertsi* (Horak *et al.*, 1992).

No pattern of seasonal abundance was evident.

Rhipicephalus longiceps

Walker (1991) cites this as a rare tick found only in Namibia and Angola. It has been recovered from cattle, klipspringer and gemsbok (Walker, 1991), also from 3 of 37 warthogs examined in the northern bushveld of Namibia (Horak *et al.*, 1983). Its recovery from one of the giraffes appears to constitute a new host record.

Rhipicephalus turanicus

This tick has previously been recovered in the Etosha National Park and from Grootfontein in northern Namibia (Walker, 1991). Its adults have a very wide host range, and amongst the wild animals ostriches and zebras appear to carry the largest numbers (Pegram, Clifford, Walker & Keirans, 1987).

Rhipicephalus sp. (near *R. oculatus*)

The problems surrounding the species diagnosis of this tick and *Rhipicephalus oculatus sensu stricto* have been discussed by Walker (1991). She also records it as being widely distributed in Namibia, especially south of Windhoek, an observation confirmed by the present findings.

Walker (1991) lists the wild hosts as being mostly antelopes, particularly gemsbok and kudus. It has also been recorded (as *R. oculatus*) from 7 of 37 warthogs examined in the northern bushveld region of Namibia (Horak *et al.*, 1983). In the present survey gemsbok were more heavily infested than kudus, possibly owing to the more southerly locality at which they were examined. In a recent survey in South Africa, kudus just north of Grahamstown, in the eastern Cape Province, were more heavily infested than sheep, goats, cattle and scrub hares from the same locality (Horak & Knight, 1986).

No clear pattern of seasonal abundance could be seen on the eastern Cape kudus, but no ticks of this species were present on the animals examined during May and June (Horak *et al.,* 1992). The scrub hares from that particular locality, however, generally carried larger numbers of adult ticks during August and from November to April (Horak & Fourie, 1991). In the present survey the gemsbok in the Hardap Nature Reserve harboured the greatest numbers of ticks during November and February (Fig. 1). The largest numbers of ticks (a total of only 6 on 4 animals) were recorded on the kudus in the Etosha National Park during June and during August.

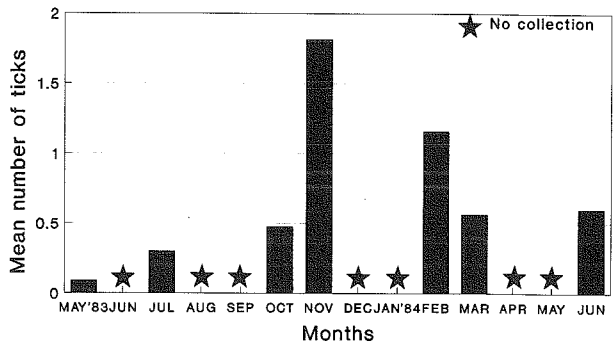

FIG. 1 The seasonal abundance of a *Rhipicephalus* sp. (near *R. oculatus*) on gemsbok in the Hardap Nature Reserve, Namibia [$\log_{10}$ (x + 1)]

Rhipicephalus zambeziensis

This tick has been recorded in northern Namibia in the Kunene (Kaokoland) and the Otjozondjupa (Grootfontein) districts (Norval, Walker & Colborne, 1982). Namutoni, in the Etosha National Park, lies

between these 2 regions. *R. zambeziensis* infests a large variety of hosts, including carnivores, suids and bovids (Walker, 1991). Within its distribution range kudus appear to be amongst the preferred hosts of all stages of development (Horak *et al.*, 1992).

R. zambeziensis can transmit *Theileria parva parva* and *Theileria parva bovis,* the cause of East Coast fever and January disease respectively in cattle (Lawrence, Norval & Uilenberg, 1983). It also transmits *Theileria parva lawrencei* to buffaloes and cattle. In the former animals *T. parva lawrencei* is not pathogenic, but it produces the usually fatal Corridor disease in cattle.

Lice

The springbok harboured the greatest number of lice species, but the total burdens of individual animals were low (Table 3). No pattern of seasonal abundance was evident. De Villiers *et al.,* (1985) examined springbok near Kimberly in the Cape Province, South Africa, for parasites at fairly regular intervals for a period of 14 months. They recovered 6 lice species from these animals and the 4 major species all exhibited peak burdens during September.

TABLE 3 Lice recovered from springbok, gemsbok and kudus in Namibia

Host and lice species	Number of hosts examined	Number infested	Number of lice recovered		
			Nymphs	Adults	Total
Springbok					
Damalinia antidorcus	48	8	3	16	19
Linognathus antidorcitis	48	23	45	43	88
Linognathus armatus	48	1	0	11	11
Linognathus bedfordi	48	1	3	2	5
Linognathus euchore	48	15	35	40	75
Gemsbok					
Haematopinus oryx	48	3	38	5	43
Linognathus oryx	48	28	3567	737	4304
Kudu					
Linognathus taurotragus	23	17	582	311	893

Two lice species were recovered from the gemsbok, of which *Linognathus oryx* was the most abundant. The seasonal abundance of the latter species on the gemsbok is illustrated in Fig. 2.

Lice numbers started to increase sooner on the animals in the Hardap Reserve than on those in the Etosha Park. Peak numbers were recorded during November and December respectively (summer).

In contrast peak burdens of the louse *Linognathus taurotragus* were recorded in June (winter) on the kudus examined at Namutoni in the Etosha National Park (Fig. 3). No lice were recovered from the giraffes.

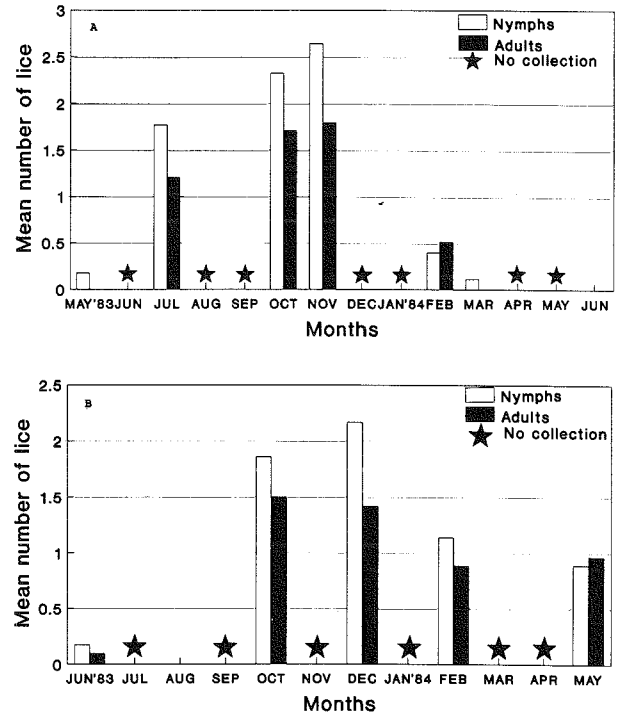

FIG. 2 The seasonal abundance of *Linognathus oryx* on gemsbok in Namibia [$\log_{10}$ (x + 1)]
A. in the Hardap Nature Reserve
B. in the Etosha National Park

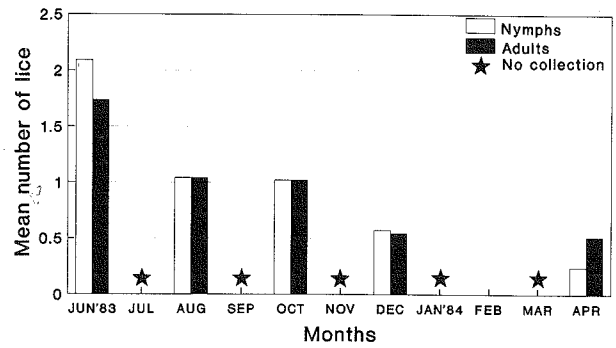

FIG. 3 The seasonal abundance of *Linognathus taurotragus* on kudus in the Etosha National Park, Namibia [$\log_{10}$ (x + 1)]

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with the identification of *R. longiceps.* Miss Andrea van Niekerk drew the graphs.

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A ten-year study of ixodid tick infestations of bontebok and grey rhebok in the Western Cape Province, South Africa

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Two to four bontebok *Damaliscus pygargus dorcas* and three to four grey rhebok *Pelea capreolus*, in the Bontebok National Park, Western Cape Province, South Africa, were examined for ticks during February of each year from 1983 to 1992. A total of 34 bontebok and 37 grey rhebok were examined. The bontebok harboured eight ixodid tick species of which *Rhipicephalus glabroscutatum* and *Rhipicephalus nitens* were the most abundant. The grey rhebok harboured six species of which the former two ticks and *Ixodes pilosus* were the most numerous. With the exception of 1986 and 1989, when *R. glabroscutatum* was most abundant on the bontebok and grey rhebok respectively, and 1985 when *I. pilosus* was most plentiful on the grey rhebok, *R. nitens* was the most abundant tick species on both host species. Despite *Boophilus microplus* being present on animals outside the Park, as well as the translocation of Cape mountain zebras *Equus zebra zebra* and red hartebeest *Alcelaphus buselaphus* to the Park, no foreign tick species became established on the two hosts during the 10 years of observation. Nor did any of the tick species present only in low numbers become more plentiful.

Keywords: bontebok, grey rhebok, ixodid ticks, 10-year study

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Introduction

The adverse effects, including mortality, of ticks on wild artiodactylids, are well documented (Lightfoot & Norval 1981; Melton 1987; Fourie & Vrahimis 1989). The nature and extent of host injury are dependent on the tick species and burdens (Lightfoot & Norval 1981; Fourie & Kok 1992). In order to anticipate such tick-related problems it is important to determine the status of wild animals as hosts for the various tick species which infest them. Several abiotic and biotic factors may affect tick burdens (Randolph 1994) and may also influence the various tick species differently (Theiler 1970). This implies that species which are dominant during a particular year may occur in lower numbers during subsequent years and *vice versa*. In addition translocation of animals or physical alteration of the environment may result in ticks and the diseases they transmit becoming established in regions in which they did not occur historically (Barré, Uilenberg, Morel & Camus 1987; Spickett & Heyne 1988). Such dynamic changes can only be established by long-term studies.

During 1983–84 a survey was conducted to quantify the arthropod parasites, particularly ticks, of bontebok *Damaliscus pygargus dorcas*, grey rhebok *Pelea capreolus* and scrub hares *Lepus saxatilis* in the Bontebok National Park (Horak, Sheppey, Knight & Beuthin 1986b). Nine ixodid tick species were collected from both bontebok and grey rhebok, whilst the scrub hares harboured 11 species. The ticks *Rhipicephalus glabroscutatum* and *Rhipicephalus nitens* were considered to be the definitive parasites of bontebok, *R. nitens* and *Ixodes pilosus* those of grey rhebok and *R. nitens* of scrub hares (Horak *et al.* 1986b). Two *Boophilus* nymphs were collected from the grey rhebok and five from scrub hares. A grey rhebok examined immediately outside the borders of the Park, however, harboured small numbers of *Boophilus microplus* and of *B. decoloratus*. This implied a potential for these ticks to become established in greater numbers within the Park.

During the present study ticks infesting bontebok and grey rhebok in the Bontebok National Park were collected over a period of 10 years. The objectives were to ascertain whether any foreign tick species became established in the Park and also to determine possible changes in the relative abundance of the ticks parasitizing the two host species.

Methods

Study site

The Bontebok National Park (34°02'S;20°25'E; alt. 90–200 m) encompasses 2803 ha and is situated in the southern Western Cape Province, South Africa. The vegetation, which forms part of the Cape macchia, is described as Coastal Renosterbosveld (Acocks 1988) and the Park topography consists of a series of gravel terraces gradually rising to the north-eastern corner. Sand flats, surrounded by low hills occur in the south-west (Theron 1967). Wildlife census results for the Park during the year preceding and for the 10 years of the survey are summarized in Table 1. During this period the bontebok and grey rhebok numbers were stabilized

Table 1 Wildlife counts in the Bontebok National Park, 1982–1992

		Numbers of animals counted		
Year	Month	Bontebok	Grey rhebok	Other species
1982	March	352	160	Springbok 16
1983	February	279	181	
1984	February	305	175	Grysbok 17; Steenbok 12
	September	232	148	
1985	January	274	180	Grysbok 15; Steenbok 18
	September	239	173	
1986	February	285	207	Grysbok 24; Steenbok 14
	September	268	211	
1987	June	208	153	
	September	215	122	
1988	January	253	112	
	June	178	185	Red hartebeest 5; Mountain zebra 2
	October	192	197	
1989	August	205	128	Red hartebeest 7; Mountain zebra 2
1990	January	256	142	
	August	198	64	Red hartebeest 8; Mountain zebra 5
1991	February	206	106	
	April	203	156	
	May	231	147	
	September	233	102	Red hartebeest 10; Mountain zebra 8
1992	February	252	95	Red hartebeest 13; Mountain zebra 11

or reduced by culling and by translocation. Cape mountain zebras *Equus zebra zebra* and red hartebeest *Alcelaphus buselaphus* were introduced during 1988 and their numbers increased naturally and by further translocations. Although steenbok *Raphicerus campestris* and Cape grysbok *Raphicerus melanotis* were not counted during 1983 or subsequent to 1986 it can be assumed that the numbers of these small antelopes remained fairly constant. Rainfall was recorded daily in the Park.

Survey animals

During February of each year from 1983 to 1992 two to four bontebok and three to four grey rhebok were shot for survey purposes. The animals examined during February of 1983 and of 1984 in the previously mentioned survey (Horak *et al.* 1986b) have been included in this survey for those years.

Parasite recovery and counting

The skins of the animals were processed for arthropod parasite recovery as described by Horak, Boomker, Spickett & De Vos (1992) and the parasites identified and counted under a stereoscopic microscope.

The lungs, livers and gastro-intestinal tracts of the antelopes were processed for the recovery of helminths. These findings will be reported separately, as will those of the arthropods other than ticks recovered from the animals.

Results

A total of 34 bontebok and 37 grey rhebok were examined. The ticks infesting the two hosts are summarized in Tables 2 & 3. Eight species were collected from bontebok of which *Boophilus* sp., *Haemaphysalis aciculifer*, *R. evertsi evertsi* and *Hyalomma truncatum* were present only occasionally and in very low numbers (Table 2). Six species were collected from grey rhebok, with *H. aciculifer* and *R. evertsi evertsi* present in low numbers and only infrequently (Table 3).

The relative abundances of the major tick species infesting the two hosts are graphically presented in Figures 1 & 2. Large variations in relative abundance were recorded during the 10 year study period. The relative abundance of *R. glabroscutatum* on the bontebok increased steadily from 1984, reached a peak (58%) during 1986 and declined to its lowest level (0.5%) during 1991 (Figure 1). *R. nitens* was the most abundant tick during nine of the 10 years (Figure 1). On grey rhebok, *I. pilosus* displayed the highest relative abundance during 1985 and *R. glabroscutatum* during 1989. During the other years *R. nitens* was the dominant species (Figure 2).

Discussion

The diversity of tick species which occurred on the two hosts during the 10 years of observation stayed the same. None of the ticks which were previously collected in low numbers by Horak *et al.* (1986b) became more abundant.

One of the ways in which ticks are introduced into new areas is by host translocation (Braack, Maggs, Zeller & Horak 1995). Either the ticks that were present on the Cape mountain zebras and red hartebeest when they were introduced into the Bontebok National Park during 1988 did not survive in the new habitat, or their numbers are still too low to be detected on other hosts. The zebras and hartebeest could potentially serve as hosts for *Boophilus* spp., *Hyalomma truncatum* and *R. evertsi evertsi.* Mountain zebras are particularly good hosts of the latter two ticks and of *Margaropus winthemi*, the dominant species in the mountainous regions from which these animals came (Horak, Knight & De Vos 1986a).

The relative abundance of the various tick species on the hosts displayed long-term fluctuations. These fluctuations were chiefly caused by considerable variations in the numbers of the immature stages of *R. glabroscutatum*, a two-host tick, and the larvae of *I. pilosus* and of *R. nitens*, both three-host species. The fluctuations could be associated with climatic factors which affect the various tick species differently, or which affect the vegetation, causing the animals to feed in different localities to those normally utilized at a particular time of the year. Analysis of individual tick species indicated that all stages of development of *R. glabroscutatum* appeared to decrease on the bontebok from February 1985 to February 1991 and the adults of *R. nitens* from 1984 until 1990. The adults of the latter tick also decreased, albeit erratically, on the grey rhebok from 1984 and 1985 to 1991. In the case of *R. nitens*, where the adult ticks attach to the ears and lower jaws, and of *I. pilosus*, of which the adult ticks attach to the head and body, intraspecific or interspecific competition (Andrews & Petney 1981; Petney & Al-Yaman 1985) for the site of attachment may also influence population size. The implication is

Table 2 Ixodid ticks collected from bontebok in the Bontebok National Park during February of each year from 1983–1992

Year	*Amblyomma marmoreum*				*Boophilus sp.*				*Haemaphysalis aciculifer*				*Hyalomma truncatum*				*Ixodes pilosus*				*Rhipicephalus e. evertsi*				*Rhipicephalus glabroscutatum*				*Rhipicephalus nitens*			
	L	N	♂	♀	L	N	♂	♀	L	N	♂	♀	L	N	♂	♀	L	N	♂	♀	L	N	♂	♀	L	N	♂	♀	L	N	♂	♀
1983																																
x	4.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9.0	0	0	1.0	0	0	0	0	22.0	4.0	2.0	0	666.0	5.0	3.0	3.5
SD	2.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12.7	0	0	1.4	0	0	0	0	22.6	2.8	2.8	0	169.7	4.2	1.4	4.9
1984																																
x	1.0	0	0	0	0	0	0	0	0	0	0	1.0	0	0	0	0	12	1.5	0	0	0	0	0	0	60.0	9.5	0	0	140.0	1.0	27.5	42.0
SD	1.4	0	0	0	0	0	0	0	0	0	0	1.4	0	0	0	0	2.8	2.1	0	0	0	0	0	0	70.7	7.8	0	0	65.1	1.4	24.7	48.1
1985																																
x	2.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.3	0.7	0	0.7	0	8.7	0	0	357.0	32.7	2.7	1.3	564.0	14.0	20.7	27.0
SD	4.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.2	1.2	0	1.2	0	9.0	0	0	349.9	22.5	2.5	1.5	387.0	15.1	15.6	26.6
1986																																
x	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.0	1.5	0	0.5	0	0	0	0	242.5	10.0	0.5	1.0	148.0	2.5	14.0	17.5
SD	1.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.3	1.9	0	1.0	0	0	0	0	446.7	14.9	1.0	1.2	96.7	3.0	10.1	10.0
1987																																
x	8.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7	0.7	0	0	0	0	0	0	19.3	38.7	0	0.7	42.0	2.0	11.3	12.3
SD	15.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.2	1.2	0	0	0	0	0	0	15.0	60.2	0	1.2	10.6	2.0	8.4	9.7
1988																																
x	3.5	0	0	0	0	0	0	0	1.0	0	0	0	0	0	0	0	0.5	0.5	0.5	0	2.0	0	0	0	4.0	5.5	0.5	0.5	92.0	1.0	7.5	7.0
SD	5.7	0	0	0	0	0	0	0	2.0	0	0	0	0	0	0	0	1.0	1.0	1.0	0	2.8	0	0	0	6.7	11.0	1.0	1.0	118.1	2.0	3.4	3.8
1989																																
x	1.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7.8	6.8	0	1.3	101.0	0.5	7.8	6.8
SD	1.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9.7	9.9	0	1.5	97.1	0.6	5.7	5.6
1990																																
x	0	0	0	0	1.0	0	0	0	0	0	0	0	0	0	0	0	3.0	0.5	0	0	0	0	0	0	6.0	0	0	0	272.5	1.0	7.0	1.0
SD	0	0	0	0	2.0	0	0	0	0	0	0	0	0	0	0	0	6.0	1.0	0	0	0	0	0	0	1.6	0	0	0	81.4	1.2	6.2	1.2
1991																																
x	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.0	0	0	0	191.5	1.5	7.3	7.0
SD	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.2	0	0	0	177.1	1.9	8.4	5.3
1992																																
x	1.0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	4.0	1.0	0	0	0	0.5	0	0	17.5	7.0	1.0	2.5	615.0	9.0	19.0	19.3
SD	2.0	0	0	0	0	0	0	0	0	0	0	0	1.0	0	0	0	4.9	1.2	0	0	0	1.0	0	0	21.7	8.7	2.0	3.0	658.4	7.6	14.3	10.3

Table 3 Ixodid ticks collected from grey rhebok in the Bontebok National Park during February of each year from 1983–1992

Year	*Amblyomma marmoreum*				*Haemaphysalis aciculifer*				*Ixodes pilosus*				*Rhipicephalus evertsi evertsi*				*Rhipicephalus glabroscutatum*				*Rhipicephalus nitens*			
	L	N	♂	♀	L	N	♂	♀	L	N	♂	♀	L	N	♂	♀	L	N	♂	♀	L	N	♂	♀
1983																								
x	9.0	0	0	0	0	0	0	0.3	36.5	4.0	1.0	3.5	0	0	0	0	1.0	0	1.0	0	155.5	4.5	15.8	21.8
SD	13.2	0	0	0	0	0	0	0.5	15.1	4.3	0.8	4.1	0	0	0	0	2.0	0	1.2	0	163.5	4.1	20.8	22.5
1984																								
x	1.0	0	0	0	0	0	0	0	2.0	3.0	0.3	4.8	0	0	0.5	0	4.5	0	0.5	0.5	32.0	0	20.3	26.8
SD	2.0	0	0	0	0	0	0	0	2.8	4.8	0.5	3.6	0	0	1.0	0	5.7	0	1.0	1.0	38.1	0	16.8	22.2
1985																								
x	6.7	0	0	0	0	0	0	0	148.0	12.7	1.7	5.7	0	0	0	0	4.0	14.0	0.7	0.7	52.0	0.7	4.3	10.0
SD	3.1	0	0	0	0	0	0	0	126.6	12.1	0.6	2.5	0	0	0	0	2.0	22.5	1.2	1.2	84.9	1.2	2.9	4.6
1986																								
x	2.7	0	0	0	0	0	0	0	2.7	0.7	0	0.7	0	0	0	0	0	0	0	0	0.7	0	2.0	1.3
SD	4.6	0	0	0	0	0	0	0	4.6	1.2	0	1.2	0	0	0	0	0	0	0	0	1.2	0	2.0	1.2
1987																								
x	2.7	0	0	0	0	0	0	0	7.3	2.0	0	1.7	2.0	0.7	0	0.3	2.0	0	4.0	1.3	157.3	0	12.7	16.7
SD	3.1	0	0	0	0	0	0	0	12.7	2.0	0	1.5	3.5	1.2	0	0.5	3.5	0	3.5	1.6	231.6	0	10.0	17.7
1988																								
x	0	0	0	0	0	0	0	0	0.5	0	0.3	0	0	0	0	0	5.0	0.5	0.5	0.5	31.0	0	5.3	12.8
SD	0	0	0	0	0	0	0	0	1.0	0	0.5	0	0	0	0	0	7.6	1.0	1.0	1.0	12.5	0	4.3	11.2
1989																								
x	1.0	0	0	0	0	0	0	0	1.0	0.5	0	0.3	0.3	0	0	0	60.5	3.0	1.0	0.3	31.5	0.3	2.5	0.5
SD	2.0	0	0	0	0	0	0	0	1.4	1.0	0	0.5	0.5	0	0	0	77.1	4.1	1.4	0.5	42.4	0.5	1.7	0.6
1990																								
x	0	0	0	0	0	0	0	.0	7.5	2.5	0.5	3.5	0	0	0	0	3.0	2.5	0	0	37.0	0	1.5	0.5
SD	0	0	0	0	0	0	0	0	9.0	3.0	1.0	3.4	0	0	0	0	6.0	3.8	0	0	42.4	0	3.0	1.0
1991																								
x	0	0	0	0	0	0	0	0.5	6.0	0.5	1.0	0.5	0	0	0	0	0	1.5	0	0	24.5	0	0	0.5
SD	0	0	0	0	0	0	0	1.0	4.9	1.0	2.0	1.0	0	0	0	0	0	3.0	0	0	39.7	0	0	1.0
1992																								
x	4.0	0	0	0	0	0	0	0	50.0	0.5	0.3	2.3	1.0	5.5	0	0	128.0	2.0	0	1.0	353.0	2.0	3.0	5.3
SD	8.0	0	0	0	0	0	0	0	80.1	1.0	0.5	1.5	2.0	11.0	0	0	244.0	4.0	0	2.0	446.6	4.0	2.4	8.5

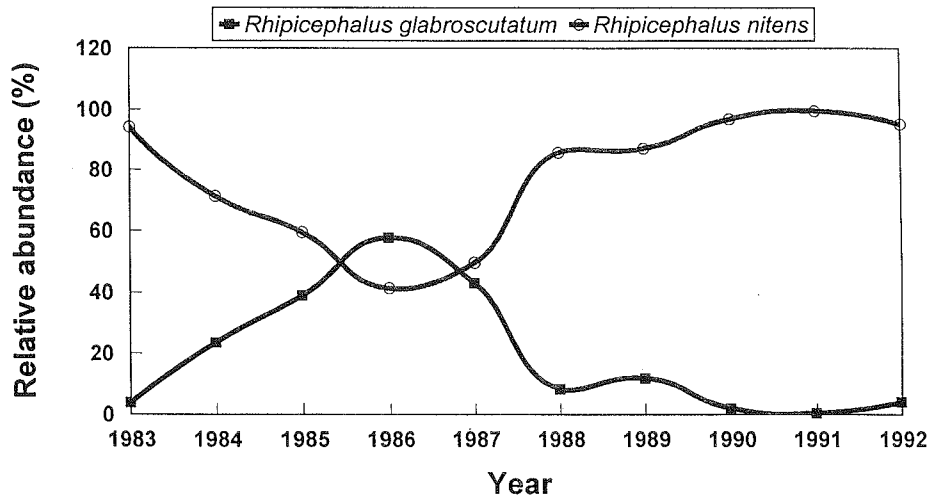

Figure 1 The relative abundance of the major tick species which infested bontebok in the Bontebok National Park as determined during February of 1983–1992.

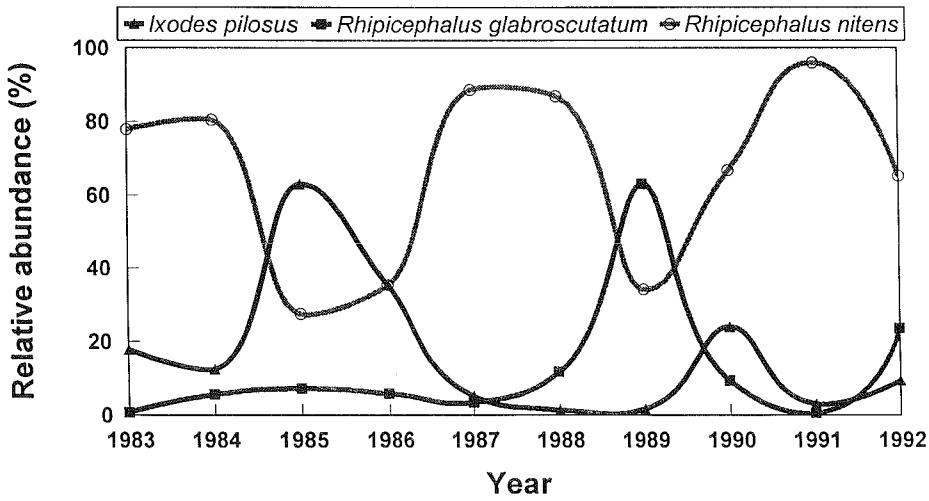

Figure 2 The relative abundance of the major tick species which infested grey rhebok in the Bontebok National Park as determined during February of 1983–1992.

that ticks attaching to non-preferential feeding sites may be removed more easily by the grooming actions of the host.

In terms of general tick ecology and host-tick interactions the results obtained during this long-term study are important for a number of reasons. Firstly, they illustrate the dynamic nature of tick populations on hosts in which a tick species, which is most abundant during a particular year, may not necessarily be so during subsequent years. This demonstrates the danger of determining relative species abundance for a region from a once-off collection, even though the latter may involve the examination of a number of endemic host species. This applies even more so in a stock-farming situation where several tick species may be more severely affected than others by acaricidal intervention.

Secondly, in terms of the epidemiology of tick-transmitted diseases, the population size of certain disease-inducing tick species may increase gradually until critical levels are reached, and hosts are affected. Karoo paralysis, caused by *Ixodes rubicundus*, is a pertinent example where a specific infestation level is required before paralysis is induced (Fourie & Horak 1987; Fourie & Vrahimis 1989). *R. nitens* may also cause a tick toxicosis similar to that recorded in cattle for *Rhipicephalus appendiculatus* by Thomas & Neitz (1958). Springbok *Antidorcas marsupialis* in the southern Western Cape Province, infested with large numbers of *R. nitens* during February, have been severely affected and have died (Horak, unpublished data). Whether this is also the case for bontebok and grey rhebok in the study area is unknown.

Furthermore, if drastic increases in total tick burdens were noted during a long-term study these could indicate management problems. This is particularly true in small nature reserves where overstocking could lead to territorial or nutritional stress or into which too many individuals of tick susceptible host species had been introduced during translocation operations. Finally, such studies could indicate whether non-endemic tick species had been introduced and become established in a particular habitat over a period of years.

Despite *B. microplus* being fairly widespread in South Africa (Howell, Walker & Nevill 1978), the recovery of small

numbers of this tick from a single grey rhebok grazing in a paddock with cattle outside the perimeter of the Park by Horak *et al.* (1986b), is the only record on a wild host in this country from the more than 1000 potentially suitable wild ruminant and equid hosts examined over a period of some 20 years by one of us (I.G.H.). Consequently its continued absence in the Park in spite of cattle grazing up to the boundary fences is not unexpected.

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Parasites of domestic and wild animals in South Africa. XXXV. Ixodid ticks and bot fly larvae in the Bontebok National Park

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ABSTRACT

HORAK, I.G. & BOOMKER, J. 1998. Parasites of domestic and wild animals in South Africa. XXXV. Ixodid ticks and bot fly larvae in the Bontebok National Park. *Onderstepoort Journal of Veterinary Research*, 65:205–211

Ixodid ticks were collected during February of each year from 1983–1992 from bontebok and grey rhebok in the Bontebok National Park, Western Cape Province. When available other mammals as well as ground-nesting birds and leopard tortoises were examined. Eleven tick species were recovered. *Rhipicephalus nitens* followed by *Rhipicephalus glabroscutatum* and an *Ixodes* sp. (near *I. pilosus*) were the most abundant, while *Amblyomma marmoreum* infested the widest host range.

The larvae of three bot flies were also collected. *Gedoelstia* sp. and *Strobiloestrus* sp. larvae were recovered from bontebok and grey rhebok and larvae of *Oestrus ovis* only from grey rhebok.

Keywords: Birds, bontebok, Bontebok National Park, bot fly larvae, grey rhebok, hares, ixodid ticks, rodents, tortoises

INTRODUCTION

A bi-monthly study, lasting 13 months, of some of the arthropods infesting animals in the Bontebok National Park, Western Cape Province, South Africa, has already been conducted (Horak, Sheppey, Knight & Beuthin 1986b). That survey was carried out to ascertain not only the arthropod species, particularly ixodid ticks and bot fly larvae, parasitizing animals in the Park but also their seasonal abundances. The present study extended the scope of the previous one by including ground-nesting birds and tortoises. It also looked at possible changes that might have occurred in tick burdens of bontebok and grey rhebok over a period of 10 years. The latter aspect has been addressed in a separate publication (Horak, Fourie & Boomker 1997).

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MATERIALS AND METHODS

Study locality

The study was conducted on animals resident in the Bontebok National Park (34°02'S, 20°25'E). The physiography of this park has previously been described by Boomker, Horak & De Vos (1981).

Survey period

Animals were examined during February of each year over a period of 10 years from 1983–1992. The animals examined during February 1983 and 1984 in the earlier study conducted by Horak *et al.* (1986b) have been included in this survey as being the first 2 years of the 10-year period.

Survey animals

The mammal, bird and tortoise species and the numbers of each examined are summarized in Table 1.

The species examined comprised two ruminants, two rodents, a hare, three ground-nesting birds and the leopard tortoise. The larger mammals and birds were

TABLE 1 Mammals, birds and reptiles examined for ixodid ticks in the Bontebok National Park

Common name	Specific name	No. examined
Mammals		
Bontebok	*Damaliscus pygargus dorcas*	34
Grey rhebok	*Pelea capreolus*	37
Cape gerbil	*Tatera afra*	1
Four-striped grass mouse	*Rhabdomys pumilio*	25
Scrub hare	*Lepus saxatilis*	11
Birds		
Cape francolin	*Francolinus capensis*	7
Greywing francolin	*Francolinus africanus*	7
Helmeted guineafowl	*Numida meleagris*	4
Reptiles		
Leopard tortoise	*Geochelone pardalis*	9

shot while the rodents were either shot or were trapped and then killed. The tortoises were examined alive.

Parasite recovery

The ticks on the antelopes were collected, identified and counted as described by Horak, Boomker, Spickett & De Vos (1992); those on the rodents and hares as described by Horak *et al.* (1986b); and those on the birds as described by Horak & Williams (1986). All ticks visible on the tortoises were removed with the aid of forceps and placed in 70% ethyl alcohol for later identification and counting. The length of the idiosoma of all engorging female ticks was measured to ascertain how many would have been likely to detach within the next 24 h.

Bot fly larvae were collected from the nasal passages and paranasal sinuses, the eyes, heart and the skin and subcutaneous tissue as described by Malan, Reinecke & Scialdo (1981), Horak, Brown, Boomker, De Vos & Van Zyl (1982) and Horak *et al.* (1986b).

RESULTS AND DISCUSSION

Ixodid ticks

Eleven species of ticks were recovered. Large numbers of four of them were collected and are listed in Table 2. The ticks collected in relatively small numbers or only from a few host species are listed in Table 3.

Amblyomma marmoreum

This tick was present on seven of the nine host species examined. The leopard tortoises were infested with all stages of development and the other animals mainly with larvae. Tortoises are the preferred hosts of the adults (Norval 1975). The immature stages, and particularly the larvae, will infest a large variety of reptiles, mammals and birds (Norval 1975; Horak, MacIvor, Petney & De Vos 1987a). As in the case of *Amblyomma hebraeum* the immature stages do not favour the four-striped grass mouse (Howell, Petney & Horak 1989), or probably any other rodent species, as hosts.

Boophilus sp.

Although no specific identification of the larvae recovered could be made both *Boophilus decoloratus* and *Boophilus microplus* have been collected from a grey rhebok just outside the park (Horak *et al.* 1986b). Infestations of these ticks are maintained by domestic cattle on the farms adjoining the park.

Haemaphysalis aciculifer

Both immature and adult stages were collected. Although this tick is widely distributed, particularly in the eastern regions of South Africa, where its presence is associated with bush and scrub, it is never encountered in large numbers (Walker 1991). The preferred hosts of the adults are various small and large wild bovids while the immatures feed on rodents and hares as well as on other small mammals and carnivores (Hoogstraal & El Kammah 1972; Walker 1991). Cape francolin also appear to be good hosts of the immature stages as nearly all were infested in the present study.

Haemaphysalis leachi

Adult ticks prefer domestic dogs and the larger wild carnivores while the immature stages can be found on these animals, hares and rodents (Norval 1984; Horak, Jacot Guillarmod, Moolman & De Vos 1987b; Fourie, Horak & Van den Heever 1992; Horak, Spickett, Braack & Penzhorn 1993). The source of infestation in the Bontebok Park is probably caracal (*Caracal caracal*) and feral domestic cats as well as domestic dogs which occasionally gain entrance.

TABLE 2 Host records of the more abundant ixodid tick species in the Bontebok National Park

Tick and host species	No. of hosts examined	No. infested	Total numbers of ticks collected				
			Larvae	Nymphs	Males	Females	Total
Amblyomma marmoreum							
Bontebok	34	11	70	0	0	0	70
Grey rhebok	37	11	96	0	0	0	96
Scrub hare	11	3	12	2	0	0	14
Cape francolin	7	3	15	1	0	0	16
Greywing francolin	7	4	129	0	0	0	129
Helmeted guineafowl	4	2	9	1	0	0	10
Leopard tortoise	9	7	7	5	77	19	108
Ixodes sp. (near *I. pilosus*)							
Bontebok	34	16	92	21	2	6	121
Grey rhebok	37	28	888	90	18	83 (11)	1 079
Four-striped grass mouse	25	2	1	1	0	0	2
Scrub hare	11	6	24	3	1	8	36
Rhipicephalus glabroscutatum							
Bontebok	34	29	2 408	358	20	27 (5)	2 813
Grey rhebok	37	27	828	80	26	15	949
Scrub hare	11	4	6	2	0	0	8
Rhipicephalus nitens							
Bontebok	34	34	9 110	122	407	469 (34)	10 108
Grey rhebok	37	35	3 306	29	250	357 (73)	3 942
Scrub hare	11	11	292	176	69	54 (14)	591
Helmeted guineafowl	4	1	1	0	0	0	1

( ) = number of engorging female ticks that could detach within the next 24 h

Hyalomma truncatum

All stages of development were recovered. Adult ticks prefer large herbivores (Norval 1982; Horak, Fourie, Novellie & Williams 1991b) and in the Bontebok Park the adults may be maintained by the Cape mountain zebras (*Equus zebra zebra*) introduced in 1988 and red hartebeest (*Alcelaphus buselaphus caama*). Leopard tortoises, which abound in the park, probably also harbour some adult ticks (Hoogstraal 1956; Table 3). Scrub hares and various rodents are the preferred hosts of the immature stages (Rechav, Zeederberg & Zeller 1987; Horak *et al.* 1991b, 1993). The Western Cape Province south of the Langeberg mountain range does not appear to be a particularly good habitat for this tick, hence the relatively small numbers collected.

Ixodes sp. (near *I. pilosus*)

This tick has been described by McKay (1994) as the "hairless palp" species within the *I. pilosus* group whose distribution is restricted to the coastal forests and coastal fynbos of the eastern and southern Cape. Grey rhebok appear to be its preferred host. This assumption, however, may be partially related to the habitat preferences of both the antelope and the tick. The grey rhebok frequent the gravel terraces and low hills within the park and the tick probably also prefers this habitat. *Ixodes rubicundus*, which is present in the Karoo less than 100 km to the north of the park, is more abundant on hill and mountain slopes than on open plains (Stampa 1959). All stages of development of the *Ixodes* sp. (near *I. pilosus*) were collected also from bontebok and from scrub hares. Females considerably outnumbered males on all hosts infested with adult ticks. As with other species in this genus copulation probably takes place off the host thus accounting for the small number of parasitic males collected (Fourie & Horak 1994).

Rhipicephalus evertsi evertsi

Both the immature and adult stages of development of this two-host tick prefer zebras as hosts (Hoogstraal 1956; Norval 1981; Horak *et al.* 1991b). The population in the park is probably now sustained by the mountain zebras, while the antelope and scrub hares serve as additional hosts for the immature stages.

Rhipicephalus gertrudae

Adults have previously been collected from bontebok and grey rhebok in the park (Horak *et al.* 1986b). The mountain zebras now in the park are also good hosts of the adults (Walker 1991). The latter author suggested

TABLE 3 Host records of the less abundant ixodid tick species in the Bontebok National Park

Tick and host species	No. of hosts examined	No. infested	Total numbers of ticks collected				
			Larvae	Nymphs	Males	Females	Total
Boophilus sp.							
Bontebok	34	1	4	0	0	0	4
Scrub hare	11	2	9	0	0	0	9
Haemaphysalis aciculifer							
Bontebok	34	2	4	0	0	2	6
Grey rhebok	37	2	0	0	0	3 (3)	3
Four-striped grass mouse	25	7	6	5	0	0	11
Cape francolin	7	6	11	7	0	0	18
Haemaphysalis leachi							
Four-striped grass mouse	25	4	83	2	0	0	85
Scrub hare	11	1	7	1	0	0	8
Hyalomma truncatum							
Bontebok	34	1	0	2	0	0	2
Cape gerbil	1	1	1	2	0	0	3
Four-striped grass mouse	25	2	0	4	0	0	4
Scrub hare	11	5	84	23	0	0	107
Leopard tortoise	9	2	0	0	0	2	2
Rhipicephalus evertsi evertsi							
Bontebok	34	5	8	28	0	0	36
Grey rhebok	37	4	11	24	2	1	38
Scrub hare	11	3	7	19	0	0	26
Rhipicephalus gertrudae							
Four-striped grass mouse	25	17	45	28	0	0	73
Scrub hare	11	1	0	3	0	0	3
Cape francolin	7	1	1	0	0	0	1
Helmeted guineafowl	4	1	1	0	0	0	1
Rhipicephalus lounsburyi							
Four-striped grass mouse	25	1	0	1	0	0	1

( ) = number of engorging female ticks that could detach within the next 24 h

that when the hosts of the immature stages were discovered they were likely to be small mammals, probably rodents. This supposition has been confirmed with the collection of larvae and nymphs from Namaqua rock mice (*Aethomys namaquensis*) in the Free State (Fourie *et al.* 1992), and from four-striped grass mice in the present study. The single larva collected in each case from a francolin and from a guineafowl must be regarded as accidental infestations.

Rhipicephalus glabroscutatum

All stages of development were present on the bontebok and grey rhebok. Both adult and immature ticks attach to the lower legs and around the hooves of wild and domestic ruminants and equids (Horak & Knight 1986; Horak, Knight & De Vos 1986a; Horak *et al.* 1991b). Although few ticks were found on scrub hares in the present study, they can be good hosts of the immature stages (Horak & Fourie 1991; Horak *et al.* 1991b).

The life cycle of *R. glabroscutatum* takes a year to complete. Adults are most abundant from July or August to January or February (Horak *et al.* 1986b; MacIvor & Horak 1987) and immatures from February or March to August or September (Horak *et al.* 1986b, 1991b; Horak & Fourie 1991). In the present study a considerably larger number of larvae than nymphs of this two-host tick were collected. This reflects the fact that all the animals were examined during February, at the very commencement of immature activity and consequently few larvae had probably as yet moulted to nymphs.

Rhipicephalus lounsburyi

Adults attach around the feet and hooves of several wild ruminants and of sheep (Walker 1990). The collection of a single nymph from a four-striped grass mouse in the present study is the first record of a host for the immature stages. Adults were previously recorded as *Rhipicephalus* sp. from bontebok and grey rhebok in the park (Horak *et al.* 1986b).

Rhipicephalus nitens

The distribution of this tick is associated with Cape shrubland vegetation (fynbos) in a coastal strip from Cape Town to approximately 60 km west of Port Elizabeth (Walker 1991). It is a three-host species and all stages of development were present on bontebok, grey rhebok and scrub hares. The adults are most abundant from November to February, larvae from February to June and nymphs from June to October (Horak *et al.* 1986b; Horak, Williams & Van Schalkwyk 1991a). These authors remarked that female ticks usually outnumbered males late in the season of adult activity. This trend is discernible in the present study.

The biology of *R. nitens* differs from those of *Rhipicephalus appendiculatus* and *Rhipicephalus zambeziensis*, two ticks that are morphologically similar to it and which also occur in South Africa. The adults of *R. nitens* are most abundant during the hot fairly dry summer and the immature stages during the cool wet winter of the Western Cape Province, and all stages of development are found on antelopes as well as on scrub hares (Horak *et al.* 1986b). The other two ticks occur in the North-West, Northern and Mpumalanga Provinces with *R. appendiculatus* also being present in KwaZulu-Natal and the Eastern Cape Province (Howell, Walker & Nevill 1978; Norval, Walker & Colborne 1982). Their adults are most abundant during the hot wet summer and cooler dry winter months characteristic of their habitats, and all stages of development are found on antelopes, while scrub hares harbour only the immature stages (Horak & Fourie 1991; Horak *et al.* 1992, 1993).

Bot fly larvae

The numbers of bot fly larvae collected from the bontebok and grey rhebok are summarized in Table 4.

Oestrus ovis

The larvae of this fly parasitize domestic sheep and goats and have also been collected from some wild sheep (*Ovis* sp.) and goats (*Capra* sp.) (Zumpt 1965). No wild bovids in Africa south of the Sahara have been found to serve as suitable hosts for the larvae (Zumpt 1965). Although seven grey rhebok in the present study were infested, the fly was apparently unable to complete its life cycle in these animals as all third stage larvae collected were dead. The reason for this failure is possibly twofold. Firstly in sheep and goats the development of second and third stage larvae takes place within the protected environment of the frontal sinuses (Horak 1977). In grey rhebok, which appear to have no frontal sinus cavities, this development has to take place in the more exposed nasal passages. Secondly some of the larvae enter the large maxillary sinuses of the grey rhebok and develop there to mature third stage larvae. These large larvae are, however, unable to leave these sinuses because of the narrowness of the openings and consequently die. The infestation in the park is maintained by sheep on the surrounding farms.

Gedoelstia sp.

No specific identification could be made but the spinulation and the shape of the post-anal bulge of the third stage larvae collected from the bontebok lie

TABLE 4 Host records of oestrid fly larvae collected in the Bontebok National Park

Fly and host species	No. of hosts examined	No. infested	Total numbers of larvae collected			
			1st stage	2nd stage	3rd stage	Total
Oestrus ovis						
Grey rhebok	37	7	2	5	14 (14)	21 (14)
Gedoelstia sp.						
Bontebok	34	34	1 464	765	1 093	3 322
Grey rhebok	37	1	2	0	0	2
Strobiloestrus sp.						
Bontebok	34	4	0	7 (5)	0	7 (5)
Grey rhebok	37	35	0	607	0	607

( ) = dead larvae included in totals

between those of *Gedoelstia cristata* and *Gedoelstia hässleri*. These larvae may well belong to a hitherto undescribed species of oestrid fly.

All the bontebok were infested. Twenty-two first stage larvae were recovered from the corneas of five animals, 639 first stage larvae from the auricle and the ventricle of the right heart and the commencement of the pulmonary artery of 23 animals, and two from the lungs of a single antelope. A slight corneal opacity was evident on an eye of one animal. The first stage larvae migrate via the eyes, the vascular system, the heart, the lungs and the trachea to reach the paranasal sinus cavities of the bontebok. The fairly large proportion of first stage larvae recovered from the chambers of the right heart implies that they may accumulate here before completing their migration. In blue wildebeest (*Connochaetes taurinus*) first stage *Gedoelstia* spp. larvae appear to accumulate on the dura mater before migrating to the paranasal sinus cavities (Horak, De Vos & Brown 1983).

Basson (1962, 1966) has described the pathology of infestation in natural and abnormal hosts. First stage *Gedoelstia* spp. larvae cause little macroscopically-visible damage to the eyes of their natural hosts, which include the bontebok (Basson, 1966). Hence the virtual absence of lesions in this animal. Grey rhebok are abnormal or accidental hosts of these fly larvae and corneal lesions were present in 11 animals, with both eyes of two rhebok being affected. The lesions varied from slight opacities to purrulent conjunctivitis, and in one case enucleation. Two first stage larvae were collected from the cornea of one animal. Basson (1962) also noted that the life cycle cannot progress beyond the first larval stage in abnormal hosts and no second or third stage larvae were collected from the grey rhebok.

Strobiloestrus sp.

The larvae collected from the grey rhebok and from the bontebok are probably those of *Strobiloestrus clarkii* (Zumpt 1965). As no mature third stage larvae were present we were unable to rear flies and confirm this.

All but two of the grey rhebok were infested with second instar larvae, the largest number harboured by a single animal comprising 130 larvae. The life cycle of this fly takes a year to complete, and only second stage larvae are present during February, the month in which all the animals were examined (Horak *et al.* 1986b). Grey rhebok are the normal hosts as virtually all were infested and third stage larvae, which were nearly mature, have previously been collected from these animals (Horak *et al.* 1986b). The small number of bontebok infested and the large proportion of dead larvae collected from them indicate that they are abnormal hosts and the infestations accidental. Accidental infestations have also been recorded in domestic cattle and in Merino sheep (Horak & Boomker 1981; Brain, Van der Merwe & Horak 1983).

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Ixodid tick infestations of wild birds and mammals on a game ranch in Central Province, Zambia

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ABSTRACT

ZIEGER, U., HORAK, I.G., CAULDWELL, A.E. & UYS, A.C. 1998. Ixodid tick infestations of wild birds and mammals on a game ranch in Central Province, Zambia. *Onderstepoort Journal of Veterinary Research,* 65:113–124

Ticks were collected at irregular intervals from December 1995 to November 1996 from wildlife on Mtendere Game Ranch in the Chisamba District of Central Province, Zambia. Total collections were made from two species of ground-nesting birds and 20 species of small and large mammals. Thirteen species/subspecies of ixodid ticks were recovered. *Rhipicephalus appendiculatus* was the most abundant, followed by *Boophilus decoloratus* and *Rhipicephalus evertsi evertsi.*

Small numbers of immature ticks of only a few species were collected from the birds and rodents. The lagomorphs carried large numbers of predominantly immature *R. appendiculatus.* Most of the ungulates harboured several tick species and had high infestations of *R. appendiculatus.* The seasonal abundances of *Amblyomma variegatum, B. decoloratus, R. appendiculatus* and *R. evertsi evertsi* were determined.

Keywords: Parasitic ixodid ticks, wildlife, Zambia

INTRODUCTION

Tick infestation is considered to be one of the constraints to successful game ranching (Horak 1980; Lightfoot & Norval 1981; Norval & Lightfoot 1982). Direct effects of ticks on their hosts include tick toxicosis, metabolic disturbances, anaemia and tick worry which can result in production losses or deaths (O'Kelly & Seifert 1969). Tick-bite wounds can become secondarily infected with bacteria or maggots (Lightfoot & Norval 1981). Several blood parasites are transmitted by ticks and have been incriminated as the cause of death in several wildlife species (Young & Basson 1973; Grobler 1981; Lightfoot & Norval 1981; Pandey, Minyoi, Hasebe & Mwase 1992). Although wild animals native to a specific region are seldom adversely affected by the endemic tick-borne blood parasites, translocations of hosts and/or ticks into non-endemic areas can cause severe losses amongst susceptible animals (Lightfoot & Norval 1981; Meltzer 1993). Furthermore, stress can break down a host's inherent resistance to endemic parasites and these may then cause disease (O'Kelly & Seifert 1969).

Commercial game ranching in Zambia commenced in 1989 when the law pertaining to wildlife was amended. Severe tick infestations of wildlife on a game ranch in the Chisamba District of Central Province, Zambia, were reported by the owner in 1995. During a study of the free-living stages of ticks on this ranch (Zieger, Horak & Cauldwell 1998), the opportunity arose to investigate the tick burdens of various wild animal species as well. It was, impossible, however, to examine a number of wildlife species on a regular monthly or bi-monthly basis. Nevertheless, the results presented here portray the tick species that infest wild animals in this region of Zambia, their host ranges and preferences, the magnitude of the hosts' total tick burdens and the seasonal abundances of some ticks.

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Various birds and small mammals were included in this investigation as these may play an important role as hosts of the immature stages of certain ticks.

MATERIAL AND METHODS

Study area

The investigation was conducted on Mtendere Game Ranch (15°05´S, 28°16´E) in the Chisamba District of Central Province, Zambia. The altitude in this region ranges from 1 100–1 200 m above sea level. Mean annual rainfall is 850 mm (Hutchison 1974). Three distinct seasons can be distinguished. These are the warm rainy season from December to April, the cool dry season from May to August and the hot dry season from September to November. The monthly mean temperatures of January, July and October are 20,0 °C, 15,0 °C and 22,5 °C, respectively (Ansell 1978). The major vegetation type is classified as miombo woodland, which is dominated by trees of the genera *Brachystegia* and *Julbernardia* (Trapnell 1953). Miombo woodland is typically interspersed with dambos. These are shallow, seasonally waterlogged drainage lines. Dambos support open grasslands dominated by *Hyparrhenia, Brachiaria*, *Echinochloa* and *Setaria* spp.

The ranch has operated commercially since 1990. It is situated approximately 20 km north of Lusaka and encompasses an area of 960 ha. It was stocked with several species of wildlife during 1990 and 1991. In January 1996 it contained some 570 larger ungulates. This is equivalent to 205 large stock units at a stocking rate of one large stock unit per 4,7 ha. The wildlife comprised 34 Burchell's zebra (*Equus burchellii);* 10 warthog (*Phacochoerus africanus*); 25 bushpig (*Potamochoerus larvatus*); 135 impala (*Aepyceros melampus);* 18 tsessebe *(Damaliscus lunatus lunatus*); 48 Lichtenstein's hartebeest (*Sigmoceros lichtensteinii*); four oribi (*Ourebia ourebi*); 22 eland (*Taurotragus oryx*); 35 bushbuck (*Tragelaphus scriptus*); two sitatunga (*Tragelaphus spekii*); 43 greater kudu (*Tragelaphus strepsiceros*); 20 common duiker *(Sylvicapra grimmia);* four roan antelope (*Hippotragus equinus*); 30 sable antelope (*Hippotragus niger*); 62 defassa waterbuck (*Kobus ellipsiprymnus defassa*); 20 Kafue lechwe (*Kobus leche kafuensis*); 36 puku (*Kobus vardonii*); and 22 reedbuck (*Redunca arundinum*). An unknown number of Sharpe's grysbok (*Raphicerus sharpei*) were also present.

All newly introduced animals were treated with the acaricide flumethrin (Drastic Deadline, Bayer Animal Health) prior to release. Five Duncan Applicators (Duncan & Monks 1992) were set up during the hot dry season (October 1996) and filled with a dicalcium-phosphate and coarse sodium-chloride salt mixture. The applicators themselves were charged with the acaricide flumethrin (Drastic Deadline, Bayer Animal Health) from November 1996 onwards once animals had become attracted and accustomed to them.

Survey animals

The birds and mammals examined and their dates of collection are summarized in Table 1. Two species of ground-nesting birds and 20 mammal species were examined during the period December 1995 to November 1996. Most of the larger mammals were shot either for venison or as trophies. The Lichtenstein's hartebeest and one eland were killed because of leg injuries. The Sharpe's grysbok and the sable antelope, a juvenile, were found freshly dead. Two bushpigs were shot as trophies in September 1996 and only the skins of their backs and legs were available for tick recovery. Their tick burdens are included in Fig. 1, 3 and 4, as no other animals became available during that month, but are not listed in the tables. Two sable antelope bulls were shot as trophies in July 1996 and only the back and leg skins were available for examination. These animals are mentioned as hosts of certain ticks, but their tick counts are not included in any of the tables or figures. The birds and scrub hares (*Lepus saxatilis*) were shot for the study. Except for the dormouse (*Graphiurus* sp.) that was found injured, the mice were trapped for the study and were killed with chloroform .

Collection of ticks

The birds were processed for tick recovery as described by Horak & Williams (1986); the lagomorphs and rodents as described by Horak, Sheppey, Knight & Beuthin (1986); and the ungulates as described by Horak, Boomker, Spickett & De Vos (1992).

Presentation of data

Because of the overdispersed nature of parasitic ticks (Petney, Van Ark & Spickett 1990), the tick counts of various host animals were transformed logarithmically [ln (number of ticks +1)] before being pooled to illustrate the ticks' seasonal occurrences (Fig. 1–4). The number of larvae, nymphs and adults were pooled for the one-host tick *Boophilus decoloratus* (Fig. 2), and the number of larvae and nymphs were pooled for the two-host tick *Rhipicephalus evertsi evertsi* (Fig. 4).

RESULTS AND DISCUSSION

The number of tick species and mean total number of ticks collected per host species are summarized in Table 1. The species and/or subspecies of ixodid ticks recovered and their presence on birds, lagomorphs, rodents and ungulates are listed in Table 2.

TABLE 1 The mean total tick burdens and number of tick species infesting birds and mammals examined on Mtendere Game Ranch, Central Province, Zambia

Host species (Common name)	Number examined	Mean total tick burden	Number of tick spp.	Date examined
Birds				
Numida meleagris (Helmeted guineafowl)	2	15,5	2	Jun. 96; Nov. 96
Francolinus swainsonii (Swainson's francolin)	3	1,0	1	Jun. to Nov. 96
Lagomorphs				
Lepus saxatilis (Scrub hare)	4	1 251,0	6	Jun. to Sep. 96
Rodents				
Saccostomus campestris (Pouched mouse)	2	2,0	3	Jun. 96
Aethomys chrysophilus (Red veld rat)	1	4,0	1	Aug. 96
Mastomys sp. (Multimammate mouse)	6	2,0	3	Jun. to Aug. 96
Pelomys fallax (Grooved-toothed mouse)	10	2,1	3	Jun. to Sep. 96
Graphiurus sp. (Dormouse)	1	2,0	1	Sep. 96
Ungulates				
Equus burchellii (Burchell's zebra)	1	2 204,0	5	Jan. 96
Potamochoerus larvatus (Bushpig)	2	10 379,0	3	Apr. 96
Aepyceros melampus (Impala)	12	4 975,2	7	Dec. 95 to Nov. 96
Damaliscus lunatus lunatus (Tsessebe)	3	7 111,3	6	Jan. to Aug. 96
Sigmoceros lichtensteinii (Lichtenstein's hartebeest)	1	3 724,0	7	Dec. 95
Raphicerus sharpei (Sharpe's grysbok)	1	144,0	4	Jun. 96
Taurotragus oryx (Eland)	2	11 956,0	7	Dec. 95; Feb. 96
Tragelaphus scriptus (Bushbuck)	2	15 951,0	6	Jun. 96; Aug. 96
Tragelaphus strepsiceros (Greater kudu)	2	10 098,0	8	Feb. 96; Mar. 96
Hippotragus niger (Sable antelope)	1	4 119,0	5	Nov. 96
Kobus ellipsiprymnus defassa (Defassa waterbuck)	6	10 460,6	6	Dec. 95 to Nov. 96
Kobus leche kafuensis (Kafue lechwe)	2	1 074,0	5	Dec. 95; Nov. 96
Kobus vardonii (Puku)	1	8 458,0	3	Aug. 96
Redunca arundinum (Reedbuck)	1	17 608,0	3	Aug. 96

TABLE 2 Ixodid ticks (x) collected on Mtendere Game Ranch, Central Province, Zambia, from birds (B), lagomorphs (L), rodents (R) and ungulates (U)

Tick species	B	L	R	U
Amblyomma variegatum	x			x
Boophilus decoloratus				x
Haemaphysalis leachi group			x	
Rhipicephalus appendiculatus	x	x	x	x
Rhipicephalus evertsi evertsi		x		x
Rhipicephalus kochi				x
Rhipicephalus lunulatus		x	x	x
Rhipicephalus punctatus				x
Rhipicephalus simus			x	x
Rhipicephalus sulcatus		x		x
Rhipicephalus supertritus				x
Rhipicephalus zambeziensis		x		
Rhipicephalus sp.		x	x	x

The host records for each of the tick species and/or subspecies collected on Mtendere Game Ranch are summarized in Tables 3–8. The seasonal abundances of those ticks of which sufficient numbers had been collected are graphically illustrated in Fig. 1–4. The histograms are based on the pooled monthly mean numbers of ticks collected from those animals which appeared to be suitable hosts for the particular tick species.

The birds and rodents were infested with only a few tick species and harboured small numbers of immature ticks only. The most prevalent and abundant tick on the birds was *Amblyomma variegatum,* while *Rhipicephalus appendiculatus* was the most prevalent, and *Rhipicephalus simus* the most abundant, on the rodents. The scrub hares harboured large numbers of immature *R. appendiculatus* and *R. evertsi evertsi. R. appendiculatus* was the most prevalent and most abundant tick on the ungulates. The largest number of ticks was collected from a defassa waterbuck with a total count of 30 718, followed by an impala with a total of 25 735 ticks.

Amblyomma variegatum (Table 3; Fig. 1)

This tick was collected from birds and most ungulates, but was absent on lagomorphs and rodents. The birds were infested only with the immature stages. Bushpig, tsessebe, Sharpe's grysbok and reedbuck carried only immature ticks, Burchell's zebra only adults, and the other animals both immatures and adults. Larvae of *A. variegatum* were recovered from

TABLE 3 Host records of *Amblyomma variegatum* on Mtendere Game Ranch, Central Province, Zambia

Host	Number examined	Number infested	Mean number of ticks collected (+/– S.E.)				
			Larvae	Nymphs	Males	Females	Total
Helmeted guineafowl	2	2	10,5	1,0	0,0	0,0	11,5 (3,7)
Swainson's francolin	3	2	0,0	1,0	0,0	0,0	1,0 (1,0)
Burchell's zebra	1	1	0,0	0,0	10,0	8,0	18,0
Bushpig	2	2	64,5	0,0	0,0	0,0	64,5 (9,2)
Impala	12	7	20,8	1,4	0,7	0,2	23,1 (6,2)
Tsessebe	3	3	23,3	11,3	0,0	0,0	34,6 (5,6)
Lichtenstein's hartebeest	1	1	0,0	2,0	24,0	6,0	32,0
Sharpe's grysbok	1	1	1,0	0,0	0,0	0,0	1,0
Eland	2	2	0,0	2,0	30,0	13,0	45,0 (6,8)
Bushbuck	2	2	29,0	1,0	0,0	1,0	31,0 (6,4)
Greater kudu	2	2	44,0	0,0	0,0	2,0	46,0 (7,7)
Sable antelope	1	1	0,0	4,0	2,0	0,0	6,0
Defassa waterbuck	6	5	8,0	3,0	0,7	0,0	11,7 (4,2)
Kafue lechwe	2	2	0,0	5,0	5,0	5,0	15,0 (4,3)
Reedbuck	1	1	0,0	10,0	0,0	0,0	10,0

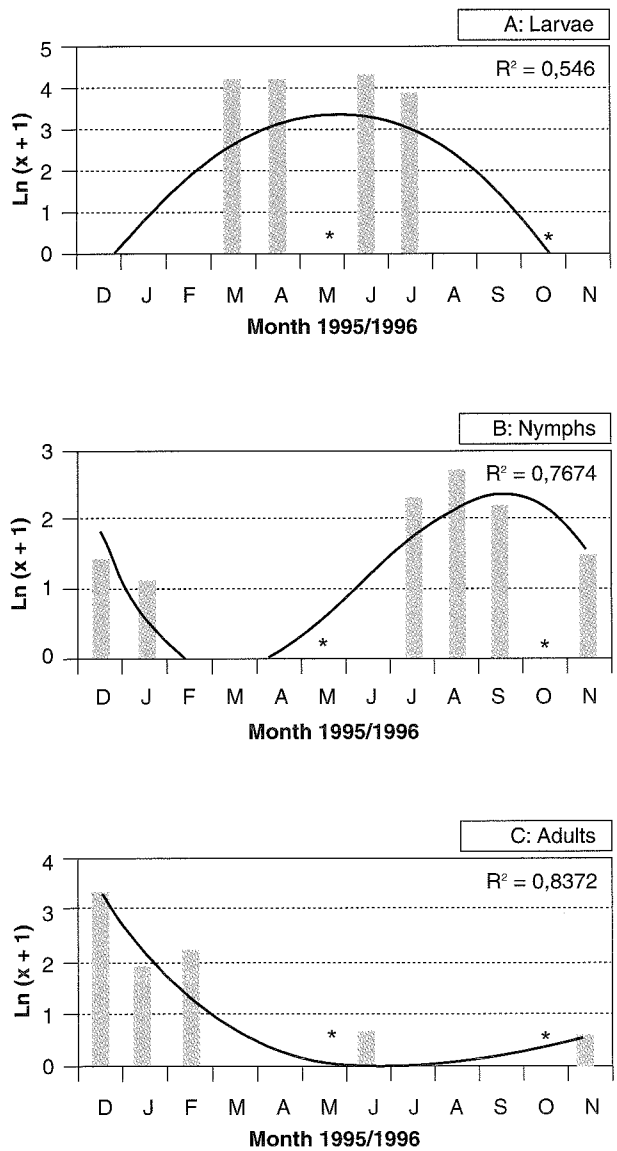

FIG.1 The seasonal abundance of (A) larvae, (B) nymphs and (C) adults of *Amblyomma variegatum* on Burchell's zebra, bushpig, impala, tsessebe, eland, bushbuck, greater kudu and defassa waterbuck on Mtendere Game Ranch, Central Province, Zambia (* no collection)

March to July, nymphs in December and January and again from July to November, and adults mainly from December to February.

A. variegatum has been described from a wide variety of domestic and wild hosts in Africa (Petney, Horak & Rechav 1987). Cattle appear to be a major host of this tick. Adults are also found on medium to large wild herbivores, whereas immatures occur on a variety of hosts (Norval 1983; Petney *et al.* 1987; Walker 1991). Larvae and nymphs have been collected from ground-nesting birds (Theiler & Salisbury 1959; Walker 1974) and feed mostly on the birds' heads and upper necks. Colbo & MacLeod (1976) have recovered immatures in low numbers from several bird species in Zambia. Lagomorphs and rodents have also been listed as hosts of the immature stages of other *Amblyomma* spp. in Africa (Theiler 1962). Hares are good hosts of *Amblyomma hebraeum* and *Amblyomma marmoreum* (Horak & Fourie 1991) and Matthysse (1954) has reported large numbers of *A. variegatum* nymphs from hares in Zambia. Moderate numbers of nymphs of an *Amblyomma* sp. have also been collected from hares by MacLeod (1970) and Colbo & MacLeod (1976) in the latter country. It is therefore surprising that no *A. variegatum* larvae or nymphs were recovered from the scrub hares in the present study.

Except for puku, all the ungulates examined hosted *A. variegatum*. It is impossible to identify the preferred hosts of *A. variegatum* in this study because of the strictly seasonal occurrence of this tick. For several of the host species only one or a few individuals were

TABLE 4 Hosts records of *Boophilus decoloratus* on Mtendere Game Ranch, Central Province, Zambia

Host	Number examined	Number infested	Mean number of ticks collected (+/– S.E.)					
			Larvae	Nymphs	Males	Females	Total	
Burchell's zebra	1	1	260,0	172,0	86,0	124,0	642,0	
Impala	12	12	255,2	76,9	28,6	18,4	379,1	(15,8)
Tsessebe	3	3	245,3	29,3	4,0	4,0	282,6	(15,5)
Lichtenstein's hartebeest	1	1	242,0	1 364,0	678,0	376,0	2 660,0	
Eland	2	2	1 301,0	1 790,0	1 672,0	388,0	5 151,0	(63,1)
Bushbuck	2	2	17,0	35,0	1,0	0,0	53,0	(7,6)
Greater kudu	2	2	2 216,0	788,0	307,0	188,0	3 499,0	(36,2)
Sable antelope	1	1	1 393,0	910,0	582,0	279,0	3 164,0	
Defassa waterbuck	6	6	31,7	0,7	0,3	0,0	32,7	(5,7)
Kafue lechwe	2	2	30,0	21,0	29,0	7,0	87,0	(12,0)
Puku	1	1	10,0	0,0	2,0	2,0	14,0	

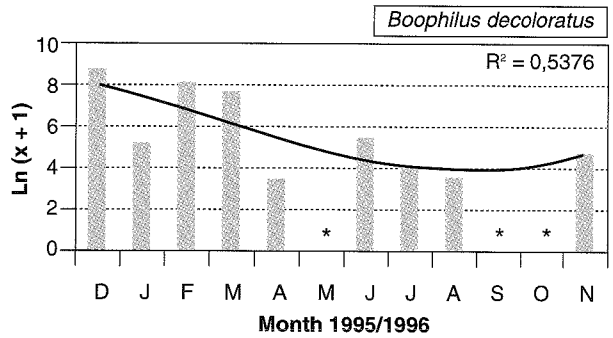

FIG. 2 The seasonal abundance of all stages of *Boophilus decoloratus* on impala, tsessebe, eland, bushbuck and greater kudu on Mtendere Game Ranch, Central Province, Zambia (* no collection)

available for tick collection and the time of examination may not have coincided with the tick's peak activity period. Impala were examined throughout the year and hosted all life stages but carried few adults. One of the three tsessebe was examined during the peak activity period of adult ticks. No adults were collected from this animal, indicating that tsessebe are possibly unsuitable hosts for this life stage. The greatest numbers of adults were present on the Lichtenstein's hartebeest and on eland. In previous studies in Zambia, Burchell's zebra, warthog, impala, eland, greater kudu, sable antelope and Kafue lechwe had been found to host this tick (Matthysse 1954; MacLeod 1970; Colbo 1973; Pandey *et al.* 1992).

A. variegatum occurs in semi-arid as well as humid regions and appears to require a minimum annual rainfall of 400 mm (Yeoman & Walker 1967). It completes one generation per year in regions with a single annual rainy season (Wilson 1950; Matthysse 1954). Adults are most abundant on cattle in Zambia from November to January (Matthysse 1954; MacLeod 1970; MacLeod, Colbo, Madbouly & Mwanaumo 1977), while larvae are most abundant on these animals from March to May and nymphs from April to December (MacLeod & Colbo 1976). In the present study, all stages of this tick showed a pattern of seasonal occurrence similar to that recorded on cattle.

Boophilus decoloratus (Table 4; Fig. 2)

B. decoloratus was collected only from ungulates, but was absent on bushpig, Sharpe's grysbok and reedbuck. Large numbers were present on Lichtenstein's hartebeest, eland, greater kudu and sable antelope. It occurred throughout the year with a peak in abundance during the height of the rainy season (December to March).

B. decoloratus is primarily a tick of larger herbivores (Walker 1991). In South Africa it has been found in large numbers on Burchell's zebra, giraffe (*Giraffa camelopardalis*), greater kudu, nyala (*Tragelaphus angasii*), bushbuck, eland and impala (Horak, Potgieter, Walker, De Vos & Boomker 1983; Horak, De Vos & De Klerk 1984; Horak *et al.* 1992). In the present study the preferred hosts were Lichtenstein's hartebeest, eland, greater kudu and sable antelope. Burchell's zebra and impala were also good hosts, but mean tick numbers were not as high as they were on these animals in the Kruger National Park, South Africa (Horak 1995). Few ticks were collected from the other ungulates. Both the defassa waterbuck and the tsessebe can be considered virtual dead-end hosts for this one-host tick. This is indicated by the ratios of larvae to nymphs and nymphs to adults, of 105,7: 2,3:1 and 30,6:3,7:1, respectively, implying a poor translation to adulthood, compared with 4,5:1,6:1 on the greater kudu, which are good hosts.

The smaller mammals and birds did not carry any *B. decoloratus* in this study. Colbo & MacLeod (1976) have collected some adults from hares and from a groove-toothed mouse (*Pelomys fallax*) in Zambia. With the exception of defassa waterbuck, Kafue lechwe and puku, the larger mammals reported here have previously been listed as hosts of *B. decoloratus*

in Zambia (Matthysse 1954; MacLeod 1970; Colbo 1973; MacLeod *et al.* 1977).

Reports on the seasonal abundance of this tick vary. Two main activity periods have been found on cattle in Zambia, namely the rainy season and the hot, dry season (MacLeod 1970; MacLeod *et al.* 1977). In South Africa, two or three peaks of abundance have been recorded (Baker & Ducasse 1967; Rechav 1982; Horak *et al.* 1992), while in Zimbabwe, Jooste (1966) speculated that four generations may occur in one year. Free-living *B. decoloratus* larvae collected from the vegetation of Mtendere Game Ranch showed two peaks of abundance, namely during the rainy season and the hot, dry season (Zieger *et al.* 1998). In the present study, *B. decoloratus* was most active during the rainy season from December to March. It is possible, however, that the second peak of abundance during the hot, dry season recorded on the ranch for free-living ticks (Zieger *et al.* 1998) was missed. The only animals that were examined in September were two bushpigs, and these did not host any *B. decoloratus.* No animals were available for tick collection in October.

Haemaphysalis leachi group (Table 8)

This group of ticks contains both *H. leachi* and *H. spinolusa*, of which the immature stages are extremely difficult to differentiate. In this survey, only one *Haemaphysalis* nymph belonging to this group was found on a pouched mouse (*Saccostomus campestris*). Adults of this group are typically parasites of domestic dogs and a variety of wild carnivores (Walker 1991). *H. leachi* has been reported from jackal (*Canis* sp.) and civets (*Civettictis* sp.) in Zambia (Colbo 1973; MacLeod *et al.* 1977). As very few wild carnivores are present on Mtendere Game Ranch it is not surprising that the immature stages of the *H. leachi* group were not collected more frequently from rodents which are their preferred hosts (Walker 1991).

Rhipicephalus appendiculatus (Table 5; Fig. 3)

This tick occurred on all host groups. Small numbers of immatures only were collected from some of the birds and rodents while the scrub hares carried large numbers. Bushpigs, impala, tsessebe, Sharpe's grysbok, bushbuck, puku and reedbuck carried mostly or only immature ticks. Except for the Burchell's zebra, which carried only adults, the remaining animals carried both immature and adult ticks. Most larvae were recovered from February to September, nymphs from June to September and adults from December to March and again in November.

R. appendiculatus has an extremely wide host range (Walker 1991). Among wild animals its preferred hosts are Artiodactyla. All life stages generally occur on the same host species, but the smaller hosts are usually mostly infested with the immature stages (Horak 1982; Norval, Walker & Colborne 1982; Walker 1991). *R. appendiculatus* is the dominant tick on Mtendere Game Ranch. Its larvae accounted for 91,6% of all ticks collected from scrub hares. It also constituted 99,4% of all ticks present on bushpig, 88,5% on tsessebe, 93,8% on Sharpe's grysbok, 98,8% on bushbuck, 91,9% on defassa waterbuck and 98,4% on puku. Adults occurred in the greatest numbers on eland, greater kudu and defassa waterbuck which can all be considered preferred hosts. The partial counts of the two sable antelope bulls examined

TABLE 5 Host records of *Rhipicephalus appendiculatus* on Mtendere Game Ranch, Central Province, Zambia

Host	Number examined	Number infested	Mean number of ticks collected (+/– S.E.)					
			Larvae	Nymphs	Males	Females	Total	
Helmeted guineafowl	2	1	4,0	0,0	0,0	0,0	4,0	(2,4)
Scrub hare	4	4	941,0	205,0	0,0	0,0	1 146,0	(37,5)
Multimammate mouse	6	3	1,0	0,0	0,0	0,0	1,0	(1,0)
Groove-toothed mouse	10	2	0,6	0,0	0,0	0,0	0,6	(1,3)
Dormouse	1	1	1,0	1,0	0,0	0,0	2,0	
Burchell's zebra	1	1	0,0	0,0	746,0	400,0	1 146,0	
Bushpig	2	2	10 243,0	43,0	12,0	14,5	10 312,5	(80,4)
Impala	12	12	3 079,8	653,1	12,3	5,8	3 751,0	(84,2)
Tsessebe	3	3	4 278,6	1 965,3	24,7	22,6	6 291,2	(76,6)
Lichtenstein's hartebeest	1	1	0,0	2,0	542,0	150,0	694,0	
Sharpe's grysbok	1	1	127,0	8,0	0,0	0,0	135,0	
Eland	2	2	942,0	5,0	3 292,0	1 456,0	5 695,0	(39,1)
Bushbuck	2	2	13 957,0	1 806,0	1,0	0,0	15 764,0	(20,9)
Greater kudu	2	2	3 554,0	14,0	866,0	892,0	5 326,0	(59,8)
Sable antelope	1	1	3,0	69,0	33,0	6,0	111,0	
Defassa waterbuck	6	6	4 550,8	3 281,5	1 121,7	662,8	9 616,8	113,4)
Kafue lechwe	2	2	1,0	48,0	247,0	68,0	364,0	(19,2)
Puku	1	1	3 956,0	4 370,0	0,0	0,0	8 326,0	
Reedbuck	1	1	5 758,0	6 922,0	2,0	2,0	12 684,0	

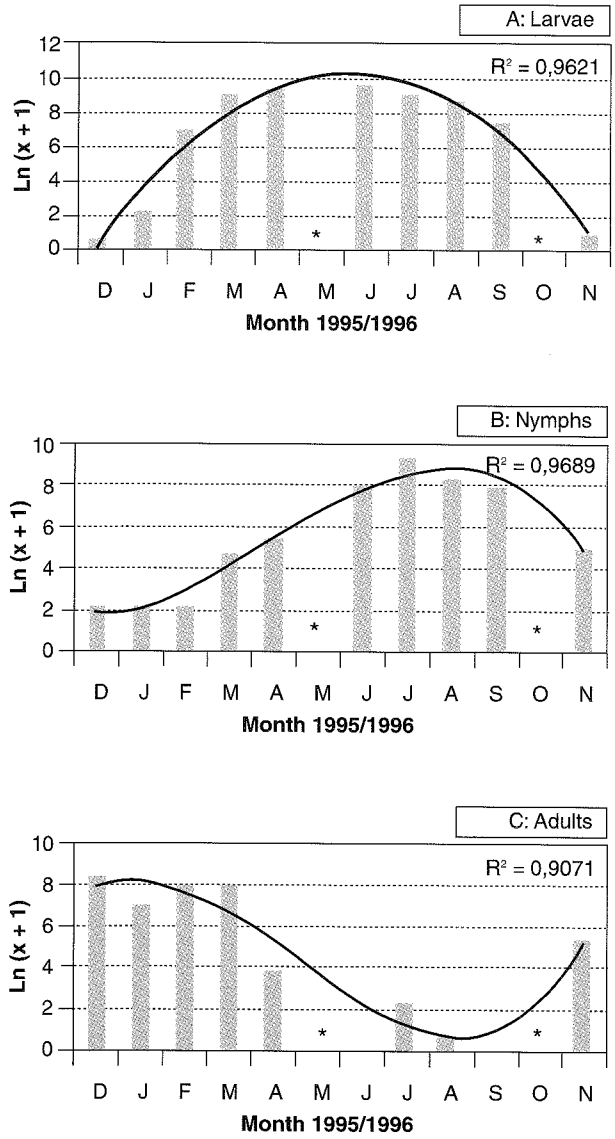

FIG. 3 The seasonal abundance of (A) larvae, (B) nymphs and (C) adults of *Rhipicephalus appendiculatus* on bushpig, impala, tsessebe, eland, bushbuck, greater kudu, defassa waterbuck, puku and reedbuck on Mtendere Game Ranch, Central Province, Zambia (* no collection)

in July revealed no fewer than 9 264 and 4 676 ticks respectively (numbers are not included in Table 1). The large number of adults collected from the Burchell's zebra, which is usually not considered to be a good host, probably reflects the superabundance of *R. appendiculatus* on the ranch.

R. appendiculatus has been recorded as one of the major ticks occurring on cattle in the Southern and Central Provinces of Zambia (MacLeod 1970; MacLeod *et al.* 1977; Pegram, Perry, Musisi & Mwanaumo 1986). Most of the wildlife species previously examined in the same regions carried this tick, but only in small numbers (MacLeod 1970; Colbo 1973; MacLeod *et al.* 1977).

This three-host tick has a well-defined pattern of seasonal abundance reflecting the completion of a single generation per year. This pattern of abundance has been described in several African countries (Wilson 1946; Baker & Ducasse 1967; Matson & Norval 1977; Gallivan & Surgeoner 1995). In Zambia, MacLeod *et al.* (1977) found a distinct seasonal pattern with the highest numbers of adults present on cattle during the rainy season. Adults, however, were also present in low numbers throughout the year (Matthysse 1954; MacLeod *et al.* 1977), a phenomenon seen in the present study. The seasonal abundance of free-living *R. appendiculatus* collected from the vegetation of Mtendere Game Ranch revealed a pattern similar to that described on the host animals (Zieger *et al.* 1998). However, in that study adults disappeared from the vegetation during the dry months (July to November).

Rhipicephalus evertsi evertsi (Table 6; Fig. 4)

This tick was absent on birds and rodents, while all the scrub hares were infested with the immature stages. Except for the Sharpe's grysbok, all ungulates harboured *R. evertsi evertsi,* including one of the two bushpigs on which only partial counts were done. Bushbuck and puku hosted only immature stages. The number of immature ticks collected from the reedbuck far exceeded the counts on any of the other ungulates. All life stages were present throughout the year.

R. evertsi evertsi is widespread in Africa (Theiler 1962). It is a two-host tick whose adults do not usually occur in large numbers, except on zebra and eland (Horak *et al.* 1984; Horak, Fourie, Novellie & Williams 1991). These animals are also good hosts for all life stages, while other wild ruminants and scrub hares have been described as fair to good hosts of the immature stages (Horak & Knight 1986; Rechav, Zeederberg & Zeller 1987; Horak 1995). Bushpigs and bushbuck are new host records for this tick in Zambia. Burchell's zebra, Lichtenstein's hartebeest and eland were good hosts for the adults. Though results from single host collections must be interpreted with care, the translation of larvae to nymphs is apparently poor on impala, bushbuck, greater kudu and defassa waterbuck. This has also been observed on impala and greater kudu in South Africa (Horak *et al.* 1992; Horak 1995).

All life stages of this tick occurred throughout the year on Mtendere Game Ranch. No clear seasonal pattern of abundance was discernible, but adults appeared to be present in slightly larger numbers during the rainy season. Previous reports from Zambia indicate that larval abundance on cattle peaks in September and October (MacLeod 1970) and that, depending on climatic conditions, adults occur in two to three waves per year (MacLeod 1970, 1975). It is possible that, because of the irregular sampling of

TABLE 6 Host records of *Rhipicephalus evertsi evertsi* on Mtendere Game Ranch, Central Province, Zambia

Host	Number examined	Number infested	Mean number of ticks collected (+/– S.E.)					
			Larvae	Nymphs	Males	Females	Total	
Scrub hare	4	4	56,0	32,3	0,0	0,0	88,3	(9,8)
Burchell's zebra	1	1	302,0	6,0	28,0	16,0	352,0	
Impala	12	12	683,8	103,8	7,8	4,2	799,6	(28,6)
Tsessebe	3	3	364,7	126,6	5,3	4,7	501,3	(13,0)
Lichtenstein's hartebeest	1	1	80,0	140,0	34,0	12,0	266,0	
Eland	2	2	634,0	147,0	97,0	32,0	910,0	(4,7)
Bushbuck	2	2	86,0	2,0	0,0	0,0	8,0	(4,7)
Greater kudu	2	2	1 142,0	62,0	8,0	7,0	1 219,0	(29,1)
Sable antelope	1	1	458,0	342,0	11,0	5,0	816,0	
Defassa waterbuck	6	6	639,3	95,3	11,0	8,3	753,9	(31,2)
Kafue lechwe	2	2	391,0	165,0	17,0	12,0	585,0	(25,7)
Puku	1	1	90,0	28,0	0,0	0,0	118,0	
Reedbuck	1	1	1 798,0	3 106,0	6,0	4,0	4 914,0	

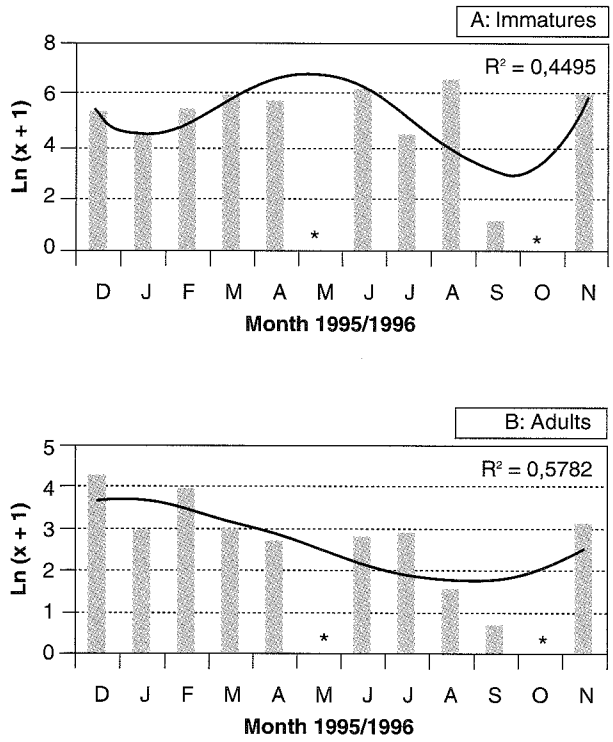

FIG. 4 The seasonal abundance of (A) immatures and (B) adults of *Rhipicephalus evertsi evertsi* on Burchell's zebra, bushpig, impala, tsessebe, eland, bushbuck, greater kudu, defassa waterbuck, puku and reedbuck on Mtendere Game Ranch, Central Province, Zambia (* no collection)

hosts in our study, the pattern of abundance was less clear than that on cattle.

Rhipicephalus kochi (Table 8)

This tick is widely distributed in East and Central Africa where it parasitizes a large variety of domestic and wild hosts (Clifford, Walker & Keirans 1983). It has been recorded from greater kudu in Zambia (Pegram *et al.* 1986) and was present in small numbers on five of the ruminant species on Mtendere Game Ranch.

Rhipicephalus lunulatus (Table 7)

Nymphs were collected from one of the scrub hares and from two multimammate mice (*Mastomys* sp.) Most of the ungulates were infested, but harboured only adults. Nymphs were present in June, and the adults from December to March and again in November.

Adults of this tick appear to be non-specific in their choice of hosts (Walker 1991). The host range reported here is probably incomplete because of the limited number of animals examined during the main activity period of adult ticks. All ungulates examined on the ranch from December 1995 to March 1996 and during November 1996 carried adults. In many African countries, peaks of adult activity are associated with hot, wet conditions (Walker, Keirans, Pegram & Clifford 1988). Larvae and nymphs have been successfully reared under laboratory conditions (Colborne 1985) but their natural hosts were not identified. In the present study, *R. lunulatus* nymphs were collected for the first time from a scrub hare and two multimammate mice.

Rhipicephalus punctatus (Table 8)

Small numbers of adults were collected from an impala, the Lichtenstein's hartebeest and Sharpe's grysbok. The immature stages of this tick are unknown. However, the *Rhipicephalus* sp. immatures, which we collected from scrub hares, a groove-toothed mouse, an impala and a bushbuck (Table 8) and which we were unable to identify, may belong to this species. In previous surveys in Zambia, Colbo (1973) and MacLeod *et al.* (1977) found *R. punctatus* on a variety of wild animals.

TABLE 7 Host records of *Rhipicephalus lunulatus* on Mtendere Game Ranch, Central Province, Zambia

Host	Number examined	Number infested	Mean number of ticks collected (+/– S.E.)					
			Larvae	Nymphs	Males	Females	Total	
Scrub hare	4	1	0,0	0,3	0,0	0,0	0,3	(0,7)
Multimammate mouse	6	2	0,0	0,8	0,0	0,0	0,8	(1,3)
Burchell's zebra	1	1	0,0	0,0	42,0	4,0	46,0	
Impala	12	8	0,0	0,0	16,6	4,8	21,4	(5,9)
Tsessebe	3	1	0,0	0,0	0,7	0,0	0,7	(1,0)
Lichtenstein's hartebeest	1	1	0,0	0,0	42,0	14,0	56,0	
Eland	2	2	0,0	0,0	109,0	24,0	133,0	(13,3)
Kudu	2	2	0,0	0,0	3,0	1,0	4,0	(0,0)
Sable antelope	1	1	0,0	0,0	18,0	4,0	22,0	
Defassa waterbuck	6	4	0,0	0,0	28,3	17,0	45,3	(8,6)
Kafue lechwe	2	2	0,0	0,0	16,0	7,0	23,0	(4,6)

Rhipicephalus simus (Table 8)

The immature stages of this tick were collected only from the rodents. These animals are the preferred hosts of these stages (Norval & Mason 1981). They have previously been recorded on a variety of small mammals in Zambia (Colbo 1973; Colbo & MacLeod 1976). Adults were recovered from bushpigs and eland in the present study, whereas MacLeod (1970), Colbo (1973) and MacLeod *et al.* (1977) have recovered them from several wild animal species in Zambia.

Rhipicephalus sulcatus (Table 8)

In the present study, adults were collected from one scrub hare, from the Lichtenstein's hartebeest and one greater kudu. This tick is widely distributed in East and Central Africa (Pegram, Clifford, Walker & Keirans 1987). Adults are commonly found on dogs and hares, and less frequently on wild carnivores and antelopes (Pegram *et al.* 1987). The hosts of the immature stages are unknown (Walker 1991). Among Zambian wild ungulates it had previously been collected only from Lichtenstein's hartebeest and defassa waterbuck (MacLeod 1970; Colbo 1973).

Rhipicephalus supertritus (Table 8)

A few adults of this tick were collected from eland and greater kudu on the ranch. MacLeod (1970) also recovered small numbers of adults from eland and greater kudu in Zambia, while Colbo (1973) found adults also on Burchell's zebra. This tick is consistently present in large numbers on cattle in a small area south-east of Lusaka but is otherwise rare (Matthysse 1954; MacLeod *et al.* 1977). No explanation has been found for this phenomenon. The hosts of the immature stages are unknown.

Rhipicephalus zambeziensis (Table 8)

One larva only was collected from a scrub hare. Twenty-one larvae and a nymph were also collected from the vegetation on the ranch (Zieger *et al.* 1998). This tick is closely related to *R. appendiculatus* and replaces the latter in the hot, dry, low-lying areas of south-eastern Africa (Norval *et al.* 1982). Their distributions overlap in the Southern Province of Zambia along the Zambezi Valley. Hosts of *R. zambeziensis* include numerous wild ungulates (Norval *et al.* 1982). Its low incidence on Mtendere Game Ranch indicates that the ranch is located near the limit of its distribution in this region.

GENERAL

The dominant tick on Mtendere Game Ranch is *R. appendiculatus.* It is followed by *B. decoloratus* and *R. evertsi evertsi.* These three species accounted for 99,2 % of all mean total tick counts. All the tick species/subspecies collected in this survey have already been recorded in Zambia (Matthysse 1954; Theiler & Robinson 1954; MacLeod 1970; Colbo 1973; MacLeod *et al.* 1977; Pegram *et al.* 1986). Though the tick collection techniques differed in each of these studies, none of the authors commented on a clear dominance of one or several tick species on the animals examined. However, a situation comparable to that on Mtendere Game Ranch was observed by MacLeod (1970) on cattle in the Southern Province of Zambia. Here the dominating frequency of *B. decoloratus, R. appendiculatus* and *R. evertsi evertsi* on intensely farmed cattle was thought to be 'not a necessary concomitant of cattle, but rather an effect of their ecologically unnatural density'. MacLeod (1970) concluded that the concentration of cattle under commercial ranching conditions, and possibly its consequent effect on the vegetation cover, had upset the balance between tick species.

The total tick burdens of wild animals on Mtendere Game Ranch appear to be heavy but are comparable to the burdens collected from animals in natural wildlife areas in South Africa. In the Kruger National

TABLE 8 Host records of the less common tick species on Mtendere Game Ranch, Central Province, Zambia

Tick and host	Number examined	Number infested	Mean number of ticks collected (+/– S.E.)					
			Larvae	Nymphs	Males	Females	Total	
Haemaphysalis leachi group								
Pouched mouse	2	1	0,0	0,5	0,0	0,0	0,5	(0,8)
Rhipicephalus kochi								
Impala	12	1	0,0	0,0	0,2	0,0	0,2	(0,8)
Tsessebe	3	1	0,0	0,0	0,0	0,7	0,7	(1,1)
Sharpe's grysbok	1	1	0,0	0,0	2,0	3,0	5,0	
Bushbuck	2	2	0,0	14,0	0,0	0,0	14,0	(3,8)
Greater kudu	2	1	0,0	0,0	2,0	0,0	2,0	(1,7)
Rhipicephalus simus								
Pouched mouse	2	2	1,5	0,0	0,0	0,0	1,5	(0,8)
Red veld rat	1	1	1,0	3,0	0,0	0,0	4,0	
Multimammate mouse	6	1	0,0	0,2	0,0	0,0	0,2	(0,6)
Grooved-toothed mouse	10	2	0,6	0,7	0,0	0,0	1,3	(1,9)
Bushpig	2	2	0,0	0,0	0,5	1,5	2,0	(1,2)
Eland	2	2	0,0	0,0	7,0	0,0	7,0	(1,8)
Rhipicephalus punctatus								
Impala	12	1	0,0	0,0	0,0	0,2	0,2	(0,8)
Lichtenstein's hartebeest	1	1	0,0	0,0	2,0	2,0	4,0	
Sharpe's grysbok	1	1	0,0	0,0	3,0	0,0	3,0	
Rhipicephalus sulcatus								
Scrub hare	4	1	0,0	0,0	0,3	0,3	0,6	(0,8)
Lichtenstein's hartebeest	1	1	0,0	0,0	10,0	2,0	12,0	
Greater kudu	2	1	0,0	0,0	1,0	0,0	1,0	(1,2)
Rhipicephalus supertritus								
Eland	2	1	0,0	0,0	15,0	0,0	15,0	(4,6)
Kudu	2	1	0,0	0,0	0,0	1,0	1,0	(1,2)
Rhipicephalus zambeziensis								
Scrub hare	4	1	0,3	0,0	0,0	0,0	0,3	(0,7)
Rhipicephalus sp.								
Scrub hare	4	3	4,3	11,5	0,0	0,0	15,8	(5,1)
Grooved-toothed mouse	10	1	0,1	0,0	0,0	0,0	0,1	(0,5)
Impala	12	1	0,7	0,0	0,0	0,0	0,7	(1,5)
Bushbuck	2	1	1,0	0,0	0,0	0,0	1,0	(1,2)

Park, South Africa, the mean tick burdens of Burchell's zebra, impala and greater kudu during several years of investigation were between 3000 and 5000 per animal (Horak *et al.* 1992; Horak 1995). Buffalo in the Hluhluwe Game Reserve carried close to 20000 ticks (Horak *et al.* 1983). With the exception of the Lichtenstein's hartebeest and one eland, which were both shot on the ranch because of leg injuries, and the sable antelope and Sharpe's grysbok which were found dead, all other animals were shot for venison or as trophies and were apparently in good condition. The year of investigation had been a year of good rainfall and, despite the high stocking density on the ranch, the overall food supply was adequate during the entire study period. The numbers of ticks collected therefore represent the normal burdens of healthy animals on the ranch.

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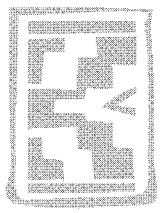
Sympatric wild and domestic animals

One of the current focus areas in veterinary science is disease at the domestic stock/wildlife interface. Although the publications on the ticks of the various host species on the farm “Bucklands” in the Eastern Cape Province were each devoted to a single host species, and are listed under these host species in the earlier chapters of this dissertation, all the animals involved were present on the same farm and were examined during the same 2-year time frame. The hosts involved were cattle (Horak 1999), Dorper sheep (Horak, Williams & Van Schalkwyk 1991a), Angora goats (Horak, Knight & Williams 1991d), greater kudus, *Tragelaphus strepsiceros* (Horak, Boomker, Spickett & De Vos 1992b), scrub hares, *Lepus saxatilis* (Horak & Fourie 1991) and helmeted guineafowls, *Numida meleagris* (Horak, Spickett, Braack & Williams 1991c). The single publication listed in the present chapter comprises findings on the tick burdens of six host species examined at monthly intervals at the same time on the same farm in the Eastern Cape Province (MacIvor & Horak 2003). Seven tick species were recovered, and with the exception of *Rhipicephalus oculatus*, of which all stages of development prefer scrub hares as hosts, the findings of this publication and those mentioned above illustrate that for many tick species there are no natural barriers to cross-infestation. The fact that the interface between the ticks that infest wildlife and domestic livestock appears to be nearly completely porous, has important implications for the management of tick-borne diseases in the latter group of animals.

MacIvor, K.M. De F. & Horak, I.G. 2003. Ixodid ticks of Angora and Boer goats, grysbok, common duikers, kudus and scrub hares in Valley Bushveld in the Eastern Cape Province. *Onderstepoort Journal of Veterinary Research*, 70: 113-120.

Onderstepoort Journal of Veterinary Research, 70:113–120 (2003)



Ixodid ticks of Angora and Boer goats, grysbok, common duikers, kudus and scrub hares in Valley Bushveld in the Eastern Cape Province, South Africa

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ABSTRACT

MACIVOR, K.M. DE F. & HORAK, I.G. 2003. Ixodid ticks of Angora and Boer goats, grysbok, common duikers, kudus and scrub hares in Valley Bushveld in the Eastern Cape Province, South Africa. *Onderstepoort Journal of Veterinary Research*, 70:113–120

At monthly intervals from February 1983 to January 1984 two Angora goats, two Boer goats, one grysbok, *Raphicerus melanotis*, one common duiker, *Sylvicapra grimmia*, one greater kudu, *Tragelaphus strepsiceros*, and four scrub hares, *Lepus saxatilis*, were killed on a farm in Valley Bushveld in the Eastern Cape Province, South Africa and examined for ticks. Seven ixodid tick species were collected, of which *Rhipicephalus glabroscutatum* followed by *Amblyomma hebraeum* and *Rhipicephalus oculatus* were the most numerous. *Amblyomma hebraeum* was mainly a parasite of the two goat breeds, with the Angora goats harbouring greater numbers than the Boer goats, while large numbers of *R. glabroscutatum* parasitized the goats and the antelopes. *Rhipicephalus oculatus* was nearly exclusively a parasite of scrub hares.

The larvae of *A. hebraeum* were most numerous on goats from May to July, the nymphs from September to November and the adults from August to December and during February, while the immature stages of *R. glabroscutatum* were most numerous on these animals from April to July and the adults from August to December. Peak activity periods of the latter tick were somewhat longer on kudus than on goats; the immature stages were most numerous from January to August and the adults from July to February. The larvae of *R. oculatus* were most numerous on scrub hares from March to May, nymphs from September to November and adults from October to December.

Keywords: Angora goats, Boer goats, common duikers, grysbok, ixodid ticks, kudus, scrub hares, seasonality, Valley Bushveld

INTRODUCTION

Angora and Boer goats are farmed extensively in the Valley Bushveld regions of the Eastern Cape Province, South Africa, and on many farms they are sympatric with various browsing antelope species, particularly greater kudus, *Tragelaphus strepsiceros*, and common duikers, *Sylvicapra grimmia*. The Valley Bushveld north of Uitenhage is an important goat farming area and, in addition, kudus and other antelope species are frequently hunted commercially as an extra source of income. A number of studies on the ticks infesting goats and kudus in Valley Bushveld as well as those infesting scrub hares, *Lepus saxatilis*, that are also present on nearly every farm, have already been published (Knight & Rechav 1978; Rechav 1982; Horak & Knight 1986; Horak & MacIvor 1987; MacIvor & Horak 1987; Horak & Fourie 1991; Horak, Knight & Williams 1991b; Horak, Boomker, Spickett & De Vos 1992).

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The present study was undertaken to determine the role that goats and wild animals might play in the maintenance of two tick species that impact negatively on goat farming in the Uitenhage region. These are *Amblyomma hebraeum*, the vector of *Ehrlichia (Cowdria) ruminantium*, the causative organism of heartwater in goats and other domestic and wild ruminants (Oberem & Bezuidenhout 1987), and *Rhipicephalus glabroscutatum*, whose adults are associated with foot abscess in goats (MacIvor & Horak 1987).

MATERIALS AND METHODS

Study area

The farm "Brakhill" (33°33'S, 25°25'E; Alt. 200–400 m), 25 km north of Uitenhage in the Eastern Cape Province, comprises approximately 4 000 ha of hilly country divided into 25 large and 45 small stock camps. Although it lies on the coastal plateau, it only receives approximately 300 mm of rain annually. The vegetation on the farm is typical Fish River scrub, which is considered by Acocks (1988) to be a subsection of Valley Bushveld, and has been described in detail in the publication by Boomker, Horak & MacIvor (1989) on the helminths infecting goats and antelopes on the farm.

A large camp, 355 ha in extent, was selected as the study site because of a reported annual mortality of 15 %, presumably due to heartwater, in goats kept in this camp. Approximately 2 000 Angora goats and 600 Boer goats were kept in camps on the farm, and numerous wild antelopes, that were not restricted by the internal fencing, inhabited the whole farm.

Survey animals

At monthly intervals from February 1983 to January 1984, two 2–3-year-old Angora goats and two similarly aged Boer goats, from a mixed flock of approximately 70 Angora and Boer goats running in the survey camp, were slaughtered. No acaricidal treatment had been applied to animals in the study camp for 2 years prior to the commencement of the survey and none was applied during its conduct. In addition one grysbok, *Raphicerus melanotis*, one common duiker, one kudu and four scrub hares were shot at night, wherever they could be found on the farm, in the same months as the goats were killed.

Tick recovery

The hides of the goats and antelopes were processed for tick recovery as described for kudus by Horak *et al.* (1992), and the scrub hares were processed as described by Horak, Sheppey, Knight & Beuthin (1986).

RESULTS AND DISCUSSION

The species and numbers of ticks collected from the Angora and Boer goats are summarized in Tables 1 and 2, and those from the antelopes and scrub hares in Tables 3–6. The seasonal occurrence of *A. hebraeum* and *R. glabroscutatum* on the two goat breeds is graphically illustrated in Fig. 1, and that of the latter tick on kudus and of *Rhipicephalus oculatus* on scrub hares in Fig. 2.

Seven ixodid tick species were collected from the survey animals, and all host species examined were infested with *A. hebraeum*, *Haemaphysalis silacea*, *Rhipicephalus evertsi evertsi*, *R. glabroscutatum* and *R. oculatus*. With the exception of scrub hares, on which it was the second most numerous species, *R. glabroscutatum* was the dominant species on all hosts and a total of 98 386 ticks was recorded. It was followed by *A. hebraeum*, which was the

TABLE 1 Ixodid ticks on 24 Angora goats on the farm "Brakhill", Eastern Cape Province

Tick species	Number collected					Proportional density (%)
	Larvae	Nymphs	Male	Female	Total	
Amblyomma hebraeum	10 059	1 770	295	92	12 216	31.71
Haemaphysalis silacea	150	29	11	2	192	0.50
Hyalomma truncatum	0	0	46	20	66	0.17
Rhipicephalus evertsi evertsi	24	81	8	8	121	0.31
Rhipicephalus glabroscutatum	13 226	11 099	953	635	25 913	67.26
Rhipicephalus oculatus	0	0	1	1	2	0.01
Rhipicephalus simus	0	0	7	7	14	0.04
Total	23 459	12 979	1 321	765	38 524	

TABLE 2 Ixodid ticks on 24 Boer goats on the farm "Brakhill", Eastern Cape Province

Tick species	Number collected					Proportional density (%)
	Larvae	Nymphs	Male	Female	Total	
Amblyomma hebraeum	5573	1348	114	70	7105	26.66
Haemaphysalis silacea	282	53	5	9	349	1.31
Hyalomma truncatum	0	0	6	9	15	0.06
Rhipicephalus evertsi evertsi	8	78	13	5	104	0.39
Rhipicephalus glabroscutatum	11 395	6 230	894	559	19 078	71.57
Rhipicephalus oculatus	0	0	0	1	1	0.004
Rhipicephalus simus	0	0	2	1	3	0.01
Total	17 258	7 709	1 029	649	26 655	

TABLE 3 Ixodid ticks on 12 grysbok on the farm "Brakhill", Eastern Cape Province

Tick species	Number collected					Proportional density (%)
	Larvae	Nymphs	Male	Female	Total	
Amblyomma hebraeum	260	40	0	0	300	3.81
Haemaphysalis silacea	40	32	2	0	74	0.94
Rhipicephalus evertsi evertsi	0	3	1	0	4	0.05
Rhipicephalus glabroscutatum	5 897	1 409	116	55	7 477	94.95
Rhipicephalus oculatus	0	16	3	1	20	0.25
Total	6 197	1 500	122	56	7 875	

TABLE 4 Ixodid ticks on 12 common duikers on the farm "Brakhill", Eastern Cape Province

Tick species	Number collected					Proportional density (%)
	Larvae	Nymphs	Male	Female	Total	
Amblyomma hebraeum	848	47	0	0	895	6.38
Haemaphysalis silacea	196	157	22	6	381	2.72
Hyalomma truncatum	0	0	1	0	1	0.007
Rhipicephalus evertsi evertsi	1	2	0	0	3	0.02
Rhipicephalus glabroscutatum	9 118	3 113	302	209	12 742	90.86
Rhipicephalus oculatus	1	0	1	0	2	0.01
Total	10 164	3 319	326	215	14 024	

TABLE 5 Ixodid ticks on 12 greater kudus on the farm "Brakhill", Eastern Cape Province

Tick species	Number collected					Proportional density (%)
	Larvae	Nymphs	Male	Female	Total	
Amblyomma hebraeum	1 064	29	1	1	1 095	3.11
Haemaphysalis silacea	673	325	403	16	1 417	4.03
Rhipicephalus evertsi evertsi	1	4	0	0	5	0.02
Rhipicephalus glabroscutatum	21 647	8 974	1 365	650	32 636	92.77
Rhipicephalus oculatus	16	0	5	4	25	0.07
Total	23 401	9 332	1 774	671	35 178	

TABLE 6 Ixodid ticks on 48 scrub hares on the farm "Brakhill", Eastern Cape Province

Tick species	Number collected					Proportional density (%)
	Larvae	Nymphs	Male	Female	Total	
Amblyomma hebraeum	125	29	0	0	154	2.48
Haemaphysalis silacea	32	32	0	0	64	1.03
Hyalomma truncatum	60	248	0	0	308	4.96
Rhipicephalus evertsi evertsi	4	0	0	0	4	0.07
Rhipicephalus glabroscutatum	435	102	3	0	540	8.69
Rhipicephalus oculatus	3 720	1 152	175	94	5 141	82.77
Total	4 376	1 563	178	94	6 211	

second most numerous species on goats, grysbok and duikers, and a total of 21 765 was recorded. *Haemaphysalis silacea* was the second most numerous species on kudus, while *R. oculatus* outnumbered all other species on the scrub hares.

Amblyomma hebraeum

Adult *A. hebraeum* prefers large animals as hosts (Horak, MacIvor, Petney & De Vos 1987), with male kudus at the lower end of the size scale and female kudus generally too small to be parasitized (Horak *et al.* 1992). Kudus are, however, excellent hosts of the immature stages of this tick and *A. hebraeum* was the dominant species on these animals in the Andries Vosloo Kudu Reserve to the north of Grahamstown in the Eastern Cape Province (Horak *et al.* 1992). The relatively small numbers of all stages of development, and particularly adults, collected from kudus in the current study could have been due to the regular acaricidal treatment of goats in all but the study camp, thus eventually leading to a reduced challenge.

A similar phenomenon has been recorded on kudus, scrub hares and helmeted guinea fowls, *Numida meleagris*, on the farm "Bucklands", north of Grahamstown, on which the domestic stock were regularly treated with an acaricide. As in the present study, only *A. hebraeum* and no other tick species appeared to be affected by the treatment regime on that farm (Horak & Knight 1986). Whereas the kudus in the present survey were shot wherever they were encountered on the farm, the goats came only from the study camp, in which no acaricide had been used for at least 2 years. Consequently the goats were the major, if not the only, potential host species in this camp, and it is thus not surprising that they were infested with large numbers of adult *A. hebraeum* despite their relatively small size.

The Angora goats harboured nearly twice as many larvae and more than twice the number of adult *A. hebraeum* as the Boer goats, while the numbers of nymphs on the two goat breeds were nearly the same. These differences may be due to differences in habitat utilization, immune status, efficiency of grooming by the two breeds, or host preference of the ticks. The fairly discrete peak in larval numbers on the goats from May to July indicates that this tick probably completes a single cycle annually, a finding similar to that on kudus in the Andries Vosloo Kudu Reserve (Horak *et al.* 1992). Nymphs were most numerous on the goats from September to November and adults from August to December and during February.

Haemaphysalis silacea

The distribution of *H. silacea* is limited to South Africa where it is confined to pockets of Valley Bushveld in the Eastern Cape Province and in north-eastern KwaZulu-Natal (Howell, Walker & Nevill 1978; Walker 1991). It has a wide host range (Rechav 1982; Horak & Knight 1986) and is adapted to surviving in humid valleys as well as in extremely hot and dry heavily bushed regions, such as the present study site. Kudus and other browsing tragelaphine antelope species appear to be the hosts of choice (Horak *et al.* 1992; Horak, Boomker & Flamand 1995).

Hyalomma truncatum

This tick is widespread and commonly encountered in drier inland regions (Howell *et al.* 1978), but is usually only present in small numbers in the southern coastal regions. Some of the goats and one of the duikers were infested with adult *H. truncatum*, while 11 of the 48 scrub hares were infested with the immature stages of this two-host species.

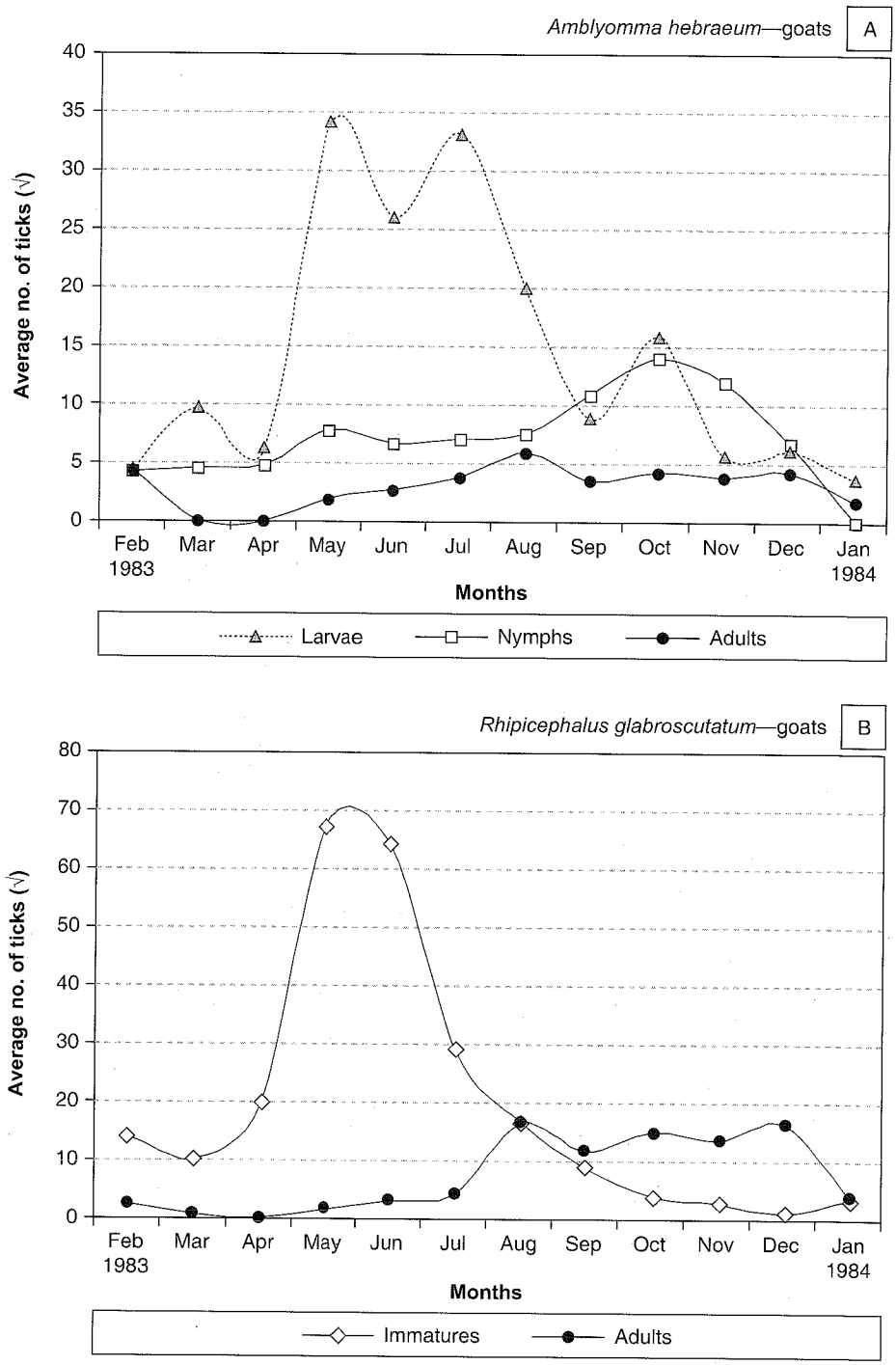

FIG. 1 The seasonal occurrence of [A] *Amblyomma hebraeum* and [B] *Rhipicephalus glabroscutatum* on Angora and Boer goats in Valley Bushveld in the Eastern Cape Province

Rhipicephalus evertsi evertsi

Although *R. evertsi evertsi* is very widely distributed on the African continent, particularly in the eastern regions, with the exception of on equids and on eland, *Taurotragus oryx*, it seldom occurs in large numbers (Walker, Keirans & Horak 2000). The small numbers recovered in this survey are not only an indication of the absence of preferred hosts, but also of the unsuitability of the habitat for a tick that is more common in regions receiving between 400 and 1 000 mm of annual rainfall.

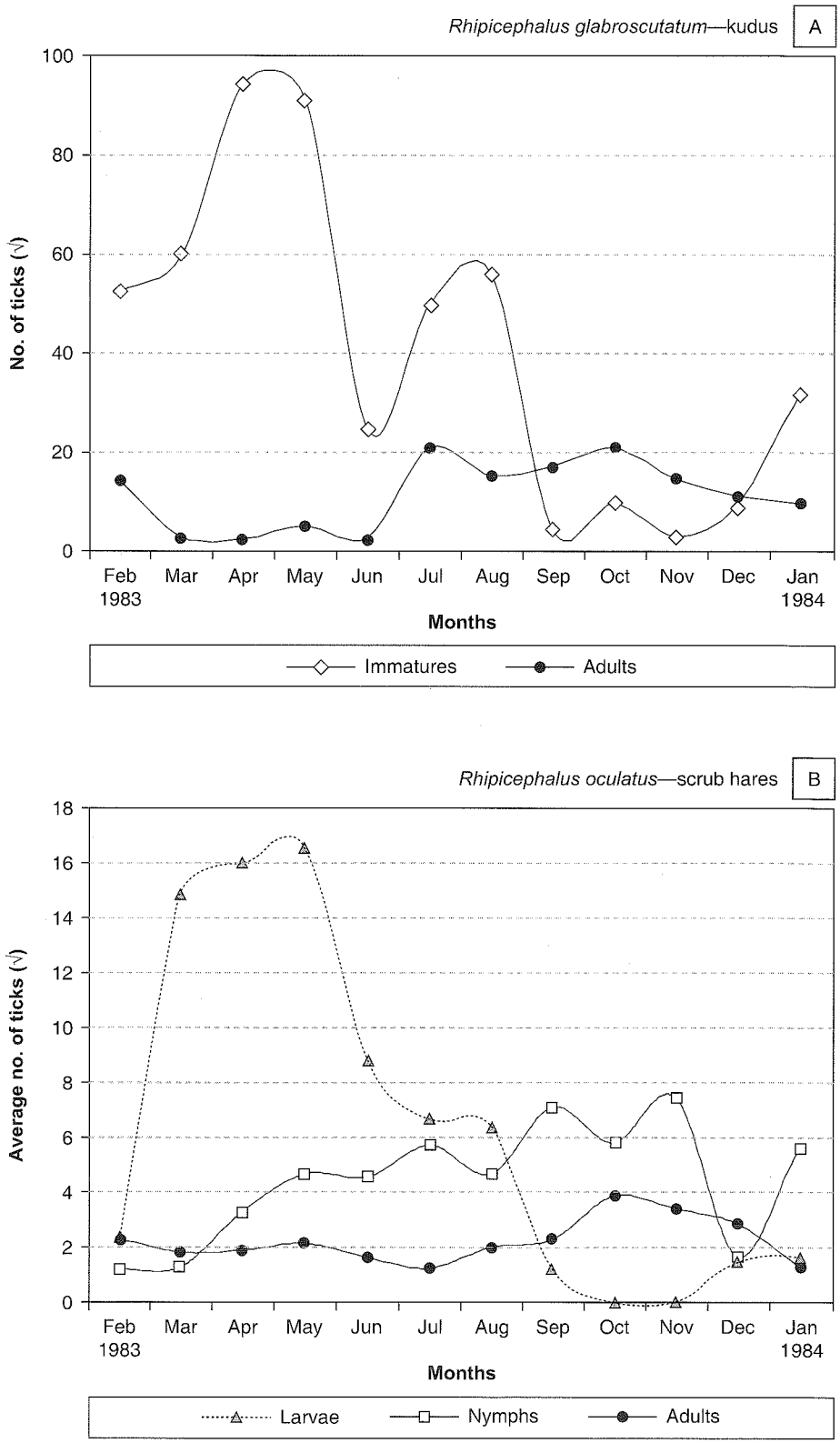

FIG. 2 The seasonal occurrence of [A] *Rhipicephalus glabroscutatum* on greater kudus, and [B] *Rhipicephalus oculatus* on scrub hares in Valley Bushveld in the Eastern Cape Province

Rhipicephalus glabroscutatum

This two-host tick occurs only in South Africa and is present in a broad southerly band extending from approximately the Andries Vosloo Kudu Reserve in the east (MacIvor 1985), to the Atlantic seaboard at Langebaan in the west (Walker *et al.* 2000). It is the dominant ixodid tick species in the study site and kudus are the host species of preference, with 12 of these animals harbouring more immature and more adult *R. glabroscutatum* than 24 goats of either breed, or than the combined burdens of the grysbok and duikers. The total numbers of larvae and adults harboured by the Angora and Boer goats did not differ substantially, but the Angora goats were infested with nearly twice as many nymphs as were the Boer goats, indicating a better translation of larvae to nymphs on the former than on the latter animals. Considerable numbers of larvae and nymphs have previously been collected from scrub hares in the Andries Vosloo Kudu Reserve and on the adjacent farm "Bucklands", as well as from scrub hares in the Mountain Zebra National Park (Horak & Fourie 1991; Horak, Fourie, Novellie & Williams 1991a).

The immature stages of *R. glabroscutatum* were most numerous on goats from April to July and the adults from August to December, while the peak activity periods of both the immatures and the adults were somewhat longer on the kudus, extending from January to August for the larvae and nymphs and July to February for the adults. Its seasonal occurrence on the goats and kudus was similar to that on Angora goats on the farm "Bucklands" and on kudus in the adjacent Andries Vosloo Kudu Reserve in the east of the tick's distribution range; on four antelope species in the Mountain Zebra National Park near Cradock in the north-east of its range; and on two antelope species in the Bontebok National Park, near Swellendam, in the south-west of its range (Horak *et al.* 1986; 1991a, b; 1992). All stages of development attach to the lower legs and around the hooves of their preferred ruminant hosts (MacIvor & Horak 1987). While no adult ticks were found between the hooves of the antelopes examined on "Brakhill", the goats frequently harboured large numbers. The spring to mid-summer increase in adult tick numbers is positively correlated with the occurrence of foot abscess in Angora and Boer goats on the survey farm "Brakhill". In fact, 49 abscessed feet were detected between July and December 1983 on ten Angora goats and ten Boer goats running in the same camp as the survey goats (MacIvor & Horak 1987), whereas no abscesses were encountered on the feet of any of the antelopes from which ticks were collected.

Rhipicephalus oculatus

Although this tick has in the past been confused with the more recently described *Rhipicephalus exophthalmos* (Keirans, Walker, Horak & Heyne 1993), its presence in the current survey was confirmed not only by its taxonomic features, but also by its preference in all stages of development for scrub hares. The recovery of some immature and adult *R. oculatus* from the goats and antelopes can possibly be ascribed to the large numbers present on the farm as evidenced by the burdens of the scrub hares. Few specimens of immature *R. exophthalmos* have ever been collected, and the adults, although found on scrub hares, equally prefer cattle, sheep, goats and kudus as hosts (Walker *et al.* 2000). We would, however, like to emphasize that we may still have made some mistakes when identifying adult *R. oculatus* on the goats, antelopes and hares as, at the time of the study, *R. exophthalmos* had not been described.

The peak in seasonal occurrence of *R. oculatus* larvae on the scrub hares from March to May, nymphs from September to November and adults from October to December is not unlike that recorded on scrub hares in the Andries Vosloo Kudu Reserve and in the Mountain Zebra National Park (Horak & Fourie 1991; Horak *et al.* 1991a).

Rhipicephalus simus

The preferred hosts of adult *R. simus* are carnivores, suids and equids, but domestic stock, and particularly cattle are also frequently infested. This tick is more prevalent in the moister eastern summer rainfall regions of the country than in the southern and western winter rainfall or semi-arid regions (Walker *et al.* 2000). Both the availability of preferred hosts and the unfavourable climate on "Brakhill" militated against its presence there.

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CHAPTER 8

CONTROL

Various authors have elucidated the tick species preferences of, and the numbers of ticks that oxpeckers, *Buphagus* spp., can consume, and the role that certain other birds may play as tick predators has also been reported. Here we mention the role of pale-winged starlings, *Onychognathus nabouroup* as opportunistic predators of ticks on Cape mountain zebras, *Equus zebra zebra* (Penzhorn & Horak 1989).

Fire is often used as a means of vegetation control or improvement, and it has frequently been suggested that fire will also control free-living ticks on the vegetation at the time of the burn. Some of our results, however, appear to indicate the converse (Spickett, Horak, Van Niekerk & Braack 1992; Horak, Gallivan, Spickett & Potgieter 2006b).

Zieger, Horak, Cauldwell, Uys & Bothma (1998c) demonstrated that the regular application of acaricides to domestic cattle on a mixed wildlife and stock farm in Zambia markedly reduced the numbers of certain tick species on impalas, *Aepyceros melampus*, as well as the numbers of questing ticks on the vegetation on the same farm. The rationale behind this approach is that because of their size, domestic cattle are good hosts of the adults of those tick species that normally infest them as well as several medium–sized and larger wildlife species. By regularly applying acaricides to cattle on a farm on which there is also wildlife, the majority of adult ticks on the property will be killed on the cattle, thus resulting in a marked reduction in the numbers of questing ticks, and particularly larvae, on the vegetation.

I counted and identified nearly all the ticks in the studies by Spickett *et al*. (1992) and Zieger *et al*. (1998c), and all the ticks in that by Horak *et al*. (2006b).

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Natural History Note

Starlings, mountain zebras and ticks

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Association between palewinged starlings *Onychognathus nabouroup* and Cape mountain zebras *Equus zebra zebra* was recorded in the Mountain Zebra National Park between April and November only, and then mainly during July and August (Penzhorn 1981, *Ostrich* 52: 63-64). It was suggested that starlings visited the zebras to glean ectoparasites. This occurred because the birds may be forced to exploit a marginal food source during the cold, dry winter months when the items which comprise their normal diet could be in short supply.

These mountain zebras harbour massive loads of ixodid ticks, particularly *Margaropus winthemi,* during winter (Horak, Knight & De Vos 1986, *Onderstepoort J. vet. Res.* 53: 127-152). Three zebras examined during July had a mean burden of 31 433 *M. winthemi* (range: 25 684 — 37 847) consisting of all developmental stages attached mainly to their necks, backs and sides. At the same time the zebras also harboured a mean burden of 1 166 ixodid ticks of other species. The predilection sites of attachment of the latter ticks are the inner thighs, ear canals, under the tail and around the hooves. Thus they would not have been readily accessible to the starlings, which alighted on the back or rump of a zebra, fluttered down the flanks of the animal or proceeded to the mane or base of the tail before flying off. Five zebras examined during the summer months (December, February and March) had a mean burden of 1 951 ticks (range: 366 — 4 350), of which fewer than 15 were *M. winthemi.* Gleaning ticks from zebras in winter could therefore be a rewarding strategy for starlings.

Large numbers of both immature and adult *Rhipicephalus evertsi mimeticus* have been recovered from Hartmann's mountain zebras *Equus zebra hartmannae* in Namibia (Horak, Biggs & Reinecke 1984, *Onderstepoort J. vet. Res.* 51: 183-187). The predilection sites of attachment of the adults of this species are the perianal area and the inner thighs. Joubert (1972, *Madoqua Ser. I* 6: 17-56) reported both palewinged starlings and forktailed drongos *Dicrurus adsimilis* associating with Hartmann's mountain zebras. The birds would alight on a zebra's back, run towards the tail and, while perched there, "pick off the ticks around the anus".

Although stomach contents of palewinged starlings have not, as far as we could ascertain, been analysed, the difference in behaviour between starlings in the Mountain Zebra National Park and those observed in Namibia strongly suggests that they are, in fact, gleaning ticks.

Onderstepoort J. vet. Res., 59, 285–292 (1992)

THE EFFECT OF VELD-BURNING ON THE SEASONAL ABUNDANCE OF FREE-LIVING IXODID TICKS AS DETERMINED BY DRAG-SAMPLING

A. M. SPICKETT[1], I. G. HORAK[2], ANDREA VAN NIEKERK[1] and L. E. O. BRAACK[3]

ABSTRACT

SPICKETT, A. M., HORAK, I. G., VAN NIEKERK, ANDREA & BRAACK, L. E. O., 1992. The effect of veld-burning on the seasonal abundance of free-living ixodid ticks as determined by drag-sampling. *Onderstepoort Journal of Veterinary Research*, 59,285–292 (1992)

A supervised veld-burn in the *Sclerocarya caffra/Acacia nigrescens* Savanna landscape zone in the south-eastern region of the Kruger National Park was carried out during September 1988. The effect of the fire on the free-living tick population was determined by comparing the numbers of ticks collected by monthly drag-sampling in the burnt zone with those collected in an adjacent unburnt zone over a 2-year period. A total of 13 ixodid tick species were involved.

Tick numbers were reduced after the burn but rose again after varying periods of time. The length of these periods depended upon a number of variables. These included tick species, patterns of seasonal abundance, and host preferences. The original reduction in numbers seemed to result in subsequent cyclical population fluctuations and in some instances overcompensation was noted.

Veld-burning as a control technique may be effective with tenuously adapted tick species or reduced populations and may be enhanced by the exclusion of major hosts for a critical period after the fire.

INTRODUCTION

The value of veld-burning as a means of controlling tick populations has mostly been a matter of conjecture and its use to date mainly haphazard. Theiler (1959, 1969), theorized that veld-burning does not destroy the developing stages but rather increases environmental exposure, resulting in shortened developmental periods. Minshull & Norval (1982) found that fire affected the distribution of all tick stages because of the increased density of grazing herbivores on recently burnt areas. Traditional winter burning practised by farmers to encourage new growth, does not coincide with the seasonal activity periods of the questing stages of most ixodid ticks (Norval, 1977). This, coupled with the environmental harm caused by winter burning according to agronomists, has resulted in the practice generally being considered an unsuccessful biological control measure for ticks (Galun, 1978).

The scientifically planned, routine, supervised veld-burning of certain regions in the Kruger National Park, eastern Transvaal Lowveld, presented an opportunity to monitor the long-term effect of fire on the questing stages of ticks compared to those on an adjacent unburnt area.

MATERIALS AND METHODS

Study site

The study was carried out in the extreme south of the *Sclerocarya caffra/Acacia nigrescens* Savanna zone (Landscape Zone 17 of Gertenbach, 1983) of the Kruger National Park. A full description of the geomorphology, climate, soil and vegetation patterns of this region has been provided by Gertenbach (1983). Generally it is an open, tree savanna with a moderate shrub and dense grass layer. The study site lies within an area described as tropical with an above average rainfall for this zone, i.e. the long term average for the nearest station, Crocodile Bridge, is 599,6 mm. The study site encompassed an area approximately 20 × 10 km in extent (25° 10′–25° 21′ S and 32° 02′–32° 05′ E), along the Nhlowa tourist road, between Crocodile Bridge in the south and Lower Sabie in the north. The southern portion of this area, immediately to the west of the road, was subjected to a total veld-burn during the second week of September 1988. The northern portion of the area, to the east of the road, was utilized as the unburnt control zone. The burnt and unburnt zones displayed no obvious differences in topography or vegetation.

Tick collection

Ticks questing on the vegetation were collected by drag-sampling (Zimmerman & Garris, 1985; Petney & Horak, 1987). A detailed description of our collection method is given in Spickett, Horak, Braack & Van Ark (1991). In addition a 95 mm long steel rod was sewn into the end of each flannel drag strip to aid in keeping these down on the vegetation while dragging, and flannel leggings were also worn. The latter consisted of 2 flannel strips, sewn together at the waist, and covering the front of the drag operator from the waist to the ankles. The leggings were tied to the operator at the waist, knees and ankles and provided an additional surface for the attachment of questing ticks while the drag strips were being pulled through the vegetation.

Three drags were performed in each of 3 representative subzones within both the burnt and unburnt zones. These subzones were open grassland, gully and woodland. The collections were usually made on the same day in the first week of each calendar month, commencing in August 1988,

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TABLE 1 The total number of ticks recovered over a 2-year monitoring period from the vegetation of a burnt and an unburnt zone in the Kruger National Park

	Larvae	Nymphs	Males	Females	Total
Burnt zone					
Amblyomma hebraeum	10 979	13	0	0	10 992
Amblyomma marmoreum	11	0	0	0	11
Boophilus decoloratus	5 395	0	0	0	5 395
Haemaphysalis leachi	14	0	22	12	48
Rhipicephalus appendiculatus	2 810	87	9	6	2 912
Rhipicephalus evertsi evertsi	1 233	0	0	0	1 233
Rhipicephalus simus	1	2	6	11	20
Rhipicephalus turanicus	0	0	2	4	6
Rhipicephalus zambeziensis	229	5	0	0	234
Totals	20 672	107	39	33	20 851
Unburnt zone					
Amblyomma hebraeum	27 608	11	0	0	27 619
Amblyomma marmoreum	58	1	0	0	59
Boophilus decoloratus	5 405	0	0	0	5 405
Haemaphysalis leachi	7	1	9	8	25
Haemaphysalis sp.	1	0	0	0	1
Hyalomma truncatum	4	0	0	0	4
Ixodes sp.	0	1	0	0	1
Rhipicephalus appendiculatus	7 477	93	6	5	7 581
Rhipicephalus evertsi evertsi	352	0	0	0	352
Rhipicephalus maculatus	0	1	0	0	1
Rhipicephalus simus	1	0	13	21	35
Rhipicephalus turanicus	0	0	6	2	8
Rhipicephalus zambeziensis	116	20	0	0	136
Totals	41 029	128	34	36	41 227

for a period of 2 years. A controlled, hot veld-burn of the designated zone, to burn off the existing dense vegetation layer, was supervised by National Parks Board staff after the September 1988 drags had been completed in both study areas.

Ticks collected monthly in the subzones from the flannel drag strips plus the leggings were identified and totalled separately for the burnt and unburnt zones. These counts were transformed [Log_{10} (x + 1)] and, where applicable, differences between monthly collections were analysed using the non-parametric Wilcoxon paired observation test (Petney, Van Ark & Spickett, 1990). Each monthly total therefore represents questing ticks recovered from 9 drags in each zone.

RESULTS

The collection method used favours the recovery of larvae (Spickett *et al.*, 1991) although nymphs and/or adults of some species were consistently recovered. The tick species and total numbers recovered from the vegetation of the burnt and unburnt zones of the study area during the 2-year monitoring period are summarized in Table 1.

In total, 13 tick species were collected, the unburnt zone yielding small numbers of 4 species not recovered in the burnt zone. These were *Haemaphysalis* sp. (1 larva), *Hyalomma truncatum* (4 larvae), *Ixodes* sp. (1 nymph) and *Rhipicephalus maculatus* (1 nymph). Of the remaining 9 species, 6 were more numerous in the unburnt zone than in the burnt zone, some significantly so and others only marginally. The 3 species which were more numerous in the burnt than in the unburnt zone were *Haemaphysalis leachi, Rhipicephalus evertsi evertsi* and *Rhipicephalus zambeziensis.*

In the burnt zone the order of predominance of the species (and developmental stage recovered) was, *Amblyomma hebraeum* (larvae) followed by *Boophilus decoloratus* (larvae), *Rhipicephalus appendiculatus* (larvae), *R. evertsi evertsi* (larvae), *R. zambeziensis* (larvae), *H. leachi* (adults), *Rhipicephalus simus* (adults), *Amblyomma marmoreum* (larvae) and *Rhipicephalus turanicus* (adults). In the unburnt zone this order was *A. hebraeum* (larvae), *R. appendiculatus* (larvae), *B. decoloratus* (larvae), *R. evertsi evertsi* (larvae), *R. zambeziensis* (larvae), *H. leachi* (adults), *A. marmoreum* (larvae), *R. simus* (adults) and *R. turanicus* (adults). The burnt zone yielded about half the total number of ticks recovered in the unburnt zone.

The monthly total numbers of ticks (irrespective of species) collected from the burnt and unburnt zones are graphically illustrated in Fig. 1. An initial drop in

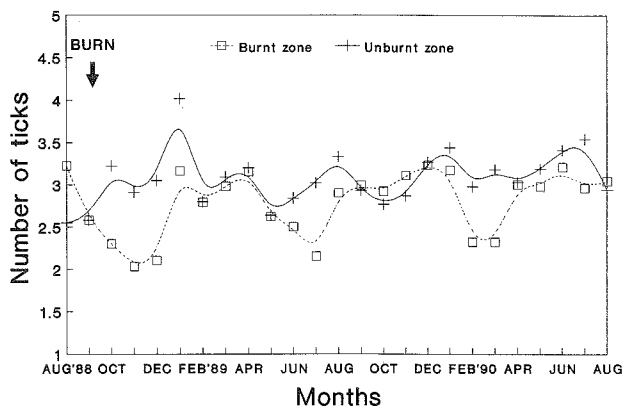

FIG. 1 The monthly total numbers of ticks [Log_{10} (x+1)] recovered by means of drag-sampling from a burnt and unburnt zone in the Kruger National Park. The burn took place in September 1988, after the second monthly drag

numbers occurred in the burnt zone immediately after the fire. These started to increase 4 months later and reached levels similar to those in the unburnt zone 5 months after the burn. However, cyclic declines in tick numbers in the burnt zone occurred at 10 and 17 months and a marginal overcompensation at 13 months after the burn. Paired analysis of monthly collections showed the total number of ticks collected in the burnt zone to be significantly less than in the unburnt zone (P=0,005; T=52,0).

The numbers of *A. hebraeum* larvae recovered are illustrated in Fig. 2. No change in numbers was recorded in the burnt zone 1 month after the fire, while those in the unburnt zone rose sharply. Thereafter the fluctuations in larval numbers paralleled each other with the totals in the 2 zones being nearly equal 6 and 7 months after the burn. This was followed by 4 sharp declines in larval numbers interspersed by short periods of recovery in the burnt zone. The initial reduction in numbers coupled with these declines resulted in less than half the number of *A. hebraeum* larvae being recovered from the burnt zone than from the unburnt zone (Table 1). Paired analysis of monthly collections indicated larval numbers in the burnt zone to be significantly less than in the unburnt zone (P=0,009; T=65,0).

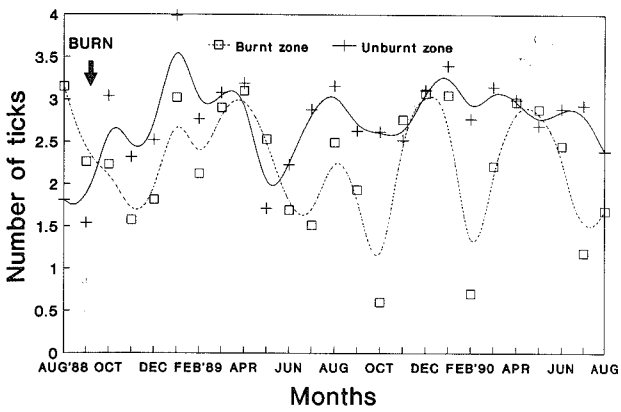

FIG. 2 The monthly total numbers of *Amblyomma hebraeum* larvae [Log_{10} (x+1)] recovered by means of drag-sampling from a burnt and unburnt zone in the Kruger National Park. The burn took place in September 1988, after the second monthly drag

In the burnt zone, *A. marmoreum* larvae were recovered in August 1988 before the burn and only again in January, April and June 1990, 16–21 months after the burn. In the unburnt zone larvae were active from March–September 1989 and from March–June 1990 (Fig. 3). The numbers of larvae recovered from the burnt zone during the 2-year monitoring period were significantly less than in the unburnt zone on paired analysis of monthly collections (P=0,021; T=9,5).

B. decoloratus larvae declined sharply in the burnt zone immediately after the burn and increased equally rapidly to nearly equal the number of those in the unburnt zone within only 4 months (Fig. 4). A 3

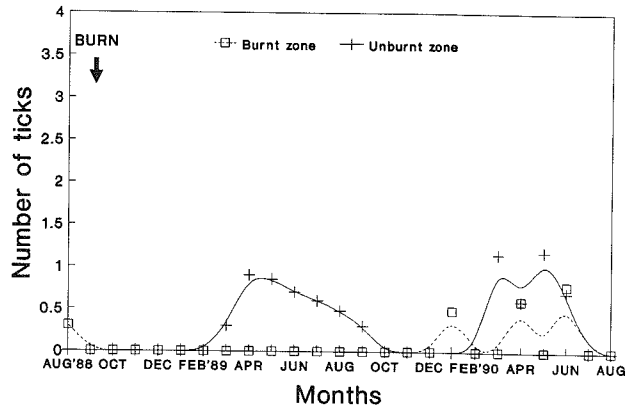

FIG. 3 The monthly total numbers of *Amblyomma marmoreum* larvae [Log_{10} (x+1)] recovered by means of drag-sampling from a burnt and unburnt zone in the Kruger National Park. The burn took place in September 1988, after the second monthly drag

month period of overcompensation followed this recovery in the burnt zone, while larval numbers in the unburnt zone underwent a seasonal decline. The subsequent decline in larval numbers in the burnt zone reached its lowest level 4 months after that in the unburnt zone. The increase in larval numbers following this decline was more rapid in the burnt than in the unburnt zone. Overcompensation resulted in peak abundance 2 months prior to that in the unburnt zone. After this, larval numbers in both zones stabilized and for approximately 6 months remained similar though fewer were recovered in the burnt zone. Larvae in the latter zone displayed another peak during June 1990, 21 months after the burn had taken place. A total of only 10 fewer *B. decoloratus* larvae were recovered from the vegetation of the burnt zone than that of the unburnt zone (Table 1). Despite the fluctuations in the numbers recovered monthly (Fig. 4), paired analysis showed no significant difference between the burnt and unburnt zones (P=0,542; T=139,5).

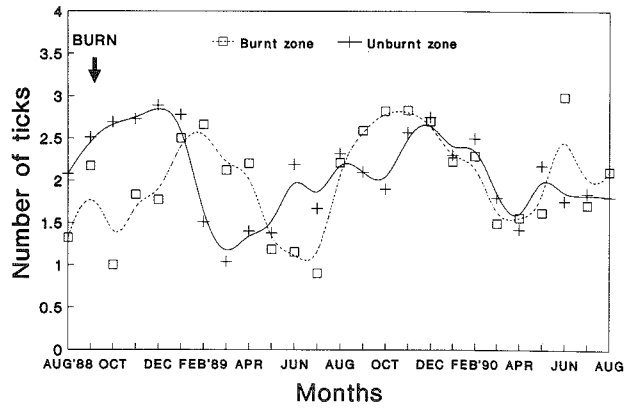

FIG. 4 The monthly total numbers of *Boophilus decoloratus* larvae [Log_{10} (x+1)] recovered by means of drag-sampling from a burnt and unburnt zone in the Kruger National Park. The burn took place in September 1988, after the second monthly drag

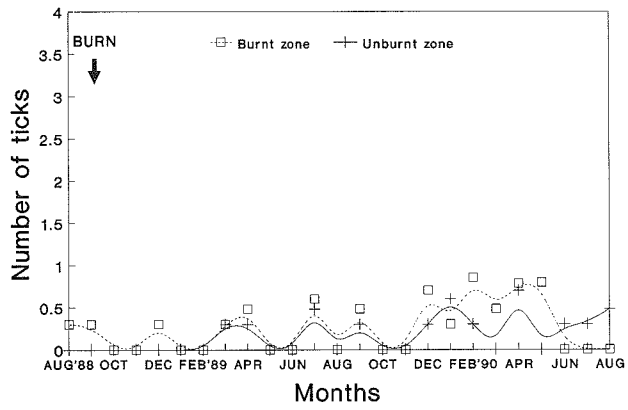

FIG. 5 The monthly total numbers of *Haemaphysalis leachi* adults [Log_{10} (x+1)] recovered by means of drag-sampling from a burnt and unburnt zone in the Kruger National Park. The burn took place in September 1988, after the second monthly drag

Cyclic variations in the small numbers of adult *H. leachi* recovered were evident in both the burnt and unburnt zones (Fig. 5). Slightly more adults were recovered in the burnt zone, especially during the second year of observation. These numbers were considered too small for meaningful analysis.

The larvae of *R. appendiculatus* were in a seasonal population decline at the time of the burn and no effect on larval numbers or seasonal activity was evident (Fig. 6). In both burnt and unburnt zones the larval activity period spanned 8 months, from April to November 1989. Peak abundances were recorded during May or June to August 1989, and activity commenced again in March or April 1990 and peaked in July. The numbers of larvae recovered from the burnt zone were consistently, as well as significantly less than those from the unburnt zone (P=0,0028; T=16,5).

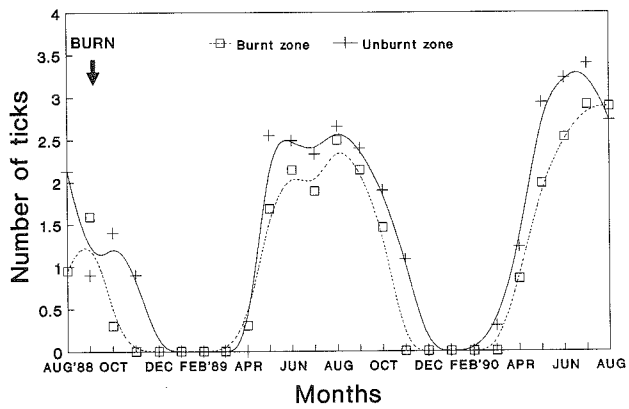

FIG. 6 The monthly total numbers of *Rhipicephalus appendiculatus* larvae [Log_{10} (x+1)] recovered by means of drag-sampling from a burnt and unburnt zone in the Kruger National Park. The burn took place in September 1988, after the second monthly drag

Small numbers of *R. appendiculatus* nymphs were recovered from both burnt and unburnt zones (Table 1). A marked decline in nymphal numbers was evident immediately after the burn in the burnt zone. However, nymphal activity in this zone continued for 2 months thereafter and ended only 2 months prior to that in the unburnt zone (Fig. 7). Subsequent resumption of nymphal activity occurred marginally sooner in the burnt zone than in the unburnt zone and reached slightly higher numbers, but with a shorter period of peak abundance. The unburnt zone yielded only 6 more nymphs in total than the burnt zone and paired analysis of monthly collections indicated no significant difference in the numbers recovered (P=0,465; T=76,5).

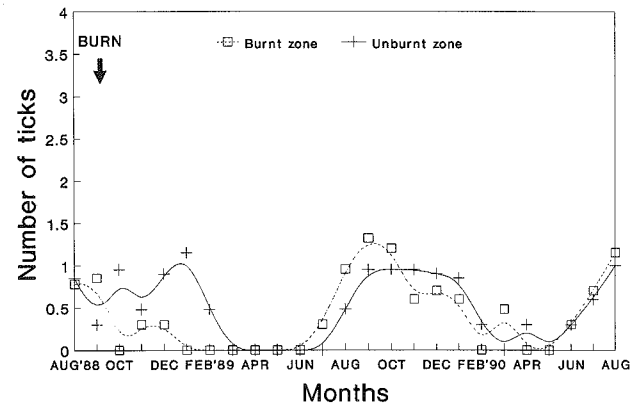

FIG. 7 The monthly total numbers of *Rhipicephalus appendiculatus* nymphs [Log_{10} (x+1)] recovered by means of drag-sampling from a burnt and unburnt zone in the Kruger National Park. The burn took place in September 1988, after the second monthly drag

R. appendiculatus adults, although present in the unburnt zone, were not collected in the burnt zone until 7 months after the burn had taken place (Fig. 8). Thereafter adults were collected in low numbers in this zone for 2 months only, before their seasonal

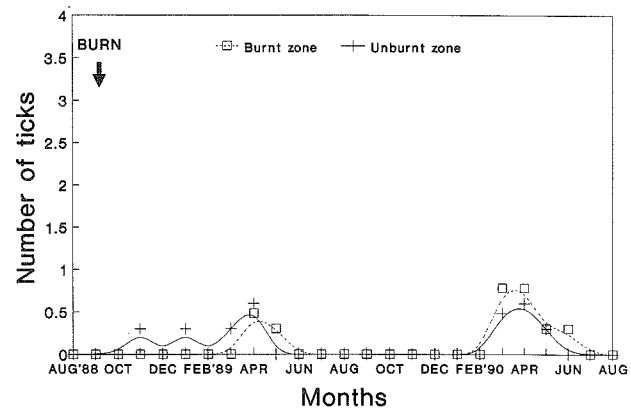

FIG. 8 The monthly total numbers of *Rhipicephalus appendiculatus* adults [Log_{10} (x+1)] recovered by means of drag-sampling from a burnt and unburnt zone in the Kruger National Park. The burn took place in September 1988, after the second monthly drag

decline in June 1989. Adult activity resumed in both zones from March to May or June of the next year. The numbers collected were too low for meaningful analysis of differences.

R. evertsi evertsi displayed cyclic activity throughout the monitoring period with no definite pattern of seasonal abundance (Fig. 9). No larvae were recovered in the burnt zone in September 1988 immediately preceding the burn. Their numbers increased thereafter to reach numbers similar to those in the unburnt zone within 4 months. A cyclic 2-month pattern of high and low numbers followed, similar to that in the unburnt zone but with larger fluctuations. Consistently higher numbers of larvae were recovered from the burnt than from the unburnt zone during the period September 1989 to January 1990 (12 to 16 months after the burn) and again from April 1990 to August 1990 (19 to 23 months after the burn) (Fig. 9). This resulted in approximately 4 times more *R. evertsi evertsi* larvae being recovered from the burnt than from the unburnt zone (Table 1). Paired analysis of monthly collections, however, showed no significant differences in larval numbers between the 2 zones (P=0,200; T=114,5).

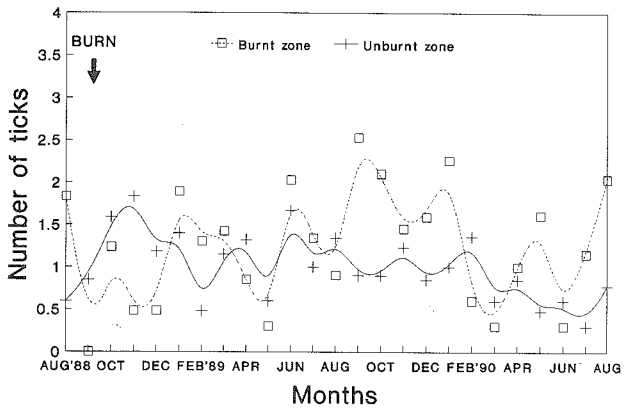

FIG. 9 The monthly total numbers of *Rhipicephalus evertsi evertsi* larvae [Log_{10} (x+1)] recovered by means of drag-sampling from a burnt and unburnt zone in the Kruger National Park. The burn took place in September 1988, after the second monthly drag

Low numbers of *R. simus* adults were present from December or January to May in both years, in both the burnt and unburnt zones (Fig. 10). The burn seemed to have some effect in that no adults were collected in the burnt zone during the earlier portion of the first activity period (up to 7 months after the burn). The second activity period (16 months after the burn) appeared to be shorter in the burnt than in the unburnt zone. The numbers of adults collected were too low for meaningful analysis.

The numbers of adult *R. turanicus* recovered in both zones were too low to permit meaningful analysis.

The larval population of *R. zambeziensis* was in a period of seasonal decline at the time of the burn (Fig. 11). The burn therefore had very little effect

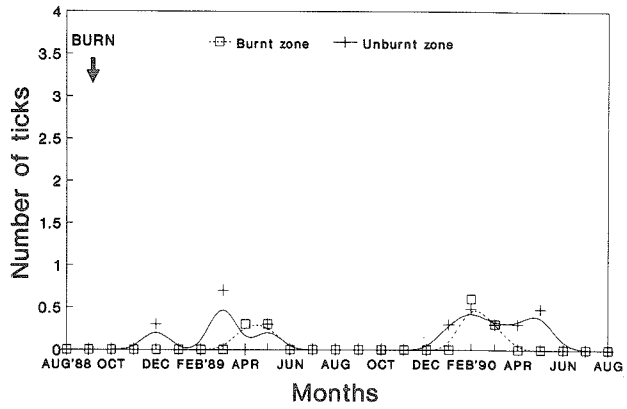

FIG. 10 The monthly total numbers of *Rhipicephalus simus* adults [Log_{10} (x+1)] recovered by means of drag-sampling from a burnt and unburnt zone in the Kruger National Park. The burn took place in September 1988, after the second monthly drag

except perhaps that larval activity was less pronounced during the subsequent activity period May 1989 to September 1989 (8 to 12 months after the burn). Larval numbers had stabilized by the next season, in which activity commenced during May 1990 (20 months after the burn) and lasted till the end of the monitoring period. Paired analysis of monthly collections revealed no significant difference in larval numbers between the 2 zones (P=0,726; T=24,0).

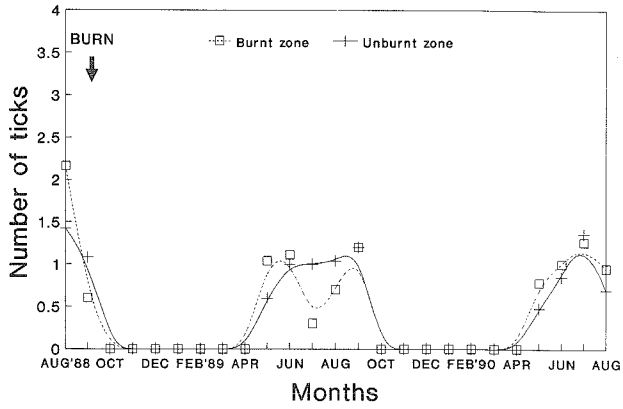

FIG. 11 The monthly total numbers of *Riphicephalus zambeziensis* larvae [Log_{10} (x+1)] recovered by means of drag-sampling from a burnt and unburnt zone in the Kruger National Park. The burn took place in September 1988, after the second monthly drag

R. zambeziensis nymphs were recovered from the burnt zone before and in the month immediately after the burn (Fig. 12). Thereafter none were found for the remainder of the monitoring period. In contrast, *R. zambeziensis* nymphs recovered from the unburnt zone, albeit in low numbers, displayed activity over the winter and spring months, from August to November 1989. Although adults of *R. zambeziensis* have previously been collected in other land-

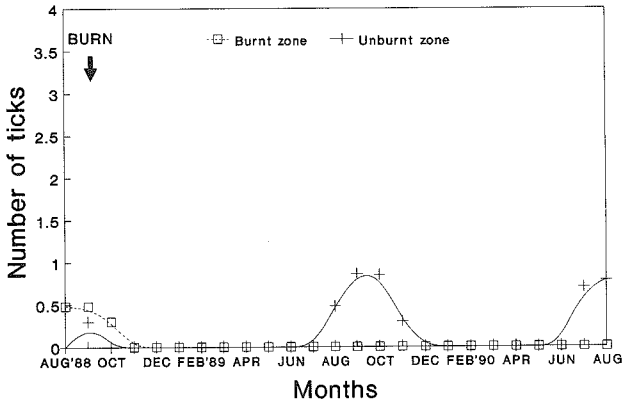

FIG. 12 The monthly total numbers of *Rhipicephalus zambeziensis* nymphs [Log_{10} (x+1)] recovered by means of drag-sampling from a burnt and unburnt zone in the Kruger National Park. The burn took place in September 1988, after the second monthly drag

scape zones using the same sampling technique (Spickett *et al.*, 1991), no adults were recovered in this study from the burnt or unburnt zones.

DISCUSSION

It could be expected that a hot veld-fire would destroy virtually all free-living tick stages present at the time. However, even the first drags after the burn, which were conducted after a 3-week interval, yielded ticks from the vegetation of the burnt zone. The larvae present on these first drags must have survived the burn or have hatched within the 3-week interval from eggs that were present at the time of the burn. The relatively short period of 4–5 months for the recovery of the free-living tick population as a whole in the burnt zone, after its initial decline, also indicates that some eggs and perhaps even engorged females had survived the effects of the fire. The initial reduction caused by the burn did, however, affect overall tick numbers in that 2 further cyclic declines were evident in the burnt zone, 10 and 17 months after the fire, resulting in significantly fewer ticks being recovered from this zone than from the unburnt zone.

The effects of the burn on the total tick population are largely a reflection of its effects on the 3 major species viz., *A. hebraeum, B. decoloratus* and *R. appendiculatus.* These and *R. evertsi evertsi* and *A. marmoreum,* were the most drastically affected in respect of numbers recovered or seasonal activity. The increase in larval numbers of *A. hebraeum* and *B. decoloratus,* after their initial decline in the burnt zone, is probably a result of exposure of their eggs to higher temperatures after removal of the vegetation layer and hence more rapid hatching. The overcompensation in the number of *B. decoloratus* larvae exhibited in the fifth to seventh month after the burn, is most likely due to the relatively early hatch of eggs from engorged females, detached from hosts which had been attracted to the burnt zone by new growth, 2 to 5 months previously. Because of the absence of vegetation cover, soil surface temperatures would have been higher and oviposition and egg hatch could have been completed within the space of 2 months (Robertson, 1981; Spickett & Heyne, 1990). The continued attraction of herbivores to the new growth in this zone during the following months would have contributed more engorged female *B. decoloratus.* The increased protection afforded to these females by the developing vegetation cover, as well as the onset of winter would delay oviposition and consequently egg development. The synchronous hatching of these eggs in spring (Robertson, 1981; Spickett & Heyne, 1990), could account for the next period of overcompensation in larval numbers from September to November 1989, 12 months after the burn.

The same host attraction effect is evident in the higher numbers of *R. evertsi evertsi* recovered from the burnt zone during the latter portion of the monitoring period. Grazers utilizing long grass would have frequented the burnt zone only after an extended period of recovery of the vegetation layer. The increased presence of these animals and particularly zebras, which are the preferred hosts of *R. evertsi evertsi* (Horak, De Vos & De Klerk, 1984), in the burnt zone some time after the fire would have resulted in many engorged females being dropped and consequently an increase in larvae during the second half of the monitoring period. The greater number of adult *H. leachi* in the burnt zone compared with the unburnt zone during the latter portion of the monitoring period can possibly be ascribed to carnivores, which are the preferred hosts of this stage (Horak, Jacot Guillarmod, Moolman & De Vos, 1987), following the grazers into the zone with the development of new growth in the previous year.

An opposite effect of the burn on the hosts and hence on tick numbers is clearly illustrated in the case of *A. marmoreum.* Larvae were recovered in the burnt zone for the first time 16–21 months after the burn, whereas activity occurred in the unburnt zone 4–10 months earlier and also during the 18–21 month period after the burn had taken place. The preferred hosts of *A. marmoreum* adults are tortoises (Norval, 1975). Many of these were probably destroyed in the fire and, judging by larval activity, only moved back into the zone approximately 10–12 months later. These is, however, another explanation for this phenomenon. All parasitic stages of *A. marmoreum* may spend several months on their tortoise hosts (Dower, Petney & Horak, 1988), and hence the life-cycle may be longer than 1 year. Any disruption of this life-cycle, such as the destruction of the free-living stages by fire, might therefore result in a period of a year or more for the cycle to be rectified.

The normal seasonal fluctuations of the various life stages of the tick populations at the time of the burn also played a role in the direct or long-term effect of the fire. In contrast to *A. hebraeum* and *B. decoloratus,* the larval populations of both *R. appendiculatus* and *R. zambeziensis* were in a state of seasonal decline at the time of the burn. The fire to a small extent accellerated this decline and also indirectly reduced larval numbers of *R. appendiculatus* during the subsequent activity periods. However,

the onset of the subsequent larval activity period of both species was not affected. The effect of the burn on the nymphs of the latter 2 ticks was direct at the time of the burn. This and the direct effect on the larvae at the same time affected both subsequent nymphal activity and numbers and the nymphs of *R. zambeziensis* disappeared entirely from the burnt zone. The absence of adult *R. appendiculatus* during their normal activity period after the burn was probably a consequence of the free-living nymphs being destroyed by the fire. No adult *R. zambeziensis* were collected from either zone during the monitoring period.

The large numbers of *R. appendiculatus* compared to the small numbers of *R. zambeziensis* recovered from both burnt and unburnt zones, indicate that the former species is ecoclimatically favoured in this landscape zone, while the presence of the latter is tenuous. The fire thus affected the less secure species to a greater extent resulting in the disappearance of *R. zambeziensis* nymphs from the burnt zone. Adult *R. simus,* like adult *R. appendiculatus,* appear to be affected only directly after the burn with a minimal, if any, effect on numbers during the second activity period. The virtual absence of the immature stages of both *R. simus* and *H. leachi* on the drags can be ascribed to their questing behaviour. Both prefer rodents during these stages of development (Norval, 1984: Hussein & Mustafa, 1985) and would hence be unlikely to quest from vegetation.

The presence of 4 additional tick species in the unburnt zone is probably unrelated to the effects of veld-burning. The recovery of only 4 *H. truncatum* larvae, despite their occurrence in large numbers on scrub hares in the Park (Horak & Spickett, unpublished data), confirms the inability of the sampling technique employed to adequately monitor this species (Spickett *et al.,* 1991). The collection of a nymph of *R. maculatus* is surprising as its distribution is confined to the coastal regions of northern Natal (Walker, 1991). This species could have been introduced into the Kruger National Park with hosts transferred to the Park from Zululand. Its subsequent establishment in the Park has been confirmed by the recent recovery of a male and an engorged female from an elephant in the Park (L.E.O. Braack, unpublished data).

The temporary and generally short-lived reductions in tick populations recorded after the fire in the present study, indicate little practical benefit from veld-burning during spring as a method of tick control. The effects of fire are influenced by the developmental status of the tick population at the time of the burn, subsequent host influx or exclusion from the burnt area, and the ecoclimatic suitability of the region for tick species. The technique may, however, be effective if aimed at specific tick species, either tenuously adapted to an area or with populations already reduced by chemical control. Efficacy could be enhanced by the exclusion of major hosts for a critical period after the burn to prevent or delay population recovery, a strategy advocated by Minshull & Norval (1982).

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The effect of chemical tick control on cattle on free-living ixodid ticks and on ticks parasitic on sympatric impala in the Central Province, Zambia

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Cattle on a mixed cattle and wildlife farm in the Central Province of Zambia were regularly treated with acaricides. This resulted in a reduction in the abundance of certain free-living ixodid ticks on the vegetation, and of ticks parasitic on sympatric impala *Aepyceros melampus* when compared with a neighbouring ranch where only game is kept and no chemical control is practised. The ticks most severely affected by chemical control were *Amblyomma variegatum*, *Rhipicephalus appendiculatus* and *Rhipicephalus evertsi evertsi*. *Boophilus decoloratus* appeared to be unaffected, possibly because of acaricidal resistance. Some tick control measures on wildlife are discussed.

Key words: free-living ticks, parasitic ticks, impala, tick control, acaricides, Zambia

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Introduction

Tick infestation of wild animals is considered a constraint to successful game ranching as it may lead to production losses and even deaths (Horak 1980; Lightfoot & Norval 1981). Ticks can affect their hosts directly or indirectly by causing tick toxicosis, metabolic disturbances, anaemia or tick worry (O'Kelly & Seifert 1969). Tick-bite wounds can become secondarily infected with bacteria or other organisms. Infestation of these wounds with maggots of the familiy Calliphoridae is particularly damaging to the host (Lightfoot & Norval 1981). Various blood parasites can be transmitted by ticks and have been incriminated as the cause of death in buffalo *Syncerus caffer* (Lightfoot & Norval 1981), eland *Taurotragus oryx* (Young & Basson 1973), sable antelope *Hippotragus niger* (Grobler 1981), waterbuck *Kobus ellipsiprymnus* (Lightfoot & Norval 1981) as well as Kafue lechwe *Kobus leche kafuensis* (Pandey, Minyoi, Hasebe & Mwase 1992). Although wild animals endemic to a specific region are usually not greatly affected by the tick-borne blood parasites present in that region, introductions of hosts and/or ticks into non-endemic areas through wildlife translocation operations can lead to severe losses amongst susceptible animals (Lightfoot & Norval 1981; Meltzer 1993).

Chemicals are widely used to control ticks on domestic livestock. The use of cattle that are regularly treated with acaricides has been suggested as a means of controlling tick numbers on sympatric wild animals (Horak 1980; Horak & Knight 1986; Petney & Horak 1987). In the present study, the efficacy of acaricidal treatment of cattle in reducing the numbers of free-living ticks on the vegetation and those parasitic on impala was evaluated on two properties. On the one property only wildlife is kept and no regular tick control is practised except for an initial treatment of newly released animals. On the other cattle and wildlife are maintained. A strict tick control programme aimed at the cattle is in place and wild animals are treated once prior to release.

Material and methods

Study localities

The investigation was conducted on two properties in the Chisamba District of the Central Province of Zambia. The altitude in this region ranges from 1100 to 1200 m above sea level. Annual rainfall varies between 800 and 900 mm (Hutchison 1974), and rain falls mainly between November and April. The vegetation is classified as miombo woodland, which is dominated by trees of the genera *Brachystegia* and *Julbernardia* (Trapnell 1953). Miombo woodlands are typically interspersed with dambos. These dambos are shallow, seasonally waterlogged drainage lines, which support open grasslands. The dominant grasses in the dambos are *Hyparrhenia*, *Brachiaria*, *Echinochloa* and *Setaria* spp.

Mtendere Game Ranch (15°05'S, 28°15'E) has operated as a commercial game ranch since 1990. It is situated approximately 20 km north of Lusaka and comprises an area of 960 ha. In January 1996 the ranch contained some 570 larger ungulates (Table 1) which is equivalent to 205 large stock units at a stocking rate of one large stock unit per 4.7 ha. All newly introduced animals are treated with the acaricide flumethrin (Drastic Deadline: Bayer) prior to release.

Mubanga Farm (15°01'S, 28°29'E) lies approximately 11 km north-east of Mtendere Game Ranch. It covers an area of 1100 ha. Cattle have been farmed since the 1960s, while game was first introduced in 1993. A herd of 180 Boran cattle is kept on the farm from November to April, and these are dipped at weekly intervals, currently with the acaricide alphamethrin (Paracide: Pfizer A.H.) The herd is reduced to 80 head from May to October during which time the animals are treated at 2-weekly intervals, currently with the acaricide cypermethrin (Blitzdip: Agricura, Sanvet). A similarly timed tick control programme has been followed for at least 15 years. During this time the active ingredients in use have been changed every two to three years in an attempt to avoid the development of tick resistance to the acaricides. In addition to cattle, Mubanga Farm also accommodates some 291 larger wild

ungulates (Table 1). All newly introduced wild animals are treated with the acaricide flumethrin (Drastic Deadline: Bayer) before being released onto the farm. A combined total of 179 large stock units of cattle and wildlife is supported on this farm, representing a stocking rate of one large stock unit per 6.1 ha.

Table 1 Species and numbers of wildlife on Mtendere Game Ranch and on Mubanga Farm

Species	Number of animals	
	Mtendere Game Ranch	Mubanga Farm
Burchell's zebra *Equus burchellii*	34	15
Warthog *Phacochoerus africanus*	10	0
Bushpig *Potamochoerus larvatus*	25	20
Impala *Aepyceros melampus*	135	120
Tsessebe *Damaliscus lunatus lunatus*	18	0
Lichtenstein's hartebeest *Sigmoceros lichtensteinii*	48	2
Oribi *Ourebia ourebi*	4	10
Eland *Taurotragus oryx*	22	0
Bushbuck *Tragelaphus scriptus*	35	25
Sitatunga *Tragelaphus spekii*	2	0
Greater kudu *Tragelaphus strepsiceros*	43	12
Common duiker *Sylvicapra grimmia*	20	20
Roan antelope *Hippotragus equinus*	4	0
Sable antelope *Hippotragus niger*	30	14
Defassa waterbuck *Kobus ellipsiprymnus defassa*	62	0
Kafue lechwe *Kobus leche kafuensis*	20	28
Puku *Kobus vardonii*	36	0
Reedbuck *Redunca arundinum*	22	25
Total number	**570**	**291**

Sampling of free-living ticks

Ticks questing on the vegetation were collected by drag-sampling as described in detail by Spickett, Horak, Braack & Van Ark (1991). In addition a 95-mm long steel rod was sewn into the distal tip of each flannel strip to keep it down on the vegetation while dragging. At both localities two sites each were sampled in each of the two major vegetation types: miombo woodland and dambo. At each site three replicate drags of 250 m each were performed at monthly intervals. After each drag all ticks were removed from the flannel strips and stored in vials containing 70% ethyl alcohol for later identification and counting. Drags were done between 10h00 and 16h00 during the first week of every calendar month. Sampling commenced on Mtendere Game Ranch in January 1996 and on Mubanga Farm in April 1996. It ceased on both properties in December 1996.

Sampling of parasitic ticks

A subadult male impala was shot for venison on each property in February 1996. Two subadult male impalas were also shot for venison during March at each locality. The carcasses were skinned immediately after death. Ticks were collected from the skins, identified and counted as described by Horak, Boomker, Spickett & De Vos (1992).

Presentation of data

The ticks collected each month from the three replicate drags per site were pooled. Because of the overdispersed nature of free-living ticks, all counts had to be transformed for statistical analysis (Petney, Van Ark & Spickett 1990). The natural logarithm [ln (number of ticks + 1)] of the raw data was found to be the best suited type of transformation, as the variance to mean ratio after transformation approximated the value of one, indicating a random distribution. Statistical tests were performed on the transformed data only, using the two-tailed, paired t-test.

Of all the ticks collected the seasonal abundance of only the predominant species, *Rhipicephalus appendiculatus*, is graphically illustrated.

Results

Free-living ticks

The ticks collected from the vegetation of the two properties are summarized in Table 2. Eight species or subspecies of ticks were recovered on Mtendere Game Ranch. *Rhipicephalus appendiculatus* comprised 92,3 % of the ticks collected from April to December. Other ticks on the ranch in order of abundance were: *Boophilus decoloratus* (4.2 %), *Rhipicephalus evertsi evertsi* (2.9 %) and *Amblyomma variegatum* (0.4 %). The remaining species were collected in small numbers only. The species spectrum of ticks collected on Mubanga Farm was fairly similar to that on the game ranch. *Rhipicephalus lunulatus* was absent, and the *Amblyomma* larvae could not be identified to species level but were not *A. variegatum*. The most abundant tick on the farm was *B. decoloratus* (46.9 %) followed by ticks resembling *Rhipicephalus pravus* (20.6 %). The total number of ticks collected from the vegetation on Mubanga Farm was equivalent to 1.2 % of that collected on Mtendere Game Ranch over the same period. Comparing the mean numbers of ticks collected on Mtendere Game Ranch to those collected on Mubanga Farm (data not shown), the differences were statistically significant for the following ticks: *R. appendiculatus* larvae ($p < 0,001$), *R. appendiculatus* nymphs ($p < 0,001$), *R. appendiculatus* adults ($p < 0,05$), *R. evertsi evertsi* ($p < 0.05$) and the total number of ticks ($p < 0,001$).

The monthly mean numbers of larvae and of nymphs of *R. appendiculatus* collected from the vegetation of the four sites on Mtendere Game Ranch (January to December 1996) and on Mubanga Farm (April to December 1996) are illustrated graphically in Figure 1. Larval abundance peaked on Mtendere Game Ranch during the cool and dry season (May to September) (Fig. 1a). Nymphs were most abundant from the end of the cool season to the end of the hot and dry season (August to November) (Fig. 1b). No seasonal pattern of abundance was discernible on Mubanga Farm and numbers were consistently low throughout the study period (Fig. 1a and 1b).

Table 2 Total numbers and species of ticks collected by drag-sampling the vegetation of Mtendere Game Ranch and Mubanga Farm in central Zambia from April to December 1996. [L=larvae; N=nymphs; M=males; F=females; ( ) number of ticks collected on Mtendere Game Ranch from January to March 1996]

Tick species	Total numbers of ticks collected				
	L	N	M	F	Total
Mtendere Game Ranch					
Amblyomma variegatum	59	0	0	0	59
Boophilus decoloratus	596 (236)	0	0	0	596 (236)
Rhipicephalus appendiculatus	11340 (36)	586 (7)	10 (53)	9 (62)	11945 (158)
Rhipicephalus evertsi evertsi	403 (35)	0	0	0	403 (35)
Rhipicephalus lunulatus	0	0	6	2	8
Rhipicephalus sp. (like *R. pravus*)	5	0	0	0	5
Rhipicephalus sulcatus	0	0	4	2	6
Rhipicephalus zambeziensis	9	1	0	0	10
Total	12412 (307)	587 (7)	20 (53)	13 (62)	13032 (429)
Mubanga Farm					
Amblyomma sp.	1	12	0	0	13
Boophilus decoloratus	75	0	0	0	75
Rhipicephalus appendiculatus	5	8	0	0	13
Rhipicephalus evertsi evertsi	10	0	0	0	10
Rhipicephalus sp. (like *R. pravus)*	33	0	0	0	33
Rhipicephalus sulcatus	2	1	1	0	4
Rhipicephalus zambeziensis	11	1	0	0	12
Total	137	22	1	0	160

Parasitic ticks

The ticks collected from impala are summarized in Table 3. Six species or subspecies were present on the impala examined on Mtendere Game Ranch. The major ticks in order of abundance were *R. appendiculatus* (74.6 %), *R. evertsi evertsi* (18.9 %), *B. decoloratus* (5.5 %), and *A. variegatum* (0.9 %). The species spectrum of ticks on the impala on Mubanga Farm was fairly similar to that on the game ranch, except that *A. variegatum* was not found on Mubanga Farm. In addition a few adult *Rhipicephalus kochi* and *Rhipicephalus sulcatus* were collected there. The other ticks in order of abundance on Mubanga Farm were *B. decoloratus* (80.1 %), *R. evertsi evertsi* (11.9 %), larvae and adults resembling those of *R. pravus* (2.5 %), *R. appendiculatus* (1.5%) and *R. lunulatus* (0.5 %). The mean burden of the three impalas on Mubanga Farm consisted of 134 ticks. This is equivalent to 3.0 % of the mean burden of 4407 ticks per impala on Mtendere Game Ranch.

Discussion

The numbers of free-living and parasitic ticks were greatly reduced on Mubanga Farm on which tick control was practised when compared with Mtendere Game Ranch where such control was not regularly practised. The number of ticks on impala on the game ranch is comparable to that found on these animals in natural wildlife areas. In the present study the three impala, which were examined on the game ranch at the end of the rainy season, carried a mean of 4407 ticks. At Malelane in the Kruger National Park, South Africa, impala examined on a year round basis carried a mean burden of 4795 ticks (Horak, Fourie & Van Zyl 1995).

Amblyomma variegatum

This tick was found on the vegetation and on the impala of Mtendere Game Ranch. It was absent on Mubanga Farm. In a similar study conducted in the Eastern Cape Province, South Africa, Petney & Horak (1987) found significantly smaller numbers of free-living and parasitic *Amblyomma hebraeum* on a farm on which cattle were dipped regularly than on an adjacent nature reserve where no tick control based on acaricides was practised.

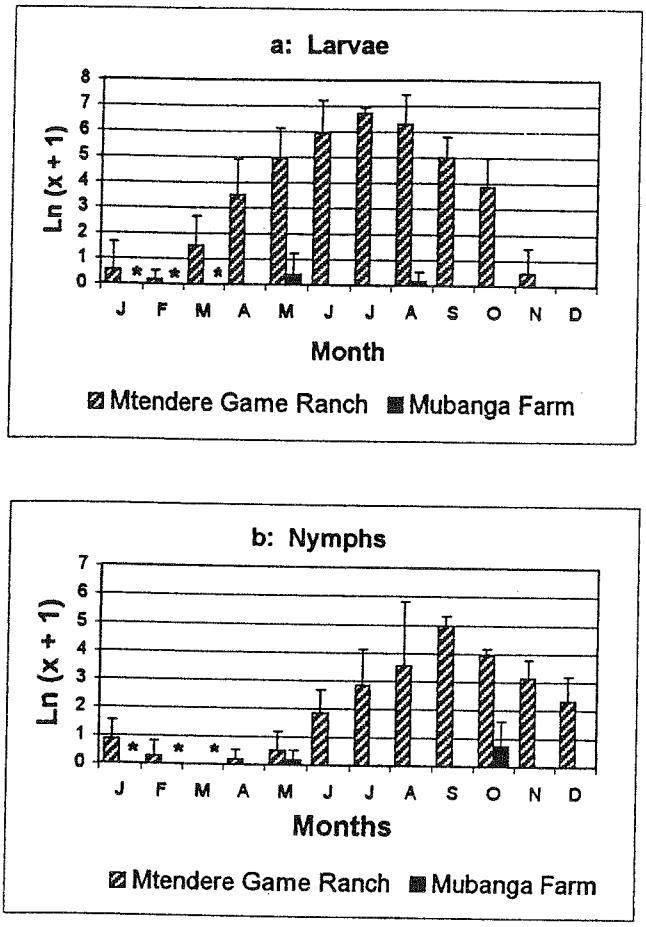

Figure 1 The mean monthly numbers [ln (x+1)] of (a) larvae and (b) nymphs of *Rhipicephalus appendiculatus* collected in 1996 by drag-sampling the vegetation of four sites on Mtendere Game Ranch and on Mubanga Farm in central Zambia (* = no collection)

A. variegatum has been recorded from a variety of wild and domestic animals. The adult ticks prefer medium to large-sized hosts (Petney, Horak & Rechav 1987). However, adults tend to be less common on wild hosts than on cattle (MacLeod, Colbo, Madbouly & Mwanaumo 1977). MacLeod & Colbo (1976) found cattle in Zambia to be excellent hosts for all life stages of *A. variegatum*. They concluded that cattle can maintain the life cycle of this tick in the absence of any alternative hosts. It therefore seems likely that the long-term and intensive tick control programme on Mubanga Farm has resulted in the eradication of *A. variegatum* on the farm on which it had occurred in the past (C. Harvey, personal communication 1996). Because all newly introduced wild ungulates are treated with an acaricide before being released onto Mubanga Farm the tick has obviously not had a chance to re-establish itself.

Boophilus decoloratus

This tick was collected at both localities from the vegetation and the impalas. Though the tick numbers were greater on Mtendere Game Ranch than on Mubanga Farm, the difference was not significant. *B. decoloratus* is a one-host tick spending approximately 21 days on its host to complete its parasitic life-cycle (Londt 1977). An intensive dipping schedule with acaricide applied at one- or two-weekly intervals should theoretically all but eradicate it. MacLeod (1970) stated that on Zambian cattle herds subjected to weekly dipping or spraying with an acaricide, the contribution of *B. decoloratus* to the total tick burden was negligible when compared to that on untreated cattle. Two explanations for the apparent lack of efficacy of the control measures against *B. decoloratus* on Mubanga Farm are proposed. Firstly it is possible that the population of this tick on the farm has been selected for resistance to the acaricides in use. Acaricide resistance is widespread in southern Africa, particularly so in *B. decoloratus* (Baker, Jordaan & Robertson 1981). Secondly alternative hosts that can maintain populations of *B. decoloratus* are present on the farm. With the exception of blue wildebeest *Conochaetes taurinus*, most of the larger wild ruminants as well as zebra are excellent hosts of this tick (Horak 1995).

Rhipicephalus appendiculatus

This is the major tick species on both the vegetation and the impala on Mtendere Game Ranch. On Mubanga Farm it has all but disappeared. The numbers of free-living and parasitic *R. appendiculatus* collected on the farm were equivalent to only 0.1 % of those collected on the game ranch. *R. appendiculatus* is one of the most abundant ticks on domestic stock in this region of Zambia (MacLeod & Colbo 1976; MacLeod et al. 1977. Although the total animal stocking rate on Mubanga Farm is slightly lower than that on the game ranch, larger numbers of *R. appendiculatus* could have been expected on the farm because cattle are the preferred hosts of this tick (Norval, Walker & Colborne 1982). It can thus be assumed that the considerable reduction in its abundance on Mubanga Farm was achieved by the intensive tick control regime.

Rhipicephalus evertsi evertsi

This tick is fairly abundant on Mtendere Game Ranch, but not so on Mubanga Farm. It feeds readily on cattle and is common in Zambia (MacLeod et al. 1977). It also occurs on a variety of wild herbivores (MacLeod et al . 1977) and its immature stages are prevalent on scrub hares *Lepus saxatilis* (Horak & Knight 1986). However, among the wild hosts only zebra, giraffe, *Giraffa camelopardalis* and eland appear to be important for the adult stage of the tick (Horak 1995). Despite the presence of cattle on Mubanga Farm, the number of *R. evertsi evertsi* was negligible. This can be attributed to the strict tick control programme. The zebra herd probably maintains a small tick population on the farm.

Other ticks

Ticks of the remaining species were collected infrequently at both localities. With the exception of *R. zambeziensis*, which can be present in large numbers, they are usually present in low numbers only and may be more abundant on wild than on domestic hosts (MacLeod et al. 1977). Consequently these ticks would hardly be affected by a tick control programme on cattle as long as suitable wild hosts are present in the same area.

Table 3 Mean numbers (+/- S.E.) and species of ticks collected in February and March 1996 from three impala each on Mtendere Game Ranch and on Mubanga Farm in central Zambia (L=larvae; N=nymphs; M=males; F=females)

Tick species	Mean numbers of ticks collected (+/- S.E.)									
	Mtendere Game Ranch					Mubanga Farm				
	L	N	M	F	Total	L	N	M	F	Total
Amblyomma variegatum	40.0 (7.8)	0.0	0.0	0.0	40.0 (7.8)	0.0	0.0	0.0	0.0	0.0
Boophilus decoloratus	163.3 (11.0)	48.7 (3.5)	18.7 (3.6)	10.0 (2.3)	240.7 (11.0)	40.0 (4.0)	48.7 (4.1)	12.0 (1.4)	6.7 (1.7)	107.4 (5.5)
Rhipicephalus appendiculatus	3203.3 (63.8)	56.0 (8.5)	15.3 (2.2)	14.7 (2.8)	3289.3 (64.3)	0.7 (1.1)	0.0	0.7 (1.1)	0.7 (1.1)	2.0 (0.0)
Rhipicephalus evertsi evertsi	678.0 (21.6)	135.3 (8.8)	10.7 (3.2)	8.0 (2.3)	832.0 (23.2)	14.0 (4.0)	2.0 (1.9)	0.0	0.0	16.0 (3.7)
Rhipicephalus kochi	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.7 (1.7)	1.3 (1.1)	4.0 (2.0)
Rhipicephalus lunulatus	0.0	0.0	1.3 (1.5)	0.7 (1.1)	2.0 (1.9)	0.0	0.0	0.7 (1.1)	0.0	0.7 (1.1)
Rhipicephalus sp. (like *R. pravus*)	2.7 (2.1)	0.0	0.0	0.7 (1.1)	3.3 (2.4)	3.3 (1.7)	0.0	0.0	0.0	3.3 (1.7)
Rhipicephalus sulcatus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7 (1.1)	0.0	0.7 (1.1)
Mean per impala	**4087.3 (68.5)**	**240.0 (11.9)**	**46.0 (3.0)**	**34.0 (2.6)**	**4407.3 (69.4)**	**58.0 (4.8)**	**50.7 (3.7)**	**16.7 (2.5)**	**8.7 (1.7)**	**134.0 (5.4)**

Conclusion

Cattle that are regularly treated with acaricides can be used to control ticks on sympatric wildlife as demonstrated in this and other studies (Horak & Knight 1986; Petney & Horak 1987). This is particularly true for those ticks which prefer cattle as hosts (Horak & Knight 1986). When cattle are not kept with game all year round, they could be introduced strategically during a specific season only. Adult ticks, particularly those of the *Rhipicephalus* genus, are generally most active during the rainy season. Cattle can be used during this time and can be herded into those areas of a ranch where adult ticks are most abundant. The acaricide used should have little or no repellent effect to ensure that the cattle pick up a maximum number of ticks between successive acaricide applications (Horak 1980). In addition cattle belonging to *Bos taurus* breeds should be used because they are more susceptible to ticks than those of the *Bos indicus* breeds (Horak 1980). There is growing evidence that the production losses caused by ticks on cattle have been overestimated in the past and may not justify intensive control measures (Norval, Barrett, Perry & Mukhebi 1992). Instead, integrated control programmes, which aim at maintaining a state of endemic stability between hosts and parasites and/or diseases, are advocated (Norval et al. 1992). It is therefore not desirable to eradicate ticks completely. Whether the use of expensive acaricides to control ectoparasite numbers on game at times of peak abundance is economically justifiable, must be evaluated critically on each individual game ranch, as this will depend upon the management objectives and the management system in use. The importance of ranching with animals endemic to the region cannot be overemphasised because these are usually able to acquire resistance to the native ticks and tick-borne diseases. In contrast, non-endemic animals are often fully susceptible to both.

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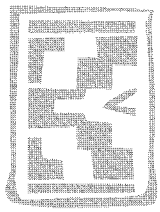

Effect of burning on the numbers of questing ticks collected by dragging

I.G. HORAK[1], G.J. GALLIVAN[2], A.M. SPICKETT[3] and A.L.F. POTGIETER[4]

ABSTRACT

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Sixteen experimental burn plot replicates, in groups of four, in four landscape zones of the Kruger National Park, South Africa, and from which wildlife are not excluded, have been subjected to fixed, regular burning regimens since 1954. In 1999, a study to determine the effect of burning on ixodid ticks questing for hosts from the vegetation of the plots was initiated, and six sub-plots, with identical histories, within each of two of the burn plot replicates in *Combretum collinum/Combretum zeyheyri* woodland on granite, were selected. With few exceptions these 12 sub-plots, as well as unburned vegetation adjacent to each of the replicates, were sampled for ticks at monthly intervals for a period of 39 months by dragging with flannel strips. The existing regimen of burning during August or during October on individual sub-plots was continued during this time. A total of 14 tick species was recovered from the plots of which nine could be considered major species. Sufficient numbers for statistical analysis of only eight species were, however, collected. Burning appeared to have little short-term effect on the number of ticks recovered. In the longer term, the response varied from no change, an increase, or a decrease in the numbers of ticks collected each year after burning. Tick species, life cycle, seasonality, questing strategy, host preference and host utilization of the habitat were important determinants of the effect of burning.

Keywords: Experimental burn plots, fire, *Amblyomma hebraeum*, *Amblyomma marmoreum*, *Haemaphysalis leachi*, *Rhipicephalus appendiculatus*, *Rhipicephalus (Boophilus) decoloratus*, *Rhipicephalus evertsi evertsi*, *Rhipicephalus simus*, *Rhipicephalus zambeziensis*

INTRODUCTION

The Kruger National Park, located in the Lowveld of north-eastern South Africa, is approximately 1.9 million ha in size and has been managed as a wildlife conservation area since its proclamation in 1926. In 1954, during a period of fire suppression within the park, a burn plot experiment was launched. The history and a description of the experimental burn plots have been recorded by Trollope, Potgieter, Biggs & Trollope (1998) and are briefly repeated here. The experiment was initially designed to obtain an understanding of the effects of season and frequency of burning on vegetation, and was conducted in four major veld types of the park, in each of which four separate replicates were laid out. Each replicate is approximately 100 ha in extent and comprises 11 to 13 treatment sub-plots and an un-burned control, each approximately 7 ha in size, in a contiguous rib-

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bon-like spatial design. Essentially unaltered burning regimens have been applied and monitored on the various treatment plots until the present. Recently, however, projects to determine the effect of burning on a wider range of elements than just the vegetation were initiated, and small mammals, reptiles, birds, insects and ixodid ticks were included.

Surveys on the seasonality of ticks infesting animals in the park were conducted intermittently between 1978 and 1994 by examining various species at monthly intervals for periods ranging from 13 to 72 consecutive months (Horak 1998). A survey on the seasonality and species diversity of ticks questing for hosts from the vegetation was initiated in 1988 (Horak, Spickett & Braack 2000b). In the latter study ticks were collected at approximately monthly intervals for 164 consecutive months, by dragging flannel strips over the vegetation of two landscape zones in the south of the park. In September 1988 part of the vegetation in one of the zones was subjected to a controlled total burn and the effect of this fire on the numbers and seasonality of questing ticks was determined (Spickett, Horak, Van Niekerk & Braack 1992). Tick numbers were reduced after the burn, but increased after varying periods thereafter depending on tick species, patterns of seasonal occurrence, and host preference.

As part of the initiatives to make greater use of the experimental burn plots and in view of our ongoing involvement in tick research in the park we were invited to determine the effect of burning on the numbers of ticks questing from the vegetation in the experimental burn plots. This report records the monthly tick counts in sub-plots within two replicates of the experimental burn plots before and after burns as well as on unburned vegetation adjacent to the replicates over a period of 39 consecutive months.

MATERIALS AND METHODS

Three of four experimental burn plot replicates are located just north and one just south of the road between the tourist rest camps of Skukuza and Pretoriuskop, and two of the northerly replicates were selected for drag-sampling (Fig. 1). The sub-plots in the more westerly replicate have for convenience been identified as the Nwaswitshaka burn plots (25°08' S; 31°38' E), while those in the more easterly replicate are referred to as the Skukuza burn plots (25°10' S; 31°44' E). Both sets of replicates are in a landscape zone described as *Combretum collinum/Combretum zeyheyri* woodland on granite (Zone 3A: Gertenbach 1983).

Each replicate is surrounded by an approximately 4 m wide fire-break, which is kept reasonably free of vegetation by means of a road-grader, and is subdivided by similar fire-breaks into 12 sub-plots, each approximately 7 ha in size. Wildlife has free access to all the experimental burn plot replicates. The sub-plots within the Nwaswitskaka and Skukuza experimental burn plot replicates are paired and at the commencement of the survey the sub-plots of each pair had been subjected to the same burning regimen for the previous 45 years. Six sub-plots that had received the same treatment were selected at each locality. One sub-plot was not burned (control), a second was burned the first week of August each year, a third sub-plot was burned the first week of August every second year, a fourth was burned the first week of August every third year, a fifth sub-plot was burned the first week of October every second year, and a sixth was burned the first week of October every third year. Unburned vegetation adjacent to the fire-break surrounding the 12 sub-plots comprising the burn plot replicate was selected as a second control. As chance would have it the experi-

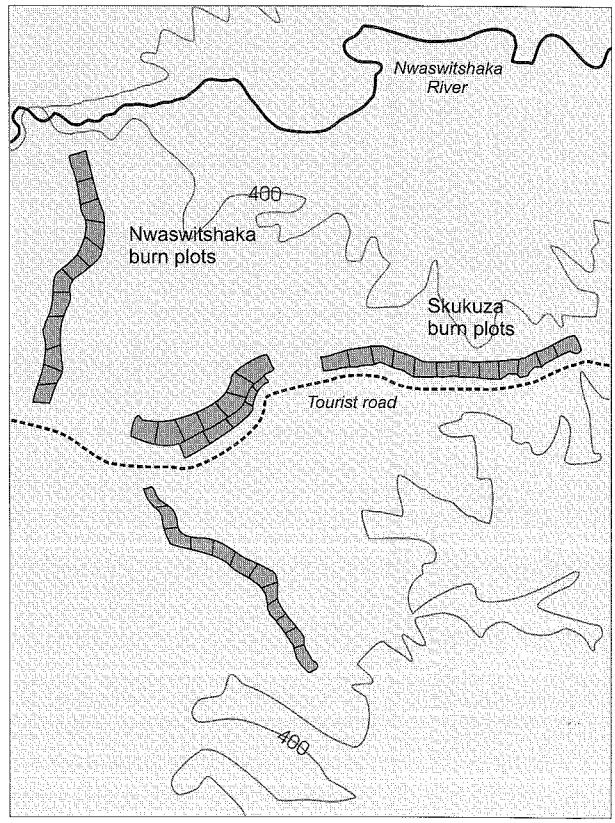

FIG. 1 Configuration of the experimental burn plot replicates located north and south of the road between the tourist rest camps of Skukuza and Pretoriuskop. The sub-plots in the westerly replicate are referred to as the Nwaswitshaka burn plots and those in the easterly replicate as the Skukuza burn plots

mental burning regimen required that all five sub-plots at both localities were burned in 2000, three during August and two during October.

Ticks were collected at approximately monthly intervals from January 1999 to March 2002 by drag-sampling the vegetation of the selected sub-plots. This was done by an operator dragging a wooden spar, with 10 x 10 cm x 100 cm weighted flannel strips attached to it, for 200 m over the vegetation of each sub-plot. After each drag all instars of all ticks on the flannel strips were collected by means of forceps and stored in 70% ethanol in labelled glass vials. At every occasion the drags were repeated six times at approximately 50 m intervals in each sub-plot, and a total of 42 x 200 m long drags were thus made within each of the two experimental burn plot replicates and their outside control localities every month. With few exceptions sampling was performed during the third week of each month so that it did not coincide with the experimental burning.

There were no drags during February 1999 because of rain, and none in February and March 2000 because of flooding in the southern regions of the park following more than 400 mm rain during February (Fig. 2). Rain during September 2000 again prevented sampling, while one of the sub-plots and both outside control areas could not be sampled during September 2001 because they were still smouldering after a huge accidental fire in the south-east of the park had jumped the fire-breaks surrounding the burn plots.

Data analysis

The tick counts were $\log_{10}$ transformed prior to analysis to reduce the effects of overdispersion (Petney, Van Ark & Spickett 1990). The seasonality of each species and stage was then tested for both locations using autocorrelation (SPSS Inc. 1994). *Amblyomma marmoreum*, *Rhipicephalus appendiculatus* and *Rhipicephalus zambeziensis* exhibited a pronounced periodicity with peaks from the summer to early winter and a marked decline in numbers in the late winter and early spring. The analyses for these species were restricted to the period from January to July, the months with the highest numbers. This reduced the number of drags with zero counts, and because burning occurred in the late winter or early spring, collections from the preceding burn year were eliminated.

To analyse the effect of burning, the year after burning was classed as the first, second or third, or unburned (control). However, the decline in tick numbers in 2001 following the burning of both sets of five sub-plots in 2000 was also confounded by the marked decrease in rainfall from 1999/2000 to 2000/2001 (Fig. 2). To allow for temporal variation among calendar and climatic years, a second variable was created with four periods corresponding to the calendar year after burning: Period 1 [prior to burn month (August or October) in 1999], Period 2 (from burn month in 1999 to burn month in 2000), Period 3 (from burn month in 2000 to burn month in 2001), and Period 4 (October 2001 to March 2002). The total tick data and data for each species were then analysed using a three factor analysis of variance with location, period and year after burning. Because year after burning was not balanced across periods, and there were often significant period effects, a multiple classification analysis (SPSS Inc. 1994) was used to adjust the means for the effect of the other variables.

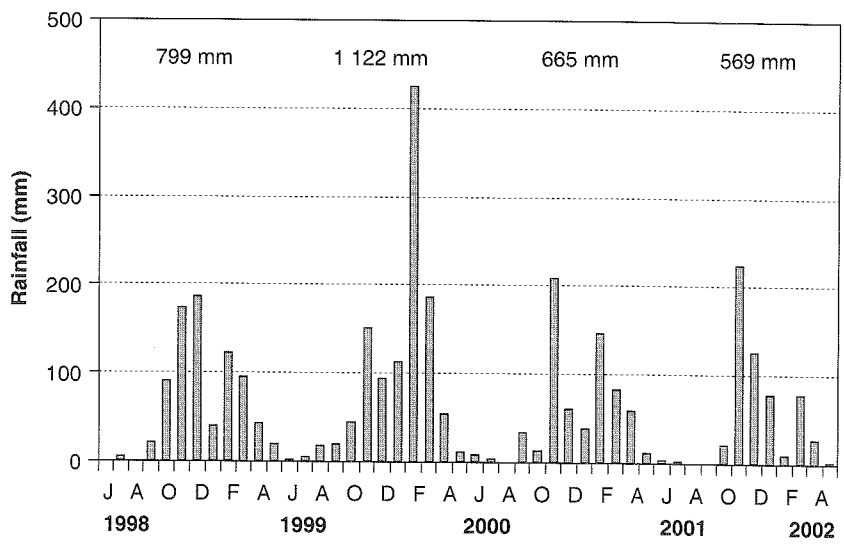

FIG. 2 Monthly rainfall (mm) measured at the Skukuza tourist rest camp during the collection period. The numbers in the figure represent total annual rainfall (June to May)

RESULTS

Fourteen tick species were collected (Table 1). *Amblyomma hebraeum* and *Rhipicephalus (Boophilus) decoloratus* were the most common species at both sites. *Amblyomma marmoreum*, *Haemaphysalis leachi*, *R. appendiculatus*, *Rhipicephalus evertsi evertsi*, *Rhipicephalus simus* and *R. zambeziensis* were also commonly collected. With the exception of *H. leachi* and *R. simus*, whose adults were most routinely recovered, larvae were the most frequently collected stage.

Total ticks

More ticks were collected from the Nwaswitshaka burn plots than from the Skukuza burn plots ($P \leq 0.001$). There was no evidence of seasonality at either location. There was a significant difference among periods ($P = 0.002$) with lower numbers in

TABLE 1 Total numbers (proportions %) of ticks collected from two sets of experimental burn plots in the Kruger National Park, South Africa

Tick species	Stage of development	Locality			
		Skukuza		Nwaswitshaka	
Amblyomma hebraeum	LL	39 980	(84.21)	35 704	(65.66)
	NN	25	(0.05)	23	(0.04)
	AA	1		0	
Amblyomma marmoreum	LL	102	(0.21)	1 690	(3.11)
	NN	1		2	
Rhipicephalus (Boophilus) decoloratus	LL	3 928	(8.27)	10 895	(20.04)
	AA	1		0	
Dermacentor rhinocerinus	LL	5	(0.01)	24	(0.04)
Haemaphysalis leachi	LL	2		5	(0.01)
	NN	3	(0.01)	4	(0.01)
	AA	921	(1.94)	960	(1.77)
Haemaphysalis spinulosa	AA	0		1	
Haemaphysalis zumpti	AA	0		2	
Hyalomma truncatum	LL	1		1	
	AA	0		1	
Rhipicephalus appendiculatus	LL	418	(0.88)	939	(1.73)
	NN	10	(0.02)	56	(0.10)
	AA	5	(0.01)	6	(0.01)
Rhipicephalus evertsi evertsi	LL	535	(1.13)	1 816	(3.34)
	AA	0		1	
Rhipicephalus follis	AA	1		0	
Rhipicephalus simus	LL	12	(0.03)	14	(0.03)
	NN	2		1	
	AA	455	(0.96)	340	(0.63)
Rhipicephalus turanicus	AA	0		1	
Rhipicephalus zambeziensis	LL	1 023	(2.15)	1 847	(3.40)
	NN	37	(0.08)	39	(0.07)
	AA	9	(0.02)	3	(0.01)
Total		**47 477**	**(100.00)**	**54 375**	**(100.00)**

LL = Larvae
NN = Nymphs
AA = Adults

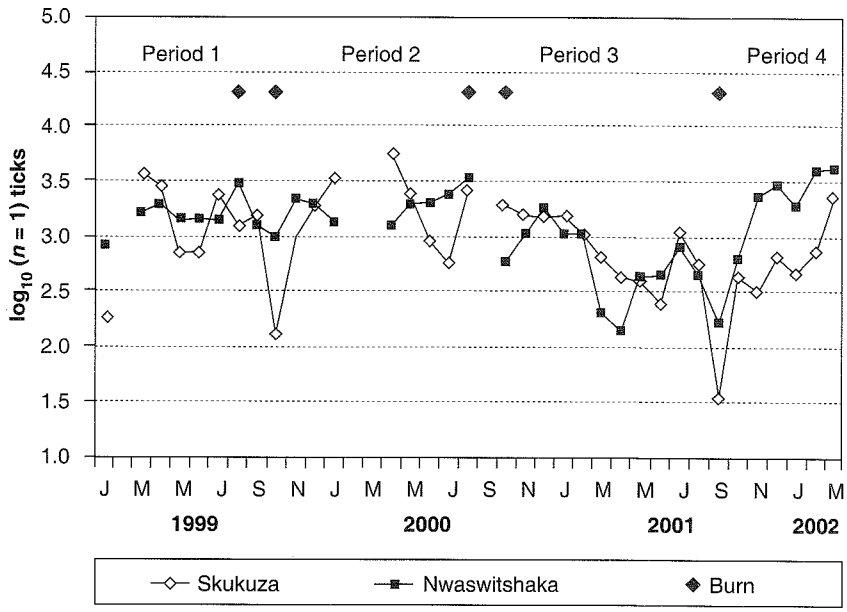

FIG. 3 Total number of ticks collected each month from the vegetation of all plots combined at Skukuza and at Nwaswitshaka. Period 1 [prior to burn month (August or October) in 1999]; Period 2 (from burn month in 1999 to burn month in 2000); Period 3 (from burn month in 2000 to burn month in 2001); and Period 4 (October 2001 to March 2002). ◆ indicates month of burning

Period 3 (2000/2001) than in the other periods (Fig. 3). Comparing between years after burning, the second year after burning and the unburned sub-plots had significantly higher tick numbers than the first and third years after burning (Table 2). Burning *per se* appeared to have little effect on the number of ticks collected, as there was no consistent pattern in the number of ticks recovered 1–2 weeks after a burn and the number recovered in the preceding month or in the subsequent 1–2 months. In 2000/2001 there was a marked drop in tick numbers relative to the preceding years in the burned sub-plots, but little change from the other years in the unburned sub-plots.

Amblyomma hebraeum

Amblyomma hebraeum larvae were the most commonly collected ticks, accounting for 84.2% of those collected at Skukuza and 65.7% of those at Nwaswitshaka. The numbers did not differ significantly between the two locations ($P > 0.15$), and there was no evidence of seasonality. There was a significant difference among periods ($P = 0.01$) with Periods 2 (1999/2000) and 4 (2001/2002) having higher numbers than Periods 1 (1999) and 3 (2000/2001) (Fig. 4A). There was also a significant difference among years after burning ($P = 0.001$) with the second year after burning and unburned sub-plots having higher numbers than the first and third years after burning (Table 2). The difference among years after burning was more pronounced at Nwaswitshaka than at Skukuza. At Nwaswitshaka the decrease in the numbers of *A. hebraeum* larvae in Period 3 occurred on both the unburned and burned sub-plots suggesting that it was related to the drier conditions in 2000/2001, but there was no effect at Skukuza. Burning *per se* appeared to have little effect on the number of *A. hebraeum* larvae recovered, as there was no consistent pattern in the number collected 1–2 weeks after a burn and the number collected in the preceding month or in the subsequent 1–2 months.

Amblyomma marmoreum

Amblyomma marmoreum larvae were collected from January to October (Fig. 4B), with the highest numbers from March to August. They were most common at Nwaswitshaka ($P < 0.001$). The numbers were highest in 2000, and none were collected in 2002 ($P < 0.001$). There was no significant difference ($P = 0.12$) among the years after burning.

Rhipicephalus (Boophilus) decoloratus

Rhipicephalus (Boophilus) decoloratus larvae were the second most commonly collected tick (Table 1). The numbers were significantly higher ($P < 0.001$) at Nwaswitshaka, where they accounted for 20.0% of the ticks collected, than at Skukuza where they accounted for 8.3% of the ticks collected. There was no evidence of seasonality. The numbers were significantly lower in Period 3 than in the other periods ($P < 0.001$), and significantly lower in Period 4 than in Period 2 ($P < 0.05$) (Fig. 4C). The numbers were higher in the second year after burning than in the first and third years and in the unburned sub-plots ($P = 0.009$). Burning *per se* did not appear to affect the numbers of *R. (B.) decoloratus* larvae.

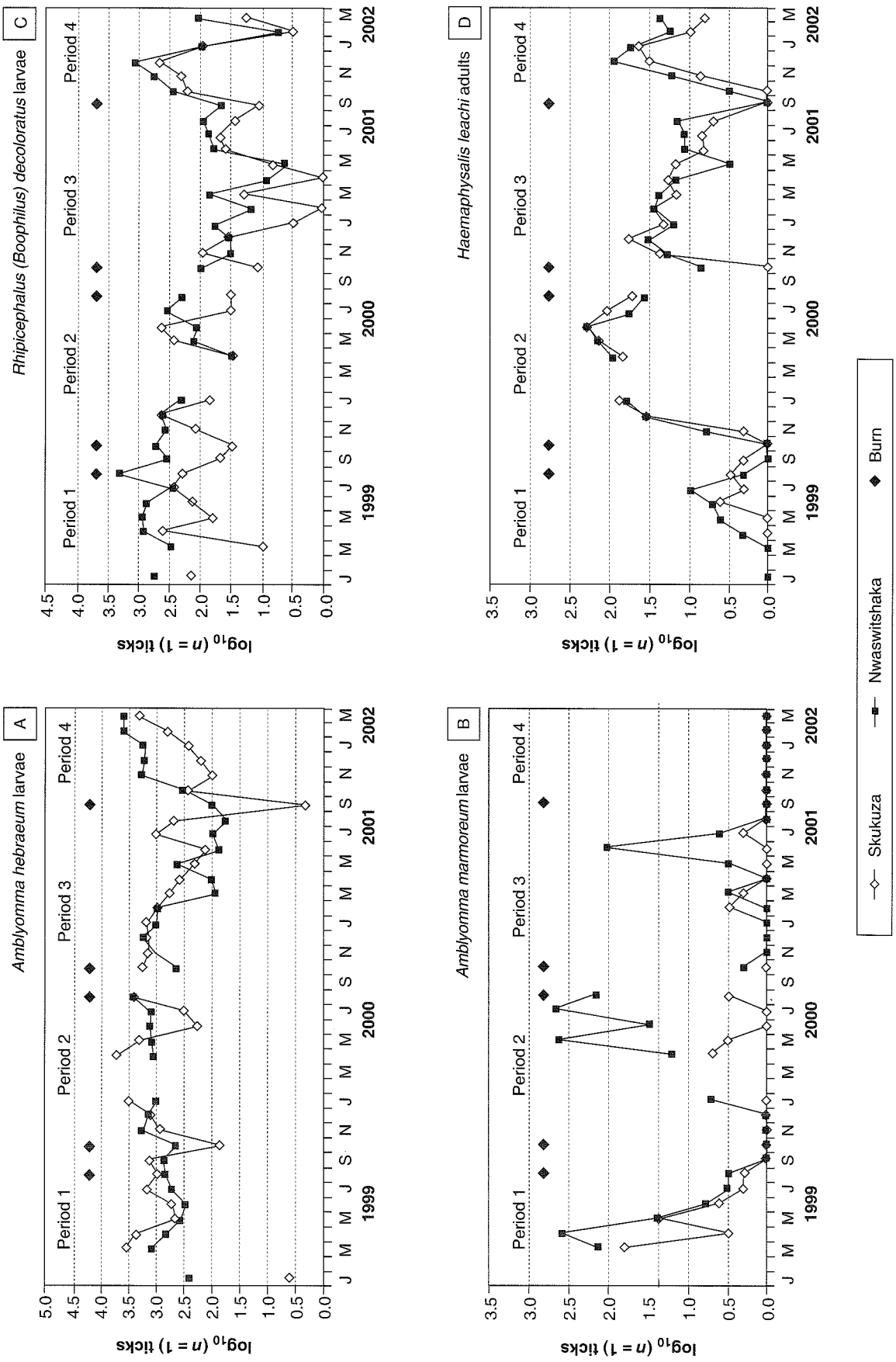

FIG. 4 Total number of (A) *Amblyomma hebraeum* larvae, (B) *Amblyomma marmoreum* larvae, (C) *Rhipicephalus (Boophilus) decoloratus* larvae, and (D) *Haemaphysalis leachi* adults collected each month from the vegetation of all plots combined at Skukuza and at Nwaswitshaka. Period 1 [prior to burn month (August or October) in 1999]; Period 2 (from burn month in 1999 to burn month in 2000); Period 3 (from burn month in 2000 to burn month in 2001); and Period 4 (October 2001 to March 2002). ◆ indicates month of burning

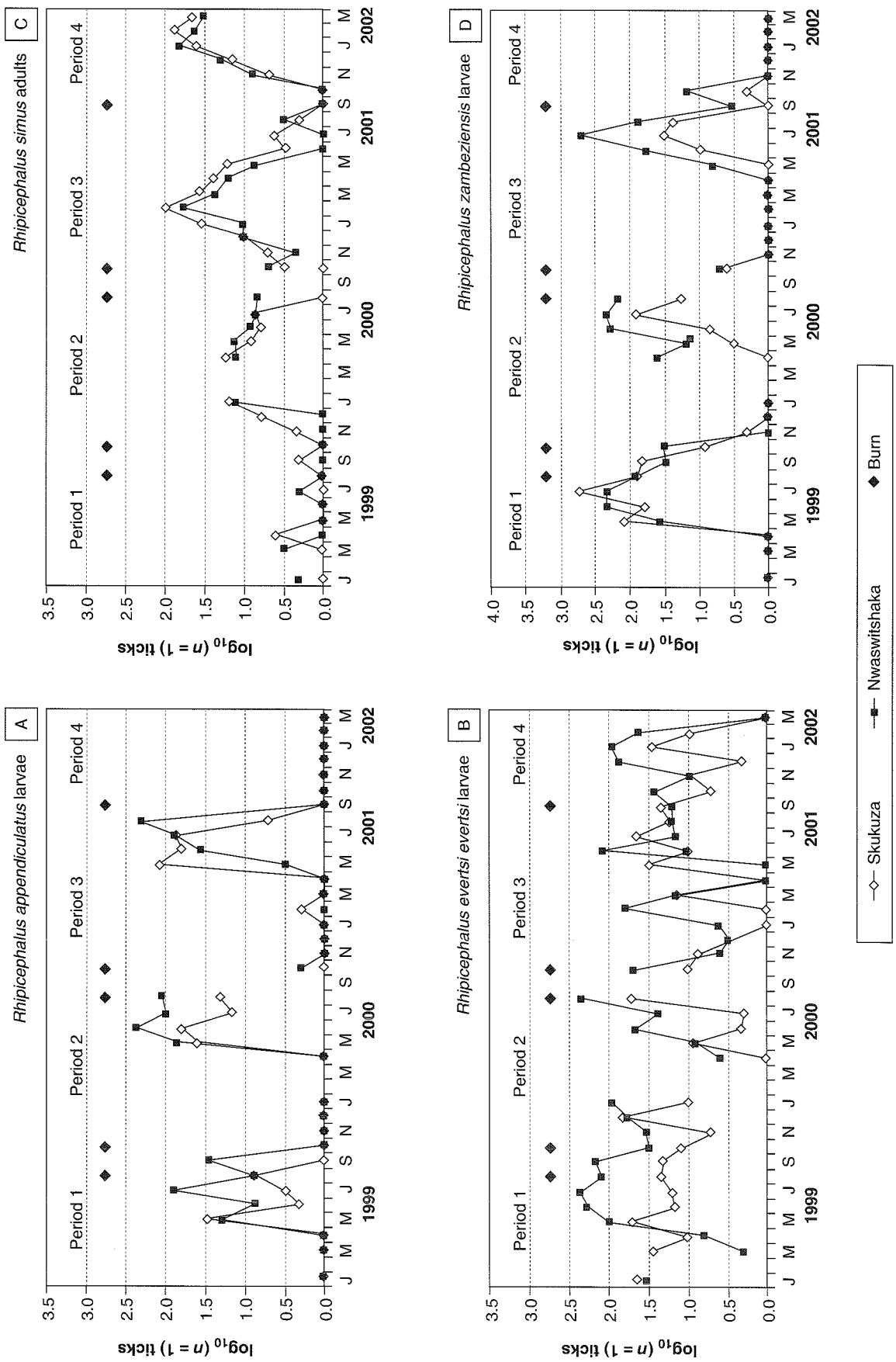

FIG. 5 Total number of (A) *Rhipicephalus appendiculatus* larvae, (B) *Rhipicephalus evertsi evertsi* larvae, (C) *Rhipicephalus simus* adults, and (D) *Rhipicephalus zambeziensis* larvae collected each month from the vegetation of all plots combined at Skukuza and at Nwaswitshaka. Period 1 [prior to burn month (August or October) in 1999]; Period 2 (from burn month in 1999 to burn month in 2000); Period 3 (from burn month in 2000 to burn month in 2001); and Period 4 (October 2001 to March 2002). ◆ indicates month of burning

TABLE 2 Adjusted means (log_{10} transformed) for the number of ticks collected each month in the burn plots by year after burning. Values with the same superscript are not significantly different ($P > 0.05$)

Tick species and stage of development	Year after burning			
	1	2	3	Unburned
Total ticks	1.81[a]	2.12[b]	1.86[a]	2.10[b]
Amblyomma hebraeum larvae	1.47[a]	1.71[b]	1.28[a]	1.74[b]
Amblyomma marmoreum larvae (January to July)	0.15[a]	0.16[a]	0.01[a]	0.19[a]
Rhipicephalus (Boophilus) decoloratus larvae	0.75[a]	1.02	0.75[a]	0.86[a]
Haemaphysalis leachi adults (December 1999 to March 2002)	0.37	0.75[a]	0.77[a]	0.65[a]
Rhipicephalus appendiculatus larvae (May to July)	0.67[a]	0.32[b,c]	0.12[c]	0.48[a,b]
Rhipicephalus evertsi evertsi larvae	0.40[a]	0.36[a]	0.40[a]	0.21
Rhipicephalus simus adults	0.15	0.24[a]	0.30[a]	0.33[a]
Rhipicephalus zambeziensis larvae (May to July)	0.75[a]	0.67[a]	0.45[a]	0.90[a]

Haemaphysalis leachi

Most of the *H. leachi* collected were adults (Table 1). The numbers did not differ between the two locations ($P > 0.5$), and there was no evidence of seasonality. The numbers of *H. leachi* adults changed markedly over time ($P < 0.001$), with few in the first year, an increase over the next 6 months, then a decrease to August 2001 and reappearance in November 2001 (Fig. 4D). The numbers were lower the first year after burning than in the other years ($P<0.001$). The effect of burning *per se* was difficult to determine because adult tick numbers usually decline on the vegetation in the park during the late winter (Horak, Emslie & Spickett 2001).

Rhipicephalus appendiculatus

Rhipicephalus appendiculatus exhibited a pronounced seasonal periodicity. Larvae were present from February to October with peak occurrence from May to August, nymphs were present from June to February with a peak in August to October, and the adults were collected from February to April (Fig. 5A). *Rhipicephalus appendiculatus* larvae and nymphs were most common at Nwaswitshaka ($P=0.035$ and $P< 0.001$, respectively). There was a marked increase in number of larvae from 1999 to 2000 in both areas and a decline in 2001 ($P < 0.001$). The number of nymphs also appeared to increase from 1999/2000 to 2000/2001, but did not appear to decline in 2001/2002. The numbers of larvae were higher in the first year after burning and lowest in the third year after burning ($P = 0.004$). The immediate effect of burning on larvae could not be assessed because the seasonal decline in numbers coincided with the timing of the fires. Nymphs were collected 1–2 weeks after burning, but the numbers were too low to assess the immediate impact of the fire.

Rhipicephalus evertsi evertsi

Rhipicephalus evertsi evertsi larvae were present throughout the year, with no evidence of seasonality (Fig. 5B). They were more common at Nwaswitshaka than at Skukuza ($P< 0.001$). There was a significant difference among periods ($P < 0.001$) as the numbers declined from Period 1 to Period 3, then increased in Period 4. The numbers were significantly higher on the burned sub-plots than on the unburned sub-plots ($P = 0.004$).

Rhipicephalus simus

Most of the *R. simus* collected were adults (Table 1). They were more common at Skukuza than at Nwaswitshaka ($P = 0.028$). The numbers increased from 1999 to 2001/2002, and there was a marked seasonality with the highest numbers from January to March and the lowest numbers from August to October (Fig. 5C). The numbers increased with year after burning ($P < 0.001$).

Rhipicephalus zambeziensis

Rhipicephalus zambeziensis was more common than *R. appendiculatus* in both areas. There was a pronounced seasonality for all stages (Fig. 5D). Larvae were collected from April to November with a peak in July, nymphs were collected from May to January with a peak in August, and adults were collected from February to April. *Rhipicephalus zambeziensis* larvae were more common at Nwaswitshaka than at Skukuza ($P = 0.001$), but the number of nymphs did not differ between the two areas. The numbers of larvae decreased from the first to the third year after burning, but the change was not statistically significant ($P = 0.16$). The immediate effect of burning on larvae could not be assessed because the seasonal decline in numbers coincided with the timing of the

fires. As with *R. appendiculatus*, *R. zambeziensis* nymphs were collected on burned sub-plots 1–2 weeks after burning, but the numbers were too low to determine the immediate impact of the burn.

DISCUSSION

Dragging is only effective for sampling those ticks and developmental stages that quest for hosts from the vegetation and that are inclined also to attach to flannel strips. Hence dragging may limit the tick species and life stage spectrum of any investigation that relies on it as the only sampling method.

Amongst the 14 tick species collected from the burn-plots the larvae of *A. hebraeum*, *A. marmoreum*. *R. (B.) decoloratus*, *R. appendiculatus*, *R. e. evertsi* and *R. zambeziensis* quest from vegetation and are inclined to attach to flannel. Although the nymphs and adults of *R. appendiculatus* and *R. zambeziensis* also quest from vegetation, they are less inclined to attach to flannel than the larvae. On the other hand, the adults of *H. leachi*, that prefer carnivores as hosts (Horak, Braack, Fourie & Walker 2000a), and of *R. simus*, that prefer monogastric animals such as carnivores, equids and suids as hosts (Walker, Keirans & Horak 2000), also quest from the vegetation and readily attach to flannel. They are probably enticed to do so by chemicals exuded by the omnivorous, monogastric persons dragging the flannel strips, and they are also amongst the tick species that are most frequently recorded as attaching to humans (Horak, Fourie, Heyne, Walker & Needham 2002). The adults of the rhinoceros tick *D. rhinocerinus* also quest from vegetation, but prefer grass species with long, thick stems, which, although present, are sparse on the burn-plots. The nymphs and adults of *A. hebraeum* and *A. marmoreum*, the larvae and nymphs of *D. rhinocerinus*, *H. leachi* and *R. simus*, the larvae and adults of *H. truncatum* and the adults of *R. e. evertsi* (the latter two ticks both have two-host life cycles) all quest for hosts from the soil surface or its immediate vicinity and are seldom collected by dragging.

With the exception of *H. truncatum*, all the major tick species that occur in the park were collected from the experimental burn-plots in sufficient numbers to make analysis possible. Without any doubt *H. truncatum* was also present on the plots as adults and larvae on the soil surface and as adults on large animals such as giraffes and zebras and as larvae and nymphs on scrub hares and gerbils (Horak, Potgieter, Walker, De Vos & Boomker 1983; Horak, De Vos & De Klerk 1984; Horak, Spickett, Braack & Penzhorn 1993; Horak 1998; Braack, Horak, Jordaan, Segerman & Louw 1996). In our experience, however, very few, if any, *H. truncatum* can be collected by drag-sampling and consequently its favoured host animals have to be examined in order to determine its presence at a particular locality.

The effects of burning on tick populations are complex because fires may affect both ticks and their host species (Spickett *et al.* 1992). Fires alter the physical environment and the nature and quatity of food and cover available to animals (Bigalke & Willan 1984). Questing ticks may be destroyed in a fire (Bigalke & Willan 1984), but some species may also exhibit avoidance strategies that enhance survival (Frost 1984). The direct impact on other free-living stages, and on small mammal hosts, will depend on the intensity of the burn. Increased temperatures and a decrease in soil moisture on burned areas (Cass, Savage & Wallis 1984) may increase the mortality of free-living ticks, although the increased temperatures may also accelerate temperature-dependent development (Spickett *et al.* 1992). Burning may also affect tick populations by altering the spatial distribution of preferred and other hosts. Many herbivores select the new growth in the burned areas (Gureja & Owen-Smith 2002; Tomor & Owen-Smith 2002; Wronski 2003; Zavala & Holdo 2005), but the populations of small mammals and birds requiring ground cover may decline (Frost 1984).

All stages of development of *A. hebraeum*, the most commonly collected species at both locations, can be found on large herbivorous animals, the size of kudu bulls and larger, as well as on warthogs (Horak, MacIvor, Petney & De Vos 1987; Horak, Boomker, De Vos & Potgieter 1988; Horak, Boomker, Spickett & De Vos 1992). With the exception of rodents, on which they do not occur, the nymphs and particularly the larvae can be found on most smaller animals, including antelopes, zebras, large and small carnivores, hares, guineafowls and leopard tortoises (Horak *et al.* 1984; 1993; 2000a; Horak, Spickett, Braack & Williams 1991; Braack *et al.* 1996; Horak 1998). This, coupled with the fact that all stages of development are present throughout the year in the park (Horak *et al.* 1992), and that the females lay exceptionally large numbers of eggs (Norval 1974), ensure that the larvae of *A. hebraeum* are more numerous on the vegetation in most habitats in the park than those of other ticks (Spickett, Horak, Braack & Van Ark 1991). Fire did not appear to have an immediate effect on the numbers of questing larvae, suggesting that many survived the fire. While there were statistically significant differences among the years after burning, there was not a consistent

trend, indicating that fire has no long-term effect probably because engorged female *A. hebraeum* are continuously brought on to the burn plots by their various large herbivorous hosts.

All stages of development of *A. marmoreum* prefer leopard tortoises (Horak, McKay, Heyne & Spickett 2006). Fire may kill many tortoises because of their limited ability to escape (Branch 1998), but larger bird species such as helmeted guineafowls and pheasants, as well as carnivores, large herbivores and scrub hares can harbour considerable numbers of larvae and some nymphs of this tick (Horak *et al.* 1991; 1993; 2000a; 2006; Uys & Horak 2005). Burning did not have a significant effect on the numbers of questing *A. marmoreum* larvae. There was a seasonal decline in the number of larvae at the time of the burns, and the 4–6 month delay between the burns and reappearance of questing larvae was probably adequate for re-colonization of the burned plots by the preferred hosts.

The one-host tick, *R. (B.) decoloratus* infests especially kudus, bushbuck, impalas and zebras in the park (Horak *et al.* 1983; 1984; 1992; Horak, Gallivan, Braack, Boomker & De Vos 2003). It is present throughout the year, but is most numerous on its hosts during spring and mid-summer, and probably completes two if not three life cycles annually. Consequently animals browsing or grazing on the burn plots, or just walking through shortly after the spring burns, will carry in large numbers of engorged female ticks. The interval between the detachment of these females and the hatching of larvae from the eggs they have laid can be as short 40 days during the summer (Spickett & Heyne 1990). Burning did not appear to have an immediate effect on the number of larvae, suggesting that substantial numbers survived the fire, or that the changes in microclimate after the burn accelerated development (Spickett *et al.* 1992). The increase in numbers in the second year after the burn may be the consequence of increased use of the burned area by preferred hosts the first year after burning.

The occurrence of two other major tick species, namely *R. appendiculatus* and *R. zambeziensis* in nearly equal numbers on the burn-plots is fortuitous. Both ticks are present in the park, but often separately in habitats only a few km apart (Horak 1998). Judging by the small numbers collected from the burn plots these were not located in an ideal habitat for either species and probably lie in a transitional zone. Minshull & Norval (1982) recorded an increase in the number of *R. appendiculatus* larvae collected the year after burning in *Hyperrhaenia* grassland on clay, but not on sandy soil. This is consistent with increases in *R. appendiculatus* and *R. zambeziensis* larvae the year after burning in the present study. This is probably caused by the influx of "burn grazers" after the fire.

The larvae and nymphs of *D. rhinocerinus*, *H. leachi*, *R. simus* and *R. turanicus* use small rodents as hosts (Norval 1984; Walker *et al.* 2000; Horak & Cohen 2001; Petney, Horak, Howell & Meyer 2004), as do the larvae of *H. truncatum* (Braack *et al.* 1996). While many small mammals survive fire, there are often marked declines in the populations of some species after a burn because of the habitat changes (Frost 1984). A reduction in the population of the hosts of their immature stages would explain the significant reduction in the numbers of adult *H. leachi* and *R. simus* collected the first year after the burn. A pack of wild dogs, with a den in the vicinity of the plots, probably played a role in seeding the area with engorged female *H. leachi* and particularly *R. simus* (Norval 1984; Horak *et al.* 2000a).

The immature stages and adults of *R. e. evertsi* utilize zebras as hosts, and can be found on these animals throughout the year (Horak *et al.* 1984). Gureja & Owen-Smith (2002) and Tomor & Owen-Smith (2002) list zebras as one of the species preferentially using burnt areas. These animals were often seen on the plots, both before and after burns, and probably seeded them with engorged nymphs and females as well as with the females of *R. simus*, which also feed on them.

Surveys on the seasonality of ticks on eight host species, ranging in size from gerbils to kudus, and including helmeted guineafowls, as well as on the vegetation of two landscape zones in the park, have been conducted intermittently since 1978 (Horak 1998). These have shown that the only stages of development present on the vegetation in substantial numbers at the time of the burns in August or October are larvae of *R. (B.) decoloratus* and nymphs of *R. appendiculatus* and *R. zambeziensis*. Thus, a burn in August or October is only likely to have a direct effect on peak numbers of single life stages of the abovementioned three major tick species. The larvae of *A. hebraeum* and *R. e. evertsi* may also be present at this time, but are non-seasonal without defined peaks in numbers. Depending on the heat generated by the fire, various life stages of other ticks questing for hosts on the soil surface, or moulting or ovipositing in sheltered spots, may also be adversely affected.

One of the reasons for the apparent lack of effect of fire on the numbers of ticks questing for hosts from

the vegetation in the present investigation could be the small size of the individual sub-plots. Although 7 ha may seem large, in the context of a large wildlife reserve and free access by animals, the plots should probably have been 10 times larger. The apparent ease with which the 7 ha sub-plots can be re-colonised by small mammals or accessed by large animals either for foraging, loafing or simply as walkways, add innumerable variables to the already complex analysis of the effects of fire on questing ticks.

Finally, the free-living stages of ticks of sub-Saharan Africa have been exposed to intermittent fires for millions of years and have probably been selected for survival strategies as yet unknown to us. Consequently they have, and probably will, successfully survive the effects of fire for centuries to come.

CONCLUSION

Unless animals are excluded from recently burned localities the effects of fire on free-living tick numbers are likely to be minimal and of short duration.

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CHAPTER 9

REVIEWS AND PROCEEDINGS

The major portions of those sections in the reviews and proceedings, listed hereunder, that pertain to ticks, come from, or relate to, my published or unpublished data. The reviews and proceedings cover amongst other parasites, the ticks of Dorper sheep (Fourie & Horak 2000), rhinoceroses (Penzhorn, Krecek, Horak, Verster, Walker, Boomker, Knapp & Quandt 1994), elephant shrews (Fourie, Du Toit, Kok & Horak 1995), African buffaloes (Boomker, Horak, Penzhorn & Keet 1996), lions and leopards (Boomker, Penzhorn & Horak 1997) and cheetahs (Penzhorn, Horak & Krecek 1998). They also deal with wildlife parasites in general (Malan, Horak, De Vos & Van Wyk 1997; Horak 1998, 2003, 2006; Boomker & Horak 2002), and the control of ticks on wildlife in small reserves (Horak 2001a). In a presentation on the conservation of rare parasites I proposed that in order to preserve their special parasitic fauna, rare wildlife species should not be treated with antiparasiticides prior to translocation (Horak 2001b). The book chapter by Norval & Horak (2004) is an updated version of a chapter originally published by Norval in 1994 before his untimely death in the same year, and has now been rewritten by me.

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Proceedings of a Symposium on "Rhinos as Game Ranch Animals", Onderstepoort, 9 & 10 September 1994

Parasites of African rhinos: a documentation

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INTRODUCTION

In free-living wild animals a balance usually exists between hosts and parasites. Both have evolved together over the millennia. The presence of parasites under these conditions is usually incidental and of limited clinical significance. Under stressful conditions, such as droughts and especially human interference such as capture, captivity, transportation and release into strange surroundings, the host's immune system is suppressed, the balance is disturbed and parasite populations may escalate to such an extent that clinical symptoms become evident.

In this paper we attempt to document all the parasites that have been recovered from both black (*Diceros bicornis*) and white rhinos (*Ceratotherium simum*). Very few, if any, quantitative studies have been conducted; the records are primarily random collections or observations.

PROTOZOA

Trypanosoma species

Trypanosoma brucei[9, 23], *Trypanosoma congolense*[24] and *Trypanosoma vivax*[23,25] have been reported from black rhinos. These tsetse fly-borne blood parasites cause Nagana in livestock. Wild animals born in tsetse-infested areas often serve as reservoir hosts of trypanosomes, but clinical trypanosomosis only manifests when these animals are stressed. Mortalities due to trypanosomosis have been reported in recently captured young black rhinos in Tanzania after 9–25 days in captivity[23]. The deaths of four out of five white rhinos introduced to the tsetse-infested Zambezi Valley of Zimbabwe were attributed to trypanosomosis[47].

As these rhinos originated from KwaZulu Natal and had been kept in a tsetse-free area in southern Zimbabwe, they had never been exposed to trypanosomes. Chronic trypanosome-related health problems, including abortions, arose in white rhinos introduced into Meru National Park in Kenya from KwaZulu-Natal[25].

Babesia and *Theileria* species

Large Babesias, as yet unnamed, have been reported from black rhinos in Kenya[6] and from white rhinos in KwaZulu-Natal[5]. Babesiosis was regarded as the cause of death of two black rhinos[23]. Small piroplasms, either *Babesia* sp. or *Theileria* sp. but probably the latter, have been reported from black rhinos in East Africa[6,7] and KwaZulu-Natal[5,15]. Small piroplasms were seen in 42,8% of young white rhinos and 23,9% of adults examined in KwaZulu-Natal[5].

Balantidium

Balantidiosis has been reported in white rhinos[37]; the paper was not seen by us.

ARTHROPODS

Ticks

The majority of tick species are not host-specific, but are found on a great variety of vertebrate hosts. It is not surprising, therefore, that 40 tick species have been recovered from black and white rhinos (Table 1), though there is little doubt that the vast majority of these records represent incidental infestations only. Three species, however, are primarily rhino parasites. Two, *Amblyomma rhinocerotis* and *Dermacentor rhinocerinus*, have been collected from both black and white rhinos in many parts of eastern, central and southern Africa[16,50]. The third species, *Amblyomma personatum*, has been recorded from black rhinos, originally from Gabon and Kenya and subsequently also from Tanzania[50,55,58]. With the great reduction in black rhino numbers that has occurred in recent years this tick could easily become extinct. A fourth species, *Amblyomma sparsum*, has a strong predilection for black rhinos, although it has been recorded from a wide range of other mammalian hosts and also reptiles[50,55,58]. All these ticks are large, ornate species. Unfed adults of *A. rhinocerotis* are *ca.* 9 mm long and have a pattern of dark reddish-brown spots and stripes on an ochre-yellow background. *Dermacentor rhinocerinus* are 6-8 mm long and the male bears yellow-ochrous blotches on a chocolate-brown background[16,61]. The male of *A. personatum* is distinguished by having a dark brown figure resembling a flying bird on the pale background of its scutum. *Amblyomma sparsum* also has a brownish pattern of spots and stripes against a yellowish background. As its name implies, *Cosmiomma hippopotamensis* was originally described from hippos (*Hippopotamus amphibius*), but black rhinos are now regarded as its most likely host[4,55]. Common sites of tick attachment are skin folds in the perineal region, in and around the ears and around the eyes.

Flies

Glossina species – tsetse flies

Although the occurrence of trypanosomes in rhinos indicates that tsetse flies may feed on rhinos, they are not generally considered to be preferred hosts of the flies. In Kenya, however, *Glossina longipennis*, a tsetse species living in low densities in the typical dry bushveld habitat favoured by black rhinos, was found to feed primarily on rhinos[24,57]. Stereo-electron

micrographs of the labellar armature of *G. longipennis* indicate that it is specialised for feeding on elephants and rhinos[35].

Gyrostigma species – rhinoceros bot flies

This genus is closely related to *Gasterophilus,* the horse bot flies. *Gyrostigma pavesii* occurs in both rhino species. The flies are 24-35 mm long, with an orange and reddish head, a predominantly deep black thorax with a central reddish line, and a black abdomen with a reddish tip[61]. The adults are short-lived and do not feed, their mouthparts being rudimentary. The female deposits her eggs mainly in front of and below the anterior horn and between the two horns. The larvae that hatch from the eggs are *ca.*2 mm long. These larvae are thought to migrate in the epidermal tissue of the cheeks and mouth to the oesophagus. The second and third larval stages are found in the stomach, where they grow up to 4 cm long. Mature larvae leave the host with the faeces and pupate in the soil. The flies hatch after *ca.* 6 weeks. Zumpt[61] stated that the adults are rarely seen in the field and represent great rarities for the collector. This is largely explained by the fact that they live only a few days. Another reason lies in their behaviour: they stay in the close vicinity of rhinos, their only hosts, and who would approach a rhino armed only with a fly-net? *Gyrostigma conjungens,* a smaller species, parasitises black rhinos in East Africa.

Rhinomusca dutoiti

This blood-sucking fly is closely related to the stable fly (*Stomoxys calcitrans*). The larvae develop only in rhino dung, and the adults feed on both rhino species[60, 61]. These flies are somewhat larger than a house fly (*Musca domestica*), and have a stout, horn-coloured proboscis. A similar species, *Rhinomusca brucei*, occurs in East Africa.

Lyperosia species

This small fly has been found in association with black rhinos in Kenya[32]. The adult flies spend their life closely associated with their host, and the females fly down and lay their eggs on freshly deposited dung before returning to their feeding place on the host. The use of dung middens by rhinos ensures a continuously moist breeding place for the flies.

HELMINTHS

The diversity of helminth species is extensive. At least 40 known species have been reported in the two rhinos discussed here (Table 2). While most of these are nematodes, two trematodes and two cestodes have been reported. Several strongylid nematode genera predominate, including *Khalilia*, *Kilulumа*, *Murshidia* and *Quilonia*. The most abundant species is a small pinworm, *Probstmayria*, which was recorded in black rhinos in South Africa and Namibia in numbers of 399 000 000 in a single animal (R.C. Krecek, unpublished). *Probstmayria* is an example of a nematode not previously recorded. Its absence from the literature may be attributed to the method of previous collections. *Probstmayria* is 2-3 m in size and unless collection of the worm parasites is complete, i.e. quantitative samples are collected for microscopic examination, it is quite possible to miss recovery of these nematodes. Often new species are revealed in a host when quantitative studies are undertaken. In recent zebra helminth studies, six new nematode species were revealed when quantitative studies were done[41].

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Table 1: A list of ticks recovered from white and black rhinos

Tick species	White rhino	Black rhino S. Africa	Black rhino E. & C. Africa	Reference
Amblyomma cohaerens			X	14
Amblyomma eburneum			X	54
Amblyomma gemma			X	54, 58
Amblyomma hebraeum	X	X		1, 50
Amblyomma lepidum			?	50
Amblyomma personatum*			X	50, 54, 58
Amblyomma rhinocerotis*	X	X	X	1, 22, 50, 54
Amblyomma sparsum			X	50, 54, 58
Amblyomma tholloni			X	50, 54, 58
Amblyomma variegatum	X		X	50, 54, 58
Cosmiomma hippopotamensis*		X		4, 55
Dermacentor rhinocerinus*	X	X	X	1 22, 50, 54, 58
Haemaphysalis leachi	?	?		50
Haemaphysalis silacea		X		Horak (unpubl.)
Hyalomma albiparmatum			X	50, 54, 58
Hyalomma impeltatum			X	58
Hyalomma impressum			X	31
Hyalomma marginatum rufipes			X	50, 54
Hyalomma truncatum	X	X	X	1, 50
Rhipicephalus appendiculatus	X	X	X	1, 50, 54
Rhipicephalus sp. near *bequaerti*		X		1
Rhipicephalus capensis		?		50
Rhipicephalus compositus			X	50, 54, 58
Rhipicephalus humeralis			X	50, 54, 58
Rhipicephalus hurti			X	54, 58
Rhipicephalus jeanneli			X	54, 58
Rhipicephalus kochi			X	58
Rhipicephalus longus			X	54
Rhipicephalus lunulatus			X	56
Rhipicephalus maculatus	X	X	X	1, 50, 54
Rhipicephalus muehlensi		X		1, 50, 54
Rhipicephalus pravus			X	54
Rhipicephalus pulchellus			X	50, 54, 58
Rhipicephalus sanguineus			X	31, 50
Rhipicephalus senegalensis			?	50
Rhipicephalus simus	X	X	X	1, 50, 54, 58
Rhipicephalus supertritus			X	50
Rhipicephalus zambeziensis	X			Horak (unpubl.)
Rhipicephalus ziemanni			?	50
Rhipicephalus zumpti		X		1

*** Rhinos are preferred hosts**

Table 2: Helminth parasites of white and black rhinos

Parasite	White rhino	Black rhino S. Africa	Black rhino E. & C. Africa	Reference
Trematodes				
Brumptia bicaudatum			X	21
Gastrodiscus aegyptiacus	X			45
Cestodes				
Anoplocephala diminuta			X	40
Anoplocephala gigantea	X	X	X	27, 33, 34, 38, 43, 44, 61
Nematodes				
Grammocephalus intermedius			X	28
Habronema spp.	X			59
Habronema khalili		?	?	11
Khalilia rhinocerotis			X	28
Kiluluma africana		X	X	26, 46, 48, 61
Kiluluma brevicauda			X	49
Kiluluma brevivaginata			X	49
Kiluluma cylindrica			X	49
Kiluluma goodeyi		X	X	26, 49, 61
Kiluluma macdonaldi			X	46, 49
Kiluluma magna		X	X	11, 26, 46, 48
Kiluluma pachyderma		X	X	11, 26, 48
Kiluluma rhinocerotis		X	X	11, 26, 46, 48
Kiluluma solitaria		X	X	11, 26, 46, 48
Kiluluma stylosa			X	19, 20, 42, 53
Murshidia africana			?	8, 11
Murshidia aziza			X	8, 11, 28
Murshidia bozasi			X	8, 11, 28
Murshidia memphisia			X	8, 11, 28
Murshidia omoensis			X	8, 11, 28, 29
Murshidia pugnicaudata	X			Boomker & Booyse (Unpubl.)
Necator americanus			*	3
Oxyuris equi		X		26
Oxyuris karamoja	X	X	X	2, 40, 52, 61
Parabronema rhinocerotis			X	17
Parabronema roundi			X	12, 40
Physocephalus sexalatus		?	?	11
Probstmayria species		X		Krecek & Boomker (unpubl.)
Quilonia africana			X	8, 11, 29
Quilonia parva			X	8, 29
Setaria africana		X		10
Stephanofilaria dinniki		X	X	13, 18, 39, 40, 51
Strongylus tremletti			X	23, 38
Thelazia sp.			X	40
Trichuris sp.			**	36

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Arthropod parasites of elephant-shrews, with particular reference to ticks

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ABSTRACT

Elephant-shrews from sub-Saharan Africa are infested by a large variety of arthropod parasites including ticks, mites, fleas, lice and the larvae of a calliphorid fly. Lists of the ectoparasites recorded from these animals are presented. Of particular importance are the ixodid ticks infesting elephant-shrews, as several of these can cause toxicosis, particularly paralysis in domestic animals, while others serve as important vectors of disease. Twenty-seven ixodid tick species belonging to six genera recorded from elephant-shrews are listed. Both host- and tick-dependent factors must be examined in order to determine the ecology of ticks infesting elephant-shrews and their relationship to disease in domestic and wild animals.

INTRODUCTION

The exact meaning of the term parasitism is controversial and difficult to define precisely. We prefer the definition of Kim (1985) which states that a parasite is a symbiont that lives, throughout a part or the entire period of its life, in or on the host from which its food and other biological necessities are derived.

Although many parasitological studies have concentrated on domestic livestock, investigations on wild animals, particularly on small mammals, are also important. First, they broaden our understanding of the ecology of zoonotic and veterinary diseases (Sonenshine, 1975; Fourie, Horak & Van den Heever, 1992). In this respect intensive studies on various small mammals which serve as hosts for the ticks capable of transmitting the Lyme disease agent (*Borrelia burgdorferi*) serve as a good example (Matuschka *et al.* 1991; Galbe & Oliver, 1992). Second, small mammals also act as reservoir hosts for many tick-transmitted diseases (Balashov, 1972). Consequently quantitative and qualitative data on the status of small mammals as hosts for medically and veterinary important parasites are essential. Third, there is a constant search for new and better animal models for biomedical research and small mammals should be considered (Stunkard *et al.*, 1975).

Elephant-shrews could serve as excellent subjects for the investigation of parasite–host interrelationships. Unfortunately there is a paucity of information on the parasites of these mammals. This paper deals with the diversity of ectoparasites which infest elephant-shrews, with particular emphasis on ticks. Some guidelines for future parasitological research on these animals are provided.

DIVERSITY OF PARASITES

Elephant-shrews are hosts of a variety of macroparasites. Although little is known about the endoparasites, acanthocephalans encysted in the body cavity and large intestine, have been recorded from *Elephantulus myurus* (D.J. Kok, J.S. Du Toit & L.J. Fourie, unpublished data), *Rhynchocyon chrysopygus* and *Petrodromus tetradactylus* (Rathbun, 1976). Various nematode

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species and cestodes have also been recovered from either the stomach, large intestine or the caecum of *E. myurus* (D.J. Kok, J.S. Du Toit & L.J. Fourie, unpublished data), *R. chrysopygus* and *P. tetradactylus* (Stunkard *et al.*, 1975; Rathbun, 1976). A variety of mites, lice and fleas have also been recorded from elephant-shrews and these are summarized in Table 1. Unfortunately no quantitative data on any of these ectoparasites are available.

Table 1. Host–parasite list of non-ixodid arthropod ectoparasites of various elephant-shrews. * Indicates typical elephant-shrew parasites. An asterisk followed by a question mark indicates that the parasite may typically occur on elephant-shrews but too few specimens have been found, not only on elephant-shrews, to be conclusive

Host	Parasite	Reference
Elephantulus		
E. brachyrhynchus	*Leptotrombidium subquadrata* (Acari: Trombiculidae)	Zumpt (1961)
	**?Schöngastia katangae* (Acari: Trombiculidae)	Zumpt (1961)
	**Schoutedenichia dureni* (Acari: Trombiculidae)	Zumpt (1961)
	**Schoutedenichia nasilionis* (Acari: Trombiculidae)	Zumpt (1961)
	Ctenocephalides felis (Siphonaptera: Pulicidae)	Zumpt (1966)
	Xenopsylla brasiliensis (Siphonaptera: Pulicidae)	Zumpt (1966)
	Dinopsyllus ellobius (Siphonaptera: Hystrichopsyllidae)	Zumpt (1966)
	Dinopsyllus lypusus (Siphonaptera: Hystrichopsyllidae)	Zumpt (1966)
	**Neolinognathus elephantuli* (Anoplura: Neolinognathidae)	Ledger (1980)
E. fuscipes	**Schoutedenichia dureni* (Acari: Trombiculidae)	Zumpt (1961)
	Echidnophaga gallinacea (Siphonaptera: Pulicidae)	Zumpt (1966)
	Ctenocephalides felis (Siphonaptera: Pulicidae)	Zumpt (1966)
E. myurus	**Ornithonyssus capensis* (Acari: Laelaptidae)	Shepherd & Narro (1983)
	**Neolinognathus elephantuli* (Anoplura: Neolinognathidae)	Ledger (1980)
E. rufescens	**Neolinognathus praelautus* (Anoplura: Neolinognathidae)	Ledger (1980)
E. rupestris	**Euschöngastia (?) annulata* (Acari: Trombiculidae)	Zumpt (1961)
	Echidnophaga gallinacea (Siphonaptera: Pulicidae)	Zumpt (1966)
	Ctenocephalides felis (Siphonaptera: Pulicidae)	Zumpt (1966)
	Xenopsylla brasiliensis (Siphonaptera: Pulicidae)	Zumpt (1966)
	Dinopsyllus lypusus (Siphonaptera: Hystrichopsyllidae)	Zumpt (1966)
	Listropsylla prominens (Siphonaptera: Hystrichopsyllidae)	Zumpt (1966)
	Epirimia aganippes (Siphonaptera: Chimaeropsyllidae)	Zumpt (1966)
	**Demeillonia granti* (Siphonaptera: Chimaeropsyllidae)	Zumpt (1966)

E. rupestris (as *E. vandami*)†	*Xenopsylla brasiliensis* (Siphonaptera: Pulicidae)	Zumpt (1966)
	**Demeillonia miriamae* (Siphonaptera: Chimaeropsyllidae)	Zumpt (1966)
	**Macroscelidopsylla albertyni* (Siphonaptera: Chimaeropsyllidae)	Zumpt (1966)
Macroscelides		
M. proboscideus	*Echidnophaga gallinacea* (Siphonaptera: Pulicidae)	Zumpt (1966)
	Xenopsylla occidentalis (Siphonaptera: Pulicidae)	Zumpt (1966)
	**Demeillonia granti* (Siphonaptera: Chimaeropsyllidae)	Zumpt (1966)
Petrodromus		
P. tetradactylus	**?Schöngastia howdadi zanzi* (Acari: Trombiculidae)	Zumpt (1961)
	**?Schoutedenichia oyei* (Acari: Trombiculidae)	Zumpt (1961)
	Echidnophaga gallinacea (Siphonaptera: Pulicidae)	Zumpt (1966)
	Ctenocephalides felis (Siphonaptera: Pulicidae)	Zumpt (1966)
	**Neolinognathus elephantuli* (Anoplura: Neolinognathidae)	Ledger (1980)
P. tetradactylus (as *P. sultan*)†	**Chimaeropsylla haddowi* (Siphonaptera: Chimaeropsyllidae)	Zumpt (1966)
	**Chimaeropsylla potis* (Siphonaptera: Chimaeropsyllidae)	Zumpt (1966)
Rhynchocyon		
R. chrysopygus	**Chimaeropsylla haddowi* (Siphonaptera: Chimaeropsyllidae)	Zumpt (1966)
	**Chimaeropsylla potis* (Siphonaptera: Chimaeropsyllidae)	Zumpt (1966)
R. cirnei	*Cordylobia rodhaini* (Diptera: Calliphoridae)	Zumpt (1966)
	**Chimaeropsylla potis* (Siphonaptera: Chimaeropsyllidae)	Zumpt (1966)
R. cirnei (as *R. stuhlmanni*)†	*Cordylobia rodhaini* (Diptera: Calliphoridae)	Zumpt (1966)
	**Chimaeropsylla potis* (Siphonaptera: Chimaeropsyllidae)	Zumpt (1966)
R. petersi	*Ctenocephalides felis* (Siphonaptera: Pulicidae)	Zumpt (1966)
	**Chimaeropsylla haddowi* (Siphonaptera: Chimaeropsyllidae)	Zumpt (1966)
	**Chimaeropsylla potis* (Siphonaptera: Chimaeropsyllidae)	Zumpt (1966)

† The following synonyms are recognized (Corbet, 1974; Meester *et al.*, 1986): *Elephantulus rupestris* (= *E. vandami*); *Petrodromus tetradactylus* (= *P. sultan*); *Rhynchocyon cirnei* (= *R. stuhlmanni*).

Particularly noticeable, especially to those who have captured elephant-shrews, are their tick infestations. Depending on the species and developmental stage, the ticks infesting elephant-shrews commonly attach to the head, including the ear margins, base of the tail and the tail itself (Rathbun, 1976; Du Toit, 1993). Twenty-seven ixodid tick species, belonging to six genera, have

been recorded from elephant-shrews (Table 2). Except for some adult tick species belonging to the genus *Ixodes,* elephant-shrews serve mainly as hosts for immature ticks. The immature stages of non-nidicolous two- and three-host ticks commonly feed on small mammals (Balashov, 1972; Oliver, 1989).

Table 2. Ixodid ticks recorded on various elephant-shrew species (A, adult, I, immature, L, larva, N, nymph)

Host	Tick	Reference
Elephantulus		
Elephantulus sp.	*Amblyomma sparsum* (I)	Theiler (1962)
	Haemaphysalis leachi leachi (I)	Theiler (1962)
	Hyalomma rufipes (I)	Theiler (1962)
	Ixodes sp. (I)	Theiler (1962)
	Ixodes alluaudi (I)	Theiler (1962)
	Rhipicephalus appendiculatus (I)	Theiler (1962)
	R. oculatus (A,I)	Theiler (1962)
	R. pravus (I)	Theiler (1962)
	R. sanguineus (I)*	Theiler (1962)
E. brachyrhynchus	*Ixodes* sp.	Theiler (1962)
	Rhipicephalus evertsi (I)	Theiler (1962)
	R. oculatus (I)	Theiler (1962)
	R. pravus (I)	Theiler (1962)
	R. punctatus (L, N)	Colbo & MacLeod (1976)
	R. sanguineus (I)	Theiler (1962)
	R. simus (I)	Theiler (1962)
E. fuscipes	*Rhipicephalus pravus* (I)	Theiler (1962)
E. intufi	*Rhipicephalus pravus* (I)	Theiler (1962)
E. myurus	*Amblyomma marmoreum* (L)	Fourie *et al.* (1992)
	Haemaphysalis leachi/spinulosa (L, N)	Fourie *et al.* (1992)
	Hyalomma marginatum rufipes (N)	Fourie *et al.* (1992)
	Ixodes rubicundus (L, N)	Fourie *et al.* (1992)
	Rhipicephalus arnoldi (L, N)	Fourie *et al.* (1992)
	R. distinctus (N)	Fourie *et al.* (1992)
	R. punctatus (L, N)	Fourie *et al.* (1992)
	Rhipicentor nuttalli (L, N)	Du Toit (1993)
E. edwardii	*Haemaphysalis leachi/spinulosa* (L, N)	Fourie & Horak (unpublished)
	Ixodes rubicundus (L, N)	Fourie & Horak (unpublished)
	Rhipicephalus gertrudae (L, N)	Fourie & Horak (unpublished)
	R. punctatus (L, N)	Fourie & Horak (unpublished)
E. rufescens	*Rhipicephalus evertsi* (I)	Theiler (1962)
	R. pravus (A, I)	Theiler (1962)
	R. sanguineus (I)	Theiler (1962)
E. rupestris	*Amblyomma marmoreum* (I)	Theiler (1962)
	Haemaphysalis leachi leachi (I)	Theiler (1962)
	H. leachi mühsami (I)	Theiler (1962)
	Ixodes sp. (I)	Theiler (1962)
	I. alluaudi (I)	Theiler (1962)
	I. rubicundus (I)	Theiler (1962)
	I. pilosus (I)	Theiler (1962)
	Rhipicephalus appendiculatus (I)	Theiler (1962)
	R. capensis (I)	Theiler (1962)
	R. oculatus (I)	Theiler (1962)
	R. pravus (I)	Theiler (1962)
Macroscelides		
Macroscelides sp.	*Rhipicephalus sanguineus* (I)	Theiler (1962)
M. proboscideus	*Haemaphysalis leachi leachi* (I)	Theiler (1962)
	Rhipicephalus evertsi (I)	Theiler (1962)
	R. oculatus (I)	Theiler (1962)

Petrodromus		
Petrodromus sp.	*Ixodes* sp. (I)	Theiler (1962)
	I. nchisiensis (A)	Theiler (1962)
	Rhipicephalus appendiculatus (I)	Theiler (1962)
	R. kochi	Clifford *et al.*(1983)
	R. pravus (I)	Theiler (1962)
	R. oculatus (I)	Theiler (1962)
P. tetradactylus	*Ixodes nchisiensis* (A)	Colbo & MacLeod (1976)
	I. rhabdomysae (N)	MacLeod (1970)
	Rhipicephalus appendiculatus (L, N)	MacLeod (1970)
	R. oculatus (I)	Theiler (1962)
	R. punctatus (L, N)	MacLeod (1970)
	R. pravus (L, N)	MacLeod (1970)
	R. sanguineus group (L, N)	MacLeod (1970)
	R. simus group (L)	MacLeod (1970)
	R. tricuspis (N)	MacLeod (1970)
P. tetradactylus	*Rhipicephalus pravus* (I)	MacLeod (1970)
(= *P. rovumae*)†	*R. sanguineus* (I)	MacLeod (1970)
P. tetradactylus	*Haemaphysalis leachi leachi* (I)	MacLeod (1970)
(= *P. sultan*)†	*Ixodes* sp. (I)	MacLeod (1970)
	Rhipicephalus appendiculatus (I)	MacLeod (1970)
	R. pulchellus (I)	MacLeod (1970)
	R. sanguineus (I)	MacLeod (1970)
	R. simus (I)	MacLeod (1970)
Rhynchocyon		
Rhynchocyon cirnei	*Ixodes rasus* group (A)	Colbo & MacLeod (1976)
R.. chrysopygus	*Rhipicephalus appendiculatus* (I)	Theiler (1962)
R.. petersi	*Haemaphysalis parmata* (I)	Theiler (1962)
	Ixodes vanidicus (A)	Theiler (1962)
	Rhipicephalus simus (I)	Theiler (1962)

* The records listed by Theiler (1962) as *Rhipicephalus sanguineus* may actually refer to *R. tupanicus*, a species not then known to occur in the Afrotropical region (Walker, 1991).

† The following synonyms are recognized (Corbet, 1974; Meester *et al.*, 1986): *Petrodromus tetradactylus* (= *P. rovumae*; = *P. sultan*).

In those cases for which quantitative data on tick infestations of elephant-shrews are available it is evident that these animals have the potential to carry very large burdens (MacLeod, 1970; Colbo & MacLeod, 1976; Fourie *et al.*, 1992). An examination of *E. myurus* and *Aethomys namaquensis*, which occur sympatrically in the southern Orange Free State of South Africa, has shown that the 132 elephant-shrews examined harboured a mean total burden of 121 ticks, compared to a mean of four for the 321 Namaqua mice (Fourie *et al.*, 1992). Similar observations have been made on elephant-shrews and rodents studied in Zambia (Colbo & MacLeod, 1976). It is not uncommon to record a total tick burden in excess of 400 on *E. myurus*. This species has been used in the laboratory on a routine basis to feed the larvae and nymphs of *Ixodes rubicundus*, the Karoo paralysis tick (Du Toit, 1993).

SIGNIFICANCE OF TICK INFESTATIONS

Many of the tick species that infest elephant-shrews are known to cause either tick toxicosis, including tick paralysis, or to transmit a diversity of pathogens such as viruses, bacteria, rickettsias, spirochaetes and protozoans to man and animals (Balashov, 1972). Because there is a lack of sound quantitative and qualitative data on tick infestations of elephant-shrews in general, the exact status of these animals as hosts for veterinary and medically important ticks remains uncertain. Although a total of seven ixodid tick species were recorded from *E. myurus,* two paralysis-inducing tick species, *I. rubicundus* and *Rhipicephalus punctatus,* accounted for 99% of

the ticks recovered (Fourie *et al.*, 1992). The first mentioned species is of major economic importance in South Africa because adult females are capable of causing paralysis, and consequently mortalities, amongst domestic stock (Fourie *et al.*, 1989) and wild artiodactyls (Fourie & Horak, 1987; Fourie & Vrahimis, 1989). *Elephantulus myurus* is a major host of the immature stages of this tick and large numbers have also been collected from *Elephantulus edwardii* (Stampa, 1959).

To assess the complex phenomenon of tick–host–disease relationships, detailed and simultaneous studies, generating data at the various levels of the interactions, are required. Individual interactions between ticks and their hosts may be governed by host-dependent and tick-dependent factors. Host-dependent factors include abundance, home-range size, seasonal and daily activity patterns and habitat selection. All these factors have a direct influence on the hosts' patterns of habitat utilization and hence tick–host contact. Furthermore, host-dependent factors may also include age (i.e. size) and sex-related differences in the above-mentioned factors, the ability of the host to acquire protective immunity to ticks and its susceptibility to tick-transmitted pathogens. Tick-dependent factors include parameters such as predilection (host specificity) or opportunism (indiscriminate acceptance of all hosts), the temporal and spatial distribution of the tick and appetence response (Arthur, 1973; Sonenshine, 1975).

Several of these aspects pertaining to the interaction between *I. rubicundus* (Karoo paralysis tick) and *E. myurus*, such as effect of tick feeding on the host (Du Toit, 1993), detachment rhythms (Du Toit, Fourie & Horak, 1994), abundance, spatial distribution and activity patterns of the host, have already been investigated (Du Toit, 1993). The data gained have contributed in a major way towards our understanding of interrelationships between the tick and its host and stress the importance of a holistic approach in research design. For example, factors within an agro-ecosystem which contribute towards changes in the density of *E. myurus* within the habitat may markedly affect the population dynamics of *I. rubicundus*. Alternatively, colonization of new areas by the Rock Elephant-Shrew may also contribute towards the expansion of the geographic distribution range of the tick and the disease it causes. The detailed and simultaneous study of the many complex interactions pertaining to tick–host–disease interactions constitutes a major effort. Advances in the computer modelling of such interactions have been made recently (Haile, Mount & Cooksey, 1990) and this represents a useful tool in our understanding of these processes.

In the past, few attempts have been made to understand and quantify the nutritional, ecological and physiological implications of parasitic infestations on wild hosts. The reasons for this may be diverse, but are probably related to the fact that in domesticated or laboratory animals, the effects of parasitism are more readily determined and economic considerations often dictate the choice of subject animals. In this respect elephant-shrews are promising subject animals when taking into account the diversity and quantity of parasites that infest them and the ease with which they can be maintained as laboratory animals. To support this contention the guidelines listed below for future parasitological research on elephant-shrews are suggested.

1 The status of various elephant-shrew species as hosts for medical and veterinary important ticks should be determined.

2 The ability of elephant-shrews to maintain tick-transmitted pathogens should, as a matter of urgency, receive attention.

3 Habitat requirements of elephant-shrews and factors which may contribute towards the expansion of their distribution should be investigated. This together with the relevant data on tick ecology will make it possible to delineate the area of influence of particular tick vectors.

4 Data on the prevalence and seasonality of both elephant-shrews and ticks infesting them should be obtained, analysed and incorporated into predictive models.

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PARASITES OF AFRICAN BUFFALOES: A DOCUMENTATION

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INTRODUCTION

In South Africa, the parasites of buffalo have not received much attention, despite the animals' relative abundance in this country. Although Young & van den Heever[102] and Basson *et al.*[6] examined the carcasses of many buffaloes culled in the Kruger National Park (KNP), no surveys of the parasites have been conducted and those parasites that are known have been collected incidentally. A survey involving thousands of buffaloes was conducted in Mozambique, and despite the numbers of animals involved, few parasites were reported on.

In this paper we attempt to bring together the literature pertaining to the parasites of buffaloes. The list is by no means complete as much of the older literature was inaccessible. We further attempted to separate those parasites recorded from South Africa from those of the rest of Africa, and those occurring in *Syncerus caffer caffer* from those of *Syncerus caffer nanus*.

PROTOZOA AND RICKETTSIAS (Table 1)

Babesia species and *Anaplasma* species

Although common in cattle, in which these organisms cause severe disease, they have to the best of our knowledge not yet been recorded from buffaloes in South Africa. Both of these organisms are transmitted by the blue tick, *Boophilus decoloratus*.

Theileria and *Haematoxenus* species

Buffaloes have long been known to be the main carriers of the *Theileria* spp., of which *T. parva parva*, *T. parva lawrencei* and *T. mutans* are transmissible to cattle. The first two subspecies are transmitted by one or more of the *Rhipicephalus* spp., and are highly pathogenic to cattle, causing East Coast Fever and Corridor Disease, respectively. *Theileria mutans* is a non-clinical infection that is transmitted by *Amblyomma hebraeum*. A fourth species, *Theileria barnetti* appears to be specific to buffaloes. Clinical disease or deaths due to these organisms, as well as the *Haematoxenus* spp. which are closely related to the *Theileria* spp., appear to be rare in buffaloes.

Trypanosoma species

A number of *Trypanosoma* spp. have been recorded in buffaloes in East and Central Africa, but none have been reported from buffaloes from the KNP. It is, however, quite possible that buffaloes in the northern game reserves in KwaZulu-Natal are infected since the vectors, *Glossina* spp., occur there. *Trypanosoma brucei*, *T. congolense* and *T. vivax* cause nagana in cattle but do not seem to affect the buffaloes adversely.

Sarcocystis spp.

These organisms are sometimes visible as elongated white spots in especially the tongue, oesophagus and muscles of buffaloes. In the KNP, 59 % and 86 % of buffaloes examined were

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positive[6 102]. Although not thought to be infective to man, the presence is aesthetically unacceptable.

Coccidia

Coccidia occur in the small intestine an are excreted as oocysts, which have a tough shell and can survive in the environment for quite a while. Despite these organisms being present in varying numbers in most animals examined, nothing about the species and numbers that occur in buffaloes is known.

HELMINTHS (Table 2)

A large diversity of helminths occurring in almost every organ in the animals, have been recorded. Out of the 81 species and/or genera listed, only 32 occur in buffaloes in South Africa.

Nematodes

With the exception of the *Elaeophora* spp. which occur in distensions of the blood vessels of the lung and in aneurysms of the coronary vessels, the *Gongylonema* sp. in the mucosa of the oesophagus, the *Onchocerca* spp. and *Parafilaria bassoni* in the subcutaneous tissue, the *Setaria* spp. free in the abdominal cavity and the *Thelazia* spp. in the conjunctival sac of the eyes, all the nematodes occur in the intestinal tract. Apart from *Elaeophora poeli*, *Oesophagostomum synceri*, *Onchocerca synceri* and *Toxocara manzadiensis*, which appear to occur only in buffalo, all the nematodes have been recorded from sheep, cattle or antelope. Quantitative surveys have not been reported and our limited experience indicate that buffaloes do not harbour large burdens. For example, four buffaloes from the KNP harboured a mean of 1 086 (range 148 - 2 017) nematodes, and four from the Hluhluwe-Umfolozi Park 2 096 (range 0 - 8 383). Taking the nematode species diversity into account, the burdens are not significant and animals should be in no way inconvenienced by the worms.

Trematodes

Only five of the 24 trematode species and/or genera have been found in South Africa. An interesting record is that of *Schistosoma haematobium*[6], which is primarily a parasite of man. Other noteworthy trematodes are the *Fasciola* spp. which also occur in domestic ruminants.

Cestodes

Surprisingly few cestodes have been recorded, all of which are the typical herbivore cestodes and all of which have been recorded from a number of antelopes. The larval cestodes may have some significance, depending on their potential infectivity for humans. The larvae of *Taenia saginata* have as yet only been found in Angola[78] but there is little doubt that they occur in buffalo in South Africa as well.

ARTHROPODS AND PENTASTOMES (Table 3)

Ticks

A total of 59 species and/or genera of ticks have been reported as occurring on buffaloes. Many of these ticks are the vectors of protozoal and other diseases, e.g. *Boophilus decoloratus* for *Babesia* and *Anaplasma*, *Rhipicephalus appendiculatus*, *R. maculatus*, *R. muehlensi* and *Amblyomma hebraeum* for the *Theileria* spp. and *A. hebraeum* for heartwater (*Cowdria ruminantium*). However, none of the ticks is specific for buffaloes and most occur in larger numbers on antelopes, although several of the *Rhipicephalus* spp. prefer buffaloes. A noteworthy record is that of *Amblyomma tholloni*, which occurs almost exclusively on elephant, with few records of other hosts[20 96].

Mites

Demodex infections in buffalo present as cutaneous nodules[102] and were present in 10 % of the buffaloes examined[6], while infections with *Psoroptes* cause a scaly alopecia that is greyish in colour[6]. Basson *et al.*[6] believe that the incidence in buffaloes in the KNP is fairly high.

Flies

Only a few of the flies that are associated with buffaloes have been identified. The Tabanidae are large blood-sucking flies that have a high irritation value but are opportunistic feeders. Others, like the *Haematobia* spp., are more permanently associated with the animals and they breed in freshly deposited dung. It appears that the majority of the flies have nuisance value but some are also vectors for diseases such as Wesselsbron Disease, Bluetongue and possible Ephemeral Fever and Lumpy Skin Disease[102].

Lice

Only two species of lice, both the so-called 'blue' or blood-sucking, have been described. No data as to infection rates and seasonal occurrence are available.

Pentastomes

The large carnivores, especially lions, are the final hosts of the pentastomes and various antelopes and buffaloes, the intermediate hosts. The pentastomes occur in the cardio-vascular system, notably the blood vessels of the liver and in the heart. They cause large migration tracts in the parenchyma of the liver but despite their size (8 - 10 mm) they seem to cause little damage[6,102]. The incidence in buffaloes in the KNP varied from 64 %[102] to 69 %[6].

CONCLUSION

A large number of parasites are associated with buffalo, many of which are transmissible to other wildlife as well as to man and his domestic animals. Of particular importance are the theilerioses, fasciolosis, taenioses and sarcoptic mange. In view of this situation, one should carefully consider the consequences of introducing buffalo onto a game farm.

A large diversity of helminths have been recorded, with at least 20 identified species of nematodes, five trematodes, two adult cestodes and three larval cestodes being recorded from buffaloes in South Africa. A fairly constant feature is the presence of *Elaeophora poeli* in the blood vessels of the heart and lungs in buffaloes from Mozambique, and the presence of *Onchocerca nelsoni* in the majority of buffalo throughout Africa.

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Table 1: The protozoan parasites of African buffaloes

GENUS AND/OR SPECIES	SOUTH AFRICA	REST OF AFRICA	REFERENCES
Babesia spp.	-	+	26, 46
Anaplasma centrale	-	+	11, 26, 51
Anaplasma marginale	-	+	14
Anaplasma spp	-	+	46
Haematoxenus veliferus	-	+	86
Haematoxenus sp.	-	+	101
Sarcocystis spp.	+	+	6, 26, 34, 102
Theileria barnetti	-	+	10
Theileria parva lawrencei	+	+	55, 56, 58, 102
Theileria parva parva	-	+	5, 56, 57
Theileria mutans	+	+	11, 56, 57
Theilerial piroplasms	+	+	14, 57
Trypanosoma brucei	?	+	1, 14, 57
Trypanosoma congolense	?	+	1, 14, 99, 102
Trypanosoma theileri	?	+	3
Trypanosoma vivax	?	+	1, 99
Trypanosoma uniforme	?	+	1, 99
Coccidia oocysts	+	+	36[a], 102

[a] Found in *Syncerus caffer nanus*

Table 2: The helminth parasites of African buffaloes

GENUS AND/OR SPECIES	SOUTH AFRICA	REST OF AFRICA	REFERENCE
NEMATODES			
Agriostomum gorgonis	+	+	6, 38, 102
Ashworthius lerouxi	0	+	18
Bunostomum sp.	0	+	20
Chabertia ovina	0	+	12, 34
Cooperia fuelleborni	+	+	6, 20, 30, 38, 102
Cooperia hungi	-	+	30, 38
Cooperia pectinata	+	+	38, 42[a]
Cooperia punctata	+	+	38, 42[a]
Elaeophora poeli	-	+	8, 12, 20, 27, 74, 75
Elaeophora sagitta	+	+	38, 48
Gaigeria pachyscelis	-	+	18
Gongylonema pulchrum	-	+	38
Gongylonema sp.	-	+	70
Haemonchus bedfordi	+	+	6, 20, 29, 38, 41, 42[a], 62, 102
Haemonchus contortus	+	+	6, 17, 26, 29, 32b, 38, 42[a]
Haemonchus sp.	+	-	102
Impalaia tuberculata	-	+	38
Longistrongylus meyeri	-	+	20, 38
Longistrongylus schrenki	+	-	Boomker & Horak, unpubl
Mammomonogamus sp.	-	+	69
Oesophagostomum radiatum	+	-	6, 102
Oesophagostomum synceri	-	+	85
Onchocerca armillata	-	+	75
Onchocerca gibsoni	-	+	66, 67
Onchocerca synceri	+	+	6, 75, 102
Onchocerca sp.	-	+	20, 81
Ostertagia ostertagi	+	-	Boomker & Horak, unpubl
Ostertagia sp.	-	+	20
Parabronema skrjabini	+	+	6, 12, 20, 102

Parabronema sp.	+	-	62
Parafilaria bassoni	+	-	40
Setaria africana	-	+	16
Setaria bicoronata	-	+	38
Setaria labiatopapillosa	-	+	16, 20, 26, 49, 53, 68, 72, 73, 80, 84, 87
Setaria nelsoni	-	+	76
Thelazia lachrymalis	+	-	6
Thelazia rhodesii	+	+	6, 20, 102
Thelazia sp.	+	-	102
Toxocara manzadiensis	-	+	92
Toxocara vitulorum	-	+	92
Trichuris barbertonensis	-	+	20, 38
Trichuris globulosa	+	+	6, 32, 102
Trichuris sp.	+	+	34, Boomker & Horak, unpubl
Trichostrongylus axei	+	-	6, Boomker & Horak, unpubl
Trichostrongylus colubriformis	-	+	28
Trichostrongylus deflexus	+	?	Boomker & Booyse, unpublished
Trichostrongylus sp.	+	-	102
Ascaridoidea	-	+	36[b]
Strongyloidea	-	+	36[b]
Microfilariae	-	+	4
Unidentified filarids	+	-	102
TREMATODES			
Calicophoron calicophorum	-	+	91
Calicophoron clavula	-	+	25, 38
Calicophoron microbothrium	+	+	6, 20, 38, 62, 65, 82, 102
Calicophoron phillerouxi	-	+	20, 25, 91
Calicophoron raja	-	+	25, 38
Calicophoron sukari	-	+	25, 91
Calicophoron sukumum	-	+	25, 91
Calicophoron sp.	-	+	36[b]
Carmyerius endopapillatus	-	+	21, 22

Carmyerius exporus	-	+	38, 65
Carmyerius gregarius	-	+	21, 22, 53
Cotylophoron cotylophorum	+	+	6, 20, 17, 44, 47, 49, 62, 65, 80, 88, 102
Cotylophoron fuelleborni	-	+	20, 54
Cotylophoron indicum	-	+	20
Cotylophoron macrosphinctris	-	+	20
Dicrocoelium hospes	-	+	33
Fasciola gigantica	-	+	9, 53
Fasciola hepatica	+	+	19, 62, 72, 73, 80
Fasciola sp.	-	+	36[b]
Gigantocotyle gigantocotyle	-	+	38
Schistosoma haematobium	+	-	6
Schistosoma leiperi	-	+	43
Schistosoma margrebowiei	-	+	43
Schistosoma mattheei	+	+	6, 43, 102
CESTODES			
Adult			
Avitellina centripunctata	+	+	2, 6, 38, 62, 102
Moniezia benedeni	-	+	38
Moniezia expansa	-	+	38
Stilesia hepatica	-	+	38, 79
Thysaniezia giardi	-	+	77
Thysaniezia ovilla	-	+	31
Larvae			
Cysticercus sp.	+	+	42[a], 43, 102
Diphyllobothrid tapeworm	-	+	69
Echinococcus sp.	+	+	6, 34, 102
Taenia gonyamai	+	-	6, 89
Taenia regis	+	-	6
Taenia saginata	-	+	34, 78

[a] Recovered from sheep after artifical infection with larvae obtained from the faeces of animals in the Johannesburg Zoological Gardens

[b] Found in *Syncerus caffer nanus*

Table 3: The arthropod and pentastome parasites of African buffaloes

GENUS AND/OR SPECIES	SOUTH AFRICA	REST OF AFRICA	REFERENCE
TICKS			
Amblyomma astrion	-	+	64, 83, 96
Amblyomma cohaerens	-	+	34, 64, 83, 96
Amblyomma eburnum	-	+	83
Amblyomma gemma	-	+	83, 94, 97
Amblyomma hebraeum	+	+	4, 7, 36[a] 37, 39, 59, 83, 94, 102
Amblyomma lepidum	-	+	83, 97
Amblyomma marmoreum	+	-	Horak, unpublished
Amblyomma pomposum	-	+	45, 83
Amblyomma sparsum	-	+	64, 83, 95, 96
Amblyomma splendidum	-	+	83
Amblyomma tholloni	+	+	20, 94, 83
Amblyomma variegatum	-	+	36[a], 64, 83, 97
Boophilus decoloratus	+	+	4, 7, 15, 37, 39, 83, 102
Boophilus microplus	+	+	83
Dermacentor rhinocerinus	+	+	83
Haemaphysalis aciculifer	?	?	51, 95
Haemaphysalis hoodi	?	+	26
Haemaphysalis leachi	?	+	26
Haemaphysalis parmata	-	+	83
Haemaphysalis silacea	+	-	37
Hyalomma albiparmatum	-	+	51
Hyalomma rufipes	+	+	15, 35, 39, 83, 94, 95
Hyalomma truncatum	+	+	4, 15, 35, 39, 83, 97
Ixodes cumulatimpunctatus	-	+	83
Ixodes lewisi	-	+	13, 51
Ixodes pilosus	+	-	4, 39, 83
Ixodes rasus	-	+	51
Ixodes sp.	+	-	83
Rhipicephalus appendiculatus	+	+	4, 7, 37, 39, 60, 83, 102

Rhipicephalus bequaerti	-	+	83
Rhipicephalus capensis	+	+	83
Rhipicephalus cliffordi	-	+	51, 52
Rhipicephalus complanatus	-	+	83
Rhipicephalus compositus	-	+	83
Rhipicephalus dux	-	+	83
Rhipicephalus evertsi evertsi	+	+	7, 15, 37, 83, 102
Rhipicephalus evertsi mimeticus	+	+	83
Rhipicephalus follis	+	?	Horak, unpublished
Rhipicephalus hurti	-	+	83
Rhipicephalus jeaneli	?	?	51
Rhipicephalus kochi	-	+	83
Rhipicephalus longicoxatus	-	+	83
Rhipicephalus longus	-	+	83
Rhipicephalus lunulatus	+	+	95
Rhipicephalus maculatus	+	+	7, 37, 83
Rhipicephalus masseyi	-	+	83
Rhipicephalus muehlensi	+	+	37, 83
Rhipicephalus pravus	+	+	83
Rhipicephalus pulchellus	-	+	83
Rhipicephalus reichenowi	-	+	83, 93, 103
Rhipicephalus sculptus	-	+	83
Rhipicephalus senegalensis	-	+	83
Rhipicephalus simus	+	+	15, 34, 37, 83, 95
Rhipicephalus sulcatus	-	+	63
Rhipicephalus supertritus	-	+	83
Rhipicephalus tricuspis	+	+	15, 83
Rhipicephalus turanicus	+	-	63
Rhipicephalus zambeziensis	+	+	60, Horak, unpublished
Rhipicephalus ziemanni	-	+	83
MITES			
Demodex cafferi	-	+	61
Demodex pienaari	+	?	6, 102, 105

Demodex sp.	+	-	102
Psoroptes sp.	+	-	6, 102
Sarcoptes sp.	+	-	102
FLIES			
Glossina spp.	-	+	1, 98
Haematobia thirouxi potans	+	-	23, 24, 102,104
Hippoboscid flies (includes keds)	+	-	102
Stomoxys sp.	+	-	102
Tabanidae	+	+	Boomker & Keet, unpublished
LICE			
Haematopinus bufali	+	+	7, 26, 50, 102
Linognathus sp.	+	-	101
PENTASTOMIDA			
Linguatula multiannulata	-	+	71, 90
Linguatula serrata	+	+	6, 26, 71, 102
Neolinguatula nuttalli	-	+	71

[a] Found in *Syncerus caffer nanus*

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PARASITES OF LIONS (*PANTHERA LEO*) AND LEOPARDS (*PANTHERA PARDUS*) : A DOCUMENTATION

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INTRODUCTION

As is the case with many of the wild animals in South Africa, the helminths of lions and leopards are poorly known. Young[112] listed some of the diseases and parasites found in lions in the Kruger National Park, but those occurring in leopards are largely unknown. Those helminths that have been found in these carnivores have been collected incidentally, and no surveys have been conducted.

In this paper we attempt to bring together the existing literature pertaining to the parasites of free-living lions and leopards. The parasite records have been divided into those occurring in South Africa and those occurring in the rest of Africa. Records of helminth parasites collected from these carnivores in zoological gardens have not been included, as have the numerous records from India, China and Japan.

PROTOZOA AND RICKETTSIAE (Tables 1 and 2)

Babesia spp.
Elsa, the famous lioness, is said to have died of babesiosis[1]. Various babesias have been found in lion blood smears, but specific identification has not been confirmed. A small *Babesia*, morphologically indistinguishable from *B. felis*, was found on blood smears of all lions examined in Kruger National Park (KNP)[84] and also in Kenya and Tanzania[9, 20]. The KNP parasite has been shown to be serologically distinct from *B. felis*[57]. A large *Babesia* was also found, albeit rarely, in KNP lions[84]. *Babesia pantherae*, a large piroplasm, was described from leopards in Kenya[29]. Small Babesias, morphologically similar to *B. felis*, have been seen in blood smears of leopards in Kenya and KNP[20] (own observations - BLP).

Hepatozoon
Hepatozoon sp., morphologically resembling *H. canis*, commonly occurs on blood smears of lions and leopards in the KNP and East Africa[9, 15, 20, 45, 62, 112]. *Microbesnoitia leoni* [22, 23] has been shown to be a junior synonym of *Hepatozoon canis*[33].

Trypanosoma sp.
Trypanosoma congolense and *Trypanosoma brucei* have been reported from lion blood smears[10, 14, 21, 31, 36, 69, 91]. In the Serengeti National Park and Ngorongoro Conservation Area, Tanzania, 28 % of the lions were infected with *Trypanosoma* sp.[9]. It has been postulated that lions may become infected with trypanosomes by feeding on infected animals[66].

Trypanosoma congolense has been reported from leopard blood smears[14]. Leopards have been incriminated as a possible reservoir of *Trypanosoma brucei rhodesiense* in an outbreak of human sleeping sickness in Uganda[43]. *Trypanosoma evansi* has been reported from leopards in India[27, 28, 95].

Encephalitozoon cuniculi
Encephalitozoon cuniculi has been reported from a litter of lion cubs born at a breeding centre in the Lowveld of Northern Province (P.S. Rogers, personal communication).

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Coccidia

Isospora leonina, *Isospora pantheri* and *Isopora mohini* were described from captive lions in India, while *Isospora felis* oocysts have been recovered from lion faeces[3, 47, 59, 61]. *Isospora* species are commonly reported from captive lions[56, 85]. In Serengeti National Park and Ngorongoro Crater, Tanzania, 53% of lions sampled were shedding unidentified coccidian oocysts[70].

Table 1: The protozoan parasites of lions

GENUS AND/OR SPECIES	SOUTH AFRICA	REST OF AFRICA	REFERENCE
Babesia sp.	+	+	1, 8, 9, 20, 57, 84
Encephalitozoon	+	?	P.S. Rogers, pers. comm.
Hepatozoon sp.	+	+	9, 15, 20, 45, 62, 112
Unidentified coccidia	-	+	70
Microbesnoitia (syn. *Hepatozoon*)	+	+	22, 23, 33
Sarcocystis sp.	+	+	23, 32, 83, 97
Trypanosoma spp.	+	+	10, 14, 21, 31, 36, 69, 91

Table 2: The protozoan parasites of leopards

GENUS AND/OR SPECIES	SOUTH AFRICA	REST OF AFRICA	REFERENCE
Babesia pantherae	-	+	29
Babesia sp.	+	?	20
Hepatozoon sp.	+	+	9, 15, 20, 45, 62, 112
Isospora spp.	-	+	39
Microbesnoitia (syn. *Hepatozoon*)	+	+	20, 45, 62
Trypanosoma brucei	-	+	43
Trypanosoma congolense	+	?	14

Isospora rivolta oocysts have been recovered from leopard faeces[47, 60], while unidentified *Isospora* species oocysts have been reported from captive leopards[39]. Two distinctly different *Isospora* oocysts have been reported from leopards in Thailand[83].

Cryptosporidium
Oocysts of *Cryptosporidium* species have been recovered from a captive leopard[110].

Sarcocystis sp.
A *Sarcocystis* sp. recovered from a lioness in Nairobi National Park, Kenya[23] has been named *Sarcocystis felis*[32], and *Sarcocystis* cysts were found in the myocardium of a leopard in India[97]. *Sarcocystis*-like oocysts have been reported from the faeces of leopards in Thailand[83].

Besnoitia besnoiti
The definitive host of this tissue cyst-forming coccidian in Africa is still unknown. Attempts to infect lions and leopards were unsuccessful[30].
Microbesnoitia leoni

See *Hepatozoon* sp.

Table 3: The helminth parasites of lions

GENUS AND/OR SPECIES	SOUTH AFRICA	REST OF AFRICA	REFERENCE
TREMATODES			
Pharyngostomum cordatum	-	+	13, 50
CESTODES			
Diphyllobothrium theileri	-	+	13
Dipylidium sp.	-	+	50
Echinococcus granulosus felidis	+	+	80, 103, 104, 105
Mesocestoides sp.	-	+	48, 50
Taenia gonyamai (= *T. hlosei*)	±	+	23, 81
Taenia hydatigena	-	+	40, 78
Taenia regis (=*T. bubesi*)	+	+	7, 11, 58
Taenia taeniaeformis	±	-	37
Taenia sp.	-	+	48, 75
NEMATODES			
Ancylostoma paraduodenale	-	+	18, 50
Ancylostoma tubaeforme	+	+	50, 112
Cylicospirura subaequalis	-	+	93, 94, 99
Cylicospirura sp.	+		112
Dirofilaria repens	-	+	44, 50
Dirofilaria sudanensis	+	+	108, 112
Filaria leonis	-	+	11
Filaria martis	-	+	6
Filaria latala	+	-	24
Galonchus perniciosus	-	+	50
Gnathostoma spinigerum	-	+	50
Gnathostoma sp.	-	+	41, 49
Lagochilascaris major	-	+	34, 35, 51, 55
Ollulanus tricuspis	-	+	50
Physaloptera praeputialis	-	+	5, 25, 48, 50
Physaloptera malayensis	+	-	112
Physaloptera sp.	-	+	41
Toxocara canis	-	+	23, 68
Toxocara cati	-	+	12, 67, 68, 102
Toxascaris leonina	-	+	50
Trichinella spiralis	+	+	8, 73, 74

Toxoplasma

Acute disseminated toxoplasmosis has been reported from captive lions in Nigeria[77], while antibodies to *Toxoplasma gondii* were found in sera from lions in Etosha National Park, Namibia, and captive lions in the USA[82, 89, 98]. Captive lions in Kazakhstan were reported to be final hosts of *T. gondii*[86] however, the evidence presented appears rather suspect.

Toxoplasma-like oocysts have been reported from leopards in Thailand[83]. Serum from a single captive leopard in California was negative for *Toxoplasma* antibodies[89].

Giardia sp.

Cysts of *Giardia* species have been reported from leopards in Thailand [83].

HELMINTHS (Tables 3 and 4)

Nematodes
Relatively few nematode species have been collected from these carnivores. The more important ones are *Trichinella* (from a zoonotic point of view), the various hookworms (*Galonchus*, *Ancylostoma*), which may cause clinical disease in the animals, and the ascarids *Toxocara* and *Toxascaris*, both from a zoonotic and a disease causing point of view.

Cestodes
A large variety of species of the genus *Taenia* are present in the carnivores[107] and this appears to be the main genus of cestodes in these animals. All the *Taenia* spp. utilise ruminants as intermediate hosts, which implies that the ruminant should be eaten by the carnivore in order for the life cycle to continue.

Trematodes
A single trematode species has been reported from the intestines of lions and leopards, and it appears to be an incidental finding.

ARTHROPODS (Tables 5 and 6)

Ticks
Only 12 species of ticks were found on lions and leopards in the Kruger National Park. Lions were often heavily infested with the larvae and nymphs of *Amblyomma hebraeum* and these carnivores also seem to be a favoured host of the adult stages of the yellow dog tick, *Haemaphysalis leachii*. Two of 16 lions examined had heavy burdens of the brown ticks *Rhipicephalus appendiculatus*, one a heavy burden of *Rhipicephalus simus* and yet another a heavy burden of *Rhipicephalus zambeziensis*. Leopards were not infested to the same degree as lions and the most commonly encountered tick was *Rhipicephalus zambeziensis*.

Several of the ticks are implicated in the transmission of especially protozoal and bacterial diseases. The ticks also have a worrying effect on the animals, and those with the longer mouthparts may leave wounds through which other organisms may enter, such as bacteria (causing abscesses) and helminths (by the intermediate hosts feeding on the wounds).

Mites
Sarcoptes has caused severe clinical mange in free-living lions in the Kruger National Park, but no records of mites occurring on leopards could be found in the literature.

Flies
Hippobosca longipennis is a winged fly and is semi-permanently associated with carnivores in general. It is an avid blood sucker with a high irritation value, and may also be responsible for the transmission of bacterial and/or viral diseases. Adult females produce a fully mature third instar larva, one at a time, which immediately pupates in the soil.

Cordylobia anthropophaga, the Tumbu fly, is strongly attracted to urine or faeces and will deposit its eggs on dry sand contaminated with urine of faeces. The first instar larvae must enter the skin of a suitable host, in which it will cause a large boil (warble). After two moults the fully developed third instar larvae drops out of the boil in the skin and pupates in the soil. The lesion is irritating and can easily become infected.

Fleas
Both *Echidnophaga larina* and *Echidnophaga gallinacea* are stick-tight fleas of which the females burrow deeply into the skin, especially of the feet and that around the eyes. These females have expanded bodies and are difficult to remove. Once the eggs have been laid the females die and fall out of the skin. Both species are extremely common in Africa and it is said that both are vectors of bubonic plague, although not very good ones [38].

Table 4: The helminth parasites of leopards

GENUS AND/OR SPECIES	SOUTH AFRICA	REST OF AFRICA	REFERENCE
TREMATODA			
Pharyngostomum cordatum	-	+	13
CESTODA			
Diphyllobothrium decipiens	-	+	40
Diphyllobothrium theileri	-	+	13
Diphyllobothrium ? pretoriensis	-	+	42
Taenia acinonyxi	-	+	58
Taenia ingwei	+	+	81, 63, 64
Taenia regis (= *T. bubesi*)	+	-	107
Taenia sp.	-	+	75
NEMATODA			
Ancylostoma braziliense	-	+	2, 17
Ancylostoma caninum	-	+	2
Cyathospirura chevreuxi	-	+	4
Cyathospirura seurati	-	+	96
Cylicospirura subaequalis	-	+	94
Dracunculus medinensis	-	+	52, 53, 54
Filaria martis	-	+	100
Filaria russeli	-	+	100
Galonchus perniciosus	-	+	13, 88
Gnathostoma spinigerum	-	+	99
Onchocerca sp.	-	+	16
Physaloptera praeputialis	+	+	4, 16, 19, 41, 67, 79, 92
Toxocara cati	-	+	96, 109
Trichinella spiralis	+	+	8, 72, 73, 76
Troglostrongylus subcrenatus	-	+	87
Vigisospirura grimaldiae	-	+	96

Ctenocephalides felis is a jumping flea with a cosmopolitan distribution. Apart from causing physical damage, it also is a vector for numerous pathogens, including the tapeworm *Dipylidium*.

Lice

No records of lice were encountered in the literature, which is not really surprising since carnivores in general seem to have few louse species.

Pentastomes

The two genera that are listed in the tables occur as adults in the nasal cavities of the carnivores. *Armillifer* is a large pentastome with characteristic annulations and the infective nymphal stages occur encapsulated in various tissues of their intermediate hosts, the ruminants. The infective nymphal stages of *Linguatula*, however, wander freely through especially the livers of their ruminant intermediate hosts.

Acanthocephala

The spiny-headed worms are poorly known in Africa as a whole, and only the genus *Oncicola* has been recorded, once from a leopard in the Camerouns [65] and once from the same host in the Congo [13]. The worms attach to the mucosa of the stomach and intestine by means of several rows of well-developed hooks on a retractable proboscis. No records of pathology or deaths as a result of infection with these worms could be found in the literature.

Table 5: The arthropod and pentastomid parasites of lions

GENUS AND/OR SPECIES	SOUTH AFRICA	REST OF AFRICA	REFERENCE
INSECTS: FLIES			
Hippobosca longipennis	+	-	38
INSECTS: FLEAS			
Echidnophaga larina	+	-	38
Ctenocephalides felis	+	-	38
TICKS			
Ornithodoros moubata	-	+	101
Amblyomma eburneum	-	+	101
Amblyomma gemma	-	+	101
Amblyomma hebraeum	+	+	101, 112, I.G. Horak, unpublished
Amblyomma marmoreum	+	-	I.G. Horak, unpublished
Amblyomma sparsum	-	+	101
Boophilus microplus	-	+	101
Boophilus decoloratus	+	+	101, I.G. Horak, unpublished
Haemaphysalis leachii	+	+	101, 112, I.G. Horak, unpublished
Haemaphysalis spinulosa	+	-	I.G. Horak, unpublished
Ixodes sp.	-	+	101
Rhipicentor bicornis	-	+	101
Rhipicentor nuttalli	-	+	101
Hyalomma truncatum	+	+	101, 112, I.G. Horak, unpublished
Rhipicephalus appendiculatus	+	+	101, 112, I.G. Horak, unpublished
Rhipicephalus armatus	-	+	101
Rhipicephalus capensis	?	+	101
Rhipicephalus compositus	-	+	101
Rhipicephalus evertsi evertsi	+	-	112, I.G. Horak, unpublished
Rhipicephalus evertsi mimeticus	-	+	101
Rhipicephalus kochi	-	+	101
Rhipicephalus longus	-	+	101
Rhipicephalus pravus	-	+	101
Rhipicephalus pulchellus	-	+	101
Rhipicephalus reichenowi	-	+	101
Rhipicephalus sanguineus	+	+	101, 112
Rhipicephalus senegalensis	-	+	101
Rhipicephalus simus	+	+	101, 112, I.G. Horak, unpublished
Rhipicephalus sulcatus	-	+	101
Rhipicephalus supertritus	-	+	101
Rhipicephalus tricuspis	-	+	101
Rhipicephalus turanicus	+	-	I.G. Horak, unpublished
Rhipicephalus zambeziensis	+	-	I.G. Horak, unpublished
MITES			
Sarcoptes scabei	+	-	111
PENTASTOMES			
Armillifer armillatus	+	-	113
Linguatula serrata	+	-	112
Linguatula nuttalli	+	-	113

Table 6: The arthropod, pentastomid and acanthocephalan parasites of leopards

GENUS AND/OR SPECIES	SOUTH AFRICA	REST OF AFRICA	REFERENCE
INSECTS: FLIES			
Cordylobia anthropophaga	+	-	38, 113
Hippobosca longipennis	+	-	38
INSECTS: FLEAS			
Echidnophaga gallinacea	+	-	38
Echidnophaga larina	+	-	38
Ctenocephalides felis	+	-	38
TICKS			
Amblyomma hebraeum	-	+	101
Amblyomma nuttalli	-	+	101
Amblyomma tholloni	-	+	101
Amblyomma variegatum	-	+	101
Haemaphysalis aciculifer	-	+	101
Haemaphysalis leachi	-	+	101
Haemaphysalis parmata	-	+	101
Ixodes cavipalpus	-	+	101
Ixodes cumulatimpunctatus	-	+	101
Ixodes moreli	-	+	101
Ixodes muniensis	-	+	101
Ixodes pilosus	-	+	101
Ixodes oldi	-	+	101
Ixodes rasus	-	+	101
Ixodes vanidicus	-	+	101
Rhipicentor bicornis	-	+	101
Rhipicentor sp.	-	+	101
Hyalomma truncatum	-	+	101
Rhipicephalus appendiculatus	-	+	101
Rhipicephalus armatus	-	+	101
Rhipicephalus capensis	-	+	101
Rhipicephalus compositus	-	+	101
Rhipicephalus e. evertsi	+	-	I.G. Horak, unpublished
Rhipicephalus pravus	-	+	101
Rhipicephalus pulchellus	-	+	101
Rhipicephalus sanguineus	-	+	101
Rhipicephalus senegalensis	-	+	101
Rhipicephalus simus	-	+	101
Rhipicephalus sulcatus	-	+	101
Rhipicephalus tricuspis	-	+	101
Rhipicephalus turanicus	+	-	I.G. Horak, unpublished
Rhipicephalus zambeziensis	+	-	I.G. Horak, unpublished
Rhipicephalus ziemanni	-	+	101
PENTASTOMIDA			
Armilifer annulatus	+	-	113
ACANTHOCEPHALA			
Oncicola dimorpha	-	+	65
Oncicola fraterna	-	+	13

CONCLUSION

As is evident from the tables, a large number of parasites occur in and on lions and leopards. However, the diversity is small when compared to those that occur in ruminants, and the few records from South Africa is an indication that a lot of work still remains to be done as far as the parasites of these carnivores are concerned.

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Wildlife parasites: Lessons for parasite control in livestock

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Abstract

For sustainable livestock production it is suggested that the parasitologist take a leaf out of Nature's book in the search for solutions to the mounting problems concerning parasite control. While the farmer has come to regard all parasites affecting livestock as entirely without benefit, indigenous parasites and diseases are normal and play an essential role as interacting components of a natural environment in an ecosystem such as the 19 000 km^2-sized Kruger National Park, Republic of South Africa. The parasites help to select their hosts for fitness and are assisted by predators and intra-species territorial aggression which continually eliminate the weak individuals from the system. It is essential to guard against the introduction of foreign parasites or infectious agents which have no real ecological niche or role in an established ecosystem, however, as they cause untoward interactions, sometimes of a violent nature. The policy must be to block off or, failing that, to control or eliminate these foreign parasites and diseases as far as possible. Often, when Man intervenes in an ecosystem, it leads to stress, overcrowding and stagnation and predisposes to disease and death. Intensification of the system, as in farming units, denies Nature the chance to manage on its own, because of clashing interests with Man. Frank parasitism and disease should almost invariably be seen as indicators of an imbalance in the ecosystem and should be rectified. Chemicals and vaccines should be used to produce sufficient food for all, but without exploiting Nature, or else Nature will be unable to continue catering for Man's needs.
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Keywords: Wildlife; Balance of Nature; Parasite role; Host selection: Survival of the fittest; Sustainable production; Host resilience; Host resistance

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1. Introduction

The knowledge acquired by studying the interactions between wildlife parasites, their hosts and their environment may hold the key to successful cost-effective livestock farming in the future. The aim of this paper is to stimulate thinking towards discovering novel methods or rediscovering old existent knowledge, so as to enable sustainable livestock production in the face of problems such as resistance to parasiticidal drugs.

The prevalence of anthelmintic resistance is increasing to such an extent that Waller and Larsen (1996) sounded the following warning '... the problem of anthelmintic resistance amongst nematode parasites is rapidly reaching a state of crisis....' Better use of the available anthelmintics is essential, preferably in combination with management strategies, because new drugs with different mechanisms of action or novel means of control are unlikely to appear on the market within the foreseeable future (Borgsteede et al., 1996).

In addition, more than 500 species of arthropods are known to be resistant to one or more groups of pesticides (Georghiou and Lagunes, 1991). Resistance to virtually every kind of widely used toxicant has been documented, including insect growth regulators and the insecticidal crystals produced by *Bacillus thuringiensis* (Georghiou and Lagunes, 1991; McGaughey and Whalon, 1992). Because of cross-resistance, populations are often resistant to novel insecticides even before they are introduced (Roush, 1993).

In situations where remedies have become ineffective it could be worthwhile to study the role parasites play in an ecosystem where mankind has not interfered materially. Thus insight can be gained from the natural interactions taking place between the elements, hosts and parasites, and adapted as possible alternative strategies for parasite control in production animals.

2. Nature

'Then God commanded, 'Let the earth produce all kinds of animal life: domestic and wild, large and small'—and it was done. So God made them all, and he was pleased with what he saw' (Genesis 1: 24–25).

The question is often asked whether Nature can manage on her own.

An area in the world where natural conditions still prevail today is the Kruger National Park (KNP) situated in the Mpumalanga Lowveld of the Republic of South Africa (RSA). The KNP encompasses 19 000 km^2 and is 350 km long and up to 90 km wide.

When tourists visiting the KNP report animals with conditions such as mange, skin infections, wounds and emaciation, their general expectation is that the animals will be caught and treated. Many ask whether they may see the 'hospital' where sick animals are treated. The truth is, however, that very seldom will veterinarians intervene, the reason being that it is not in accordance with the principles of nature conservation as applied in the numerous national parks of the RSA (Fig. 1).

One of the primary objectives of a national park is to conserve all biotic and abiotic components of the ecosystem in their natural state and, while having to accommodate

Fig. 1. National parks of South Africa ((from a National Parks Board brochure. Key: The figures on the map denote the following national parks: 1—Kruger; 2—Limpopo Valley; 3—Marakele; 4—Golden Gate; 5—Mountain Zebra; 6—Addo Elephant; 7—Tsitsikamma; 8—Knysna; 9—Wilderness; 10—Bontebok; 11—Table Montain; 12—West Coast; 13—Karoo; 14—Tankwa Karoo; 15—Vaalbos; 16—Augrabies Falls; 17—Kalahari Gemsbok; 18—Richtersveld).

tourists for financial reasons, to combat all foreign elements, including foreign parasites and infectious organisms.

A schematic representation of the ecosystem will help us visualise the interactions that take place in the KNP (Fig. 2).

Indigenous parasites and infectious agents are normal and essential interacting components of a natural environment and have to be conserved together with the other elements of the ecosystem. On the other hand, foreign parasites, infectious agents and hosts and other elements which are not indigenous to the ecosystem are considered alien and should as far as possible be debarred.

Indigenous, or naturally occurring parasitic or infectious life forms have had a common evolutionary history with their hosts in a specific habitat and this has led to a reduction, or a cessation in detrimental effects such as the virtual absence of nodules cause by *Oesophagostomum columbianum* in impala, *Aepyceros melampus* as opposed to domestic sheep (Horak, 1981). The co-evolutionary trajectory followed by any particular parasite-host association will depend on the manner in which the virulence and the production of transmission stages of the parasite are interlinked and on the costs to the host of evolving resistance (May and Anderson, 1983), coupled with (often involuntary) evasive habits of the host, e.g. seasonal migration.

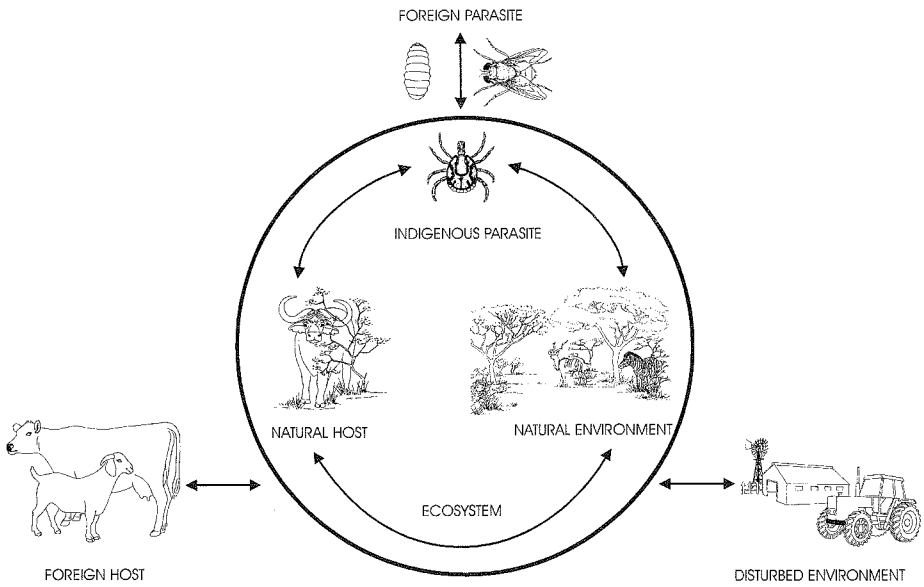

Fig. 2. A schematic representation of interactions taking place in an ecosystem such as the Kruger National Park (* Foreign parasites, such as *Theileria parva*, *Hypoderma* spp. and *Glossina* spp.).

The more complex and diverse the components of the association between host, parasite and environment are, the more stable the relationship can be expected to be. A multiple host-species situation provides the benefits of predation and scavenging, a better 'vacuum cleaner' effect of each other's parasites and ensures better and wider utilisation of the habitat without the domination and resultant over-abundance of any single species.

The diversity of the habitat in a nature reserve such as the KNP also ensures an abundance of associated life forms, a mosaic of species providing natural barriers or buffer areas to the spread of disease.

In large ecosystems free from human interference, parasites and predators fulfil an important role in the selection of host populations for fitness and by their effect upon the natural intrinsic growth rate of their host populations (Anderson and May, 1978; Anderson, 1979; Holmes, 1982). Young animals, usually until the age of 12–18 months, are often subject to large parasite infections (Horak et al., 1983), causing weaker individuals and those that have neither innate resistance nor the ability to mount an effective immune response, to succumb to predators before they can contribute to the gene pool.

Parasites may also have an effect on each other or the particular niche of a parasite might already have been occupied by another. For example, in the abomasum of the blue wildebeest, *Connochaetes taurinus*, peak burdens of *Haemonchus bedfordi* were followed by peak burdens of *Trichostrongylus thomasi*. *H. bedfordi* reached its maximum numbers during April and October in the 1–12-month-old animals and only during April

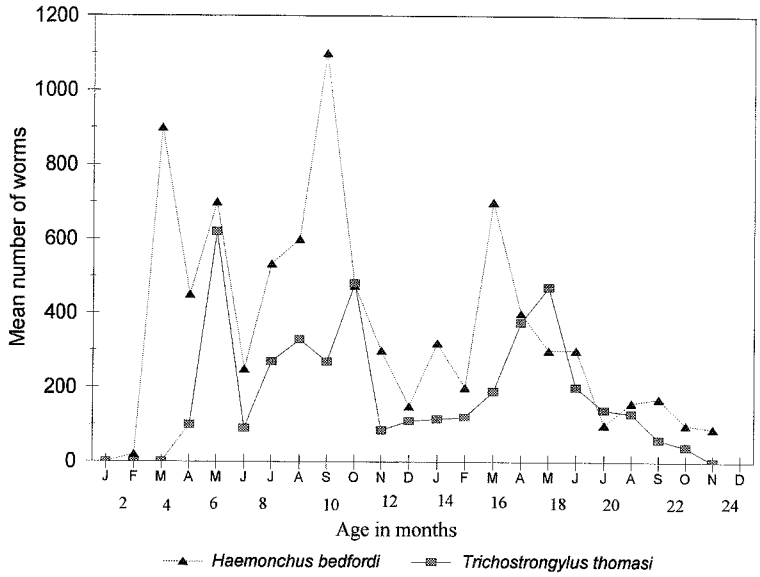

Fig. 3. Seasonal occurrence of *Haemonchus bedfordi* and *Trichostrongylus thomasi* in blue wildebeest, *Connochaetes taurinus* (Horak et al., 1983).

in the older animals. *T. thomasi* followed a similar pattern to *H. bedfordi* but its peaks were always later than those of the latter worm, namely, June and November in the younger animals and only June in the older ones (Fig. 3) (Horak et al., 1983). While there are also other possibilities, such as seasonal preferences, the staggered peaks of *H. bedfordi* and *T. thomasi* might be due to such competition. Large burdens of *Haemonchus contortus* and *Trichostrongylus axei* compete in the abomasa of sheep to the detriment of the former species (Reinecke, 1974).

Except for a few helminth species, such as *T. thomasi, Trichostrongylus deflexus, Trichostrongylus falculatus* and *Nematodirus spathiger* which occur in a wide variety of wild animals, the nematodes of wildlife are generally host specific, or infect animals within a particular genus or within a grouping of generically related animals (I.G. Horak, unpublished observations, 1996).

Lesson: For meaningful parasite control, establish the various parasite interactions taking place within the farming unit. Alternate use of pasture for animals of different species which are not susceptible to one another's worm parasites (Morley and Donald, 1980; Van Wyk, 1990), or even alternate susceptible and more resistant animals of the same species (Michel, 1969, 1976; Brunsdon, 1980).

In healthy diverse ecosystems, such as the KNP, a dynamic balance between these components has been attained. Some of the parasitic life forms may, however, be dormant at times, and flare up to cause disease only when the habitat is altered by conditions such as droughts and veld fires.

3. Drought

Droughts have been shown to have a dramatic effect on parasitic disease. For example, when a sudden drought occurred after a period of good annual rainfalls, the tick and louse burdens rose (Horak et al., 1995). Impalas, *Aepyceros melampus*, harboured a mean of 7461 ticks during such a sudden drought period, compared with 678 during a prolonged period of drought (Horak et al., 1995).

Repeated high annual rainfalls give rise to a mat of decaying vegetation under the standing grass, from which the ticks quest for their hosts. This mat supplies an ideal habitat for the survival of the ticks, even in a drought year, hence the high numbers of ticks.

In contrast, when the annual rainfall is relatively low in the years preceding a drought, there is a severe depletion of the standing grass and the mat of dead and decaying material virtually disappears. Consequently the micro-habitat, in which the female ticks lay their eggs and in which the eggs develop and hatch and the newly hatched larvae can shelter, is progressively lost.

Under natural conditions excessive infections of endoparasites seldom occur. However, in drought situations nutritional stress is severe and the immune status of hosts is compromised, and animals concentrate near water holes, leading to temporary local overpopulation and acceleration in parasite and disease transmission. Combined with the increased stress through social interactions and insufficient food, the stage is set for disease to emerge and act as a culling factor.

Worm burdens stay remarkably constant in healthy animals but rise significantly in cases where animals are under stress (such as during drought periods), or are suffering from disease or injuries. In the KNP, the total worm burdens of impalas rose from below 20 000 under normal conditions, to more than 60 000 during a drought period (Boomker, Horak and de Vos, unpublished observations, 1996).

Such a disease is density-dependent, however, and will abate when the animals scatter and develop immunity to reinfection after rain or after a certain number have been eliminated. This culling role of the parasitic life-forms is one of Nature's ways of relieving excessive pressure on the habitat, in turn ensuring maintenance of the quality and quantity of grazing that is essential for the survival of hosts and parasites.

Lesson: During and immediately after periods of drought be aware of sudden outbreaks of disease and parasitoses and be proactive in managing the problem. For instance, during a drought the bovine faecal pat, and to a lesser extent the sheep pellet, offer the free-living worm stages protection in the form of moisture and shade. With the advent of the first good rains after the drought, very large numbers of larvae may be set free within a short period of time, often with dire consequences (Barger et al., 1984; Reinecke, 1960; Van Wyk, 1990).

4. Veld fires

Veld fires originating from lightning or human intervention may influence the ecology.

The abundance of 13 ixodid tick species detected by drag-sampling of a burnt zone in the KNP was compared with that in an adjacent unburnt area over a 2-year period (Spickett et al., 1992). While numbers of ticks were reduced after the burn, they soon rose again, and there appeared to be little practical benefit from veld-burning during spring as a method of tick control.

Lesson: The effects of fire are influenced by the amount of vegetation; by the species and developmental status of the tick population at the time of the burn; by subsequent host influx or exclusion from the burnt area; and by the ecoclimatic suitability of the region for tick species. Nevertheless, burning may be effective if aimed at specific tick species, either tenuously adapted to an area or with populations already reduced by chemical control. Efficacy could be enhanced by the exclusion of major hosts for a critical period after the burn to prevent or delay population recovery, a strategy advocated by Minshull and Norval (1982). An additional potential effect is that the numbers of free-living stages of parasitic nematodes could be reduced by the heat of burning as larvae apparently migrate up and down the vegetation in the presence of moisture and light (Barger, 1978).

5. Base-line values of parasite burdens

In order to appreciate the role of indigenous parasitic life-forms in our southern African national parks, surveys have been directed at establishing parasitic and pathological norms or base-line values for many host and parasite species under different environmental conditions. In this way deviations from levels that the host can tolerate can be evaluated. Without this base-line knowledge, how would a total count of over 124 million internal parasites in a single host be judged, without knowing that this burden of *Probstmayria vivipara* was recovered from a fat zebra, *Equus burchelli antiquorum*, that was obviously unaffected by the vast numbers? Indeed, now we also know that this was no exception; 'impossible' figures of many millions of *P. vivipara* still fall within the acceptable range for zebras of that particular sex and age, under environmental conditions such as those reigning at the time the particular necropsy was performed (Krecek et al., 1987).

At no stage of a study in which two to four impalas were culled each month for a period of a year, did it appear as if the worm burdens harboured by the impalas affected them adversely (Horak, 1978). Subsequently, monthly necropsies over two consecutive years on impalas indicated that lambs up to 9 months have fewer parasites than 1 to 2-year-old impalas and that selection for the fittest animals seems to occur during the second year of life (Boomker, Horak and de Vos, unpublished observations, 1996).

While impala males have the highest parasite burdens during the mating season, possibly as a result of the stress of fighting, the burdens of the ewes peak during the lambing season.

Lesson: Without base-line values concerning parasite burdens it is impossible to evaluate the effect of the parasites on their hosts (Gordon, 1981).

6. Species diversity

Diversity appears to bring stability into natural systems. Different animals sharing the same habitat ingest and in this way help to control one another's parasites, granted that their susceptibility to the various parasites differs.

Despite regular rabies outbreaks in black-backed jackal, *Canis mesomelas*, (Mansvelt, 1956; McKenzie, 1993) and domestic dogs in the areas adjacent to the KNP, with a regular overflow of rabid dogs into the park (Swanepoel et al., 1993), rabies has never been diagnosed in the wild animal populations in the KNP. Can it be that this phenomenon is due to the fact that the rich variety of life forms within the KNP provides an adequate buffer to suppress any small outbreak which may occur? (V. de Vos, unpublished observations, 1991). Compare this situation to Namibia where poor host diversity and an over-abundance of a single species have, by horizontal transmission, caused the death of about 10 000 kudus, *Tragelaphus strepsiceros*, from rabies over a 6-year period (Barnard and Hassel, 1981). This phenomenon of stability in diversity is accepted by the National Parks Board, which aims as far as possible to re-establish the historical life forms in all the parks in the RSA, even in the so-called species parks such as the Mountain Zebra and Bontebok National Parks.

Lesson: Alternation of animals of different species may contribute to parasite control (Barger and Southcott, 1975; Southcott and Barger, 1975; Jordan et al., 1988; Nansen et al., 1990).

7. Overcrowding and stagnation

In the KNP it has been shown that elephant, *Loxodonta africana*, buffalo, *Syncerus caffer*, and to a lesser extent, hippo, *Hippopotamus amphibius*, populations have the potential to outgrow natural reduction mechanisms and enter an exponential or population explosion growth phase. History has shown that such growth is usually associated with habitat destruction and an eventual population crash through hunger and disease. Being afraid of the dimensions that this might attain, the National Parks Board has opted for control procedures, which have been successfully executed since 1970 (De Vos et al., 1983).

A predator-proof enclosure of 256 ha was erected in roan antelope, *Hippotragus equinus*, and sable antelope, *Hippotragus niger*, habitat in northern KNP for the propagation of these species. Predators and other antelopes were excluded. In the ensuing years a correlation was found between climatic factors, density of animals and the outbreak of diseases such as dermatophilosis (Senkobo disease), (De Vos and Imes, 1976), papillomatosis, cytauxzoonosis and excessive tick burdens in these animals. With the exception of low tick burdens, none of these conditions have ever been found in roan or sable antelope outside the enclosure. Significantly, at the onset of a disease outbreak, the roan antelopes usually had reached a density of about one animal per 0,1 km^2 as opposed to one animal per 14.5 km^2 for comparable habitats outside the enclosure.

Nature is largely left alone to look after other animal populations within the extensive ecosystems of the KNP and Kalahari Gemsbok National Park. Climatic factors, preda-

tors and natural parasites keep these animals in a dynamic balance. In the process, outbreaks of diseases such as mange occur sporadically and claim the lives of some animals, probably from stress, or perhaps insufficient nutrients or over-population, all of which are in time rectified by Nature. The policy is therefore not to treat these animals, but only to monitor and assess their role in the ecosystem context. There have been exceptions, however, one of which being a pride of lions, *Panthera leo*, with white cubs that were treated for mange. It is debatable whether this should have been done, however, even for white lions. By intervening, man is wittingly favouring the survival of one component over another (V. de Vos, unpublished observations, 1991).

Smaller national parks in the RSA (such as Bontebok National Park) are all fenced and have no large predators. Thus, as overflow into neighbouring areas is prevented, a tendency towards overpopulation is created, resulting in habitat destruction and disease outbreaks. As stated by Lightfoot and Norval (1981) regarding eland, *Taurotragus oryx*, which they classified as relatively susceptible to tick infestation: 'No serious tick problems have arisen in eland whose movements have been unrestricted over a large range. A common factor in almost all cases where tick problems have been encountered with eland has been the restriction of the animals within relatively small fenced areas'. Similarly, Padaiga and Marma (1970) demonstrated in Lithuania that the extent of infection of roe deer, *Capreolus capreolus*, with strongylids and coccidia correlated directly with the population density of the hosts.

Lesson: Excessively high stocking rates usually go hand in hand with a deterioration of pasture quantity and quality, and thus an increased incidence of parasitism and disease. To prevent this, ensure that grazing pressure is optimal (Morley and Donald, 1980; Van Wyk, 1990).

8. Stress

In coincidental studies in the KNP it was found that individual animals that had a previous history of stress, such as a wound or bone fracture, would invariably harbour a parasite burden far in excess of the usual levels, counts being up to 100 times higher than in healthy animals. Such animals that act as reservoirs and disseminators of parasites are rare in the KNP, as they are predator-prone. In the absence of large predators, however, they could be expected to be more common and play a much more important role in excessive contamination of grazing.

For example, a 6-month-old blue wildebeest, which had broken a leg ca. 4 weeks previously, harboured 575 adult *Strongyloides* spp. and 175 adult *T. falculatus* when shot. In contrast, a healthy calf of similar age and shot at the same time, harboured neither of these helminth species. Furthermore, while the stressed calf housed 2071 *Boophilus decoloratus*, of which more than 24% were adults, the healthy calf and 2 others (which were 12 months older when shot) were infested with only 390–805 of this tick species, only 4–12% of which were adults (Horak et al., 1983).

These results support the surmise of Grootenhuis (1979) that stress may lead to fatal infections. It has been shown in cattle in Australia that stress can decrease resistance to *Boophilus microplus* (Utech et al., 1978).

Lesson: Prevent stress, and isolate and/or cull diseased animals. The farmer must take over the role of the predator and attend to stressed animals before the parasites they harbour can bring about excessive contamination of pastures or spread diseases.

9. Fitness

Predators play the role of hatchet men in the ecosystem, but parasites have the last word by also helping to test predators for fitness.

While some hosts have an innate resistance to primary infection, others are susceptible yet able to mount a very effective immune response to secondary infection. Yet others have the ability to retain high levels of fitness and production despite heavy parasite infections. These are termed resilient hosts (Bisset and Morris, 1996).

Lions in the KNP have been shown to harbour no fewer than five infectious disease agents and 18 different parasite species, some of which have been shown to act as selection agents for lions and other predators (Young, 1975). For example, while paralysis resulting from *Trichinella spiralis* infection was recorded in lions and civets, *Civettictis civetta*, the spotted hyena, *Crocuta crocuta*, is obviously resilient as no untoward effects of trichinosis have been observed, despite an infection rate of 85% in hyena frequenting the surroundings of the Skukuza tourist camp in the KNP. Young and Kruger (1967) pointed out that overcrowding of rodents or carnivores may result in an increase in cannibalism, which may present '... favourable conditions for the transmission of trichinosis which may, depending on its lethal effect... play some part in the natural regulation of numbers of wild carnivores...'. Similarly, an unknown *Dirofilaria* spp. was the cause of paraplegia in a lion.

Sarcoptic mange, caused by *Sarcoptes scabiei*, has an extremely wide host range, but most wildlife species develop only sub-clinical mite infestations. It is only when the hosts are stressed that clinical signs are seen—and then usually only in individual animals in a herd or group. Skin lesions have been found in lions, buffalo, blue wildebeest, impalas, springbok, *Antidorcas marsupialis*, and red hartebeest, *Alcelaphus buselaphus*, often affecting the general condition of the hosts that are clinically affected (Young, 1969). Severe infestations may even result in mortality, particularly in young lion cubs. Young (1975) stated that '... in one year one pride of lions in the KNP is known to have lost all of their cubs due to a particularly severe outbreak of sarcoptic mange'. He also reported that *Linguatula serrata* has been the cause of necrotic rhinitis in lions and that *Hepatozoon* spp. may contribute to seasonal mortalities in spotted hyenas in the KNP.

Heavy tick infestation, often in association with nutritional stress, is a common direct or indirect cause of mortality and other deleterious effects, such as a low calving rate in eland and other wild ungulates (Lightfoot and Norval, 1981). Ticks are not only important parasites in their own right, but transmit a large variety of pathogenic and benign tick-borne diseases and can also lead to metabolic debilitation, tick toxicosis and secondary infection with bacteria, maggots and other organisms. Secondary bacterial infection, although not yet recorded as a direct cause of death in wild ungulates, has

been reported to lead to the death of eland calves, after tick damage to the teats of their mothers had made it impossible for them to suckle (Harthoorn, 1977).

It is important for game wardens to take note of considerable variations in susceptibility to ticks among wild ungulate species. Square-lipped rhino, *Ceratotherium simum*, warthog, *Phacochoerus aethiopicus*, blue wildebeest and tsessebe, *Damaliscus lunatus*, are apparently the most resistant to tick infestation, and can therefore be translocated almost anywhere without any consideration to ticks as a cause of morbidity. Tick species composition is of paramount importance to other ungulates such as eland, sable, and kudu, however, and these animals should not be introduced to regions where *Rhipicephalus appendiculatus* occurs in large numbers (Lightfoot and Norval, 1981).

Lice, like mange, also cause considerable debility, but likewise only in certain individuals within a herd. Impala comb their haircoat with their incisor teeth to control external parasites, such as lice (McKenzie, 1990), but as the animals age, their incisor teeth become worn, causing an explosion in their louse populations.

Lesson: In the absence of predators on a farm unit the owners should take over the responsibility for selecting for fitness. They should use Nature as a partner, by allowing parasites to help with selecting the fittest individuals in the face of parasite challenge (Bisset and Morris, 1996). In the case of helminths and ticks, farmers ignore this advice at their peril: practically unmanageable resistance to parasiticides has developed, and in certain countries especially sheep farming is almost at the crossroads for want of anthelmintics effective against some extreme cases of resistance (Van Wyk et al., 1997; Waller and Larsen, 1996).

10. Foreign parasites

A close watch should be kept for foreign or aberrant parasites or diseases in every ecosystem. Aberrance in host-parasite relationships indicates the invasion by a parasite or disease of a new host or ecosystem, usually giving rise to instability in the system and manifesting itself in the form of a disease epidemic, often of a violent nature. A classic example is the rinderpest pandemic which swept through Africa at the turn of the century, killing millions of cattle and all but wiping out the buffalo population in the Lowveld of Mpumalanga and Northern Province (Stevenson-Hamilton, 1912; Stevenson-Hamilton, 1929; Stevenson-Hamilton, 1947). Eland, kudus, warthogs and bushpigs, *Potamochoerus porcus*, were also severely affected. The area now encompassing the KNP was devastated to such an extent that a recurrence of that magnitude would today be considered a national disaster.

At least 21 species of exotic arthropods have become established in the KNP, although fortunately without serious consequences to date. Danger arises when parasites or other infectious agents are translocated on or in their hosts to places where they did not occur previously, and affect other hosts that have never previously come into contact with them. A recent example is a serious outbreak of *Mycobacterium bovis* infection in buffalo in the KNP, probably as a result of contact with infected cattle (Bengis et al., 1996). It appears that the bacterium has entered a naive population, leading to a prevalence of 92% in certain buffalo herds (V. de Vos, unpublished observations, 1996)

and also invading other hosts, such as lions, cheetahs, baboons, *Papio ursinus*, (Keet et al., 1996) and kudus (Bengis, pers. com., 1996). After post mortem examination of affected buffaloes it was estimated that at least 10% of animals in the worst-affected herd would have died of tuberculosis within a year.

Among the ticks, *Amblyomma variegatum* is a cause for concern, because, having invaded the Caribbean islands, (with *Cowdria ruminantium* 'in tow'), is now posing a threat to the USA (Barré et al., 1987). Similarly a rhino tick, *Rhipicephalus maculatus,* has established itself in the KNP, probably having been introduced on rhinoceroses or nyalas, *Tragelaphus angasii*, from KwaZulu-Natal, and *Hyalomma marginatum turanicum,* previously confined to the more arid zones of the RSA, was brought in probably on a migratory bird (Braack et al., 1995).

Lesson: Adopt rigid control measures to minimise the risk of passive transport of other organisms, not only internal and external parasites, but also the immature stages of beetles, flies and other organisms often present in faeces contaminating transport crates used for wildlife.

11. Foreign hosts

Parasites protect the environment against foreign host species. The gemsbok, *Oryx gazella*, prefers the relatively dry regions of southern Africa. When introduced to the Free State and large areas of the Cape Province, approximately 50% of sub-adult gemsbok suffered tick-induced paralysis and subsequent mortality caused by *Ixodes rubicundus* during 1987 and 1988 (Fourie and Vrahimis, 1989).

Lesson: Do not introduce species into an area which is not suitable for them, even if there are apparently sufficient chemicals to be able to keep metazoan parasites at bay.

12. Human intervention

The main lesson that can be learnt from Nature is that it can manage on its own, except if foreign or aberrant parasites, infectious diseases, or highly susceptible hosts are introduced into the ecosystem (Lawrence and Norval, 1979), in which case artificial control measures have to be adopted to achieve Man's objectives. Nature cannot manage on its own if the ecosystem is intentionally altered by Man to suit his requirements.

Human intervention frequently severely jeopardises the delicate balance between the host, the parasite and the environment. Man alters and often rapes the natural environment by erecting fences, by placing bore-holes and dams in places where Nature did not intend water to be, by indiscriminate veld-burning, or other farming practices. Often sustainable production then becomes an impossibility, as a relative over-abundance of animals results firstly in a situation in which the habitat cannot sustain them, and, secondly, in ideal conditions for a flare-up of diseases—again Nature's way of relieving the pressure which Man has forced upon it.

Nature has provided effective methods for managing ticks, such as the voracious red-billed oxpecker, *Buphagus erythorhynchus*. In a laboratory trial oxpeckers were able

to reduce the numbers of adult *Boophilus decoloratus* by 95.7% (Bezuidenhout and Stutterheim, 1980). Oxpecker populations have become markedly reduced in stock farming areas, however, probably because of Man's interference by intensive dipping of livestock with arsenicals and organophosphorus drugs and less wildlife in farming areas.

Man is also not innocent regarding the negative effects of anthelmintics on Nature, as exemplified by mounting evidence of deleterious effects of ivermectin on dung beetles and other fauna inhabiting dung (Sommer et al., 1993; Gunn and Sadd, 1994). On the other hand, Man has slowly been awakening to the possibility that organisms such as dung beetles can be allies in the struggle to produce sufficient food for the global population. For instance, dung beetles were introduced to Australia—albeit in an attempt to restore the balance after the problems created by having introduced cattle into an environment where Nature was not geared to receive them!

The results of Man's interference with the ecosystem can be summarised by the letters **SOS**, which are often also symbolically indicative of Natures' apparent desperate cry for help—to be left to its own devices:

Stagnation: Vast areas are divided by fences into smaller units that restrict hosts and parasites from moving at will, thus interfering with the normal seasonal nomadic flow of animals that usually occurs in Nature from nutritional factors and water needs. Amongst other effects stagnation often exerts undue pressure on water and grazing resources.

Overpopulation: Livestock farmers tend to overpopulate their properties with wild animals or livestock, with consequent malnutrition and greater susceptibility of the hosts to parasites. The reasons for this could be the fallacy of financial gain or plain ignorance. The result is that parasites and diseases increase as it is seemingly their task to counteract this overpopulation by taking individuals out of the system, so as to ensure survival of both parasite and host.

Stress: The effect of stagnation and overpopulation on the host is that of stress which results in a host with a lowered ability to withstand disease.

That this **SOS** is of great practical significance is evident from the toll taken among captured wildlife, such as deaths from coccidiosis in buffalo calves and impalas in captivity, and salmonellosis which is common in penned elephants and Lichtenstein hartebeest, *Sygmoceros lichtensteinii*. Internal parasites have made some farmers in South Africa give up sheep farming (Van Wyk et al., 1989; Van Wyk et al., 1991). Crowding of animals in feedlots and dog kennels, etc., lead to a plethora of diseases, such as viral and bacterial respiratory diseases that are relatively rare elsewhere. It is well-known that humans in overpopulated areas are prone to outbreaks of cholera, influenza and typhoid fever, which are major global diseases.

13. Conclusion

Unfortunately Man does not have a proud track-record regarding the use of the bounties of Nature. However, when studying the ecosystem in the KNP many answers are to be found to our questions relating to parasite and disease control:

Carefully observe the hosts within the ecosystem for conditions such as weight loss, mange, ticks and internal parasites, as these point to an underlying shortcoming in the

system, and attempt as far as possible to restore the natural balance. An outbreak of disease in Man in urban areas points to underlying causes such as overpopulation, improper water supply and sewage disposal. On the farm, select animals indigenous to the ecosystem, e.g. *Bos indicus* and Nguni breeds that are more resistant to ticks than *Bos taurus* (Spickett et al., 1989; Rechav and Kostrzewski, 1991).

Do not bring heartwater-susceptible cattle, eland, springbok, blesbok, *Damaliscus pygargus phillipsi*, and bontebok, *Damaliscus pygargus dorcas*, into heartwater areas before taking the necessary precautions. Eliminate animals within a herd which are tick 'taxis' and introduce oxpeckers (Bezuidenhout and Stutterheim, 1980) onto the farm if the habitat will accommodate them.

For control of endoparasites which is a huge problem in sheep on irrigated pastures, breed for resistance (the ability to suppress the establishment and/or subsequent development of a worm infection) and resilience (the ability to maintain relatively undepressed production while infected) as discussed by Bisset and Morris (1996). Diversify farming practices, for instance by alternating sheep and cattle. Create an environment where dung beetles (Bornemissza, 1960; Bryan, 1973; Grønvold et al., 1996) can propagate, as they aid helminth control by breaking open dung pats and pellets and in this way exposing worm eggs and larvae to the ravages of the elements.

No, Nature cannot manage on its own where Man has interfered with the ecosystem. Man therefore has the responsibility to use the tools invented by him, such as chemicals and vaccines that are slowly becoming available (Lightowlers, 1994; Opdebeeck, 1994; Emery, 1996) in a responsible and scientific way, so as to produce sufficient food for all the globe's people, but without exploiting Nature.

'Then God said, 'And now we will make human beings; they will have power over the fish, the birds, and all animals, domestic and wild, large and small. I am putting you in charge of the fish, the birds, and all the wild animals. God looked at everything he had made, and he was very pleased'' (Genesis 1: 27–31).

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THE RELATIONSHIPS BETWEEN TICKS, HOSTS AND THE ENVIRONMENT IN THE KRUGER NATIONAL PARK, SOUTH AFRICA

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ABSTRACT

Ixodid ticks were collected from several host species and from the vegetation in the southern Kruger National Park, South Africa over varying periods of time during an 18 year period. A total of 22 tick species were recovered. The major species on vegetation were the larvae of *Amblyomma hebraeum, Boophilus decoloratus, Rhipicephalus appendiculatus* and *Rhipicephalus zambeziensis*. *A. hebraeum* was also a major species on lions, Burchell's zebras, giraffes, impalas, greater kudus and helmeted guineafowls; *B. decoloratus* on zebras, giraffes, impalas and kudus; *Haemaphysalis leachi* on lions; *Hyalomma truncatum* on giraffes and scrub hares; *R. appendiculatus* on lions, zebras, giraffes, impalas and kudus; *Rhipicephalus simus* on lions, zebras, warthogs and red veld rats; and *R. zambeziensis* on lions, impalas, kudus and scrub hares. The adults of *A. hebraeum* and *H. truncatum* preferred large animals such as giraffes as hosts. Adult male kudus and nyalas harboured significantly more adult ticks of certain species than did female animals. The adults of *H. leachi, R. appendiculatus, R. simus* and *Rhipicephalus turanicus* were generally more abundant on the vegetation of gullies than on that of open grasslands and woodlands. Drought adversely affected the abundance of free-living ticks questing on the vegetation.

INTRODUCTION

The Kruger National Park (KNP), which comprises an area of approximately 2 million ha, is situated in the north-eastern Lowveld of the Northern Province and of the Eastern Transvaal, South Africa. Two major vegetation types are recognized in the Park (White 1983) and 35 landscape zones have been identified (Gertenbach 1983). The KNP is home to nearly 150 large and small mammal species and more than 500 bird species. It lies within the distribution range of more than 20 ixodid tick species.

To determine the species composition, abundance, seasonal abundance and host preference of the ticks in the Park surveys of both parasitic ticks on animals and free-living ticks on the vegetation have been conducted during the past 18 years. In these surveys eight mammal species and one bird species were examined at monthly intervals for periods varying between one and six years, and free-living ticks were collected from the vegetation of two landscape zones at monthly intervals for seven years. In addition, ticks were collected from other mammals whenever these became available. During the course of one month ticks were collected from the vegetation of 32 of the Park's 35 landscape zones (Spickett *et al.* 1991).

Twenty-two ixodid tick species were identified during the conduct of these surveys. Some of these are distributed throughout the KNP, others are present in particular regions, while those that are host specific are restricted to the habitats of their hosts.

MATERIALS AND METHODS

The majority of the surveys were conducted south of 24°30'S in the KNP at altitudes ranging between approximately 200 and 300 m. The major vegetation type of this region is South Zambezian Undifferentiated Woodland and undifferentiated woodland transition to Tongaland-Pondoland bushveld (White 1983). Mean maximum monthly atmospheric temperatures may exceed 30 °C from November to March and mean minima may be below 10 °C from May to August. Average annual rainfall is approximately 550 mm and most

precipitation takes place between October and March.

Ticks were collected at monthly intervals from the following animals: blue wildebeest from November 1977 to November 1978 (Horak *et al.* 1983a), Burchell's zebras from June 1980 to July 1981 (Horak *et al.* 1984), warthogs from January 1980 to January 1981 (Horak *et al.* 1988), impalas from January 1980 to April 1981 and from March 1992 to April 1993 (Horak *et al.* 1995b), greater kudus from April 1981 to March 1983 (Horak *et al.* 1992b), helmeted guineafowls from August 1988 to August 1990 (Horak *et al.* 1991), red veld rats and bushveld gerbils from January 1989 to December 1990 (Braack *et al.* 1996) and scrub hares from August 1988 to July 1994 (Horak *et al.* 1993; Horak *et al.* 1995c). Ticks were also collected from giraffes and lions whenever these animals became available for examination (Horak *et al.* 1983b; Horak *et al.* 1987a), and from impalas and warthogs during the drought of 1982. The lions examined were often injured or diseased individuals.

Free-living ticks were collected at monthly intervals from the vegetation of two landscape zones in the southern KNP from August 1988 to July 1995 (Spickett *et al.* 1992; Horak *et al.* 1995b; Spickett *et al.* 1995). These landscape zones are described as Thickets of the Sabie and Crocodile rivers (landscape Zone 4) in the south-west of the KNP, and as Marula/Knob thorn Savanna (landscape Zone 17) in the south-east of the KNP.

To compare the abundance and prevalence of the various tick species on the different host species the average tick burdens of each host-species and the percentages of hosts infested have been summarized in tabular form. For each of the various free-living tick species collected from the vegetation the annual total numbers from August to July were compiled. These are presented in tabular form comparing the two landscape zones. In addition a comparison of the tick burdens on adult males and females for two types of antelopes were made. Male and female kudus were examined in the KNP and male and female nyalas were examined in the KwaZulu-Natal game reserves. Comparisons have also been made between the tick burdens of impalas, warthogs and scrub hares examined during drought years and during years of normal rainfall in the KNP. Similar observations have been made for free-living ticks.

RESULTS AND DISCUSSION

Vegetation (Tables 1 and 2)

Thirteen tick species were collected from the vegetation of landscape Zones 4 and 17 by drag-sampling. *Rhipicephalus zambeziensis* followed by *Boophilus decoloratus* and *Amblyomma hebraeum* were most abundant in Zone 4 (Table 1) and *A. hebraeum* followed by *Rhipicephalus appendiculatus* and *B. decoloratus* in Zone 17 (Table 2).

The part of Zone 4 that was sampled lies along a dry riverbed and contains a high proportion of trees and shrubs. Zone 17 is a more open savanna type of habitat. Although the ten major tick species collected from both zones were the same, Zone 4 yielded considerably more *R. zambeziensis* and considerably fewer *R. appendiculatus* and *Rhipicephalus turanicus* than Zone 17. Very few larvae of *Hyalomma truncatum* were recovered from the vegetation of either zone.

Amblyomma hebraeum (Table 3)

With the exception of the gerbils and veld rats, which harboured no immature ticks, all species were fair to excellent hosts of the immature stages *A. hebraeum*. In general, the larger the host species is, the more adult ticks it can carry (Horak *et al.* 1987b). Two exceptions to this observation are warthogs, which for comparatively small animals carry fairly large burdens of adults, and blue wildebeest which harbour virtually no adults. The large infestations of all stages of development on the lions could have been influenced by the state of health of some of these animals.

The complete absence of *A. hebraeum* on gerbils and veld rats in the present study and its virtual absence on striped mice in a previous study (Howell *et al.* 1989) indicate that these rodents probably play no role in nature in the epidemiology of heartwater. This disease of wild and domestic ruminants is caused by *Cowdria ruminantium* and is transmitted by *A. hebraeum*. In contrast both scrub hares and guineafowls carry fair to substantial numbers of immature *A. hebraeum* and can artificially be infected with *C. ruminantium* (Bezuidenhout 1988).

Amblyomma marmoreum

All stages of development of this tick prefer tortoises (Walker 1991), while the immature stages may also be collected from a variety of other hosts amongst which helmeted guineafowls appear to be one of the most preferred (Horak *et al*, 1987b). Fairly large numbers of *A. marmoreum* larvae have been collected from the vegetation in the KNP during the autumn and winter months (Spickett *et al.* 1992).

Boophilus decoloratus (Table 4)

With the exception of blue wildebeest, which appear to be resistant particularly to the nymphal and adult stages of development, wild ruminants and zebras were all efficient hosts of this tick. The total numbers of *B. decoloratus* recovered from these hosts exceeded those of any other tick species on these animals. Those ticks of this species recovered from the other host species examined must be considered accidental infestations reflecting the abundance of free-living *B. decoloratus* larvae in the environment and not host preference.

B. decoloratus is not the most abundant tick on the vegetation (Tables 1 & 2). It is, however, a one-host tick occurring throughout the year (Horak *et al.* 1992b) and consequently the ticks are present on hosts for a longer time and there is also less attrition between the stages of development accounting for the large numbers collected from host animals.

Haemaphysalis leachi

I am unable to differentiate between the immature stages of this tick and those of *Haemaphysalis spinulosa*, consequently the immature stages collected could well be a mixture of these species. Only the red veld rats appeared to be efficient hosts of the immature stages, although the burdens were extremely low, and only the lions of the adults of *H. leachi.* Adults of the latter tick prefer the large carnivores (Horak *et al.* 1987a; Walker 1991). Because man is an omnivore and possibly exudes some of the attractants exuded by carnivores this may account for the comparatively large number of adults collected from the vegetation by drag-sampling.

Hyalomma truncatum

Of the animals examined, scrub hares are undoubtedly the preferred hosts of the immature stages of this species. Bushveld gerbils may also serve as hosts. Interestingly, red veld rats caught in the trap-lines along with the gerbils were not infested. Few larvae were recovered from the vegetation by drag-sampling (Tables 1 & 2), but judging by the burdens on scrub hares from Zone 4, large numbers must have been present. These larvae possibly quest for their hosts from the ground.

In the present study only giraffes were efficient hosts of adult *H. truncatum.* Horak *et al.* (1992a) state that the preferred hosts of the adults are large animals and that giraffes rank above several other species as the host of choice.

Rhipicephalus appendiculatus (Table 5)

The zebras and various ruminant species examined were good hosts of the immature stages of *R. appendiculatus*, while lions, warthogs and scrub hares also harboured small numbers. The scrub hares listed in Table 5 were in fact examined in a Valley Bushveld region of the Eastern Cape Province in which *R. appendiculatus* is present (Horak & Fourie 1991). The hares examined in the KNP all came from landscape Zone 4 in which few of these ticks are present (Table 1).

With the exception of blue wildebeest, which harboured very few adults, the wild ruminants and the zebras were reasonably good hosts of this stage of development. Lions appeared to be excellent hosts of adult *R. appendiculatus*, but this may have been occasioned by the poor health of some individuals.

Rhipicephalus evertsi evertsi (Table 6)

Burchell's zebras are the preferred hosts of the immature stages of this two-host tick. Not only do they harbour large numbers but the translation from larvae to nymphs is good. With the exception of blue wildebeest which harboured the smallest mean numbers of larvae and an even smaller proportion of nymphs, the ruminants appear to be fair to good hosts of the immature stages. Although scrub hares harboured only small numbers of ticks the translation of larvae to nymphs was excellent. Zebras and giraffes were the only significant hosts of adult *R. evertsi evertsi* among the animals examined. Lions, warthogs, gerbils, veld rats and guineafowls apparently play no role in the host requirements of this tick.

Larvae of *R. evertsi evertsi* were the fifth most abundant species from vegetation within Zone 4 and the fourth most abundant within Zone 17 (Tables 1 & 2).

Rhipicephalus simus

Among the animals examined red veld rats were the preferred hosts of immature *R. simus*. Gerbils captured in the same trap-lines as the veld rats were free from infestation. Adult ticks preferred the large monogastric animals with lions being the hosts of choice.

Of all the adult ticks collected from the vegetation by drag-sampling *R. simus* was the most numerous (Tables 1 & 2). This is probably a reflection of the fact that the samples were collected by humans, also a monogastric species.

Rhipicephalus turanicus

Three of 15 lions and five of 360 scrub hares examined were infested with adult *R. turanicus*. This result is at first surprising since scrub hares are considered one of the preferred hosts of this tick (Horak et al. 1995c). However, the scrub hares examined were from Zone 4. We speculate that had scrub hares from Zone 17 been examined, a better habitat for *R. turanicus* (Tables 1 & 2), the proportion infested would have been larger.

Rhipicephalus zambeziensis

Within the KNP, ruminants and scrub hares appeared to be good hosts of the immature stages of this species. Impalas, kudus and particularly lions were good hosts of the adults. Tick burdens of the lions may have been influenced by their state of health. The abundance of *R. zambeziensis* in landscape Zone 4 and its near absence in Zone 17 and the converse occurring for *R. appendiculatus* emphasizes the importance of habitat in the distribution of ticks.

Habitat Preferences (Table 7)

Drag-sampling for ticks within a landscape zone consisted of nine "drags" of 250 m each. Three drags were taken in each of three sub-zones within the landscape that I designated as open grassland, gully and woodland sub-zones. Drags within the gully sub-zone were taken along the banks of gullies.

Most of the adult ticks were recovered from the gully sub-zones. Though these comprise only a small area in each landscape, they appear to be important sources of tick infestations. The only exception we found was for adult *H. leachi* within Zone 4. In that case the largest number of adults was collected from the grassland sub-zone.

Host Sex Preference (Table 8)

For a tick survey on kudus in the KNP, 15 adult male and 15 adult female animals were examined in pairs (Horak *et al.* 1992b). In a similar survey conducted on nyalas in the KwaZulu-Natal game reserves, 24 adult male and 24 adult female animals were also examined in pairs (Horak *et al.* 1995a).

Male kudus harboured significantly more adult *A. hebraeum* and adult *B. decoloratus* (p=0,05) than did females. Male nyalas harboured significantly more adult *B. decoloratus, R. appendiculatus, Rhipicephalus maculatus* and *Rhipicephalus muehlensi* (p=0,05) than did females.

The Effects Of Drought (Tables 9-11)

A single year (July-June) of severe drought in 1982/1983 after a number of years of normal rainfall apparently did not reduce the numbers of free-living, questing ticks. It did, however, produce extreme stress and even mortality in certain animal species. This was reflected in increased tick burdens on impalas and warthogs (Tables 9 & 10).

A year (July-June) of severe drought in 1991/1992 preceded by two years of considerably less than normal rainfall appeared to reduce the numbers of free-living, questing ticks and cause the emigration of impalas from landscape Zone 4. It did not appear to result in morbidity and impalas examined in landscape Zone 4 toward the end of this drought year harboured significantly fewer ticks than similarly aged animals examined during a year of normal rainfall (Table 9). The large number of dry years from 1989/1990 onward, including an actual drought year (July-June) in 1991/1992, appeared to have a delayed adverse effect on the abundance of free-living ticks questing on the vegetation (Table 11).

Similar reductions were not evident in the total numbers of ticks collected annually from 60 scrub hares examined in Zone 4 (Table 11). It must be born in mind, however, that the major tick species on the scrub hares was *H. truncatum*, a tick which prefers arid conditions (Walker 1991) and is rarely collected from the vegetation (Tables 1 & 2).

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TABLE 1 Total numbers of ticks collected by drag-sampling the vegetation of landscape Zone 4 at monthly intervals from August 1988 to July 1995.

Tick species	Total numbers collected				Monthly prevalence
	Larvae	Nymphs	Adults	Total	
Amblyomma hebraeum	13952	8	0	13960	76/83
Amblyomma marmoreum	1255	5	0	1260	42/83
Boophilus decoloratus	18935	0	6	18941	79/83
Haemaphysalis leachi	32	2	55	89	25/83
Hyalomma truncatum	5	0	0	5	1/83
Rhipicephalus appendiculatus	116	8	7	131	20/83
Rhipicephalus evertsi evertsi	730	0	0	730	47/83
Rhipicephalus simus	60	1	79	140	30/83
Rhipicephalus turanicus	0	0	2	2	1/83
Rhipicephalus zambezienis	31306	2522	13	33841	70/83

TABLE 2 Total numbers of ticks collected by drag-sampling the vegetation of landscape Zone 17 at monthly intervals from August 1988 to July 1995.

Tick species	Total numbers collected				Monthly prevalence
	Larvae	Nymphs	Adults	Total	
Amblyomma hebraeum	73389	44	0	73433	84/84
Amblyomma marmoreum	201	3	0	204	26/84
Boophilus decoloratus	15486	0	0	15486	84/84
Haemaphysalis leachi	17	3	68	88	38/84
Hyalomma truncatum	7	0	2	9	8/84
Rhipicephalus appendiculatus	33402	593	64	34059	77/84
Rhipicephalus evertsi evertsi	2175	0	0	2175	82/84
Rhipicephalus simus	7	0	176	183	34/84
Rhipicephalus turanicus	0	0	74	74	23/84
Rhipicephalus zambezienis	1106	224	1	1331	45/84

TABLE 3 **Average number of *Amblyomma hebraeum* collected from various host species in the southern Kruger National Park.**

Host species	Average number collected				Prevalence
	Larvae	Nymphs	Adults	Total	
Lions (15)	845	192	17	1054	100,0
Burchell's zebras (33)	227	52	3	282	100,0
Warthogs (51)	74	59	27	160	100,0
Giraffes (6)	160	149	909	1218	100,0
Impalas (135)	697	99	0,7	797	100,0
Blue wildebeest (47)	73	4	0,3	77	87,2
Greater kudus (95)	708	103	10	821	100,0
Bushveld gerbils (46)	0	0	0	0	0,0
Red veld rats (46)	0	0	0	0	0,0
Scrub hares (360)	9	9	<0,01	18	97,2
Helmeted guineafowls (118)	185	17	0	202	99,2

( ) = Number of animals examined

TABLE 4 **Average number of *Boophilus decoloratus* collected from various host species in the southern Kruger National Park.**

Host species	Average number collected				Prevalence
	Larvae	Nymphs	Adults	Total	
Lions (15)	0,2	0	0,6	0,8	40,0
Burchelll's zebras (33)	1070	401	356 (6)*	1827	100,0
Warthogs (51)	2	1	1	4	56,9
Giraffes (6)	412	424	396 (13)*	1232	100,0
Impalas (135)	1679	755	413 (3)*	2847	100,0
Blue wildebeest (47)	420	81	47 (2)*	548	100,0
Greater kudus (95)	1703	1134	569 (4)*	3406	100,0
Bushveld gerbils (46)	0	0	0	0	0,0
Red veld rats (46)	0	0	0	0	0,0
Scrub hares (360)	0,2	0	0,01	0,2	5,3
Helmeted guineafowls (118)	0,1	0	0	0,1	5,9

( ) = Number of animals examined
( )* = Number of engorging female ticks

TABLE 5 Average number of *Rhipicephalus appendiculatus* collected from various host species in the southern Kruger National Park.

Host species	Average number collected				Prevalence
	Larvae	Nymphs	Adults	Total	
Lions (15)	6	15	166	187	93,3
Burchelll's zebras (33)	192	181	9	382	100,0
Warthogs (51)	-	30	-	-*	45,1
Giraffes (6)	271	114	9	394	100,0
Impalas (135)	171	68	15	254	85,9
Blue wildebeest (47)	52	86	0,1	138	74,5
Greater kudus (95)	125	34	50	209	92,6
Bushveld gerbils (46)	0	0	0	0	0,0
Red veld rats (46)	0	0	0	0	0,0
Scrub hares (89)**	10	8	0	18	66,3
Helmeted guineafowls (118)	0,03	0	0,01	0,04	2,5

( ) = Number of animals examined

* = I was able to differentiate the larvae and adults of *R. appendiculatus* from those of *R. zambeziensis* at the time this survey was concluded

** = From Eastern Cape Province (Horak & Fourie 1991)

TABLE 6 **Average number of *Rhipicephalus evertsi evertsi* collected from various host species in the southern Kruger National Park.**

Host species	Average number collected				Prevalence
	Larvae	Nymphs	Adults	Total	
Lions (15)	2	0	0	2	26,7
Burchelll's zebras (33)	606	259	76	941	100,0
Warthogs (51)	0,1	0,2	0	0,3	21,6
Giraffes (6)	75	32	21	128	100,0
Impalas (135)	264	41	2	307	97,8
Blue wildebeest (47)	46	2	1	49	83,0
Greater kudus (95)	95	10	2	107	96,8
Bushveld gerbils (46)	0	0	0	0	0,0
Red veld rats (46)	0	0	0	0	0,0
Scrub hares (360)	7	7	0,01	14	76,9
Helmeted guineafowls (118)	0,02	0	0	0,02	1,7

( ) = Number of animals examined

TABLE 7 **The habitat preferences of adult ticks questing off the vegetation of two landscape zones in the southern Kruger National Park.**

Tick species	Total numbers of adult ticks collected		
	Sub-zones		
	Grassland	Gully	Woodland
Landscape Zone 4			
Haemaphysalis leachi	29 (12)	16 (9)	10 (6)
Rhipicephalus appendiculatus		6 (4)	1 (1)
Rhipicephalus simus	14 (9)	39 (20)	26 (11)
Rhipicephalus turanicus		2 (1)	
Rhipicephalus zambeziensis	4 (3)	5 (5)	4 (3)
Landscape Zone 17			
Haemaphysalis leachi	8 (6)	48 (25)	12 (7)
Rhipicephalus appendiculatus	17 (9)	35 (14)	12 (6)
Rhipicephalus simus	6 (3)	156 (31)	14 (8)
Rhipicephalus turanicus	15 (9)	51 (18)	8 (5)
Rhipicephalus zambeziensis		1 (1)	

( ) = Number of collections containing adult ticks of a particular species

TABLE 8 **The average adult tick burdens of adult male and adult female kudus and nyalas.**

Tick species	Average number of adult ticks collected			
	Kudus		Nyalas	
	Males (15)	Females (15)	Males (24)	Females (24)
Amblyomma hebraeum	33	3*	3,5	2,4
Boophilus decoloratus	806	492*	105	29*
Rhipicephalus appendiculatus	39	18	345	7*
Rhipicephalus maculatus	-	-	10	1*
Rhipicephalus muehlensi	-	-	646	292*

( ) = Number of animals examined

* = Adult tick burdens of female animals significantly smaller than those of male animals of the same species ($p = 0,05$)

TABLE 9 **Average total numbers of ticks collected from impalas in landscape Zone 4 at particular times during a year of normal rainfall and during two drought years.**

Period	Total Rainfall (mm) (July-June) in two consecutive years	No. of impalas examined	Sex	Age	Average No. of ticks collected
Oct-Nov 1980	488/749 (79-80)/(80-81)	4	Mixed	Adult	4734
Oct-Nov 1982	544/272 (81-82)/(82-83)	10	Mixed	Adult	7461
Mar-Oct 1980	488/749 (79-80)/(80-81)	8†	Male	15-22 mon	8696
Mar-Oct 1992	251/595 (91-92)/(92-93)	24††	Male	15-22 mon	678*

† = one impala examined each month, †† = three impalas examined each month
* p = 0,02

TABLE 10 **Average number of *Amblyomma hebraeum* collected from warthogs during (October and November) a year with normal rainfall and during a drought year.**

	Normal year	Drought year
Number of warthogs	8	7
Months examined	Oct/Nov 1980	Oct/Nov 1982
Rainfall (mm) Feb-Nov	415	175
Average: Larvae	19	416
Average: Nymphs	24	260
Average: Adults	11	292
Average: All stages	54	968

TABLE 11 Total number of ticks collected annually from the vegetation and from scrub hares during years of normal and of reduced rainfall.

Year (Aug-July)	Annual rainfall (mm)* (July-June)	Total number of ticks collected		
		Zone 17	Zone 4	Scrub hares
1987/88	682	-	-	-
1988/89	656	20409	10964	11206
1989/90	498	19945	17474	17251
1990/91	429	27240	14228	15411
1991/92	251	30568	13221	9276
1992/93	595	16835	4637	14862
1993/94	354	6294	6721	10292
1994/95	655**	5751	1884	-

* = July-June at Skukuza; 70 year mean=547 mm

88 = 324 mm during January 1995

Proceedings of a Symposium on Cheetahs as Game Ranch Animals, Onderstepoort, 23 & 24 October 1998

CHEETAH PARASITES : A REVIEW

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Abstract - One rickettsia, nine protozoa, 14 nematodes, four cestodes, one trematode, 21 ticks, two mites, four flies, four fleas and two lice have been collected from cheetahs. Many of these collections were from captive animals. Some of the ectoparasites are normally associated with prey species of cheetahs.

INTRODUCTION

Parasites have evolved with their natural hosts, and in natural systems an equilibrium is usually established between parasite and host. Many hosts therefore harbour low levels of parasites without showing overt clinical signs. The mere presence of a parasite in or on a host therefore does not necessarily signify that the host is suffering from a parasitic disease. Problems may arise when the host is stressed and its immunity is impaired, or when a host is exposed to parasites which it would not encounter in natural systems. The latter applies to zoos, where cheetahs will be exposed to the parasites of other exotic carnivores, primarily felids, as well as to parasites of stray cats. In the following list it is clearly indicated which parasites were recovered from captive cheetahs. Carnivores sometimes harbour ectoparasites of their prey, presumably becoming infested when feeding.

PROTOZOA AND RICKETTSIALES

Eperythrozoon felis

This rickettsial organism was seen on blood smears from a cheetah in Nairobi National Park, Kenya[37, 39].

Hepatozoon sp.

A *Hepatozoon* species, morphologically indistinguishable from *H. canis*, has been reported from cheetahs in Kruger National Park[5, 32] and Hluhluwe-Umfolozi Park[25] in South Africa and from Serengeti National Park[2, 43] and Ngorongoro Crater[2], Tanzania.

Theileria-like piroplasms

Theileria-like piroplasms have been described from blood smears from cheetahs in Serengeti National Park and Ngorongoro Crater, Tanzania[2]. Many carnivore species harbour small intra-erythrocytic piroplasms; it is impossible to distinguish between these stages of *Theileria* sp., *Babesia* sp. and *Cytauxzoon* sp.

Cytauxzoon-like piroplasms

Cytauxzoon-like piroplasms have been described from captive cheetahs in the USA[61]. (See comments above.) *Cytauxzoon felis* causes a fatal disease in domestic cats.

Babesia species

Piroplasms described elsewhere as *Theileria*-like or *Cytauxzoon*-like would be regarded as small *Babesia* piroplasms by South African researchers familiar with *Babesia felis*. A parasite resembling *B. felis*, but which was not pathogenic to experimentally-infected cats, has been found in cheetahs at De Wildt (DGA Meltzer, personal communication).

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Isospora rivolta
Oocysts of *Isospora rivolta* have been recovered from faeces of semi-captive cheetahs in South Africa[44].

Sarcocystis felis
The tissue-cyst forming coccidian *Sarcocystis felis* has been reported from captive cheetahs[7].

Toxoplasma gondii
Clinical toxoplasmosis has been reported in captive cheetahs[9], and it has also been associated with spongiform encephalopathy in captive cheetahs[42]. Antibodies to *Toxoplasma gondii* have been detected in sera from captive cheetahs[11], while one report claimed cheetahs to be definitive hosts of the parasite[45].

Besnoitia besnoiti (negative)
The definitive host of *B. besnoiti*, which causes elephant-skin disease in cattle, has not yet been identified. Cheetahs were fed infected tissues, but did not shed oocysts[13].

Giardia **species**
One case of giardiosis in young, captive cheetahs has been reported[36].

Entamoeba **(?) species**
A case of "amoebiosis" associated with liver dystrophy has been reported in a captive cheetah[48].

HELMINTHS

Nematodes

Aelurostrongylus abstrusus
The feline lungworm *Aelurostrongylus abstrusus* has been recorded from a captive cheetah[57].

Ancylostoma braziliense
Ancylostoma braziliense has been reported from cheetahs in Senegal[35], Somalia[30] and in a zoo in Japan[23].

Ancylostoma caninum
Ancylostoma caninum has been reported from cheetahs in Senegal[35], Somalia[30] and in a zoo in Italy[14].

Ancylostoma iperodontatum
Ancylostoma iperodontatum was originally described from a cheetah in Zambia[29].

Ancylostoma paraduodenale
Ancylostoma paraduodenale was originally described from a cheetah in Zambia[6].

Ancylostoma tubaeforme
Ancylostoma tubaeforme has been recovered from cheetahs in Somalia[30] and in an Italian zoo[14].

Ancylostoma **species**
Ancylostoma eggs were recovered from faeces of 10 of 13 cheetahs in Serengeti National Park, Tanzania[10]

Dracunculus medinensis
This subcutaneous filarial worm has been described once from a cheetah in the Sudan[51].

Ollulanus tricuspis
The feline stomach worm *Ollulanus tricuspis* has been described from cheetahs in zoos[17, 18, 20, 243].

Spirocerca lupi
Spirocerca lupi has been found in free-ranging cheetahs in Kenya[37, 38, 39].

Toxascaris leonina
Toxascaris leonina has been found in cheetahs in Senegal[35] and in various zoos[8, 15, 34, 55]. Results of treatment with ivermectin have been reported[34].

Toxascaris **species**
An unidentified *Toxascaris* sp. was reported from cheetahs in the Giza Zoo, Egypt[19].

Toxocara cati
Toxocara cati has been reported from cheetahs in zoos in the UK and USA[31, 34, 54], while results of treating with ivermectin have also been reported[34].

***Toxocara* species**
An unidentified *Toxocara* sp. has been reported from cheetahs in San Diego Zoo, USA[16].

Trichinella nelsoni
Larvae of this worm were found in the muscles of one of five cheetahs examined in the Serengeti ecosystem, Tanzania[46].

***Trichinella spiralis* (?) (negative)**
In a survey in Kruger National Park, South Africa, cheetahs were negative for *Trichinella spiralis*[59]. (The Southern African isolates of "*T. spiralis*" have not been identified specifically[47].)

Cestodes

***Dipylidium* species**
A *Dipylidium* segment was found in faeces of one of 13 cheetahs in Serengeti National Park, Tanzania[10].

Taenia acinomyxi
This species was described by Ortlepp[41] from specimens collected from cheetahs in Namibia. In her review of the genus *Taenia*, Verster[53] spelt the species name *acinonyxi*.

Taenia hlosei
This species was described by Ortlepp[41] from specimens collected from cheetahs in Northern Province of South Africa. In her review of the genus *Taenia*, Verster[53] regarded this species as synonymous with *Taenia gonyamai*.

Taenia gonyamai
In her review of the genus *Taenia*, Verster[53] regarded *Taenia hlosei* as synonymous with *T. gonyamai*.

Taenia hydatigena
Taenia hydatigena has been reported from cheetahs in Senegal[35].

Trematodes

Pharyngostomum cordatum
This species has been recorded from cheetahs[3].

ECTOPARASITES

Ticks (Ixodidae)

Amblyomma hebraeum
The bont tick *Amblyomma hebraeum* has been reported from cheetahs in KwaZulu-Natal[4] and Kruger National Park[21, 22], South Africa, where larvae, nymphs and adults were recovered.

Amblyomma lepidum
Cheetahs were listed as hosts of *Amblyomma lepidum*, but the collection site was not mentioned[50].

Amblyomma marmoreum
Larvae and nymphs of *Amblyomma marmoreum*, the adults of which are usually found on tortoises, e.g. leopard tortoise *Geochelone pardalis*, have been collected from cheetahs in Kruger National Park, South Africa[22].

Amblyomma nuttali
Nymphs of this tick, mainly associated with tortoises and other large reptiles, have been found on a cheetah in Kruger National Park, South Africa[22].

Amblyomma variegatum
Cheetahs were listed as hosts of *Amblyomma variegatum*, which is widely distributed north of South Africa, but the collection site was not mentioned[50].

Boophilus decoloratus
Larvae of the blue tick *B. decoloratus* have been recovered from cheetahs in Kruger National Park, South Africa[22].

Haemaphysalis leachi
The yellow dog tick *Haemaphysalis leachi* has been recorded from cheetahs in in Kenya[55] and in KwaZulu-Natal[4] and Kruger National Park[22], South Africa, where larvae and adults were recovered from cheetahs.

Haemaphysalis spinulosa
Adults of this species were found on a cheetah in Kruger National Park, South Africa[22].

Hyalomma truncatum
Adult bont-legged ticks *Hyalomma truncatum* have been reported from cheetahs in KwaZulu-Natal[4] and at De Wildt[52] and Kruger National Park[22], South Africa. Toxic saliva of the tick may cause tissue necrosis at the site of attachment.

Rhipicentor bicornis
Cheetahs were listed as hosts of *Rhipicentor bicornis*, but the collection site was not mentioned[50].

Rhipicephalus appendiculatus
The brown ear tick *Rhipicephalus appendiculatus* has been reported from cheetahs in KwaZulu-Natal[4] and in Kruger National Park[22], South Africa, where larvae, nymphs and adults were collected.

Rhipicephalus armatus
Rhipicephalus armatus has been collected from cheetahs in Kenya[56].

Rhipicephalus capensis
Cheetahs were listed as hosts of *Rhipicephalus capensis*, but the collection site was not mentioned[50].

Rhipicephalus compositus
Rhipicephalus compositus has been found on cheetahs in Kenya[56].

Rhipicephalus evertsi evertsi
Larvae and and adult of the red-legged tick *Rhipicephalus evertsi evertsi* have been recovered from cheetahs in Kruger National Park, South Africa[22].

Rhipicephalus maculatus
Rhipicephalus maculatus has been reported from cheetahs in KwaZulu-Natal, South Africa[4].

***Rhipicephalus pravus*-like**
Larvae resembling those of *Rhipicephalus pravus* have been recovered from two cheetahs in Kruger National Park, South Africa[22].

***Rhipicephalus sanguineus* group**
Ticks belonging to the *Rhipicephalus sanguineus* group have been reported from cheetahs in Kenya[56].

Rhipicephalus simus
Rhipicephalus simus has been reported from cheetahs in Kenya[56] and in KwaZulu-Natal[4] and Kruger National Park[22], South Africa. Larvae and adults were found on a cheetah in the latter park.

Rhipicephalus turanicus
Adults of this species infested a cheetah in Kruger National Park, South Africa[22].

Rhipicephalus zambeziensis
All stages of development of *Rhipicephalus zambeziensis* have been recovered from cheetahs in Kruger National Park, South Africa[22].

Ticks (Argasidae)

***Ornithodoros* species**
A tampan nymph was recovered from a cheetah in Kruger National Park, South Africa[22].

Mites

Notoedres cati
Notoedres cati has been reported from cheetahs in Kruger National Park[12, 60] and KwaZulu-Natal[26], South Africa. Malathion, which was used for treating the infestation, may cause fatalities if used injudiciously[58, 60].

Sarcoptes scabei
An oubreak of sarcoptic mange in free-ranging cheetahs, which was treated with ivermectin, was reported from the Mara region, Kenya[40]. This mite was also recovered from cheetahs in Serengeti National Park, Tanzania[10].

Flies

Hippobosca longipennis
Hippobosca longipennis is well known as an ectoparasite of cheetahs[62] which can increase to large numbers on captive cheetahs (DGA Meltzer,personal communication). It was introduced into the USA on cheetahs, but subsequently eradicated[1, 16, 27]. A hippoboscid (*H. longipennis* ?) was found on cheetahs in Serengeti National Park, Tanzania[10].

***Cochliomyia* species**
Fatal myiasis caused by the New World screwworm has been reported in a captive cheetah[33].

Lipoptena paradoxa
Lipoptena paradoxa has been recorded from a cheetah in Kruger National Park, South Africa[22]. This louse fly is associated with medium-sized antelope such as bushbuck *Tragelaphus scriptus*; cheetah may become infected when feeding on such antelopes.

Stomoxys calcitrans
Lesions caused by feeding stable flies *Stomoxys calcitrans* have been seen on the ears of cheetahs at breeding centres in South Africa[23, 52].

Fleas

Ctenocephalides felis
The cat flea *Ctenocephalides felis* has been reported from cheetahs in KwaZulu-Natal, South Africa[26].

***Ctenocephalides* species**
Adult fleas have been recovered from cheetahs in Kruger National Park, South Africa[22].

Echidnophaga larina
This stick-tight flea, normally associated with warthogs *Phacochoerus aethiopicus*, was found on a cheetah in Kruger National Park, South Africa[22].

***Echidnophaga* species**
Stick-tight fleas have been reported from cheetah cubs at a breeding centre in South Africa[52].

Moepsylla sjoestedi
This flea, normally associated with warthogs *Phacochoerus aethiopicus*, was found on a cheetah in Kruger National Park, South Africa[22].

Lice

Damalinia elongata
Nymphs and adults of this louse, usually associated with impalas *Aepyceros melampus*, were recovered from a cheetah in Kruger National Park[22].

***Felicola* species**
Adults of this louse were found on a cheetah in Kruger National Park, South Africa[22].

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Status of Dorper sheep as hosts of ectoparasites

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Abstract

Seventeen ixodid tick species or subspecies have been collected from Dorper sheep in South Africa. The diseases transmitted or the conditions caused by these ticks in sheep are discussed. Although Dorper sheep may be infested with the scab mite, *Psoroptes ovis*, this does not seem to cause production losses. These sheep may, however, serve as a source of mite infestation for woolled sheep. The majority of Dorper sheep are infested with the larvae of the nasal bot fly, *Oestrus ovis*, they may also be subject to myiasis caused by the larvae of two calliphorid flies. In certain regions of the country Dorper sheep are prone to serious fly worry by female *Simulium chutteri*. Although Dorper sheep may be infested by various louse species these do not seem to reach large numbers or cause production losses. © 2000 Elsevier Science B.V. All rights reserved.

Keywords: Dorper sheep; Ixodid ticks; *Psoroptes ovis*; Lice; Myiasis; *Simulium chutteri*; Production losses

1. Introduction

Sheep form a critical component of most livestock production systems in every continent. According to recent FAO estimates the world sheep population numbers 1,070 million and with the increase in human population numbers of small ruminants are also increasing. The various sheep breeds are able to survive and be productive in a wide range of ecotypes, in many cases exploiting the scarce feed resources available. The Dorper sheep, which was recognised as a breed in 1950, has shown an unparalleled increase in numbers in South Africa. According to Marais and Schoeman (1990) this is because this breed met a very real need for a fertile and productive mutton breed for the extensive and arid grazing areas in much of the country. However, there is a continual need to improve management and reduce the impact of major limiting factors affecting productivity for every breed of livestock. One such limiting factor is ectoparasites and the diseases they transmit. Although sheep may be infested with a wide diversity of ectoparasites many of these may have no, or little influence on productivity. This paper reviews some of the ectoparasites which occur on Dorper sheep in South Africa. Some of the arthropods (flies) referred to may not fall into the traditional definition of an ectoparasite but are nevertheless included because of their potential impact on productivity. Most of the available information deals with ticks and hence the main focus of this paper is on these ectoparasites.

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2. Ticks infesting dorper sheep

World-wide sheep are known to be infested by about 97 tick species belonging to 10 genera (Liebisch, 1997). These ticks and the diseases they transmit are of considerable economic and social importance to commercial enterprises and individual livestock owners. Besides the pathogens and toxins they transmit, ticks can also cause direct damage to the host including blood loss anaemia and skin wounds as well as lameness due to foot abscesses or large infestations of ticks feeding on the feet. The impact of tick infestations on production losses in sheep is, however, poorly understood and has received little attention from the scientific community (Uilenberg, 1997).

The results of tick surveys covering the major production areas of Dorper sheep in South Africa, have shown that 17 different tick species or subspecies belonging to six genera infest this breed (Horak et al., 1991a; Horak and Fourie, 1992) (Table 1). Of these all developmental stages (larvae, nymphs and adults) of six tick species (*A. hebraeum, B. decoloratus, H. silacea, R. appendiculatus, R. evertsi evertsi* and *R. glabroscutatum*) feed on Dorper sheep. In the case of *A. marmoreum* only immature ticks occur on the sheep and for 10 other species only the adults feed on sheep (Table 1). Seven of the species which infest Dorper sheep can either transmit pathogens or cause direct damage to sheep (Table 2).

2.1. *Amblyomma hebraeum*

This tick is distributed mainly in the higher rainfall regions in the northern and northeastern provinces of South Africa and also along the eastern coast as far as Humansdorp (Walker, 1991). The larvae and nymphs utilise a large variety of small and large mammals and some ground-nesting birds. The adults prefers large hosts such as cattle, kudu, eland, buffalo and giraffe (Horak et al., 1987a,b).

In South Africa *A. hebraeum* is the main vector of *Cowdria ruminantium*, the cause of cowdriosis (heartwater) in sheep, goats and cattle (Bezuidenhout, 1987). Sheep may not only act as a source of ticks but also of *C. ruminantium* for goats or cattle and vice versa (Horak et al., 1991a). Data on exact impact of

Table 1
Ticks infesting Dorper sheep in South Africa[a]

Tick species	Larvae	Nymphs	Male	Female	Province	Reference
Amblyomma hebraeum	+	+	+	+	E.C.	Horak et al. (1991a)
A. marmoreum	+	+			E.C.	Horak et al. (1991a)
Boophilus decoloratus	+			+	E.C.; W.C.; F.S.	Horak et al. (1991a); Horak and Fourie (1992)
Haemaphysalis silacea	+	+	+	+	E.C.	Horak et al. (1991a)
Hyalomma m. rufipes			+	+	E.C.; F.S.	Horak et al. (1991a); Horak and Fourie, 1992; Fourie and Kok, 1995
H. m. turanicum			+	+	E.C.; N.C.	Horak and Fourie (1992)
H. truncatum			+	+	N.C.; W.C.; E.C.; F.S.	Horak and Fourie (1992)
Ixodes rubicundus			+	+	N.C.; W.C.; E.C.; F.S.	Horak and Fourie (1992)
Rhipicephalus appendiculatus	+	+	+	+	E.C.	Horak et al. (1991a)
R. evertsi evertsi	+	+	+	+	N.C.; W.C.; E.C.; F.S.	Horak et al. (1991a); Horak and Fourie (1992)
R. exophthalmos[b]			+	+	E.C.	Horak et al. (1991a); Horak and Fourie (1992)
R. follis			+	+	E.C.; F.S.	Horak and Fourie (1992)
R. gertrudae			+	+	N.C.; W.C.; E.C.; F.S.	Horak and Fourie (1992)
R. glabroscutatum	+	+	+	+	E.C.; W.C.	Horak et al. (1991a); Horak and Fourie (1992)
R. neumanni			+	+	N.C.; E.C.	Horak and Fourie (1992)
R. simus			+	+	E.C.	Horak et al. (1991a)
R. near *R. punctatus*			+	+	F.S.	Horak and Fourie (1992)

[a] +: infestation; E.C.: Eastern Cape; N.C.: Northern Cape; F.S.: Free State; W.C: Western Cape.
[b] R. sp. near oculatus.

Table 2
Diseases of sheep associated with tick infestation

Tick species	Disease	Reference
Amblyomma hebraeum	Heartwater, foot abscess	Bezuidenhout (1987); MacIvor and Horak (1987)
Hyalomma spp	Foot abscess and lameness	Fourie and Kok (1995)
Ixodes rubicundus	Karoo paralysis	Fourie and Kok (1996)
Rhipicephalu Evertsi evertsi	*Theileria separata* (as *T. ovis*), spring lamb paralysis	Jansen and Neitz (1956); Hamel and Göthe (1987)
Rhipicephalus glabroscutatum	Foot abscess	MacIvor and Horak (1987)
Rhipicephalus neumanni	Lameness	Walker (1990)
Rhipicephalus sp. near *punctatus*	Brown tick paralysis	Fourie et al. (1988)

cowdriosis on Dorper sheep production are lacking. When viewed against the geographical distribution of *A. hebraeum* it is likely to be limited. It has been reported (Alexander, 1931) that Persian crossbred sheep have a strong natural resistance to *C. ruminantium*.

2.2. *Hyalomma spp*

The two species of this genus found in South Africa prefer the drier regions of the country (Howell et al., 1978). The immature stages prefer scrub hares as hosts (Horak and Fourie, 1991) whereas the adults prefer large herbivores, such as cattle, eland and zebras (Horak et al., 1991a, b). Where sheep are farmed in regions in which these ticks abound they are also good hosts for the adults (Horak and Fourie, 1992). *H. marginatum rufipes* and *H. truncatum* attach mainly to the anogenital/inguinal region of Dorper sheep (>63%) (Fourie and Kok, 1995) and clusters of ticks in excess of 50 are not uncommon (Kok and Fourie, 1995). In the case of *H. truncatum* a significant proportion of the ticks may also attach to the feet (Fourie and Kok, 1995). *Hyalomma* spp, because of their long mouthparts, cause wounds that may be invaded either by the larvae of blowflies (*Chrysomya* spp) or by bacteria, resulting in the formation of abscesses, lameness and footabscess.

2.3. *Ixodes rubicundus*

This tick, known as the Karoo Paralysis tick, is widespread in the southern, central and eastern Free State, the Karoo regions of South Africa and in a number of districts in the Western Cape Province. In other provinces its distribution is more confined (Walker, 1991). The preferred hosts of the immature stages are rock elephant shrews, red rock rabbits and caracals (Fourie et al., 1992; Horak and Fourie, 1992). Sheep, goats and cattle (Spickett and Heyne, 1988; Fourie et al., 1989) as well as wild ungulates (Fourie and Horak, 1987) can be paralysed by a toxin produced by *I. rubicundus* females. Of all the tick species infesting Dorper sheep the Karoo paralysis tick is most likely to cause the greatest production losses. If no prophylactic measures are taken during years of high abundance, in excess of 50% of a flock may become paralysed and suffer mortality if not treated (Fourie; unpublished data). The chances of a sheep becoming paralysed is related to infestation density (Fourie et al., 1989). In a comparative study it was shown that Dorper sheep are more at risk of becoming paralysed than Merino sheep (Fourie and Kok, 1996). This is not necessarily related to a greater susceptibility to the toxin but rather to generally higher tick burdens on the Dorper sheep. The differences in tick burdens between the two sheep breeds are possibly related to differing grazing patterns and diet selection. The feeding behaviour of the host plays a major role in determining tick/host sympatry and hence the chances of a host becoming infested with *I. rubicundus* (Fourie and Kok, 1992). *I. rubicundus* is confined mainly to hilly or mountainous terrain (Fourie et al., 1991).

2.4. *Rhipicephalus evertsi evertsi*

Of all the tick species infesting Dorper sheep *R. evertsi evertsi* most probably has the widest distribution. The preferred hosts of all stages of development are equids and eland (Horak et al., 1991b) but sheep

are also efficient hosts of the adults (Horak et al., 1991a). Engorging female ticks can cause paralysis in adult sheep (Hamel and Göthe, 1987), but this usually occurs in young, spring-born lambs, hence the name spring-lamb paralysis (Howell et al., 1978). *R. evertsi evertsi* is also a vector of *Borrellia theileri* causing spirochaetosis in sheep (Howell et al., 1978) and of *Theileria separata* (as *T. ovis)* causing theileriosis in sheep (Jansen and Neitz, 1956).

2.5. *Rhipicephalus glabroscutatum*

This species occurs in the Eastern Cape Province as well as in areas of the Western Cape Province (Walker, 1991). Kudu are the preferred hosts of all stages of development of *R. glabroscutatum* while cattle and Angora goats are better hosts than are Dorper sheep (Horak and Knight, 1986). Large numbers of larvae appear to die or detach before moulting to nymphs on these sheep (Horak et al., 1991a). Adult *R. glabroscutatum* attach around and between the claws of their host's hooves and are a major contributory cause to foot abscesses, and hence, lameness in small livestock (MacIvor and Horak, 1987).

2.6. *Rhipicephalus neumanni*

This tick occurs in scattered localities in the Karoo (Walker, 1991) and sheep are one of its most commonly recorded hosts (Walker, 1990; Horak and Fourie, 1992). Adults attach between the claws of the hooves and are a contributory cause of lameness (Walker, 1990).

2.7. *Rhipicephalus sp. near punctatus*

This species has only been recorded in the central, southern and southwestern Free State and adjacent regions of the Northern Cape Province. The preferred hosts of all stages of development are scrub hares, while the immature stages also feed on rock elephant shrews and the adults on goats (Fourie and Horak, 1991; Horak and Fourie, 1991; Fourie et al., 1992).

This tick has been associated with paralysis in Angora goat kids in the southwestern Free State (Fourie et al., 1988). It is not known whether this tick can cause paralysis in lambs of Dorper sheep.

3. Sheep scab

Sheep scab is caused by the non-burrowing, astigmatid mite *Psoroptes ovis*. It is one of the oldest sheep diseases known to man, and was regarded as a serious disease as early as 180 B.C. Feeding mites causes intense irritation and the sheep become pre-occupied with scratching, cease to feed and rapidly become emaciated (Kirkwood, 1986). Mite feeding is not the direct cause of lesion formation, but sheep scab is a form of allergic dermatitis initiated by the mites faeces. The heat and humidity produced by the inflammatory reaction results in the micro-climate needed for mite survival and the leakage of serous exudate the basis of the mites nutrition (Bates, 1996).

The disease, which occurs commonly in South Africa, is believed to be out of control. Although sheep scab was previously thought to be a winter disease only, recent research (Fourie, unpublished data) has shown that it can occur in South Africa during winter and summer on both Merino and Dorper sheep. There is, however, a profound difference in the scab symptomatology between Dorper and Merino sheep. Comparative studies have shown that lesion size is significantly greater in Merino sheep, while the growth of the lesion is significantly slower in Dorper sheep (Fourie and Meintjes, unpublished data). Whereas infested Merino sheep lost 30% of their initial body mass over a 16 week period Dorper sheep maintained or increased their body mass. These differences are believed to be related to the fact that the density of hair follicles is less in Dorper compared to Merino sheep resulting in a less favourable microclimate for the propagation and survival of the mite (Fourie and Meintjes, unpublished data).

As is the case with ticks the ability of sheep to develop resistance to *P. ovis* has been poorly studied. From a control perspective the slow growth of lesions and the sub-clinical nature of sheep scab on many Dorper sheep, make detection difficult. Because of this it is thought that Dorper sheep could be important disseminators of the disease in non-infested flocks or regions.

4. Flies and bot flies

Metallic blowflies belonging to the genera *Lucilia* and *Chrysomya* are the most important species caus-

ing myiasis in sheep in South Africa (Howell et al., 1978). *Lucilia cuprina* is a primary blowfly and is mainly responsible for myiasis in woolled sheep breeds (Leipoldt, 1996). Blowfly strike in Dorper sheep caused by *L. cuprina* is very rare and has only been observed in those sheep with a high wool component, most probably the result of previous crossings with Merino sheep. Myiasis caused by the secondary blowfly *Chrysomya albiceps* has been observed more frequently in Dorper sheep and is related to abscesses caused by tick feeding or wounds resulting from other factors (Fourie, unpublished data).

Female blackflies (*Simulium chutteri*) are known to annoy livestock along the Orange River system. It has been conjectured that at certain times of the year the annoyance levels can be such that the condition of especially small livestock can be detrimentally affected. Decreased lambing percentage and occasional deaths have also been reported (Jordaan and Van Ark, 1990). In a comparative study between Dorper and Merino sheep there were no significant differences in the attraction of blackflies to either breed. However, significantly fewer females engorged on Dorper than on Merino sheep (Kok et al., 1994).

The sheep nasal bot fly (*Oestrus ovis*) has a worldwide distribution wherever sheep and goats are kept and occurs in most parts of South Africa (Howell et al., 1978). It has previously been shown that infestations with the larvae of *O. ovis* retards the live mass gains of Merino lambs (Horak and Snijders, 1974). In a comparative study between Merino and Dorper sheep it was found that the percentage of sheep infested and the level of infestation is practically the same for the two breeds (Horak, 1977). It can, therefore, be presumed that infestation of Dorper lambs with the larvae of *O. ovis* will affect live mass gain.

5. Lice

Sheep in South Africa may be infested with three sucking louse species (*Linognathus africanus*, *L. pedalis* and *L. ovillus*) and two biting louse species (*Damalinia ovis* and *D. peregrina*) (Howell et al., 1978). Biting lice (*D. ovis*) can cause production losses in wool sheep breeds (Howell et al., 1978). It is, however, perceived that lice infestation may have little or no effect on the production of Dorper sheep, and reports of heavy louse infestations are lacking. Besides the above mentioned lice Dorper sheep may also carry small burdens (nymphs and adults) of the Angora goat louse *D. limbata*, specifically where these two breeds are farmed together and are in close contact (Horak, unpublished data). Previous observations, have, however, shown that such infestations are not permanent.

6. Host resistance

Numerous reports on the resistance of sheep to various ectoparasitic infestations are based on anecdotal evidence and adequately quantified studies are generally lacking. Although it has been reported that certain sheep breeds can develop resistance to the feeding of particular tick species (Tatchell, 1997) few well documented reports are available. Experimental infestations of crossbred Dorper and Merino sheep with *A. hebraeum* adults over a 23 period produced a small reduction (20%) in tick numbers form acquired resistance (Norval et al., 1988). With specific reference to *I. rubicundus* field observation have also shown that Dorper sheep may become paralysed more than once within a specific season (Fourie, unpublished data) indicating that acquired resistance to tick feeding may not be well established. Clearly more research is required to quantify host resistance in Dorper sheep against diseases and the feeding of ticks. Through selection, it should, however, be possible to breed Dorper sheep displaying a high degree of resistance to certain diseases and ectoparasitic infestations.

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TICK CONTROL ON WILDLIFE IN SMALL RESERVES

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Healthy wild herbivores in Africa usually harbour tick burdens in excess of several thousand. However, with the exception of very large animals such as giraffes (*Giraffa camelopardalis*), African buffaloes (*Syncerus caffer*) and eland (*Taurotragus oryx*), which may harbour large burdens of adult ticks, the majority of ticks parasitic on wildlife are usually larvae and nymphs. Severe tick infestation of wildlife in small reserves is frequently an indication of an underlying management problem. Once this has been solved animals that are visually very heavily tick infested or diseased or weak should be culled. Provided the habitat is suitable, the introduction of tick-resistant wildlife species such as blue wildebeest (*Connochaetes taurinus*) can be contemplated, as well as the introduction of oxpeckers (*Buphagus* spp.) that are dependent upon ticks as a food item. Although fire may kill most of the free-living ticks on the vegetation, its long-term effects seem to be limited, particularly if animals are not excluded from the burnt area. Regular acaricidal treatment of domestic stock on mixed livestock and game farms can result in a significant reduction in tick numbers on wildlife and the vegetation on the farms. Wildlife can also be treated with acaricides administered via self-medicating applicators. With the exception of rare or endangered wildlife, on which some of the tick species may be just as rare, no wild animals should be introduced into a reserve without prior treatment with an acaricide.

INTRODUCTION

Tick control on wildlife in large reserves should not be necessary, particularly if a sustainable number of large carnivores are present to remove stressed, weak, sick or injured animals. Problems with ticks usually occur in small wildlife reserves, on which it is not practical to also keep the larger wild carnivores. Severe tick infestation of wildlife is frequently an indication of an underlying management problem. This might be gross overstocking (Norval & Lightfoot 1982) or overstocking with particular species such as eland, which are animals that are highly susceptible to tick infestation (Lightfoot & Norval 1981; Horak *et al.* 1991). It could also be due to the introduction of wildlife species not indigenous to a region and hence not adapted to the local tick species. In this communication I will attempt to show that healthy wild animals harbour burdens in excess of several thousand ticks, that the distribution of the intensity of tick infestations within host populations is over-dispersed, and that normal phenomena within host populations lead to considerable differences in the magnitude of tick populations on individual animals. I will also discuss measures that can be taken to control ticks on wildlife in small reserves using examples of the success that has been achieved with some of these.

MATERIALS AND METHODS

Healthy wild animals in both small and large wildlife reserves in South Africa were shot, sometimes at regular intervals, and their tick burdens determined. Injured or obviously sick animals were also shot and examined for ticks as were animals during severe droughts. In addition wild animals on mixed wildlife and cattle ranches in South Africa and Zambia, on which tick control was practised on the domestic stock, and animals in adjacent or nearby wildlife reserves were shot and examined for ticks. At some localities free-living ticks were collected by dragging flannel strips over the vegetation, and in two instances the effect of fire on free-living ticks was determined. The numbers of parasitic and free-living ticks collected during these surveys have been assembled in various combinations to support the gist of this communication. Partially tame eland on the Game Ranching Research Station of the Mushandike Sanctuary, Zimbabwe were treated with 1% flumethrin pour-on administered by means of a Duncan Applictor, which is a self-medicating device coupled to a bin containing feed concentrates to which the animals are

attracted. Tick counts were done on animals that frequented the applicators and compared with those of animals that did not visit the applicators.

The average tick burdens of several species of healthy wildlife examined in the eastern reserves of South Africa are summarized in Table 1. In general the larger the host species the more adult ticks it harbours. However, blue wildebeest (*Connochaetes taurinus*) harbour significantly fewer ticks than other animals, whereas impalas (*Aepyceros melampus*) harbour as many ticks as considerably larger animals.

Table 1 Tick burdens of healthy wildlife in the eastern reserves of South Africa

Host species	Number examined	Mean number of ticks		
		Larvae	Nymphs	Adults
Burchell's zebras	33	2 095	874	456
Blue wildebeest	47	593	173	50
Impalas	135	3 086	1 030	449
Bushbuck	13	3 337	361	177
Nyalas	73	5 662	1 086	580
Greater kudus	95	2 787	1 302	648
African buffaloes	15	16 108	3 844	827
Giraffes	5	1 102	827	1 523

An apparently healthy adult warthog (*Phacochoerus africanus*) carried more than twice as many ticks as the combined burdens of ten other animals examined in the same habitat (Table 2). Adult male nyalas (*Tragelaphus angasii*) and greater kudus (*Tragelaphus strepsiceros*) had significantly more adult ticks than adult female animals examined in the same habitat at the same time (Table 3).

Table 2 Adult *Amblyomma hebraeum* on adult warthogs in the Kruger National Park

Number of warthogs	Adult *A. hebraeum*	
	Total no collected	Average no.
8	123	15
1	64	64
1	68	68
1	653	653

Table 3 Adult ticks on adult male and female nyalas and greater kudus

Tick species	Mean number of adult ticks			
	Male nyalas (24)	Female nyalas (24)	Male kudus (15)	Female kudus (15)
Amblyomma hebraeum	3	2	33	3*
Boophilus decoloratus	105	29*	806	492*
Rhipicephalus appendiculatus	345	7*	39	18
Rhipicephalus maculatus	10	1*	-	-
Rhipicephalus muehlensi	646	292*	-	-

( )= No. of animals examined *= significantly fewer than on males (p=0.05)

A blue wildebeest calf with a broken leg harboured significantly more *Boophilus decoloratus* than apparently healthy calves examined from the same calf crop (Table 4). Adult blesbok (*Damaliscus pygargus phillipsi*) in historically suitable habitat carried considerably fewer ticks than animals in marginal or unsuitable habitat (Table 5).

Table 4 *Boophilus decoloratus* on healthy blue wildebeest calves and on an injured calf

Status	Number of calves	Mean number of *B. decoloratus*			
		Larvae	Nymphs	Adults	Total
Healthy	5	321	41	19	381
Broken leg	1	1 069	486	516	2 071

Table 5 Tick burderns on blesbok in favourable and unsuitable habitats

Locality	No. of blesbok	Mean tick burden
Karoo	2	27
Eastern Free State	2	2
Gauteng middleveld (marginal)	3	390
Mpumalanga savanna (unsuitable)	4	8 236

The total numbers of free-living larvae collected from the vegetation in the Kruger National Park before and after deliberate fires are summarized in Table 6. At one locality there was an apparent reduction in the total numbers of larvae immediately after the burn followed by a return to earlier numbers 5 months later, whereas at the other no such immediate reduction in tick numbers was evident.

Table 6 Tick larvae collected from unburned and burned vegetation in the Kruger National Park

Month	Total number of larvae	Month	Total number of larvae		
	Unburned zone	Burned zone		Unburned plots	Burned plots
Aug 1988	351	1 658			
Sep 1st week	381	378			
Sep 2nd week	Nil	Fire	Jun 2000	788	1 625
Oct 1st week	1 670	200	July	1 296	932
Nov	817	106	Aug 1st week	Nil	Fire
Dec	1 133	125	Aug 3rd week	1 840	3 593
Jan 1989	10 439	1 448			
Feb	627	613			
Mar	1 233	948			
Apr	1 594	1 416			

Helmeted guineafowls (*Numida meleagris*), scrub hares (*Lepus saxatilis*) and greater kudus on a mixed goat, cattle and sheep farm in the Eastern Cape Province, South Africa, on which the domestic stock were regularly treated with acaricides, harboured very few *Amblyomma hebraeum* compared to the same wildlife species in an adjacent nature reserve in which no acaricides were used (Table 7).

Table 7 *Amblyomma hebraeum* on wildlife on a mixed South African farm on which acaricides were used and on the same wildlife species in an adjacent nature reserve

Host species	No. examined	Locality	Total number of *A.hebraeum* collected		
			Larvae	Nymphs	Adults
Helmeted guineafowls	37	Farm	670	19	0
	39	Reserve	22 152	995	0
Scrub hares	47	Farm	10	3	0
	42	Reserve	1 948	638	0
Greater kudus	9	Farm	153	27	18
	8	Reserve	25 504	2 600	528

The same reduction in numbers did not occur with *Haemaphysalis silacea* or *Rhipicephalis appendiculatus*. Impalas on a mixed wildlife and cattle ranch in Central Province, Zambia, on which the cattle were regularly treated with an acaride, harboured considerably fewer *Amblyomma variegatum*, *R. appendiculatus* and *Rhipicephalus evertsi evertsi* than animals on a nearby game farm on which no acaricide was administered (Table 8). Similar observations were made for the free-living larvae of these ticks on the vegetation of the two properties.

Table 8 Ticks on three impalas and the vegetation of a Zambian mixed farm on which acaricides were used and on three impalas and the vegetation on a game farm

Tick species	Locality	Total number of ticks collected			
		Impala		Vegetation	
		Larvae	Nymphs	Adults	Larvae
Amblyomma variegatum	Mixed farm	0	0	0	0
	Game farm	120	0	0	59
Boophilus decoloratus	Mixed farm	120	147	57	75
	Game farm	489	147	87	596
Rhipicephalus appendiculatus	Mixed farm	3	0	6	5
	Game farm	9 609	168	90	11 340
Rhipicephalus evertsi evertsi	Mixed farm	42	6	0	10
	Game farm	2 034	405	57	403

Eland that utilized the four Duncan Applicators charged with 1% flumethrin in the Mushandike Sanctuary, Zimbabwe had considerably lower total adult tick burdens, consisting mainly of *R. appendiculatus* and *Rhipicephalus zambeziensis*, than animals that did not visit the applicators (Table 9).

Table 9 The mean tick burdens of eland treated with flumethrin by means of a Duncan Applicator compared to those of apparently untreated animals

Eland group	Approximate mean tick burdens and dates of applicator activation					
	14 Dec 87	28 Dec	28 Jan 88	14 Feb	28 Feb	28 Apr
Treated	220	40	35	50	30	20
Untreated	225	250	325	530	550	110

Healthy wild herbivores in Africa usually harbour tick burdens in excess of several thousand (Horak *et al.* 1991; 1992; 1995; Zieger *et al.* 1998a). However, with the exception of very large animals such as giraffes, African buffaloes and eland, which may carry large burdens of adult ticks, the majority of ticks parasitic on wildlife are usually larvae and nymphs (Horak *et al.* 1987; Gallivan & Horak 1997; Horak 1998). Severe tick burdens on wildlife are usually an indication of an underlying problem and before control measures are instituted the cause of the problem should be addressed. Thereafter any animals that are visually very heavily tick-infested as well as any diseased or weak animals should be culled. The latter animals are usually severely stressed and may harbour massive tick burdens leading to contamination of their surroundings. However, it must be remembered that male animals harbour more ticks than females, particularly during the breeding season (Mooring & Hart 1993), and this should not be a reason for culling. Provided the habitat is suitable, tick-resistant species such as blue wildebeest could be introduced (Horak 1998). If the reserve is large enough to accommodate them, or the surrounding cattle farmers use only acaricides that do not affect the birds, the introduction of oxpeckers (*Buphagus* spp.) is feasible. These birds are nearly entirely dependent upon ticks for food (Bezuidenhout & Stutterheim 1980).

On condition that the burn is hot and slow, fire may kill most of the free-living ticks on the vegetation. However, its long-term effects seem to be limited, particularly if animals are not

excluded from the burnt area (Minshull & Norval 1982; Spickett *et al.* 1992). If the use of acaricides is unavoidable they can be applied to wildlife by means of a self-medicating applicator coupled to a bin containing an attractant feed (Duncan & Monks 1992). Or they can be administered by constructing a single entrance to a watering point, thus forcing animals to step on a pressure-plate or interrupt a light beam activating a jetting or pour-on device (Fourie *et al.* 1998; Meintjes 1997). Adult domestic cattle, regularly treated with an acaricide, can be used to control ticks in a small wildlife reserve. These animals should be introduced during the wet summer months when adult ticks are most abundant and can be herded into those parts of the reserve where ticks are deemed to be most numerous. Because of the cattle's size most adult ticks will attach to them rather than to the wildlife that are generally smaller. The regular treatment of domestic animals on mixed cattle and game farms has resulted in a significant reduction in tick numbers on sympatric wildlife and on the vegetation (Horak & Knight 1986; Petney & Horak 1987; Zieger *et al.* 1998b). With the exception of rare or endangered wildlife, on which some of the ticks can be just as rare, no wildlife should be translocated without prior treatment with an acaricide. This will reduce the risk of introducing tick species into a region in which they did not previously occur as well as decreasing the stress of existing tick burdens on the new introductions.

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CONSERVATION OF RARE PARASITES

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Black rhinoceroses (*Diceros bicornis*) are infected with a number of unique helminths, and also with the larvae of a stomach bot fly *Gyrostigma pavesii*, and the ixodid ticks *Amblyomma rhinocerotis* and *Dermacentor rhinocerinus*. Several of these parasites are host-specific to these animals and to white rhinoceroses (*Ceratotherium simum*) and will cease to exist if rhinoceroses become extinct. Bontebok (*Damaliscus pygargus dorcas*) are an endangered subspecies of *Damaliscus pygargus* and were found only in the Western Cape Province, South Africa. They share many nematodes with the blesbok (*Damaliscus pygargus phillipsi*) and ticks with other antelopes within their distribution range, but are infected with a lungworm *Protostrongylus capensis* that apparently is host-specific, and with larvae of a *Gedoelstia* sp. that are unlike those of the two species of this nasal bot fly that have been described. Both the lungworm and the fly could thus be as endangered as their host. Grey rhebok, *Pelea capreolus* have a widespread but patchy distribution in South Africa. In the Western Cape Province they are infected with two apparently host-specific nematodes, the one an exceptionally large species of *Haemonchus* and the other an intestinal trichostrongylid, *Paracooperioides peleae*. They are also infested with the larvae of a warble fly of the genus *Strobiloestrus*. Although grey rhebok are not endangered, these parasites could well be if their distribution does not extend beyond the Western Cape Province. Except where the possibility exists of introducing a new disease into a region, it is proposed that in order to preserve their special parasitic fauna, rare wildlife species should not be treated with antiparasiticides prior to translocation.

INTRODUCTION

South Africa is home to many endangered larger wildlife species and considerable care is taken to conserve and boost the populations of hunting dogs (*Lycaon pictus*), cheetahs (*Acinonyx jubatus*), Cape mountain zebras (*Equus zebra zebra*), white and black rhinoceroses (*Ceratotherium simum* and *Diceros bicornis*), and bontebok (*Damaliscus pygargus dorcas*). What is often not realised or is simply ignored is that many of these animals are hosts to equally rare parasites, and that to conserve the one without considering the other can lead to the extinction of unique parasitic fauna.

Other wildlife species, although not endangered, may inhabit a single or a number of geographically isolated habitats, and with the animals their specific parasitic fauna are restricted to these habitats. Major perturbations could lead to the disappearance of hosts within these regions, but more importantly to the extinction of their parasites that may not be capable of adapting to another habitat. One of the most endangered species on the African continent is the black rhinoceros and but for a few countries its numbers are steadily dwindling. These animals are infected with a number of host-specific helminths. They and white rhinoceroses are also infested with the larvae of a stomach bot fly and with the adults of two host-specific ixodid tick species (Penzhorn *et al.* 1994).

Bontebok were rescued from the brink of extinction by the conservation efforts of a group of Cape Province farmers in the 1830's. However, they are still considered to be one of the least common antelope in southern Africa. Although they share most of their nematode fauna with blesbok (*Damaliscus pygargus phillipsi*) and their ticks with other antelopes within their preferred habitat, they are infected with an apparently host-specific lungworm and with the larvae of a *Gedoelstia* sp. that are unlike those of the two species that have been described within this genus of tuberculous nasal bot flies. Grey rhebok (*Pelea capreolus*), although not rare, only occur where the habitat is suitable and consequently their distribution is discontinuous and patchy. Those occurring in the Western Cape Province are infected with two unique helminth species and with the larvae of a warble fly.

MATERIALS

Whenever the opportunity arose helminth and arthropod parasites were collected from the carcasses of black rhinoceroses that had recently died or been killed (Knapp *et al.* 1997). Bontebok and grey rhebok were shot during December 1979 in the Bontebok National Park, Western Cape Province and again at 2-monthly intervals from February 1983 to February 1984 and thereafter every February until 1992 (Horak *et al.* 1982b; 1986; Boomker & Horak 1992; Horak & Boomker 1998). The carcasses of all these animals were processed for the recovery of helminth and arthropod parasites.

RESULTS

Two black rhinoceroses examined in South Africa for helminths were infected with eight nematode species, a cestode, and also with the larvae of a stomach bot fly, *Gyrostigma pavesii* (Table 1). Four animals examined for ectoparasites harboured five ixodid tick species including one of the rhinoceros ticks, *Dermacentor rhinocerinus* (Table 2).

Table 1 Helminths collected from two black rhinoceroses in South Africa

Helminth species	
Nematodes	Cestodes
Kiluluma goodeyi	***Anaplocephala gigantea***
Kiluluma magna	
Kiluluma rhinocerotis	
Diceronema versterae	
Probstmayria vivipara	
Draschia megastoma	
Parabronema roundi	
Oxyuris karamoja	

Bold type = Host specific

Table 2 Arthropods collected from four black rhinoceroses in South Africa

Arthropod species	
Ixodidae	Diptera
Amblyomma hebraeum	***Gyrostigma pavesii***
Dermacentor rhinocerinus	
Haemaphysalis silacea	
Rhipicephalus maculatus	
Rhipicephalus muehlensi	

Bold type = Host specific

Bontebok were infected with seven species of gastro-intestinal nematodes, three species of lungworms, nine species of ixodid ticks, two louse species and the larvae of a tuberculous nasal bot fly belonging to the genus *Gedoelstia* and the larvae of a warble fly (Tables 3 and 4).

Table 3 Nematodes collected from bontebok in the Western Cape Province

Helminth species	
Gastro-intestinal worms	Lungworms
Longistrongylus curvispiculum	*Bronchonema magna*
Longistrongylus namaquensis	*Pneumostongylus cornigerus*
Nematodirus spathiger	***Protostrongylus capensis***
Trichostrongylus axei	
Trichostrongylus falculatus	
Trichostrongylus pietersei	
Trichostrongylus rugatus	

Bold type = Host specific

Table 4 Arthropods collected from bontebok in the Western Cape Province

Arthropod species	
Bot fly larvae	Ixodid ticks
***Gedoelsta* sp.**	*Amblyomma marmoreum*
Strobiloestrus sp.	*Boophilus* sp.
	Haemaphysalis aciculifer
Lice	*Ixodes pilosus* group
Damalinia sp.	*Rhipicephalus evertsi evertsi*
Linognathus sp.	*Rhipicephalus gertrudae*
	Rhipicephalus glabroscutatum
	Rhipicephalus lounsburyi
	Rhipicephalus nitens

Bold type = Host specific

Grey rhebok were infected with ten gastro-intestinal nematode species. A particularly large *Haemonchus* sp. with very long spicules, apparently identical in shape but considerably longer than those of *Haemonchus contortus*, was collected from the abomasum, and the trichostrongylid, *Paracooperioides peleae* from the small intestines (Table 5). In addition to nine ixodid tick species, the antelopes were infested with two louse species and the larvae of two nasal bot flies and a warble fly (Table 6). The larvae of one of the nasal bot flies, which were present in only one animal, were those of the *Gedoelstia* sp. infesting the bontebok. The larvae of the other belonged to *Oestrus ovis,* the common nasal bot fly of sheep. The warble fly larvae were those of a fly of the genus *Strobiloestrus* and were collected from the subcutaneous tissues of the antelopes.

Table 5 Nematodes collected from grey rhebok in the Western Cape Province

Nematode species	
***Haemonchus* sp.**	*Ostertagia hamata*
Longistrongylus curvispiculum	***Paracooperioides peleae***
Longistrongylus namaquensis	*Trichostrongylus falculatus*
Longistrongylus schrenki	*Trichostrongylus pietersei*
Nematodirus spathiger	*Trichostrongylus rugatus*

Bold type = Host specific

Table 6 Arthropods collected from grey rhebok in the Western Cape Province

Arthropod species	
Bot fly larvae	Ixodid ticks
Gedoelsta sp.	*Amblyomma marmoreum*
Oestrus ovis	*Boophilus* sp.
***Strobiloestrus* sp.**	*Haemaphysalis aciculifer*
	Ixodes pilosus group
Lice	*Rhipicephalus evertsi evertsi*
Damalinia pelea	*Rhipicephalus gertrudae*
Linognathus peleus	*Rhipicephalus glabroscutatum*
	Rhipicephalus lounsburyi
	Rhipicephalus nitens

Bold type = Host specific

DISCUSSION

The majority of nematodes and the cestode *Anaplocephala gigantea* collected from the black rhinoceroses are specific to these animals and to white rhinoceroses. The monotypic atractid species *Diceronema versterae* has only recently been described and then only from the former animals (Gibbons *et al.* 1996). *Draschia megastoma* collected from the descending colon of one of the black rhinoceroses was twice the length of the same species encountered in the stomachs of equids, and was not associated with granulomatous lesions as it is in the latter animals. This begs the question, are rhinoceroses the original hosts of this helminth? The cyathostome *Kililuma rhinocerotis* was first described from a black rhinoceros in Ethiopia (Nevue-Lemaire 1924). Its collection from black and white rhinoceroses in southern Africa is the first report of this parasite subsequent to its original description 73 years previously (Knapp *et al.* 1997).

It is most likely that extinction of both the stomach bot fly *G. pavesii* and the ixodid tick *D. rhinocerinus* had already occurred in South Africa in the region where the Kruger National Park is currently situated when white rhinoceroses became extinct in the old province of the Transvaal in 1896 and black rhinoceroses in 1940. These arthropods were in all likelihood reintroduced into the Park with rhinoceroses translocated there from north-eastern KwaZulu-Natal from 1961 onwards (Braack *et al.* 1995). This serves as an example of unintentional conservation of an endangered species with its parasites. Those helminths that are host-specific to rhinoceroses were undoubtedly reintroduced into the Kruger National Park in the same way.

One of the gastro-intestinal nematodes and the lungworm *Bronchonema magna* should be regarded as accidental infections in the bontebok. The large *Haemonchus* sp. collected from only one animal came from grey rhebok, and the lungworm from springbok (*Antidorcas marsupialis*) present in the Bontebok National Park at the time the first group of bontebok were examined. This lungworm, as its name signifies, is exceptionally large and contributed to morbidity and mortality in the bontebok population. Once the springbok, which are not historically indigenous to the region in which the Park is located, were removed *B. magna* disappeared. The lungworm *Protostrongylus capensis* has only been encountered in bontebok and hence may also be considered an endangered species. Ticks on the bontebok were the same species as those on the grey rhebok, while the warble fly larvae, which never developed beyond the second instar, were an accidental infestation resulting from the proximity of the latter animals. *Gedoelstia* sp. larvae collected from the paranasal sinuses of the bontebok differed from those of the two *Gedoelstia* spp. described to date, namely *Gedoelstia cristata* and *Gedoelstia hässleri*, both of which may be encountered in blesbok. If flies are collected this may prove to be a new species.

The exceptionally large species of *Haemonchus* collected from the grey rhebok is apparently host-specific. No springbok (*Antidorcas marsupialis*), examined in the Bontebok National Park at the same time as the first group of grey rhebok, were infected with the adults of this nematode, and only one of 24 bontebok, and then only with 25 worms (Horak *et al.* 1982a; Boomker *et al.* 1983; Boomker & Horak 1992). The intestinal trichostrongylid, *Paracooperioides peleae* is a monotypic species and has only been found in grey rhebok (Boomker *et al.* 1981; Horak *et al.* 1982b; Boomker & Horak 1992). It is not known whether the distribution of either of these helminths extends beyond the Western Cape Province. Hence if, because of agricultural expansion, grey rhebok disappear from this region both these parasites might become extinct.

Several of the grey rhebok had mild to severe eye lesions resulting from accidental infestation with first instar larvae of the *Gedoelstia* sp. that infest bontebok. The *Strobiloestrus* sp. warble fly infesting the rhebok completes a single life cycle annually with larvae in the subcutaneous tissues for 7 or 8 months and adults probably only active during spring (Horak *et al.* 1986). Flies were last collected in 1837 (Zumpt 1965). Although grey rhebok are not endangered this fly may well be because of its suspected limited distribution in the Western Cape Province.

One of the ways to ensure survival of endangered wildlife is to translocate small founding populations to suitable habitats within their original distribution range. I wish to make a plea that when rare species are to be translocated they should not be treated with antiparasiticides prior to transportation. This may assist in the survival of their sometimes equally rare parasites. Many of these parasites are host-specific and thus should pose no threat to other animals within the new environment, while those that are not host-specific are often likely to already be present in or on the resident wildlife.

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30 Parasites

Parasites are found on, and in, all wild animals. Parasite management and control are integral parts of game ranch management. Neglecting this aspect will not only harm the animals, but could also have serious ecological and economic consequences. The aim of this chapter is to make the game rancher more aware of the parasites that may occur on and in wild animals. A brief description of the way in which these parasites can be controlled is also given.

Ecto- and endoparasites

J. BOOMKER & I.G. HORAK

Parasites are organisms that are dependent on a host to a greater or lesser degree. They live on, or in, a host for their entire life or a part of it, without necessarily adversely affecting the host. The change from a free-living to a parasitic lifestyle has resulted in a number of natural adaptations. Complex life cycles that ensure the continued existence of the parasite is but one of these. The whole aim of parasitism is to allow the parasite to complete its life cycle without killing its host in the process. The parasites and their wild animal hosts have developed together, and the association has been refined over time to a near perfect balance.

The parasites of wild animals can be divided into two major groups. Ectoparasites live on the surface of the skin of a host. They are invertebrate animals such as ticks, lice, fleas and certain fly species that visit their hosts only to feed. In contrast, the endoparasites, namely roundworms, tapeworms and flukes, live within the organs of the host and are totally dependent on the host for their continued existence.

1 ECTOPARASITES

Most ectoparasites have jointed legs and are therefore classified in the Phylum Arthropoda. While they occur mainly on their hosts, some are parasitic only in their immature stages of development. An example of the latter is certain flies of which the adults live as non-parasites, while their larvae live in the sinuses, intestines and wounds of their hosts. Two large groups known as the Acarina and the Insecta represent the more important ectoparasites.

1.1 Acarina

The Acarina include the ticks and mites. Of these, the ticks are more visibly a problem because they are larger than the mites.

1.1.1 Ticks

It is generally believed that, with the exception of those animals encountered in zoos, all wild animals are relatively parasite free. However, surveys

have shown that most wild animals found in all regions of South Africa carry varying numbers of ticks. A general rule is that the blue wildebeest and smaller antelope mainly carry ticks in their immature stage, while larger animals such as the kudu, eland, buffalo and giraffe carry large numbers of ticks in both their immature and adult stages.

Blue wildebeest appear to have an inherent resistance to tick infestation and they usually carry exceptionally few ticks. However, the impala is probably one of the antelope most susceptible to ticks. For its size, it carries many more ticks than would be expected. A normal, healthy blue wildebeest usually carries about 800 ticks, a Burchell's zebra about 4000, an impala and a kudu about 5000 each, and an eland and buffalo between 10 000 and 20 000 ticks each. In the months in which tick activity reaches a peak, these figures may increase by thousands. Smaller animals may carry many hundreds of immature ticks.

Ticks have a simple life cycle that can be described briefly as follows. The fully engorged, adult female tick drops from the host and lays her eggs in a protected place. In time, the eggs hatch and the small larvae, sometimes known as pepper ticks, climb onto grass stems to await the arrival of a suitable host. The larvae then attach themselves onto the host and gorge on its blood.

- When the tick is a single-host type, such as the blue tick, the larvae moult into nymphs on the host. They in turn engorge and then moult into adults while still on the host. The adults mate on the host and the female engorges and drops off.
- When the tick is a two-host type, such as the red-legged and the bont-legged ticks, the larvae and nymphs remain on the host, but the engorged nymphs drop from it and moult into adults on the ground. The adult must then attach itself to a second host to be able to complete its life cycle.
- In the case of a three-host tick, such as the brown ear tick and the bont tick, the larvae attach themselves to the first host, engorge, drop off and moult into nymphs on the ground. The nymph must then climb onto the second host, engorge, drop off and moult into an adult on the ground. The adult then climbs onto the third host, engorges and drops off after mating to complete its life cycle.

In all cases, the eggs are laid on the ground. Most tick species have certain preferred attachment sites on the host. These sites and the ticks that attach there by preference are illustrated in Figure 30.1.

Ticks generally show a seasonal pattern of occurrence. Most of the larvae occur during the autumn and winter, most of the nymphs during the winter and spring, and most of the adults during the summer. Exceptions are the winter horse tick and the Karoo paralysis tick that are both active mainly during the late autumn and winter. A single mountain zebra in the Cradock district can carry more than 30 000 winter horse ticks during the winter.

Ticks can harm wild animals in several ways. They can cause anaemia because of their feeding habits. When large numbers are present, especially on young animals, the effect can be extremely detrimental. In KwaZulu-Natal, such a heavy tick load can be an important cause of death in waterbuck calves. Ticks also reduce the physical condition of an animal and its resistance to diseases. Ticks with long mouthparts, such as the bont and bont-legged ticks, cause sores on the skin that may either form abscesses or become infested with maggots, or cause the loss of tail switches, teats and ears. Apart from these direct effects, ticks are also the carriers of diseases such as corridor disease and heartwater.

An old point of contention is whether ticks make the animal sick and then cause it to lose condition, or whether the animal must first become sick before the ticks will have a notable effect on it. Studies conducted on various types of wildlife clearly indicate that a healthy animal can cope better with the effects of ticks than a sick or injured one. For example, the number of blue ticks on healthy blue wildebeest calves increased from 770 to 2070 on a calf that had broken its leg and had become stressed.

Animals that do not normally occur in a region, such as gemsbok in Mpumalanga or the Free State, can be heavily infested with ticks or suffer from tick paralysis or a tick-borne disease when they are newly introduced to the region. They may also never adapt. In this way, ticks contribute to protecting the environment against the establishment of exotic animals.

It is virtually impossible to control ticks efficiently on wildlife as wild animals cannot be rounded up and dipped like domestic ones. However, when both wild and domestic animals are present on a game ranch, the following combined

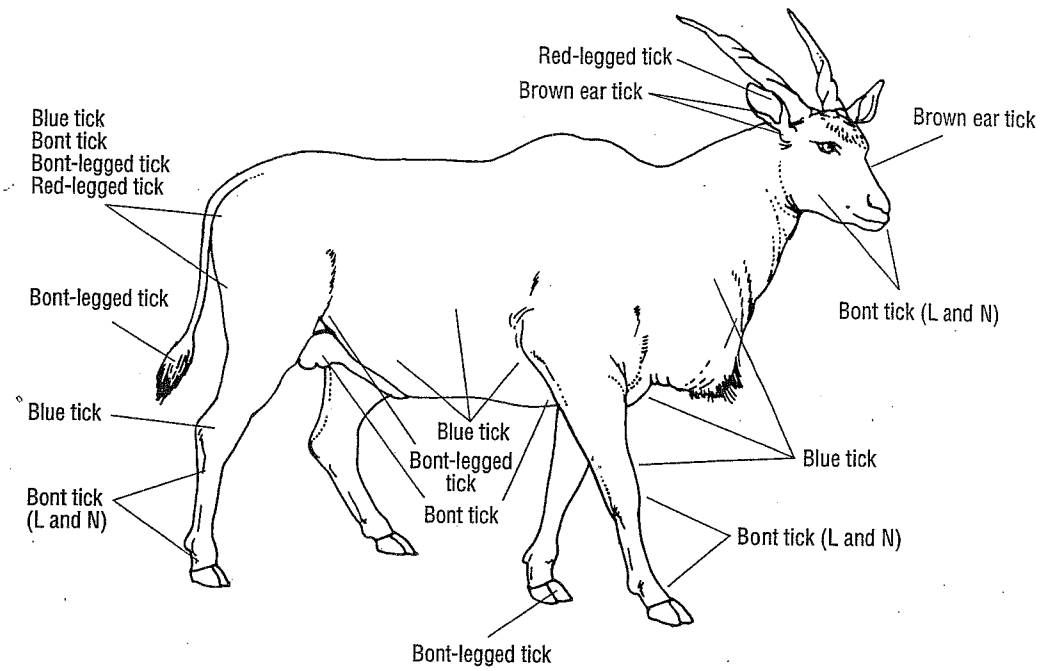

Figure 30.1 The preferred attachment sites for the important types of tick that occur on wildlife.

Note: L = larvae and N = nymphs.

tick control method may be applied with varying degrees of success. During the times when ticks are active, cattle and wild ungulates can be allowed to forage in the same camps so that the cattle can attract as many ticks as possible in a relatively short time. European cattle breeds will most probably attract more ticks than Zebu cattle, as they are more susceptible to tick infestation. When cattle and wildlife are on the same ranch or use the same camps in the autumn and winter, the cattle will become infected with various tick larvae and also with the nymphs of the two- and three-host tick species. However, there will still be large numbers of immature ticks on the wild ungulates because both large and small antelope are suitable hosts for these ticks. When the cattle are allowed to graze with the wild ungulates in the summer when the adult ticks are active, the ticks will select the cattle, especially when most of the antelope on the game ranch are blue wildebeest or small antelope.

The best time to allow cattle to forage with wild ungulates in South Africa is during January, February and March, provided that the veld condition allows it. During this time, the cattle should be dipped at maximum intervals of five days because longer intervals will allow the adults of some ticks enough time to attach, engorge and drop off before the cattle are dipped again. The dip used should have little or no residual effect; otherwise it will prevent the maximum number of ticks from climbing onto the cattle during the intervals between consecutive dips.

There is an old belief that wild ungulates eat aloes naturally because they control tick infestation. Kudu are known to eat aloes. In the Etosha National Park in Namibia, the mopane aloe *Aloe littoralis* is utilized heavily by gemsbok and possibly also by ostriches.

It is essential to treat all wild animals that are relocated against both ecto- and endoparasites in order to decrease the danger of incidentally translocating parasites and diseases to new areas. For example, the bont tick does not occur in Namibia and therefore the authorities there require that any animal moved to Namibia has to be free of ticks for at least 72 hours before entry.

Wild ungulates can generally be dipped or

treated with the same compounds as those used for cattle, provided that the directions for use are followed meticulously. Wild ungulates can also be sprayed with an ordinary hand pump after they have been captured and placed in crates. Spraying should preferably be done when it is hot, and the animals should be allowed to dry off before they are transported. If it is cool or cold, or if the animals are still wet even on a hot day, they should rather not be transported. A wet animal cools down rapidly in a moving vehicle and this could lead to lung infections.

Pour-on dips can also be used on wild ungulates. The Duncan Applicator has been used successfully for certain types of game. The animals are lured to the apparatus by means of a tasty lick. When they are eating from the lick, the neck, head and ears come into contact with a pole down which a pour-on dip runs. This contact is usually sufficient to kill many of the ticks on the animal. In the Waterberg area it is alleged that the Duncan Applicator is one of the keys to successfully keeping gemsbok.

> Duncan Applicators are available through agricultural outlets or directly from e-mail: info@tick.co.za.

The Tick-off Applicator delivers a correctly calibrated dose of flumethrin (Drastic Deadline, Bayer S.A.) to an animal and is claimed to be totally effective. It requires no power source or labour, does not waste the acaricide, and delivers the correct dose based on the weight of the animal when it steps on a waterproof hydrolic pressure plate buried underground. It can carry animals weighing from 10 kg up to elephants. Only the spray nozzles are above the ground. The apparatus can be set up in game trails, crushes and temporary bomas, at licks and near water.

> More details on the Tick-Off Applicator are available from Tick-off at P.O. Box 912-450, Silverton 0127 or tel. 012 804 4461 and e-mail: tickoff@yebo.co.za.

The supplement Browse Plus that is added to drinking water also contains a substance that combats internal and external parasites.

In the Central Province of Zambia, ticks on impala on a game and cattle ranch on which the cattle were treated with the acaricide Drastic Deadline showed a variable response. The ticks most severely affected by control with acaricides were *Amblyomma variegatum*, *Rhipicephalus appendiculatus* and *Rhipicephalus evertsi evertsi*. The tick *Boophilus decoloratus* appeared to be unaffected, possibly because of acquired acaricide resistance. The impala on a game ranch on which no tick control was applied carried a mean load of 4407 ticks per animal, compared with a mean load of 4795 ticks per impala in the southern Kruger National Park of South Africa. By comparison, the impala on a nearby cattle ranch where cattle were dipped at weekly intervals from November to April with the acaricide alphamethrin (Paracide: Pfizer A.H.), and from May to October with the acaricide cypermethrin (Blitzdip: Agricura, Sanvet) carried a mean load of only 134 ticks per animal. All newly introduced animals were treated with the acaricide flumethrin (Drastic Deadline: Bayer). The combination of acaricides used on the cattle was changed every two to three years to prevent ticks from becoming resistant to them.

Before large ungulates such as giraffe, buffalo, eland and kudu are introduced into a game ranching unit or a small nature reserve, it is essential that the implications of the build-up of heavy tick loads be carefully considered, especially if cattle or other domestic animals are to be kept on the same ranch.

1.1.2 Mites

Mites are small organisms that are usually only visible under a microscope. They occur on the skin of the ears, legs, feet, shoulders, head and neck, and around the scrotum or udder of a large variety of wild animals. Mites are similar to ticks in appearance and cause a condition known as mange. The life cycle of mites can be described briefly as follows. The adult female lays one or two eggs per day, either in tunnels excavated in the skin of the animal or on the skin surface. The eggs hatch and, in some cases, the larvae do not feed. They moult within 24 hours to the first nymph stage and the nymph starts to feed. The nymph then moults into the second nymph stage. This nymph stage moults into the adult to continue the life cycle.

Most wild animals are subclinically infested with mites. It is only when the animal is subjected to stress or becomes sick that the subclinical infestation becomes clinical and signs of mange

become apparent. However, usually only individual animals show signs of mange. To diagnose a mite infestation requires a certain degree of technical knowledge, as a skin scraping has to be done and examined under a microscope.

It is difficult to control mites, and it is virtually impossible to do so in large herds of antelope. When the infestation occurs as an individual case, the animal should be captured and dipped twice at an interval of about eight to ten days with one of the remedies containing organophosphates, chlorinated hydrocarbons or carbaryls, which are usually used for ticks on cattle. Some of the synthetic pyrethroids can also be used. The spray-on Tick-off Applicator used for ticks may possibly be adapted to spray large infected herds of antelope that have limited access to water, where the access to the water source can be equipped with the necessary spray equipment. The Scorpion Veterinary Fluid Applicator of Parasite Management Systems also sprays a measured dose of acaricide from above after an animal steps on a pressure plate.

Parasite Management Systems can be contacted at P.O. Box 14402, Lyttelton, Centurion 0140 or tel. 012 664 2567 or e-mail: parasites@mweb.co.za.

1.2 Insecta

The Insecta include the flies, fleas and lice.

1.2.1 Flies

Although there are many species of fly that live as parasites or semi-parasites, only those that are true parasites or that play a role in the decomposition of carcasses will receive attention here. The term "myiasis" refers to the condition that results when the larvae of certain fly species occur in, or on, a living host. Not all the fly genera cause myiasis, but the few that are discussed below belong to the group that do.

Species of the genera *Gedoelstia, Oestrus* and *Kirkioestrus* can almost be regarded as endoparasites because their larvae occur in the sinuses and nasal cavities of especially the Alcelaphinae, a subfamily of antelope that bob or jerk their heads. These include the blesbok, bontebok, blue wildebeest and red hartebeest. The members of the genus *Gedoelstia* have an interesting life cycle because the larvae are laid in the eyes of the host. The larvae first move through the eyeballs, and from there along the blood vessels or the optic nerve to the membranes surrounding the brain, where several hundred of them may be found. From there, the larvae may travel along the blood vessels to the heart and lungs. In the lungs, the larvae penetrate the walls of the alveoli, move to the trachea and then upwards to the nasal cavities and sinuses. Others move directly from the brain membranes along the blood vessels or nerve tracts through the bone platelets to the nasal cavities. The larval stage is completed in the nasal cavity and the larvae are then sneezed out. They pupate in the soil and after some time the adult flies appear.

The live larvae of the nasal botflies of the genera *Oestrus* and *Kirkioestrus* are deposited around the host's nostrils. They move up the nasal passages, moult on the turbinate bones and then move to the sinuses where they mature into third-stage larvae. These larvae then return to the nasal passages, are sneezed out and pupate in the soil. The adult flies emerge after a time.

The adult flies are especially abundant from October to May in the Highveld and in the higher-lying areas of the savannas, or throughout the year in the low-lying warmer regions of South Africa. From November onwards, the number of larvae in the sinuses and nasal cavities of wild animals increases, with the largest numbers usually being found from January to June. The pupae of the flies cannot survive the cold Highveld winters and the flies spend the winter as larvae inside the heads of the wild animals. As soon as it begins to get warmer from August to the beginning of September, the larvae resume their development. They are sneezed out towards the end of August or during September, after which the adult flies again appear.

Neither the larvae nor the adult flies cause serious problems in their natural antelope hosts. However, when the larvae of species of the genus *Gedoelstia* are deposited in the eyes of other hosts such as cattle or sheep, or wild animals that do not normally serve as their hosts, they cause a condition known as oculo-vascular myiasis or "uitpeuloog". This condition is virtually impossible to treat and an animal infected in this way may lose the use of the affected eye. In their natural hosts, the nasal botflies only cause a slight catarrhal nasal discharge or temporary sore eyes, especially in young animals.

It is impossible to control the adult flies. These flies do not feed, and survive exclusively on fat

reserves that they have built up as larvae. They can therefore not be attracted to bait treated with an insecticide. The larvae can be controlled by insecticides administered to the hosts in January, or particularly in June or July. However, the whole herd cannot be treated, because the animals have to be caught to do so, and it is of doubtful practical value to treat individual animals unless they are to be translocated.

The larvae of the flies that occur in the stomachs and intestines of horses and zebras are species of the genus *Gasterophilus,* commonly known as horse botflies. The eggs are laid on the hair around the lips or on the lower section of the legs and must first be licked before they will hatch. The larvae are ingested and migrate through the tongue and mucous membranes to the spaces between the molars. There they moult into the second stage, are swallowed and develop further in the stomach or intestines of the zebra or horse. When mature, the larvae detach themselves from the wall of the stomach or the intestines and are excreted with the faeces. They pupate in the soil. The flies only complete one life cycle or generation per year and the larvae can be treated at the same time of the year as the nasal botflies.

Lumps are sometimes seen under the skin of especially the klipspringer, grey rhebok, steenbok and common duiker when the animals are slaughtered. These lumps contain the larvae of flies belonging to the genus *Strobiloestrus.* The larvae occur under the skin from spring to midwinter and the mature larvae crawl out to pupate in the soil. The following generation of flies hatches in the spring. Only one life cycle is completed per year. Some cattle dips that contain organophosphates will kill the larvae.

Cattle ranchers in the savannas of Limpopo (Northern Province) and Mpumalanga are familiar with screw-worm, the larvae of the fly *Chrysomya bezziana.* This fly lays its eggs in and around a fresh wound. The larvae that hatch crawl into the wound and enlarge it. Larvae or maggots of this fly have been found on some of the larger antelope. When this occurs, the infested animals must be treated individually.

The next group of flies are those that live mainly on carcasses and are involved in the decomposition of carcasses in the veld. They are the green blowfly *Lucilia cuprina,* the copper-tailed blowfly *Chrysomya chloropyga,* the banded blowfly *Chrysomya albiceps,* and the bluebottle blowfly *Chrysomya marginalis.*

The green blowfly is responsible for the blowfly infestation of sheep that gives ranchers problems in certain parts of South Africa. The banded green blowfly and the copper-tailed blowfly infest sheep to a lesser degree. The bluebottle blowfly does not infest live sheep at all and only breeds on carcasses. Therefore, when only sheep and wild ungulates are kept on the same ranch, it is essential that all carcasses be destroyed to prevent blowfly infestation or limit it to a minimum. Adult blowflies can also play a role in spreading anthrax to browsing antelope by regurgitating blood containing spores onto the leaves of woody plants around infected carcasses on which the flies have fed.

Louse-flies or keds occur on nearly all wild ungulates. Some of the winged louse-flies, such as the genus *Hippobosca,* occur on antelope with both short and long hair, but the wingless genus *Lipoptena* occurs mainly on animals with long hair. Both types of fly cause irritation in their hosts because they have well-developed, piercing and sucking mouthparts and live on blood. As with the majority of ectoparasite infestations, it is virtually impossible to treat herds infested with louse-flies. Individual animals that are severely infested should be caught and treated with one of the approved insecticides.

1.2.2 Midges, mosquitoes, horseflies and stable flies

During certain times of the year, midges, mosquitoes, horseflies and stable flies are abundant. This usually happens after good rains when there are stagnant pools of water in the veld and on rocky outcrops. These flies all cause severe irritation when they bite and the wild animals are unable to feed because they are too busy trying to rid themselves of the flies. There are no specific control measures for these flies and the best method is to drain or close the pools. However, this is not always practically possible or even desirable.

1.2.3 Lice

Lice are relatively small insects without wings. They live permanently on their hosts and cannot survive for more than a few days away from them. They only occur on specific hosts and often only on highly specific sites on the host. They are therefore highly specialized and host-specific. Three main groups of lice can be distinguished: the blue or sucking lice of the genus *Linognathus,*

the red or biting lice of the genus *Damalinia,* and the porcine lice of the genus *Haematopinus.*

The life cycle of lice may be described briefly as follows. The eggs are known as nits and are glued to the hair. After a time, the first nymph stage hatches. This nymph resembles the adult, but it cannot reproduce because the reproductive organs are not yet developed. The nymph feeds on the host and moults several times. After the last moult, it becomes a reproductive adult. Lice are spread by close contact between animals, especially between the mother and her offspring.

Blue lice suck blood and have a pointed head. They can be easily distinguished from red lice, which have a round head and live on skin flakes and hair. Both types of louse occur on a variety of wild animals and are usually present in large numbers on some animals during the winter or in the early spring. Lice infestations are not a problem in herds of antelope, but individual animals may have less resistance to such infestations owing to, for example, the stress of capture, diseases, worn teeth or broken limbs. Infected animals appear out of sorts, do not eat properly and tend to stay away from the herd. The only control measure is to capture the infected animals and to dip them individually or to spray them with insecticides.

Porcine lice have the same life cycle as the blue and the red lice. However, they occur mainly on pigs, including the domestic pig, warthog and bushpig. These lice are large and an adult female can be from 8 to 10 mm long. The eggs are usually attached to the long, thick mane hair of a warthog or bushpig, or on hair elsewhere on the body in the case of domestic pigs that no longer have these manes.

1.2.4 Fleas

Fleas are small, wingless insects with mouthparts that have become adapted for sucking. They live on the blood of the host and are characteristically laterally flattened. Some species are recognizable by differences in the cheek combs and the combs behind the head. Two main groups of flea are distinguished: the jumping fleas and the sticktight fleas. The former are recognized by the well-developed hind legs and the fact that they are continually active on the host. The legs of the second group are not as well developed and they tend to burrow into the skin of the host so that only the posterior portion of the body is visible.

The life cycle of a flea is as follows. The female fleas lay their eggs on the host. The eggs drop off and hatch on the ground. The larvae feed on organic matter, moult a few times and then pupate in a cocoon spun during the last larval stage. A stimulus, usually in the form of vibrations and carbon dioxide gas in the breath of animals, including humans, is necessary for the adult flea to emerge from the pupa. Fleas do not become active until stimulated. This explains why humans and other animals are often covered with masses of fleas after entering a building or a cave that has been unoccupied for a long time.

The jumping fleas tend to occur on all predators, rodents, hares and pigs. The sticktight fleas more often occur on poultry, wild birds and especially warthogs. Flea numbers usually increase during the spring and remain high until autumn. Like lice, fleas usually cause problems on individual animals rather than in a herd, and the same control measures as for lice can be applied.

2 ENDOPARASITES

There are four large groups of internal or endoparasites that are of varying importance to wild animals. They are the flukes or Trematoda, the tapeworms or Cestoda, the roundworms or Nematoda, and the tongueworms or Pentastomida. Figure 30.2 indicates where these internal parasites generally occur in wild animals.

2.1 Flukes

The life cycle of flukes may be described briefly as follows. The eggs are excreted in the dung of the host and must drop into water before they can hatch. A miracidium hatches from the egg and must enter a freshwater snail within a short time or else it will die. In the snail, the miracidium transforms into a sporocyst that, in turn, gives rise to daughter sporocysts or rediae. Cercariae form in the sporocyst or daughter sporocysts or rediae, and leave the snail when they mature. In the case of the liver and conical flukes, the cercariae attach to grass or other vegetation in shallow water and form metacercariae. The metacercariae have to be consumed by the host animal. In the case of bilharzia, the cercariae penetrate the skin to enter the host. The schistosomula or cercariae that have recently entered the host enter the bloodstream and are transported by way of the liver to the fine blood vessels of the mesenterium where they mature into adults. Most wild ungulates in the Lowveld regions of South Africa

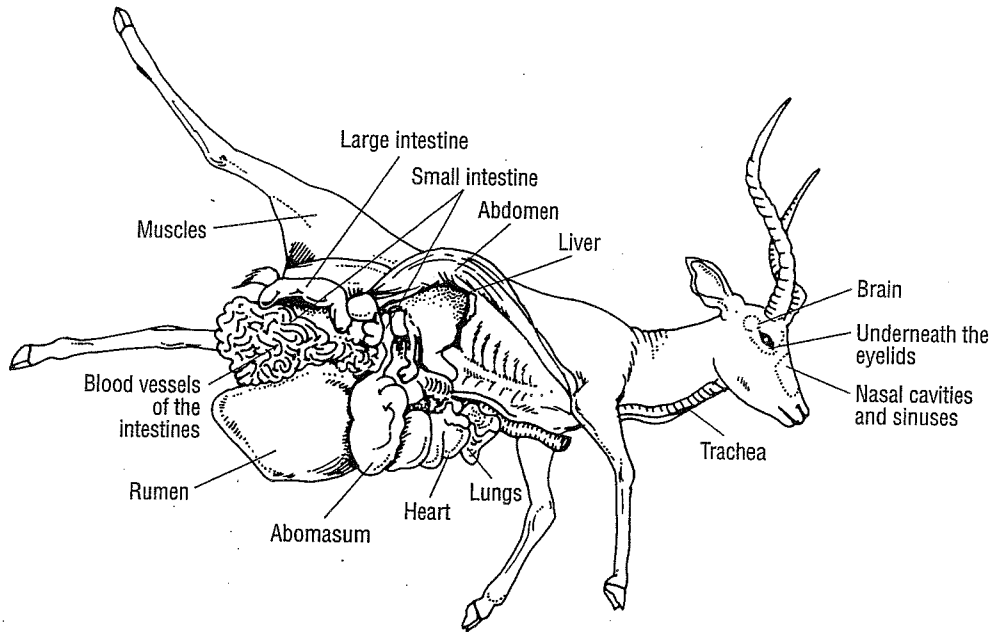

Figure 30.2 Body parts of wild animals where internal parasites generally occur.

are infected with bilharzia, but clinical cases are seldom seen.

The conical fluke is the most common fluke that occurs in wild ruminants. The light red, pear-shaped adult flukes are found in clusters in the rumen and cause little damage. In contrast, the immature flukes occur in the small intestine, and when present in large numbers, they may cause severe diarrhoea in the host.

Liver flukes occasionally occur in antelope but they are abundant in the hippopotamus. These worms live in the bile ducts of the liver and cause them to thicken. In addition, the adult flukes suck blood and cause anaemia. Infected animal livers are aesthetically unacceptable and are not suitable for human consumption.

It is difficult to treat wild animals for flukes, but the general principles of worm treatment that will be discussed later in this chapter may be of some help.

2.2 Tapeworms

Tapeworms are regularly found in wild animals. Two distinct developmental stages occur: adult worms are found in the liver or intestines, and the immature stages – bladder worms or measles and hydatid cysts – are found in various organs or the muscles.

The life cycle of the family Anoplocephalidae, which occurs in the liver and intestines of antelope in the adult stage, is as follows. The eggs are excreted with the dung of the animal and drop to the ground. They are then eaten by one of the non-parasitic soil-dwelling mites. They hatch in the mite and develop into the infective stage. The infected mite is now consumed with grass by an antelope, and the infective stage is released. In the case of tapeworms that live in the intestine, further development and growth occur there. The infective stage of the liver tapeworm penetrates through the intestinal wall and moves along the blood vessels to the liver, where it develops further in the bile ducts. Tapeworms in the liver can grow to about 100 mm long and in the intestines up to 2 m. They do not cause much damage unless they occur in large numbers. Young animals are more susceptible to infection than old animals. This is because an animal builds up a resistance to the worms as it ages.

Measles are the immature, infective stage of tapeworms of the family Taeniidae. They are

found as adults in the intestines of humans and predators. The eggs are excreted with the faeces and land on the grass. They are ingested by an antelope and the eggs hatch. The larvae or oncospheres burrow through the intestinal wall and attach to the mesentary in the connective tissue between the muscles, where they develop into measles. A measle is really the head of a tapeworm within a cyst that contains a watery fluid. It must now be eaten by a human or predator so that it can develop into an adult tapeworm in the intestine of the host.

Measles do not cause much damage in an animal, depending on where they occur. However, measles are the only source of infection for predators. Humans can contract measles accidentally from an antelope by eating uncooked meat, but the tapeworm will not develop in man. However, the measles found in wild pigs can be one of the species that may also occur in humans as an adult tapeworm. A carcass with measles is aesthetically unacceptable and not fit for human consumption, and should be destroyed.

Hydatid cysts are the immature stage of tapeworms of the genus *Echinococcus*. It is a minute tapeworm found in predators. The hydatid cysts occur especially in zebras and warthogs, but are not limited to them. They can also develop particularly in the liver of humans, and in the lungs and heart. The infection consists of a number of well-encapsulated cysts filled with a clear fluid and a large number of grains that resemble sand. These grains are the heads of the future tapeworms. Once ingested by a carnivore, their life cycle is the same as that of other tapeworms.

The hydatid cysts cause pressure on the tissue of the organ in which they occur, but because they become progressively bigger, the symptoms are not obvious initially. By the time symptoms are visible, it is usually too late for treatment. In humans, it is possible to remove the cysts surgically, provided that they are not too large or occur in a place too difficult to reach. There is, however, no effective practical treatment for infected wild animals.

The only way of controlling species of the genus *Echinococcus* and other tapeworms is not to feed any uncooked offal to dogs, and to deworm dogs regularly. Control is only possible when there are no predators such as lions, jackals or spotted hyaenas on the ranch, because the latter may be carriers of various species of tapeworm and cannot be treated effectively. The absence of jackals on a game ranch is unlikely.

2.3 Roundworms

Of all the parasites that occur in wild animals, roundworms occur in the greatest numbers. They have also been studied most. They occur particularly in the stomach and intestinal canal, but also in the lungs, heart, liver and other organs. Most are small, light brown, red or white worms about 4 to 12 mm long. Some, such as the whipworms and the nodular worms of the genus *Oesophagostomum*, are clearly visible with the naked eye. Large ascarid roundworms, which can be up to 200 mm long, sometimes occur in warthogs and zebras.

The life cycle of some of the roundworms is relatively simple. Eggs are excreted with the faeces of the animal, a larva develops and hatches. It moults twice to reach the infective stage. When there is sufficient moisture in the veld, the infective larvae climb onto plants. Animals eat the plants and in this way ingest the larvae. The larvae develop into adult worms in the animal's abomasum, small or large intestine.

Some roundworms use an intermediate host. In such cases, the eggs or larvae of the roundworms are ingested by the intermediate host, usually an insect, and develop into the infective stage. The intermediate host must now be eaten by the final host to complete the roundworm's life cycle. Examples are species of the genus *Toxocara* that are carried by dung beetles or cockroaches, and species of the genus *Pneumostrongylus* or lungworms of impalas that are carried by slugs. The larvae of the hookworm genus *Ancylostoma* in carnivores and the genera *Bunostomum* and *Gaigeria* in antelopes burrow through the skin of the host and are then transported to the lungs along the bloodstream. In the lungs they burrow through the lung alveoli, are coughed up and swallowed, and eventually reach the intestines where they develop into adults. The white bankrupt worm genus *Strongyloides* occurs in many wild animals. It has an interesting life cycle because it can be both free-living and parasitic. In the parasitic lifestyle, only female worms occur, and reproduction takes place by means of parthenogenesis. These worms usually penetrate the host through the skin, but can also be transmitted to young animals in the milk of the mother.

Under optimal conditions of 25 mm rain per month, and with a minimum ambient temperature of 17°C, the larvae of most roundworms can live outside the host for many months. Some are more susceptible to desiccation than others, but

they can all survive for a few months in the cold. The eggs of most of the worms are well protected against unfavourable weather conditions. The eggs of the large roundworms of pigs and zebras can survive outside a host for up to five years, and those of whipworms for more than a year.

An interesting aspect of the nematodes is their distribution and host preferences. Some worms occur in the more arid parts of South Africa, while others prefer the moister regions. Still others have no specific preferences and are found throughout the country. Roundworms that utilize an intermediate host are limited to those regions where that particular host occurs.

During recent intensive parasite surveys in which hundreds of antelope from various parts of South Africa were examined, clear differences were found in their worm loads. For example, kudu in the Kruger National Park had a mean worm load of 2251 worms per animal, while those in the more arid and hotter Succulent Thicket in the Eastern Cape had only 289 worms per animal. Kudu in the Etosha National Park in Namibia had 399 worms per animal. Climate appears to be the greatest limiting factor acting on the worm loads of wild antelope.

The host preferences of the worms permit them to be divided into four groups. These are the host-specific group that is limited to a specific type of animal; the definite parasites that occur in large numbers in most individuals in a herd; the occasional parasites that occur in less than half of the individuals in a herd; and the accidental parasites that occur only in individual animals for a limited time. Some of the worms are limited to certain closely related animals. For example, the species *Haemonchus vegliai* only occurs in browsers, while various species of the genus *Longistrongylus* are abundant in grazers and occur in browsers as an exception only. The species *Trichostrongylus deflexus* has a wide range of hosts. It occurs in browsers, grazers and even some hares.

There is also a significant difference in the worm burdens of grazing and browsing wildlife. Browsers usually carry about 8000 worms per animal, while grazers usually carry a mean of 20 000 worms. This difference is caused by the feeding habits of the animals. Grass has a lower nutritional value than leaves, fruits and seeds, and infective larvae occur mainly on grass. In contrast with browsers, grazers have to eat more forage and are infected in this way with a greater number of larvae. In addition, worms climb onto grasses and not onto shrubs and trees. Worm loads remain remarkably constant in healthy animals, but can increase considerably under conditions of stress, such as drought, disease or serious injury. For example, worm loads in impala can increase from 20 000 worms per animal under normal conditions to 60 000 worms per animal during a drought.

Although a load of 20 000 worms, or even one of 8000 or 5000 worms may sound excessive, it is not a heavy load in helminthological terms. Whether the worms cause damage to their host depends largely on the composition of the worm population and the ratios in which the worms occur. Wireworms of the genus *Haemonchus* can cause serious anaemia when 1500 to 2000 occur in the abomasum of an antelope. In contrast, 50 000 to 100 000 bankrupt worms of the genus *Trichostrongylus* must be present in the abomasum or small intestine before the animal develops definite symptoms of infection. Under natural conditions severe infestations do not normally occur. They do so during droughts when the animals tend to congregate in one place, or in zoos or on irrigated pastures when large numbers of worms can build up quickly. Where wild animals are concentrated, a great deal of dung is present. The dung also contains many worm eggs. When pastures are irrigated or when dung accumulates around waterholes, there is sufficient moisture to ensure the hatching and survival of the larvae. Within a short time, there will be an abundant source of infective larvae that can infect the animals.

Roundworms occur seasonally. Adult wireworms occur especially during the summer, while their immature stages occur mainly during the autumn and winter. Adult bankrupt worms occur more often during the winter because the lower temperatures favour their infective stages. However, the general tendency is that adult worms are found in animals during summer, while their immature stages are usually present in their host animals during the winter so that they can escape the adverse climatic conditions.

2.4 Tongueworms

Tongueworms are not worms in the true sense but they are parasites that make use of two hosts. The final host is a mammal predator or a snake, and the intermediate host is usually an antelope or a small rodent. The adult parasites live in the nasal cavities or sinuses of such predators and in

the lungs of the snakes. The eggs are sneezed out and are then eaten by an antelope or a rodent. The larvae hatch in the antelope or rodent and change into nymphs that occur especially in the lungs, heart and liver. The nymphs are white, have a maggot-like appearance and move around the organs. They must be eaten by a predator before they can become adult worms and complete their life cycle. For some reason or another, the nymphs do not cause much damage to the intermediate host animals, although they make holes and tunnels up to 3 mm in diameter in the organs, especially the liver. There is as yet no way to diagnose their presence clinically. Invermectin at the recommended dose is fully effective.

2.5 Control of worms

It is difficult to control mature and immature flukes and tapeworms in any wild animal. Usually only individual cases can be treated. With the exception of the roundworms that occur in predators, and the immature stages of some of the roundworms that are found in herbivores, roundworms are relatively easy to control. A suitable anthelmintic can be mixed into lick blocks or added to a lick. Ready-mixed lick blocks that contain fenbendazole and are registered for use in wildlife are commercially available. These blocks or licks should be placed out at several locations on the ranch. The supplement Browse Plus, which is added to drinking water, contains substances that can combat internal parasites. Safari Feeds will also mix anthelmintics into their supplementary licks.

The best time to provide these licks is during the winter because the worms, and especially the roundworms, spend the winter in their hosts. The licks are best introduced in July. The host animals also tend to accept the licks better in the winter because the veld is then in poor condition. The following hints may be useful when placing out anthelmintic licks:

- To get the animals to accept the lick, blocks of salt or licks consisting of coarse salt should be offered first. As soon as the animals have accepted the salt licks, they can be replaced gradually by licks that contain anthelmintics.
- The best results are obtained by placing out several licks over the whole ranch. Licks should preferably be placed in the ranges used by the different herds that occur on the ranch. When aggressive animals such as eland are present, sufficient licks should be provided so that each animal has its own lick and there are still enough licks left for the other animals present. Licks for giraffe can be provided in containers secured to trees at feeding height.
- The licks should be inspected regularly to determine which animals are utilizing them. In this way, it can be determined whether additional licks are required and whether the shy animals are also utilizing them. The inspections will also indicate the results obtained for various animals.
- Animals such as warthog and Burchell's zebra tend to take large bites out of lick blocks and licks. In doing so, they also tend to overturn or break the licks. When zebras are present on a game ranch, the licks should therefore be anchored firmly to the ground or placed in metal frames above ground level.
- To control worms effectively it is necessary for the animals to have free access to licks for two to four weeks. This will ensure that even the shy animals will take in sufficient doses of the anthelmintic.

When wild animals are fed artificially, the anthelmintic may be mixed into their food. Food pellets that contain an anthelmintic are commercially available. The use of injections or oral dosing should be limited to animals that have been captured for translocation or sale. Animals should not be captured routinely for injections or oral dosing only, as it exposes them to the stress of capture and handling. However, all wild ungulates that are taken to or from a specific ranch have to be treated against worms after capture. This can easily be done by injecting them intramuscularly or subcutaneously with one of the injectable anthelmintics. This practice will decrease the chances of bringing in new parasites and prevent large parasite loads from building up in the host animals during the stress of the adaptation period.

In conclusion, a word of warning that anthelmintics should always be used judiciously. With a few exceptions, the drugs registered for domestic animals are not registered for use on wildlife. The detrimental effects of these drugs in wildlife have yet to be studied in depth. When an anthelmintic is administered to a pregnant wild animal, the young may be born with deformities, or the mother may show signs of poisoning. Therefore, the prescribed doses have to be fol-

lowed strictly. With oral administration, it is also important that the body weight of the animal be determined as accurately as possible for the correct dose.

3 PRACTICAL PARASITE CONTROL

The nature of game ranching makes it almost impossible to apply effective parasite control easily, except as indicated above for ticks and worms generally. However, as most of the other wildlife parasites are seldom a problem, specific control on a game herd basis is usually unnecessary.

With a few exceptions, all the tick species that occur on wild animals also occur on domestic ones. Some of the tick species are important vectors of various well-known diseases that may be fatal for domestic animals. These include redwater and anaplasmosis in cattle, and heartwater in cattle, sheep and goats. Whether wild animals are also reservoirs of these diseases is not known. However, what has been established is that several antelope species are temporary carriers of heartwater, and that eland, springbok, blesbok and bontebok can become infected and die from this disease. A disease such as redwater does not occur normally in wild herbivores, but these animals may serve as hosts for the blue tick that can carry redwater to young domestic cattle for at least two generations without the female ticks being reinfected in the interval. This makes the control of redwater difficult because wild animals are so difficult to dip. The same apparently applies to anaplasmosis, of which the giraffe and buffalo are possible carriers. Buffalo disease or corridor disease is carried exclusively by buffalo. When cattle are infected by brown ear-ticks that have fed on infected buffalo as larvae or nymphs, the cattle are infected with corridor disease, with fatal results. For this reason, game ranches have to be registered with the authorities to keep buffalo. Special precautions should also be taken with buffalo and blue wildebeest, which could transmit corridor disease and snotsiekte to cattle. In nature reserves where domestic animals do not usually occur, or under extensive ranching conditions, the control of worms is unnecessary except under conditions of stress.

In cases where irrigated pastures are planted and grazed by domestic and wild grazers especially, the wildlife will host the worms of livestock more often than the reverse. This means that wild herbivores can act as reservoir hosts for the worms of domestic animals. Consequently, it may be necessary either to deworm the wildlife or to deworm the cattle more regularly than usual, or both. The question of resistance to anthelmintics is also important, but this should rather be discussed with a specialist.

An interesting remedy for internal parasites which has not been scientifically tested, comes from the late Mr H. Otto of Voëlklip in the Western Cape. On his former farm in Zimbabwe, the kudu, eland and sable antelope were especially fond of tobacco. Irrigated lands that were planted with tobacco for two years and thereafter with Rhodes grass for four years grew especially tall and dense stands of excellent grass. These pastures attracted sable antelope in particular. However, the concentration of wildlife and the moist conditions of irrigation led to the development of heavy loads of internal parasites. Waste leaves and the stems of tobacco were placed in containers at salt licks. This was done extensively and killed many internal parasites. The dung with its heavy concentration of worm eggs was raked up and burned.

It is equally important that overpopulation of wild and domestic animals be avoided, because it creates conditions favourable to the acquisition of worms. With the deterioration of the veld, overutilization also places the animals under stress and abnormally heavy worm loads develop. Similarly, wild animals that do not naturally belong in a certain habitat should not be introduced to it. Such animals are usually not adapted to survive in the new area. They are easily infected with worms and normally carry heavy worm loads. These large worm burdens serve as an excellent source of infection for other animals during the time that the worms survive. The two most important control measures for internal parasites are therefore *avoidance of cross-contamination* and *prevention of overpopulation.* On game ranches that are managed with this in mind, internal parasites will have no significant effect on the animals present.

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Biological control of ticks

J.G. DU TOIT

Red-billed oxpeckers *Buphagus erythrorhynchus* and yellow-billed oxpeckers *Buphagus africanus* are limited to the savanna areas of Africa. The distribution of these birds is limited mainly by the occurrence of large mammals that carry the main food source of ticks for these birds. The rhinoceroses are two of the associated hosts of these birds that have developed a symbiotic relationship in nature, especially with the black rhinoceros. Black rhinoceroses are solitary animals that rest in dense bush during the heat of the day. When the birds are disturbed, they fly away with a characteristic shrieking sound that immediately warns the rhinoceros. Although the black rhinoc-

1

Vectors: Ticks

R A I NORVAL† AND I G HORAK

Introduction

Ticks are of great economic importance as vectors of several diseases of domestic livestock and of commercially farmed wildlife in sub-Saharan Africa. Globally, 690 species and subspecies of ixodid ticks are recognized, and slightly more than 200 of these are present in the Afrotropical region.[27] In addition, 37 of the 179 species or subspecies of argasid ticks occur here.[27]

Only a small number of ticks are major vectors of diseases or causes of toxicoses in this region. These are *Amblyomma hebraeum, Amblyomma variegatum, Boophilus decoloratus, Boophilus microplus, Hyalomma dromedarii, Hyalomma truncatum, Ixodes rubicundus, Rhipicephalus appendiculatus, Rhipicephalus evertsi evertsi, Rhipicephalus zambeziensis* and argasid ticks of the *Ornithodoros moubata/porcinus* complex. However, several other species also serve as vectors, but to a lesser degree or in a more geographically localized context.

It is customary to consider domestic animals as the preferred hosts of those tick species that transmit diseases to them. However, the only ticks that nearly exclusively parasitize these animals are the introduced Asiatic blue tick, *Boophilus microplus,* of cattle; the shiny *Hyalomma, Hyalomma detritum,* of North Africa; and the cosmopolitan kennel tick, *Rhipicephalus sanguineus,* of domestic dogs. The vast majority of indigenous ticks in the sub-Saharan region are parasites of wildlife, and indeed a large number of species would be unable to complete their life cycles if there were no wild hosts available. Many of the tick species deemed to be parasites of domestic cattle, sheep, goats, horses and pigs are frequently more abundant or prevalent on equivalently sized or even smaller wild animals. Thus giraffe (*Giraffa camelopardalis*), African buffalo (*Syncerus caffer*) and eland (*Taurotragus oryx*) are excellent hosts of all stages of development of *A. hebraeum* and *A. variegatum*; impala (*Aepyceros melampus*), eland, bushbuck (*Tragelaphus scriptus*), greater kudu (*Tragelaphus strepsiceros*) and sable antelope (*Hippotragus niger*) of *B. decoloratus*; giraffe, African buffalo and eland of adult *Hyalomma marginatum rufipes* and *H. truncatum*; caracal (*Caracal caracal*) and mountain reedbuck (*Redunca fulvorufula*) of adult *I. rubicundus*; African buffalo, eland, male nyala (*Tragelaphus angasii*), greater kudu and sable antelope of all stages of development of *R. appendiculatus*; zebra (*Equus* spp.) and eland of all developmental stages of *R. evertsi evertsi*; zebra, black rhinoceros (*Diceros bicornis*), eland and gemsbok (*Oryx gazella*) of *Rhipicephalus pulchellus*; large carnivores, zebra and wild suids of adult *Rhipicephalus simus*; impala and greater kudu of all stages of *R. zambeziensis*; and warthog (*Phacochoerus africanus*) of ticks of the *O. moubata/porcinus* complex. Gerbilline rodents are hosts of the immature stages of *H. truncatum* and murid rodents the preferred hosts of those of *R. simus*. Scrub hare (*Lepus saxatilis*) are preferred hosts of all parasitic stages of *Rhipicephalus warburtoni*, as well as the immature stages of *H. marginatum rufipes* and *H. truncatum*. They are also good hosts of the immature stages of *A. hebraeum, R. appendiculatus, R. evertsi evertsi, R. pulchellus* and *R. zambeziensis*. Rock elephant shrews (*Elephantulus myurus*) are excellent hosts of the immature stages of *I. rubicundus* and of *R. warburtoni*. Helmeted guinea fowl (*Numida meleagris*) and leopard tortoise (*Geochelone pardalis*) are good hosts of the immature stages of *A. hebraeum*, and ground-frequenting birds of those of *H. marginatum rufipes*.

The diseases of major economic importance affecting cattle and transmitted by these and other ticks are heartwater, babesiosis, anaplasmosis, the theilerioses caused by various strains of *Theileria parva*, and tropical theileriosis. Of lesser importance in cattle are the generally non-pathogenic mild theilerioses, spirochaetosis, benign anaplasmosis, benign babesiosis and bovine ehrlichiosis. Sheep and goats are susceptible to the organisms causing heartwater, anaplasmosis, theileriosis, spirochaetosis, and to the virus

† Deceased, 8 April 1994

causing Nairobi sheep disease. Horses, mules and donkeys are affected by equine piroplasmosis as well as by spirochaetosis, and pigs by porcine babesiosis and African swine fever. In addition to transmitting infectious diseases to livestock, some tick species are also associated with toxicoses such as sweating sickness, paralysis (e.g. Karoo paralysis, spring lamb paralysis) and brown ear-tick toxicosis, or with bovine dermatophilosis. Several wild ruminant species are susceptible to *Ehrlichia ruminantium,* the causal organism of heartwater or cowdriosis, or can act as carriers of this organism (see Chapter 40: Heartwater). Some are also susceptible to certain *Theileria* spp., while zebra are susceptible to *Babesia caballi* and *Theileria equi,* the cause of equine piroplasmosis, and wild suids to *Babesia trautmanni,* the cause of porcine babesiosis, and to infection with the virus of African swine fever.

Ixodid ticks are also important vectors of several organisms causing disease in humans in sub-Saharan Africa. These are *Rickettsia conori,* the cause of tick-bite fever or tick typhus; *Coxiella burnetii,* the cause of Q-fever; and the virus causing Crimean-Congo haemorrhagic fever. In addition, argasid ticks of the *Ornithodoros moubata* complex can transmit *Borrelia duttoni,* the cause of African relapsing fever, to humans.

The known important tick vectors of the livestock diseases and causes of toxicoses are listed in **Table 1.1**. Thereafter descriptions of the identification, hosts, life cycle, seasonal occurrence, distribution and disease transmission of each tick vector species, and the control of some, are given. A section on the control of ticks and tick-borne diseases follows: this covers the concept of endemic stability, the history of tick and tick-borne disease control in southern Africa, recent research relevant to tick control, biological control, tick and tick-borne disease models, future control methods, integrated control, and the control of ticks on wildlife.

Tick vectors

Most ticks can only be identified to species level under a stereoscopic microscope and a conventional light microscope may even be necessary for the identification of the immature stages of some. There are, however, a number of elementary observations that can be made to assist with the recognition of ticks to generic level. These are geographical region or actual locality in or at which the ticks were collected, host and site of attachment, season, and any morphological features of the ticks that are discernible with the naked eye.

Free-living adult ticks can also be characterized as 'hunters' or 'waiters'. 'Hunters' actively seek hosts by scuttling along the ground when stimulated by a host's presence or by pheromones produced by ticks already attached to a host. Ticks that follow this strategy are the *Amblyomma* and *Hyalomma* spp., and *R. warburtoni.* These ticks will very rarely be collected from the vegetation. In contrast, the 'waiters' quest for hosts from the vegetation and include *Haemaphysalis* and *Ixodes* spp., and a large number of *Rhipicephalus* spp.

Amblyomma hebraeum

South African bont tick, Suid-Afrikaanse bontbosluis (Afrik.)

Identification Adult *A. hebraeum* are large, conspicuous ticks with long mouthparts, brightly coloured patterns on the scutum of both males and females, flat eyes, and brown and white banded legs. The males have yellow-coloured festoons (**Figures 1.1 and 1.2**).

Hosts The preferred hosts of the adults are the larger domestic and wild ungulates,[104, 183, 273] to which they attach in clusters in the groin and axillae as well as on the dewlap, belly, perineum and peri-anal region.[8, 216] The larvae and nymphs feed on a wide variety of large and small mammals, birds and tortoises.[54, 110, 175, 216, 273, 293] They are very rarely found on murid rodents, even in habitats where large numbers of *A. hebraeum* larvae are present.[19, 113] On domestic livestock nymphs attach most commonly to the feet, and larvae to the face, the dewlap, neck and legs.[8] On the larger ground-frequenting birds the nymphs and larvae attach mainly on the head and neck.[110]

Life cycle *Amblyomma hebraeum* has a three-host life cycle, with larvae, nymphs and adults feeding on separate hosts. On completion of feeding, engorged ticks leave the host and seek sheltered microhabitats in which to moult or to lay eggs. The developmental periods off the host can be long. In the Eastern Cape Province of South Africa, larvae may take five months to hatch from eggs laid by female ticks that detached from hosts during March or April,[230] and nymphs may remain inactive for two to three months after moulting.[168] However, the life cycle usually lasts one year under field conditions, but may for the above reasons extend for longer. The pattern of seasonal occurrence is dependent on climate and varies considerably throughout the distribution range of the tick. In general, adults tend to be most numerous during the warm, wet summer months, larvae during the colder, dry, late autumn and winter months, and nymphs during the winter and spring months. However, varying numbers of all stages of development can often be found on hosts throughout the year.[8, 89, 168, 230] In the warmer, moist, lowveld regions of the KwaZulu-Natal, Mpumalanga and Limpopo provinces in the north-east of South Africa as well as in southern Zimbabwe, the life cycle seems to be continuous with little indication of a definite seasonal pattern of abundance for the various life stages.[94, 95, 179]

Distribution *Amblyomma hebraeum* is exclusively a southern African tick. It occurs endemically in the coastal regions of the Eastern Cape and KwaZulu-Natal provinces in

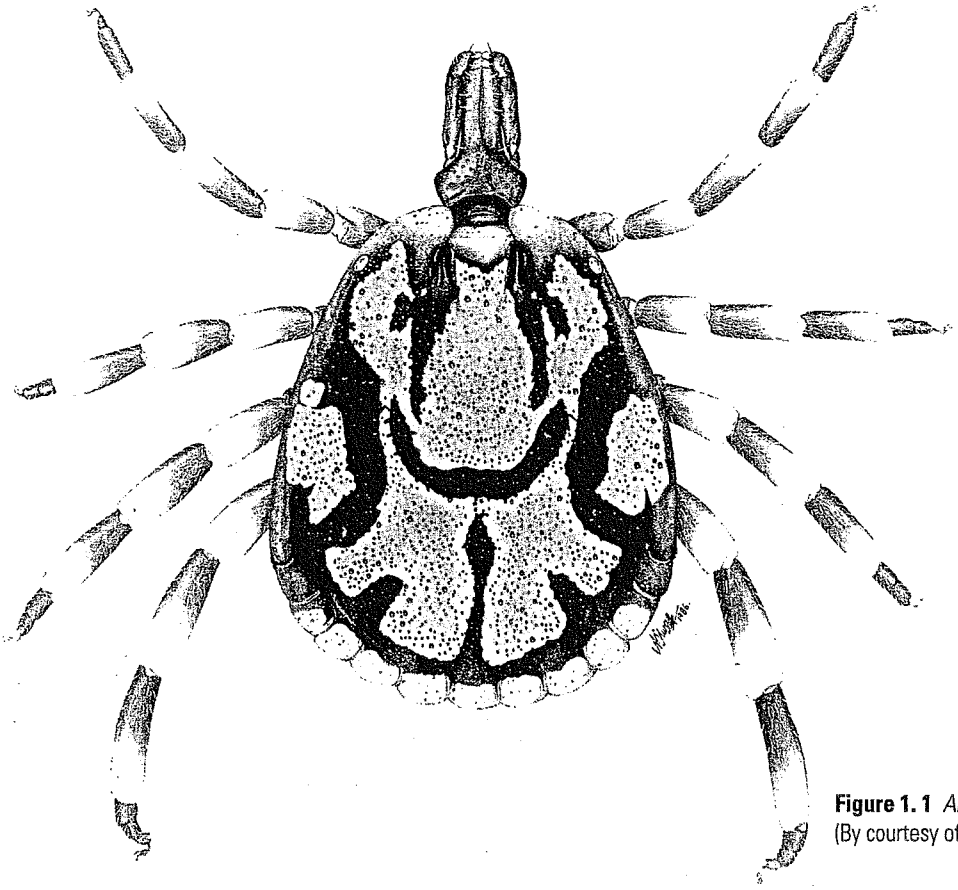

Figure 1. 1 *Amblyomma hebraeum* male
(By courtesy of J.B. Walker, OVI, Onderstepoort)

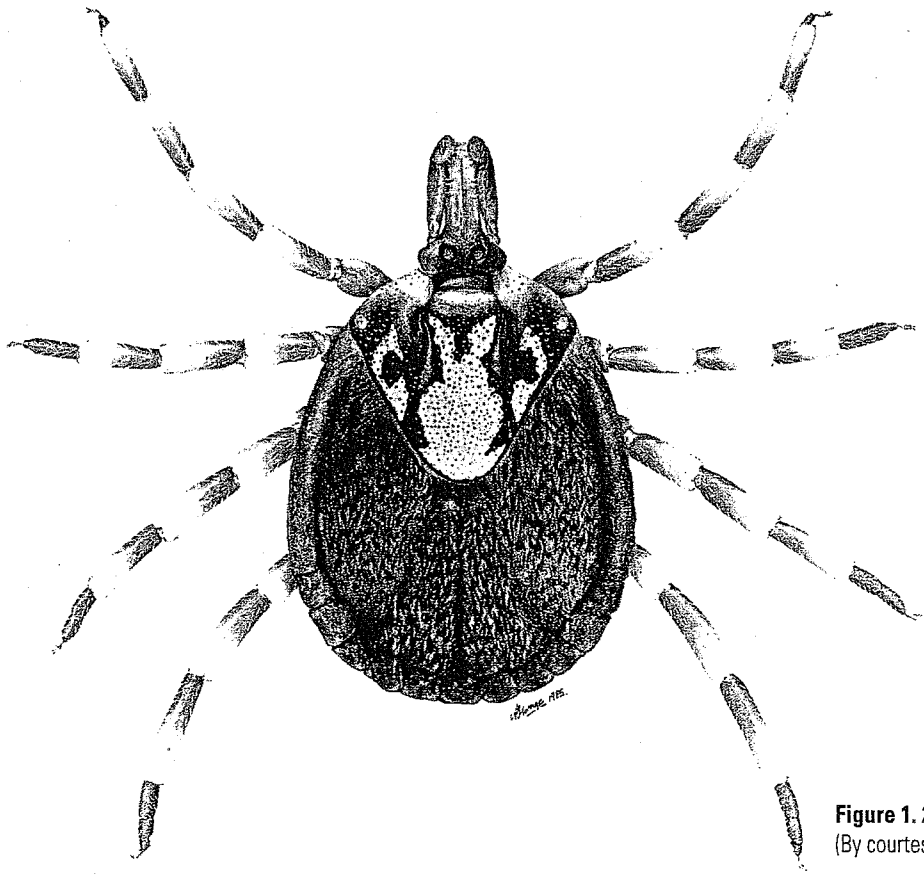

Figure 1. 2 *Amblyomma hebraeum* female
(By courtesy of J.B. Walker, OVI, Onderstepoort)

Table 1.1 Tick vectors of diseases of domestic and wild animals in sub-Saharan Africa

DISEASE (CAUSATIVE ORGANISM)	ANIMALS AFFECTED	VECTORS	METHOD OF TRANSMISSION	REFERENCES
Heartwater or cowdriosis [*Ehrlichia (Cowdria) ruminantium*]	Cattle, sheep, goats, wild antelope	*Amblyomma hebraeum*	TS, IS, TO*	2, 4, 136
		Amblyomma variegatum	TS	34
		Amblyomma pomposum	TS	160
		Amblyomma lepidum	TS	216
		Amblyomma spp.	TS	216
Bovine ehrlichiosis (*Ehrlichia bovis*)	Cattle	*Rhipicephalus appendiculatus*	TS	148, 170
		Rhipicepalus zambeziensis	TS	257
Ovine ehrlichiosis (*Ehrlichia ovina*)	Sheep	*Rhipicephalus evertsi evertsi*	TS	162
		Rhipicephalus bursa	?	288
Anaplasmosis (*Anaplasma marginale*)	Cattle, eland	*Boophilus decoloratus*	TS, IS	221
		Boophilus microplus	TS, IS	221
		Hyalomma marginatum rufipes	IS	221
		Rhipicephalus evertsi evertsi	IS	221
		Rhipicephalus simus	TS, IS	221
Benign anaplasmosis (*Anaplasma centrale*)	Cattle	*Rhipicephalus simus*	TS	224
Ovine anaplasmosis (*Anaplasma ovis*)	Sheep, goats	*Rhipicephalus bursa*	TS	229
Bovine babesiosis or African redwater (*Babesia bigemina*)	Cattle	*Boophilus decoloratus*	TO	223
		Boophilus microplus	TO, TS?	75, 235
		Rhipicephalus evertsi evertsi	TO	25
		Rhipicephalus bursa	TS, TO	75, 288
Bovine babesiosis or Asiatic redwater (*Babesia bovis*)	Cattle	*Boophilus microplus*	TO	44, 220
Benign babesiosis (*Babesia occultans*)	Cattle	*Hyalomma marginatum rufipes*	TO	81, 274
Equine piroplasmosis (*Babesia caballi*)	Horses, donkeys, mules, zebra	*Hyalomma truncatum*	TO	49
		Rhipicephalus evertsi evertsi	TS	51, 270
		Rhipicephalus bursa	TS	60
		Rhipicephalus turanicus (as *R. sanguineus*)	TS, TO	60
Equine piroplasmosis (*Theileria equi*)**	Horses, donkeys, mules, zebra	*Rhipicephalus evertsi evertsi*	TS	270
		Rhipicephalus evertsi mimeticus	TS	222
		Rhipicephalus bursa	TS	75, 288
		Rhipicephalus turanicus (as *R. sanguineus*)		60
		Hyalomma detritum (as *H. anatolicum anatolicum*)	TS	75
Porcine babesiosis (*Babesia trautmanni*)	Pigs, warthog, bushpig	*Rhipicephalus simus*	TO	50
		Rhipicephalus turanicus	TO	134
East Coast fever (*Theileria parva* strains) (syn. *Theileria parva parva*)	Cattle	*Rhipicephalus appendiculatus*	TS	10, 45
		Rhipicephalus zambeziensis	TS	129
Zimbabwe theileriosis or January disease (*Theileria parva* strains)	Cattle	*Rhipicephalus appendiculatus*	TS	148, 181, 281
		Rhipicephalus zambeziensis	TS	129
Corridor or buffalo disease (*Theileria parva* strains)		*Rhipicephalus appendiculatus*	TS	164
		Rhipicephalus zambeziensis	TS	129, 181
		Rhipicephalus duttoni	?	31

Table 1.1 (*continued*)

DISEASE (CAUSATIVE ORGANISM)	ANIMALS AFFECTED	VECTORS	METHOD OF TRANSMISSION	REFERENCES
Tropical theileriosis (*Theileria annulata*)	Cattle	*Hyalomma detritum*	TS	18
		Hyalomma dromedarii	TS	53
Benign bovine theileriosis (*Theileria mutans, T. velifera*)	Cattle	*Amblyomma hebraeum*	TS	48, 127, 279
		Amblyomma variegatum	TS	282, 283
Benign bovine theileriosis (*Theileria taurotragi*)	Cattle, eland	*Rhipicephalus appendiculatus*	TS	126, 281, 306
		Rhipicephalus zambeziensis	TS	129
Ovine theileriosis (*Theileria separata*)***	Sheep	*Rhipicephalus evertsi evertsi*	TS	115
		Rhipicephalus evertsi mimeticus	TS	165
		Rhipicephalus bursa	TS	165
Borreliosis or spirochaetosis (*Borrelia theileri*)	Cattle, sheep, goats, horses, donkeys, mules	*Boophilus decoloratus*	TO	269, 271
		Boophilus microplus	TO	?
		Rhipicephalus evertsi evertsi	TS, TO	271
African swine fever (*Asfarviridae*)	Pigs, warthog, bushpig	*Ornithodoros moubata* complex	TS, TO, S	217, 218, 219
Nairobi sheep disease (and Kisenye sheep disease?) (*Bunyaviridae*)	Sheep, goats	*Amblyomma variegatum*	TS	36
		Rhipicephalus appendiculatus	TS, TO	22, 35, 39
		Rhipicephalus pulchellus	TS, TO	209
Crimean-Congo haemorrhagic fever (*Bunyaviridae*)	Cattle, sheep	*Hyalomma marginatum rufipes*	TS	267
		Hyalomma truncatum	TS	243
		Rhipicephalus evertsi evertsi	TS (?)	267
		Rhipicephalus evertsi mimeticus	TS (?)	243
Bovine dermatophilosis (*Dermatophilus congolensis*)	Cattle	*Amblyomma variegatum*		24, 145, 178
Sweating sickness (toxicosis)	Cattle	*Hyalomma truncatum*		12, 14, 161
Karoo paralysis (toxicosis)	Calves, sheep, goats, antelope	*Ixodes rubicundus*		65, 256, 285
Spring lamb paralysis (toxicosis)	Lambs	*Rhipicephalus evertsi evertsi*		80, 82
Paralysis (toxicosis)	Sheep	*Rhipicephalus bursa*		288
Paralysis (toxicosis)	Calves, lambs	*Rhipicephalus lunulatus* (as *R. tricuspis*)		128, 197, 273
Paralysis (toxicosis)	Cattle	*Rhipicephalus praetextatus* (as *R. simus*)		202
Paralysis (toxicosis)	Calves, lambs	*Rhipicephalus simus*		185
Brown tick paralysis (toxicosis)	Goat kids	*Rhipicephalus warburtoni* (as *R. pravus* group)		69
Brown ear tick toxicosis	Cattle, antelope	*Rhipicephalus appendiculatus*		133, 274

TS = Transstadial, IS = Intrastadial, TO = Transovarial, S = Sexually transmitted between ticks

* Rarely transovarial transmission of *Ehrlichia ruminantium* by *Amblyomma hebraeum* may occur[13]

** *Babesia equi* was redescribed as *Theileria equi* by Mehlhorn and Schein in 1998.[156] It is suggested that equine piroplasmosis be used when referring to the disease caused by this organism and by *Babesia caballi*

*** The South African *Theileria ovis* described by Jansen and Neitz[115] is considered by Uilenberg[278] to be synonymous with *Theileria separata*, a parasite originally described from sheep in Tanzania.[280] *Theileria separata* does not infect goats

South Africa, and in southern Mozambique. Its distribution also extends inland through the lowveld areas of Swaziland, the Mpumalanga, Limpopo and North West provinces of South Africa, and eastern Botswana to southern and western Zimbabwe as well as parts of the Zimbabwean highveld.[20, 175, 213, 214, 273, 290, 292] It is absent from the highveld regions of South Africa, possibly because these are too cold and treeless, but may survive locally in these regions in wooded habitats such as north-facing gullies, ravines and valleys. It was originally thought that the highveld of Zimbabwe would be unsuitable for *A. hebraeum* because of its cooler temperatures.[175] However, the Climex model, indicating ecoclimatic suitability,[264] demonstrated that conditions on the Zimbabwe highveld are favourable for its survival.[188] Recent surveys conducted there confirm this prediction.[20, 213, 214] In central Botswana its distribution is limited by increasing aridity, and in northern Zimbabwe and central Mozambique it may be restricted by interspecific competition with *Amblyomma variegatum*.[175, 260] *Amblyomma hebraeum* is associated with wooded habitats, including coastal bush, riparian woodland, thornveld and mopani woodland. It does not occur in extensive open, treeless areas.

Disease transmission *Amblyomma hebraeum* is the main vector in southern Africa of *Ehrlichia ruminantium*, the cause of heartwater or cowdriosis in domestic and wild ruminants. Laboratory studies have demonstrated that *A. hebraeum* can carry higher infections and also a greater number of strains of *E. ruminantium* than *A. variegatum*, the other major vector of this disease.[141, 142] In addition, field observations seem to indicate that outbreaks of the disease are more commonly associated with the former than the latter tick and that these outbreaks are also more severe.[188, 213] Besides cattle, a number of wild ruminants,[210, 211, 212] as well as other animals such as scrub hare, helmeted guinea fowl and leopard tortoise can act as asymptomatic carriers of *E. ruminantium*. Other organisms transmitted by *A. hebraeum* are *Theileria mutans* and *Theileria velifera*, the cause of benign bovine theilerioses. The occurrence of foot abscesses in goats in the Eastern Cape Province, South Africa, is significantly related to the seasonal abundance of adult *A. hebraeum* and *Rhipicephalus glabroscutatum*.[138] The attachment sites of these ticks around and between the hooves afford entrance to secondary bacterial infections leading to abscessation.

Control Adult *A. hebraeum* have long feeding periods and consequently good control of the tick can be achieved by the treatment of cattle with conventional acaricides at two-weekly intervals. As the ticks attach predominantly to the undersides of cattle, control can be achieved by localized acaricide application. It should be noted that in endemic heartwater areas control of *A. hebraeum* is only necessary when large clumps of adults, forming potential sites for strike by the screw-worm fly (*Chrysomya bezziana*), occur on cattle, or when the udders or teats of heifers or cows are heavily infested. Over-rigorous control is likely to have the negative effect of disrupting the natural transmission of heartwater to young animals and thus reducing levels of naturally acquired immunity, consequently affecting endemic stability to the disease in domestic ruminant populations.[170, 172]

Regular acaricidal treatment of domestic livestock, and more particularly cattle, can result in the virtual disappearance of all developmental stages of *A. hebraeum* on sympatric wild animals up to and including the size of greater kudu as well as the disappearance of free-living larvae on the vegetation.[102, 215] Larger wild animals such as giraffe, African buffalo and eland, which are excellent hosts of all stages of development of the tick,[104, 106, 175] are probably capable of maintaining populations of *A. hebraeum* on a farm, even though the domestic livestock on the property are being treated with an acaricide. The residual population of ticks on wildlife on such mixed cattle and wildlife farms may serve as an important source of tick infestation, and consequently heartwater infection,[210, 211] for the domestic stock on the farm and thus assist in maintaining immunity.

Amblyomma variegatum

Tropical bont tick, tropiese bontbosluis (Afrik.)

Identification Adult *A. variegatum* have long mouthparts and banded legs like *A. hebraeum*, but the colour patterns on the scutum are different and they have beady eyes. In addition, the festoons of the males are dark brown in colour **(Figures 1.3 and 1.4)**.

Hosts and life cycle *Amblyomma variegatum* has a host range similar to that of *A. hebraeum*.[86, 175, 216, 273] It is also a three-host tick, but differs from *A. hebraeum* in that the immature stages have a more clearly defined pattern of seasonal occurrence. In Zambia adults are most abundant in the wet season (October to February), larvae from March to July, and nymphs from May to September.[206, 308] This pattern of seasonal abundance can arise from morphogenetic diapause in the females, resulting in a delay in oviposition.[205] Similar observations of only one generation per annum have been made in other regions which have a single rainy season.[216] In Zimbabwe adults can be present throughout the year, with heavier infestations in the warmer months (September to May), and with nymphs present only from June to September.[175]

Distribution *Amblyomma variegatum* is widely distributed through West, Central and East Africa and in southern Africa extends into north-eastern Botswana, the Caprivi Strip of Namibia, and northern and central Mozambique.[273, 292] Since 1986 *A. variegatum* has spread from the north-western regions of Zimbabwe to the central and eastern highveld.[213, 214] Its spread southwards appears to be limited by interspecific competition with *A. hebraeum*,[260] with which it shares similar habitats, hosts and sites of attachment.[175, 216]

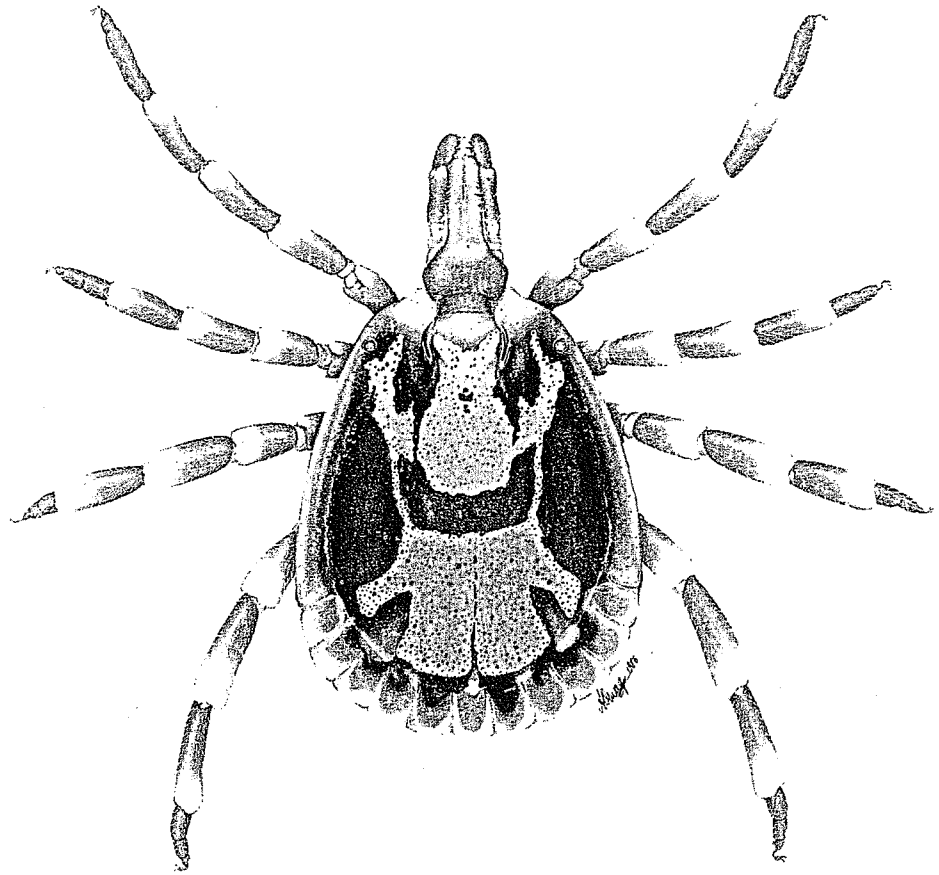

Figure 1.3 *Amblyomma variegatum* male
(By courtesy of J.B. Walker, OVI, Onderstepoort)

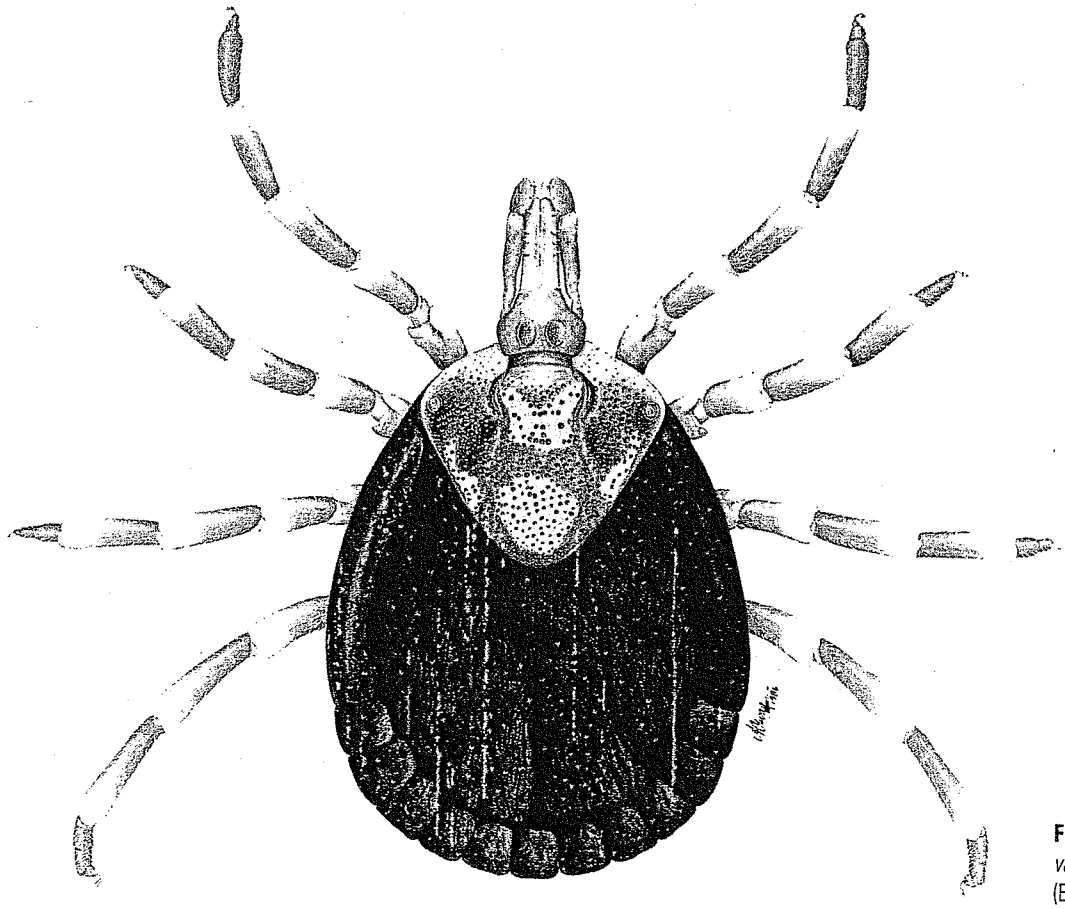

Figure 1.4 *Amblyomma variegatum* female
(By courtesy of J.B. Walker, OVI, Onderstepoort)

Disease transmission *Ehrlichia ruminantium*, the cause of heartwater or cowdriosis; *Theileria mutans* and *T. velifera*, the cause of benign bovine theilerioses; *Ehrlichia bovis*, the cause of bovine ehrlichiosis; and the virus causing Nairobi sheep disease. Bovine dermatophilosis (*Dermatophilus congolensis*) is associated with the presence of the tick.

Control The control of *A. variegatum* with acaricides is similar to that described for *A. hebraeum*. However, the more clearly defined seasonality of *A. variegatum* facilitates strategic control of the adults during the wet season.

Amblyomma pomposum

Angolan bont tick

Identification *Amblyomma pomposum* closely resembles *A. variegatum* but is more heavily punctate (**Figures 1.5 and 1.6**).

Life cycle, hosts and distribution This tick has a three-host life cycle similar to those of *A. hebraeum* and *A. variegatum* and has a similar host range.[216, 242] The adults most frequently attach on the undersides of cattle.[242] It is present in Angola, parts of western Zambia, and in the southern region of the Democratic Republic of the Congo.[292] However, unlike other southern African vectors of heartwater, *A. pomposum* occurs in wet highland areas in savanna and forest.[58, 86, 242, 273] In Angola, nymphs and adults are most abundant during the rainy season, although large variations may occur depending on the region and climate.[242]

Disease transmission *Ehrlichia ruminantium*, the cause of heartwater or cowdriosis.

Amblyomma lepidum

East African bont tick

Identification *Amblyomma lepidum* closely resembles *A. hebraeum*, but has beady eyes and the males have variably coloured light and dark festoons (**Figures 1.7 and 1.8**).

Life cycle, hosts and distribution This is a three-host tick and the adults prefer cattle as hosts, although camels (*Camelus dromedarius*) may also harbour quite large infestations.[216, 287, 302] Other domestic animals can also be infested as well as a number of wild ungulates. Adults are predominantly found attached on the ventral surface of the host from the lower dewlap and axillae to the escutcheon.[302] It is widespread in eastern Sudan, Ethiopia, southern Somalia, eastern Uganda, Kenya and the northern region of central Tanzania.[292] In Tanzania, which lies south of the equator, adult ticks are most abundant between October and February, beginning either shortly before or shortly after the onset of the rainy season. However, there may be considerable variation in the timing of the peak as well as in the numbers of ticks present.[301, 302] In Ethiopia, north of the equator, adults peak during the rainy season in May to June.[202]

Disease transmission *Ehrlichia ruminantium*, the cause of heartwater or cowdriosis.

Amblyomma spp.

A number of other African *Amblyomma* spp. have also been implicated in the transmission of heartwater to domestic livestock (**see Chapter 40: Heartwater**). Except under certain unusual circumstances the ability of several of these tick species to transmit heartwater to domestic ruminants is limited because their adults, which appear to be the most efficient vectors, by preference do not feed on these animals.[216]

The males and females of all these ticks are ornate,[292] have long mouthparts, and all have three-host life cycles.[216] These ticks include:

- *A. astrion*, of which the principal hosts of the adults are cattle, sheep and African buffalo. It is distributed mainly in the Central African Republic, the northern and western regions of the Democratic Republic of the Congo, and north-western Angola;
- *A. cohaerens*, which infests African buffalo, and domestic cattle in regions in which buffalo are, or used to be, common. It has been recorded chiefly in the eastern region of the Democratic Republic of the Congo, western Uganda and central Ethiopia;
- *A. gemma*, for which domestic cattle and large, wild herbivores are the preferred hosts of the adults. It is mainly distributed in eastern Ethiopia, northern and southern Somalia, Kenya and north-eastern Tanzania;
- *A. marmoreum*, of which all stages of development, and most particularly the adults, feed on tortoises and large varanids. Adults very rarely parasitize domestic livestock but the immature stages, especially larvae, are frequently encountered on these animals. This tick is widespread in Zimbabwe and South Africa and is probably more prevalent in Mozambique, Botswana and Namibia than current records seem to indicate;
- *A. sparsum*, of which the adults prefer large reptiles, but black rhinoceros and African buffalo may also be important hosts. It rarely infests domestic hosts. Most records of this tick's occurrence are from southern and western Kenya, northern and central Tanzania and north-western Zimbabwe; and lastly
- *A. tholloni*, of which the preferred hosts of the adults are African elephant (*Loxodonta africana*) and hippopotamus (*Hippopotamus amphibius*).[175] Although larvae and nymphs have been collected from cattle, sheep and goats, domestic stock are not common hosts.[175] This tick has been recorded in the Ivory Coast and adjacent countries to the west, and throughout Central Africa to the eastern coastal regions from Kenya in the north to north-eastern South Africa in the south.

Disease transmission *Ehrlichia ruminantium*, the cause of heartwater or cowdriosis.

Boophilus decoloratus

African blue tick, bloubosluis (Afrik.)

Identification *Boophilus decoloratus* adults are small, inconspicuous ticks with short mouthparts and slender legs. The males, which are usually considerably smaller than the females, are brownish-yellow in colour and the darker coloured intestine is visible through the lightly sclerotized scutum (**Figure 1.9**). They can usually be found paired with the females. The engorged females are blueish-brown (**Figure 1.10**) and can be seen attached particularly to the face, neck, shoulders and escutcheon of cattle.

Hosts *Boophilus decoloratus* prefers cattle as hosts. In addition to cattle it frequently parasitizes horses, donkeys, sheep and goats.[52, 111, 147, 287, 302] Contrary to earlier observations it is commonly present in large numbers on several wild ungulate species, including Burchell's zebra (*Equus burchellii*), impala, bushbuck, greater kudu, eland and sable antelope.[90, 95, 97, 106, 147, 308] Rather unusually, African buffalo do not appear to be good hosts.[106, 139, 147, 177]

Life cycle *Boophilus decoloratus* has a one-host life cycle, in which moulting from larva to nymph and nymph to adult takes place on the host.[6] The time spent on the host, from attachment of the unfed larva until detachment of the engorged female, is approximately three weeks,[6] and that spent off the host, from pre-oviposition until larval hatching and maturation, approximately five weeks. Because of this short life cycle the tick is able to pass through more than one generation annually, and is usually present in varying numbers throughout the year. In southern Africa low winter temperatures synchronize egg development and larval hatching.[236] Consequently large numbers of larvae are present on the vegetation when the weather warms in spring.[253] Waves of larvae then occur throughout the summer and into the cool months of May and June. In South Africa the largest numbers of ticks are usually present on cattle during the summer and autumn to early winter months,[8, 56, 230, 236] but a spring peak in abundance may also occur.[9, 236] In Zambia a spring peak may be followed several months later by a considerably larger late summer or winter peak.[139, 206, 207] In Nigeria, north of the equator, *B. decoloratus* is most abundant on cattle during autumn,[52] while in the Gambia peak burdens are present on these animals during the rainy season.[152] On wild herbivores in South Africa the highest burdens are usually recorded in spring and, unless these animals are stressed because of disease or drought or other conditions, their late summer and autumn burdens are low.[95, 97] Because of its one-host life cycle all stages of development occur on the host at the same time and the presence on a single host of approximately 70 engorged females can represent a total parasitic population exceeding 10 000 ticks.[95]

Distribution This tick is distributed throughout most of the moister regions of South Africa, except for areas where it has been replaced by *B. microplus*, and also occurs in cold mountainous regions such as the Drakensberg range and parts of Lesotho. It is absent from those parts of South Africa that receive an average annual rainfall of less than 380 mm, including the western Free State, and the western regions of the Northern Cape Province.[78, 112, 272] In the semi-arid to arid territory of Namibia it is present only in localized areas in the north, and in Botswana it is restricted to the higher rainfall eastern border areas and a few scattered northern localities.[290] *Boophilus decoloratus* is also present in southern Mozambique, Zimbabwe, particularly the eastern regions, Angola, much of Zambia, Malawi, south-western and northern Tanzania, Burundi, Uganda, western Kenya and in the wetter highlands and sub-highlands of Ethiopia.[147, 151, 202, 287, 302] It is also found in Central and West Africa.[52, 86, 152] It occurs in various vegetation types, including coastal mosaic, grassland, Cape shrubland, bushland, woodland and in undifferentiated montane vegetation.

Disease transmission *Babesia bigemina*, the cause of bovine babesiosis or African redwater; *Anaplasma marginale*, the cause of bovine anaplasmosis; and *Borrelia theileri*, the cause of borreliosis or spirochaetosis. Eland can be asymptomatic carriers of *A. marginale* and could thus serve as a reservoir of infection for domestic cattle.[166] *Boophilus decoloratus* is also suspected of being a vector of *Babesia trautmanni*, the cause of porcine babesiosis. However, the small numbers encountered on warthog, even in regions where large numbers of this tick are present,[90] make this seem unlikely under field conditions.

Control Because *B. decoloratus* spends approximately 21 days on its hosts to complete its parasitic life cycle it can effectively be controlled by acaricide treatment of cattle at three-weekly intervals. *Bos indicus* and Sanga-type cattle develop a considerably better resistance to this tick than *Bos taurus* cattle,[231, 232, 251] and consequently require fewer acaricide treatments.

Boophilus microplus

Asian blue tick, Asiatiese/pantropiese bloubosluis (Afrik.)

Identification Adults of *B. microplus* are slightly larger than those of *B. decoloratus*, and are slightly more red in colour, but are otherwise very similar in general appearance.

Hosts In sub-Saharan Africa domestic cattle are virtually the only hosts and other livestock species and wild ungulates are rarely parasitized, and then only if cattle infested with this tick are present.[86, 107, 147, 302]

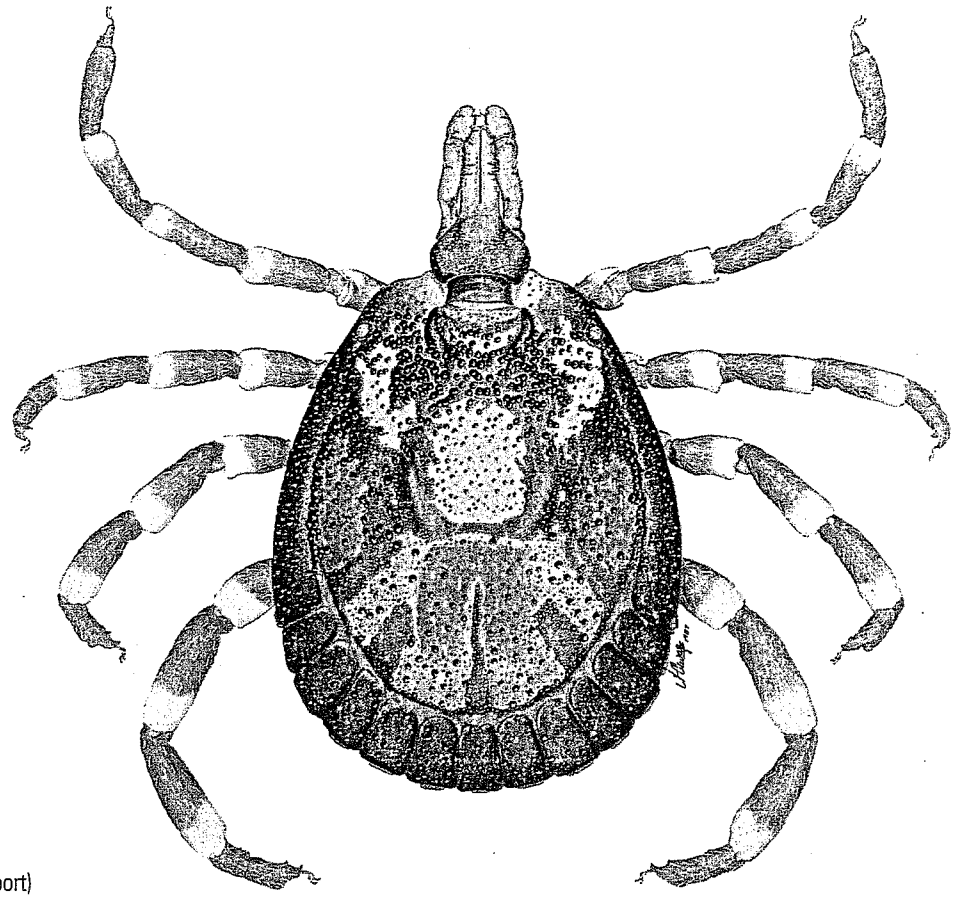

Figure 1.5 *Amblyomma pomposum* male
(By courtesy of J.B. Walker, OVI, Onderstepoort)

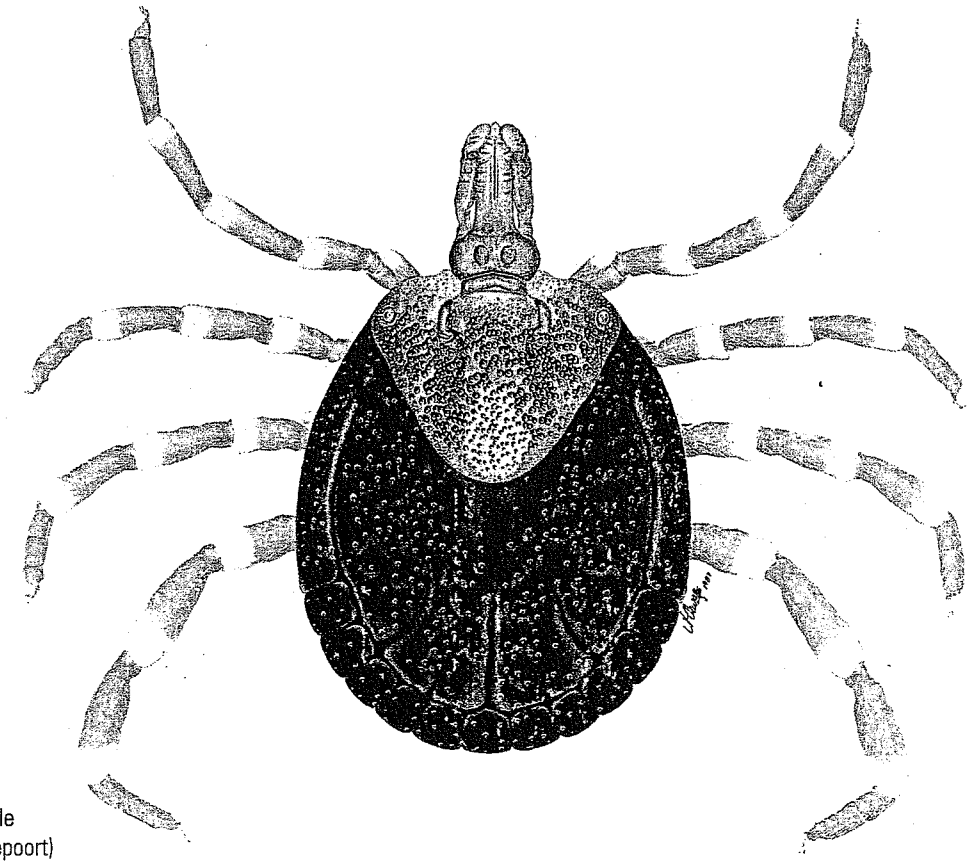

Figure 1.6 *Amblyomma pomposum* female
(By courtesy of J.B. Walker, OVI, Onderstepoort)

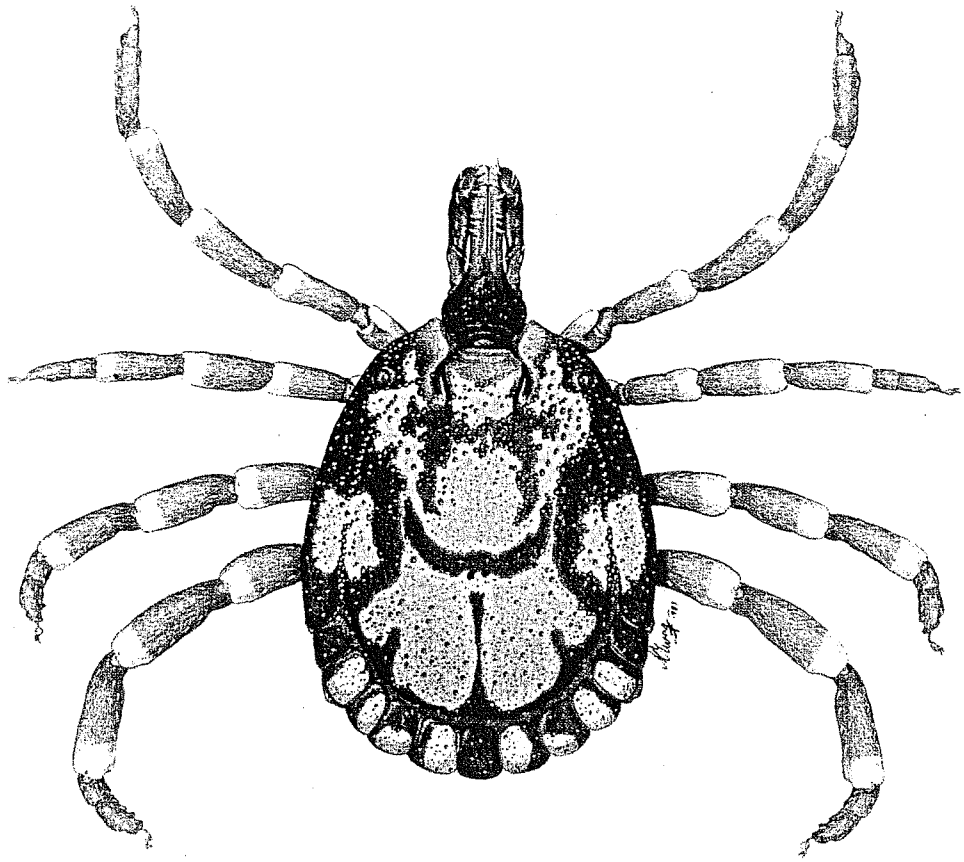

Figure 1.7 *Amblyomma lepidum* male
(By courtesy of J.B. Walker, OVI, Onderstepoort)

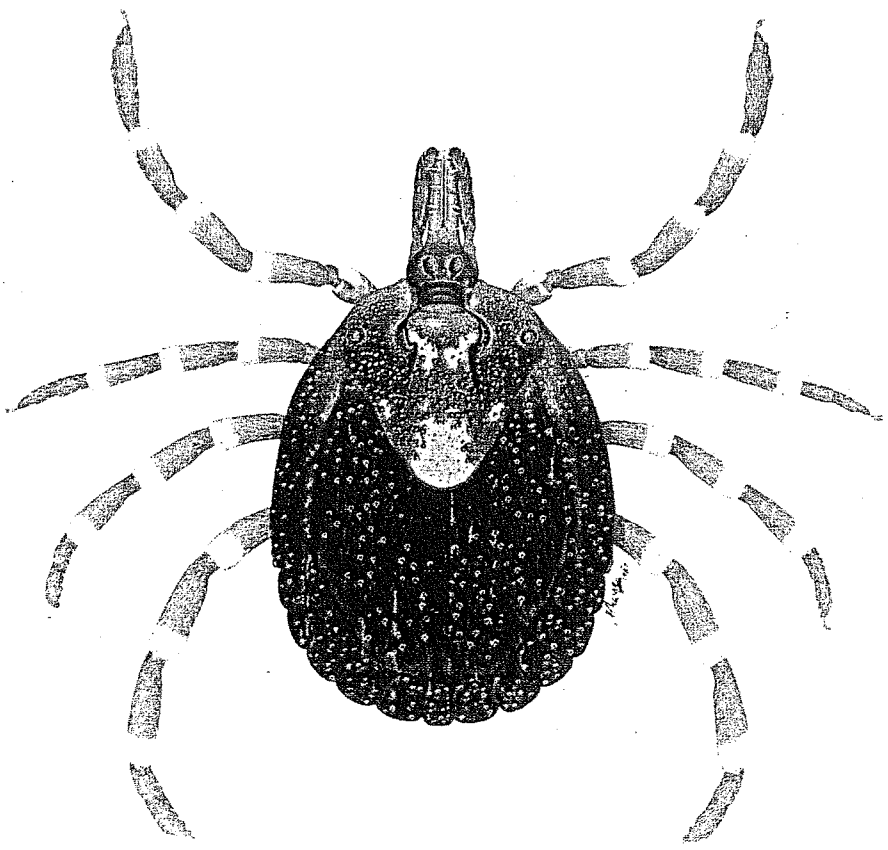

Figure 1.8 *Amblyomma lepidum* female
(By courtesy of J.B. Walker, OVI, Onderstepoort)

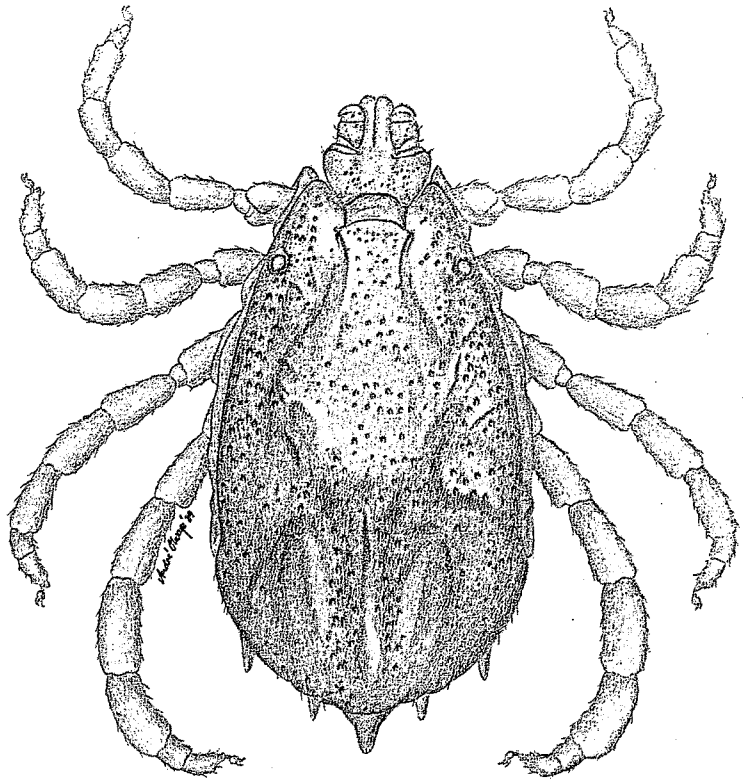

Figure 1.9 *Boophilus decoloratus* male

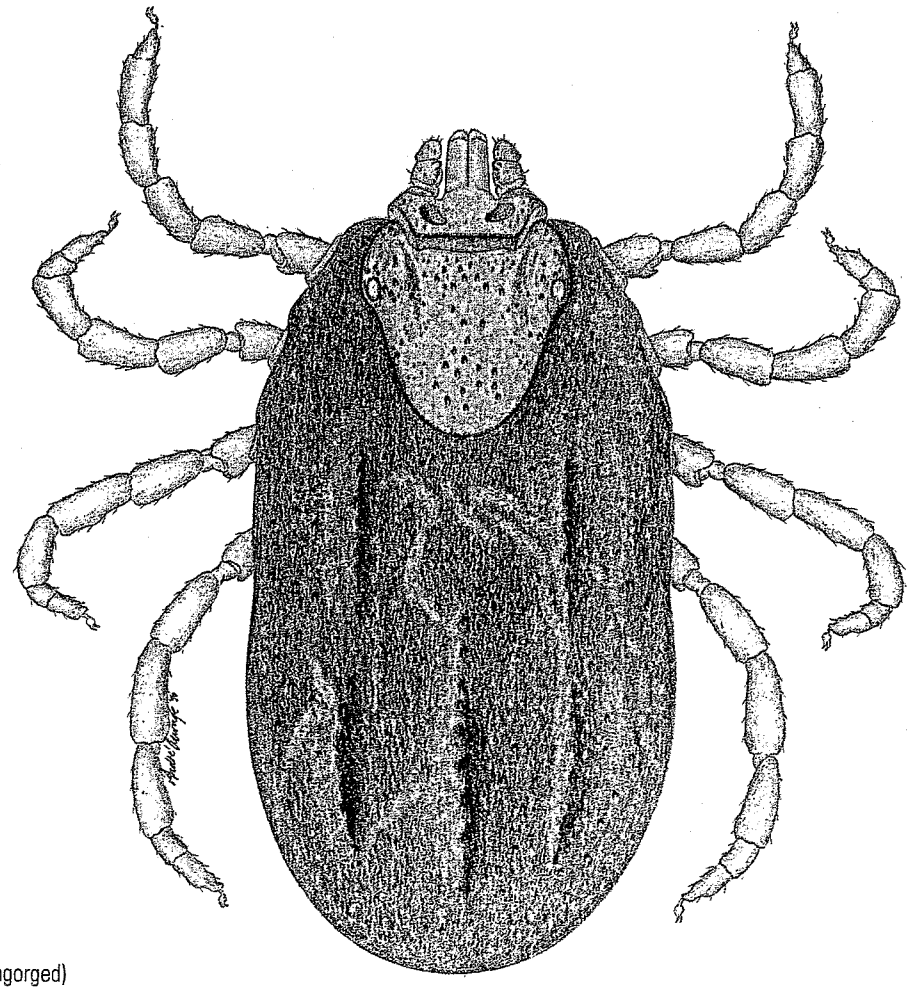

Figure 1.10 *Boophilus decoloratus* female (engorged)

Life cycle *Boophilus microplus* has a one-host life cycle, and like *B. decoloratus* is able to complete more than one generation in a year. In Zimbabwe it appears to be present in variable numbers throughout the year.[147] In south-eastern KwaZulu-Natal, South Africa, it is most abundant on cattle from mid- to late summer.[9]

Distribution Hoogstraal[86] postulated that *B. microplus* was introduced into East and South Africa from Madagascar, where it had originally arrived with cattle from southern Asia. In South Africa it is now established in scattered areas along the southern and eastern coasts of the Western and Eastern Cape provinces and of KwaZulu-Natal. It is also present in the coastal regions of Mozambique, Tanzania and Kenya. In the interior of the subcontinent it is found in scattered localities in the Mpumalanga and Limpopo provinces of South Africa, in both the south and north of eastern Zimbabwe, in parts of the Eastern and Central provinces of Zambia, throughout Malawi and to the east and north of Lake Malawi in Tanzania.[112, 147, 287, 302] There is evidence that where favourable moist and warm climatic conditions exist it competes with and is able to replace the indigenous *B. decoloratus*.[147, 189, 254] *Boophilus microplus* spread into Zimbabwe in the 1970s, when dipping was disrupted during the pre-independence war, and replaced *B. decoloratus* in several areas.[147] Long-term surveys conducted in eastern Zambia revealed that *B. decoloratus* had almost completely been replaced by *B. microplus* in the 10 years between 1972 and 1982,[11] and its westward spread appears to be continuing.[116] The spread of *B. microplus* in Zimbabwe and Zambia has been accompanied by heavy mortality in cattle due to *B. bovis* infection, of which it is the sole vector in sub-Saharan Africa.[116, 182]

Disease transmission *Babesia bovis*, the cause of bovine babesiosis or Asiatic redwater; *Babesia bigemina*, the cause of bovine babesiosis or African redwater; *Anaplasma marginale*, the cause of bovine anaplasmosis; and *Borrelia theileri*, the cause of borreliosis or spirochaetosis. Because this tick transmits both *B. bovis* and *B. bigemina* it poses a greater potential threat to livestock production than *B. decoloratus*.

Control The control of *B. microplus* is similar to that of *B. decoloratus*. *Bos indicus*-type cattle develop a considerably better resistance to this tick than *Bos taurus*-type cattle and consequently the number of acaricide treatments required can be reduced on these animals.[259, 284] However, because *B. microplus* feeds virtually exclusively on cattle, the whole parasitic population is exposed to acaricidal intervention at any particular location as there are no alternative hosts. Because of this and its slightly shorter life cycle it would appear as if *B. microplus* is selected for resistance to acaricides more rapidly than is *B. decoloratus*.

Hyalomma truncatum

Small smooth bont-legged tick, sweetsiektebosluis (Afrik.)

Identification Adults of *H. truncatum* are medium-sized ticks with long mouthparts and dark-brown bodies, beady eyes, and long, red and white banded legs. The posterior surface of the scutum in males is characterized by a depression containing numerous large punctations, otherwise it is comparatively smooth (**Figures 1.11 and 1.12**).

Hosts The preferred hosts of the adults are large ungulates, both domestic and wild.[86, 91, 174, 287] They attach in the tail switch, around the anus, on the lower perineum, and on the legs, including around the feet.[139] The immature stages feed on hares and on certain rodents, particularly gerbils.[19, 103, 174]

Life cycle *Hyalomma truncatum* has a two-host life cycle, which normally takes a year to complete under field conditions in South Africa. Adults occur in the greatest numbers in the late wet summer months and the immature stages in the dry autumn to spring months.[89, 109, 139, 174, 234]

Distribution This tick is adapted to dry climates and is absent in Lesotho and, with the exception of the Eastern Cape, the eastern half of the Free State, south-eastern Gauteng and Mpumalanga, and southern KwaZulu-Natal, it is present throughout South Africa, Zimbabwe and much of Mozambique.[112, 174, 240] It is also present in south-eastern and north-western Botswana; central and northern Namibia; southern Angola; western, southern, central and eastern Zambia; central and southern Malawi; south-western and north-eastern Tanzania; southern, central and western Kenya; and eastern Uganda.[81, 206, 287, 302] It also occurs in many countries in north-eastern, Central and West Africa.[86, 152, 202, 273] At a local level the abundance of *H. truncatum* is influenced by the abundance of hares, which are the preferred hosts of the immature stages.

Disease transmission *Babesia caballi*, the cause of equine piroplasmosis. Because the immature stages of *H. truncatum* do not feed on horses the transmission of *B. caballi* by this tick has of necessity to take place transovarially.[49] *Hyalomma truncatum* also transmits the virus causing Crimean-Congo haemorrhagic fever in humans, and the toxin causing sweating sickness in cattle and especially in young calves. Only certain strains of *H. truncatum* produce this toxin and then it is only female ticks that do so.[14] The long mouthparts of the ticks, as well as their tendency to form clusters, can cause tissue damage resulting in secondary bacterial infections and abscessation. The attachment of adult ticks to the interdigital clefts and fetlocks of lambs almost always causes lameness.[124]

Control Hand-dressing of the preferred attachment sites with an acaricide will assist in controlling the adults. It is impractical to control the immature stages because of their preference for hares and rodents.

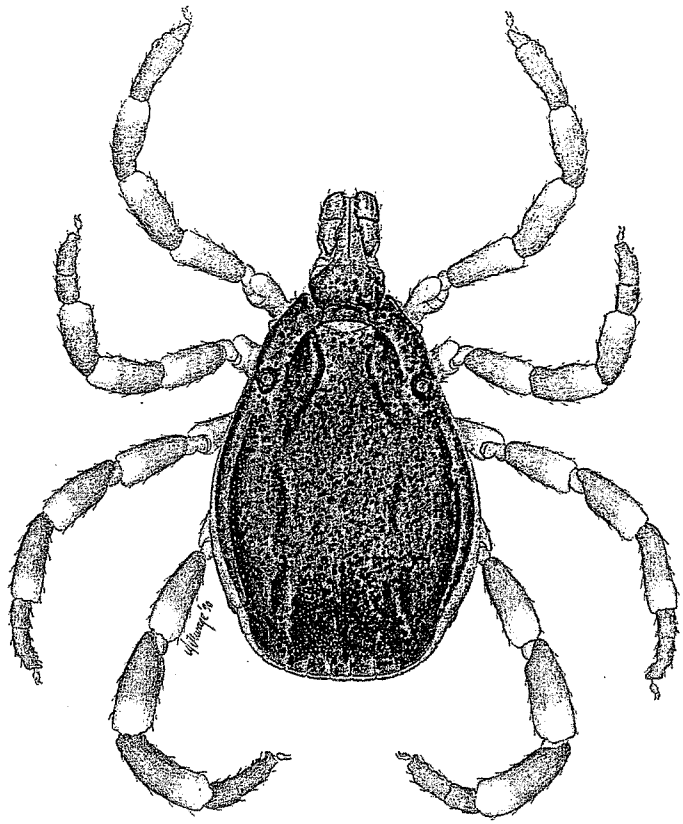

Figure 1.11 *Hyalomma truncatum* male

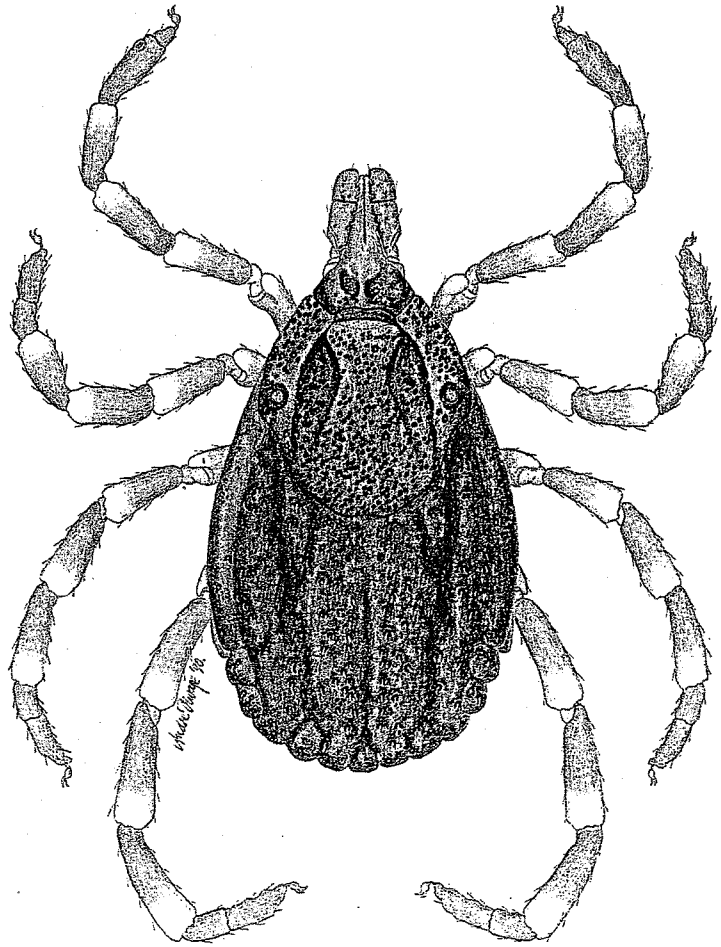

Figure 1.12 *Hyalomma truncatum* female

Hyalomma marginatum rufipes

Coarse bont-legged tick, groot bontpootbosluis (Afrik.)

Identification Adult *H. marginatum rufipes* are large ticks with dark-brown bodies, long mouthparts, a scutum that is heavily punctate, beady eyes, and long, red and white banded legs. They differ from those of *H. truncatum* in that the whole scutum is punctate and in the males it is more circular than the rather elongate shape of the latter tick. However, it is virtually impossible to distinguish between the two species by means of the naked eye.

Hosts Adults parasitize domestic and wild ungulates, showing a preference for the larger species.[91, 174, 287] They attach mainly in the hairless peri-anal region and on the lower perineum and genitalia.[8] The immature stages are parasitic on hares, particularly scrub hares, as well as on ground-frequenting birds.[103, 174, 234]

Life cycle *Hyalomma marginatum rufipes* has a two-host life cycle, which under field conditions in South Africa takes a year to complete. The adults are most numerous in the early part of the wet season and the immature stages in the dry season.[89, 139, 174]

Distribution This tick is widely distributed in southern Africa, and appears to be absent only from the winter rainfall areas of the Western Cape Province, the mountainous areas of Lesotho and KwaZulu-Natal where snow falls in winter, and some humid, subtropical habitats along the east coast and in the north-east. It is also present in the drier regions of the southern and north-western provinces of Mozambique, south-eastern and north-western Botswana, central and northern Namibia, southern Angola, most of Zimbabwe, southern and western Zambia, central and north-eastern Tanzania, central and southern Kenya, western Burundi, eastern Uganda, and in Somalia, Sudan, Ethiopia and in West Africa.[1, 86, 112, 119, 152, 174, 202, 206, 240, 287, 302] Parasitism of birds by the immature stages undoubtedly contributes to the extensive distribution of this species.

Disease transmission *Babesia occultans,* the cause of benign bovine babesiosis; *Anaplasma marginale,* the cause of bovine anaplasmosis; and the virus causing Crimean-Congo haemorrhagic fever. Secondary bacterial infection of tick attachment sites can lead to the formation of abscesses in cattle.

Control Control can be accomplished by localized acaricide treatment. *Hyalomma marginatum rufipes* is difficult to control on cattle herds even by regular acaricide application as engorged nymphs are continuously being brought in from other areas by birds.

Hyalomma detritum

The shiny *Hyalomma*

Identification Adult *H. dentritum* are medium-sized ticks with long mouthparts, a very dark-brown, smooth, shiny scutum, and long reddish or yellowish-brown legs which may have paler bands.[86]

Hosts Domestic cattle and horses are the most common hosts, but sheep, goats and camels may also be infested.[86] All stages of development feed on the same host species. Adults attach on the inner thighs, udder, scrotum and perineum of cattle.[18]

Life cycle and distribution *Hyalomma detritum* has a two-host life cycle with the adults feeding in summer and the larvae and nymphs in autumn.[86] The detached engorged nymphs undergo a winter diapause and moult to adults the following summer.[18, 86] The life cycle is often associated with barns, stables and sheds, and livestock become infested when they are housed in these structures. This *Hyalomma* is present along the Mediterranean coast of Africa as far as Algeria and Morocco in the west.[86] It is also present in sub-Saharan Africa in north-central Sudan, which it may have invaded from the Red Sea coast or via the Nile River Valley.[86]

Disease transmission *Theileria annulata,* the cause of tropical theileriosis. In those regions in which *H. detritum* is the vector of *T. annulata,* tropical theileriosis frequently occurs on small farms on which the livestock are closely associated with barns and stables where they acquire infestations with the tick. It also transmits *Theileria equi,* the cause of equine piroplasmosis.

Hyalomma dromedarii

The camel *Hyalomma*

Identification Adult *H. dromedarii* are large ticks with long mouthparts. The scutum of the male is characterized by posterior grooves and ridges. The colour of these ticks varies from yellow-brown to nearly black. The legs are paler than the scutum and may be ringed by paler bands.[86]

Hosts The preferred hosts are camels, but cattle, sheep, goats and horses may also be infested.[87] Adults attach on the inner thighs, udder and scrotum of camels. The larvae and the nymphs feed on small burrowing animals and hares, but the nymphs may also infest camels, cattle and horses.

Life cycle and distribution *Hyalomma dromedarii* has a two- or a three-host life cycle. The larvae may feed and moult to nymphs on small mammal or leporid hosts and the adults feed on large herbivores. Or the larvae may feed on small mammal hosts, drop off and moult to nymphs, which can

then either attach to other small mammal hosts or feed on the same large animals as the adults.[86] The life cycle appears to be continuous throughout the year. This tick is common wherever camels occur in the Far, Middle and Near East. It is also present in Mauritania in West Africa and in Morocco, Algeria, Tunisia and Libya in North Africa and is well-adapted to an arid and even desert environment.[53, 86] In north-eastern and East Africa it occurs in Sudan, Eritrea, northern, eastern and southern Ethiopia, northern Kenya and north-eastern Uganda.[86, 151, 202, 287]

Disease transmission *Theileria annulata,* the cause of tropical theileriosis.

Ixodes rubicundus

Karoo paralysis tick, Karoo-verlammingsbosluis (Afrik.)

Identification Adult *I. rubicundus* are small, reddish-brown, eyeless ticks with long mouthparts. Their legs appear to be grouped anteriorly (**Figures 1.13 and 1.14**). Males may sometimes be attached to females.

Hosts Sheep and goats are the preferred domestic hosts of the adults, on which they attach to the ventral parts of the body, neckline and upper half of the legs.[5, 255] Wild hosts include caracal and mountain reedbuck.[105] The preferred hosts of the immature stages are rock elephant shrews and red rock rabbits (*Pronolagus rupestris*).[70, 100, 105, 255]

Life cycle *Ixodes rubicundus* has a three-host life cycle that takes two years to complete. Larvae are active in autumn and winter, nymphs during winter and spring of the same year as the larvae, and the adults in late summer, autumn or early winter of the following year.[67, 105, 255]

Distribution This tick is associated with the southern slopes of hilly or mountainous terrain and occurs in Karoo and Karroid vegetation types in the semi-arid interior of South Africa. It is present in the Western and Northern Cape provinces, through much of the interior of the Eastern Cape, in the central and southern parts of the Free State, and in southern and western Gauteng in the Heidelberg and Bronkhorstspruit districts.[99, 112, 252]

Disease transmission Karoo paralysis (toxicosis) is caused by the engorging females and occurs most commonly in late summer, autumn and early winter when these ticks are present. The colder the mean minimum atmospheric temperatures during the two months preceding tick activity, the earlier this activity commences.[68] Paralysed animals will usually recover if the attached adults are removed or killed using rapid-acting acaricides, but severe losses in sheep, goats and even young calves can occur if preventive measures are not taken.[112, 252] Wild animals such as springbok (*Antidorcas marsupialis*) can also be affected.[65]

Control The control of *I. rubicundus* includes acaricidal treatment of sheep and goats prior to the onset of the cooler months of the year. These animals should also be moved from mountain camps with a southern aspect to other grazing from late summer to spring. The underbrush of trees or shrubs, which give protection not only to the free-living stages of the tick but also to the small mammal hosts of the immature stages, can be removed.[73, 252, 255] This can be accomplished by pruning, or fire, or by allowing goats to browse during the summer months. Cattle and sheep can be used before winter to keep the grass cover short, thereby creating conditions unsuitable for tick survival or for questing for hosts.[72, 73, 247] Fire can also be used for this purpose.

Rhipicephalus appendiculatus

Brown ear tick, bruinoorbosluis (Afrik.)

Identification Adults of *R. appendiculatus* are medium-sized brown ticks with short mouthparts. The legs of the males increase markedly in size from the first to the fourth pair and engorged males have a slender caudal process (**Figures 1.15 and 1.16**). These ticks are frequently seen questing for hosts on blades of grass during the early part of the wet season.

Hosts This species has a wide host range. Adults parasitize medium-sized to large ruminants while the immature stages feed on most ruminant species and a variety of other mammals, including equids, carnivores and hares.[198, 288, 308] Among domestic animals, cattle are the preferred hosts and can become very heavily parasitized with all stages of development.[8, 198] Several wild ruminant species, such as impala, African buffalo, eland, male nyala, bushbuck, greater kudu and sable antelope, can also be heavily infested.[94, 133, 308] Female nyala harbour few adult ticks but are good hosts of the immature stages.[94] Adults attach in the highest numbers to the ears of their hosts but are also found on other parts of the body.[8, 139] The proportion that attaches to the ears varies between host species and is also dependent on the availability of attachment sites on the ears. Larvae and nymphs may attach to the ears as well as to other parts of the body such as the head, legs, neck and dewlap.[8]

Life cycle *Rhipicephalus appendiculatus* is a three-host tick with a strictly seasonal, single annual life cycle in southern Africa. Adults are most abundant during the rainy period in summer (December to April), larvae in the late summer and cool period after the rains (April to August), and nymphs in the winter and early spring (June to October).[8, 230, 244, 307] The pattern of seasonal occurrence is regulated by the unfed adults, which enter diapause and do not engage in host-seeking until the rains start.[245] In countries close to the equator more than one life cycle can be completed annually and no clear pattern of seasonal abundance may be evident.[119, 155]

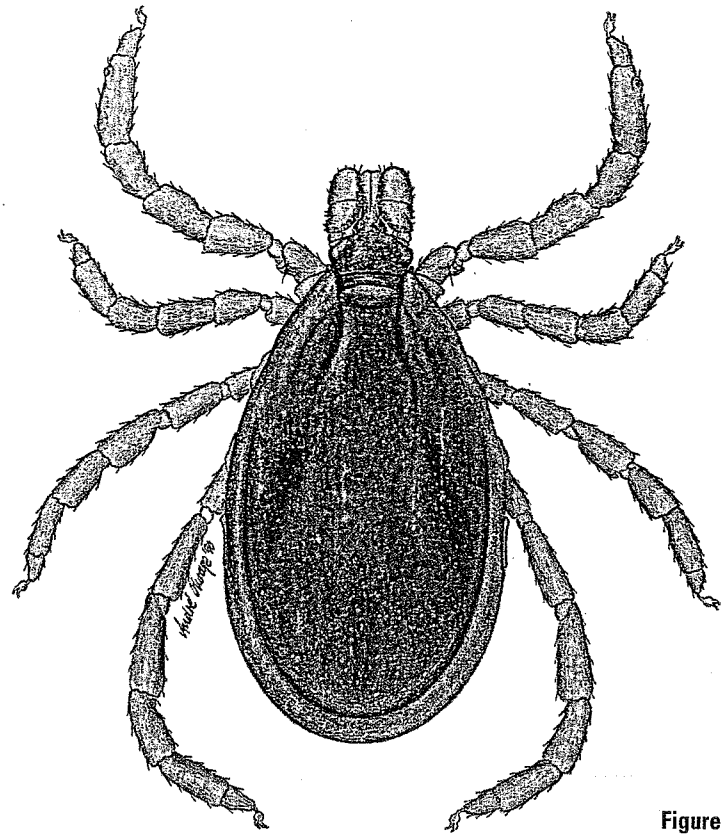

Figure 1.13 *Ixodes rubicundus* male

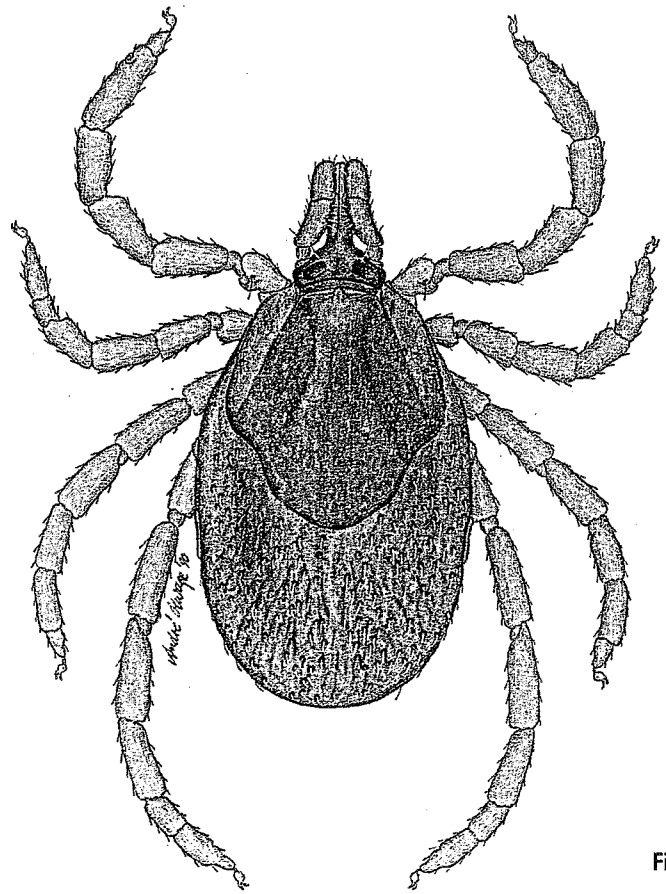

Figure 1.14 *Ixodes rubicundus* female

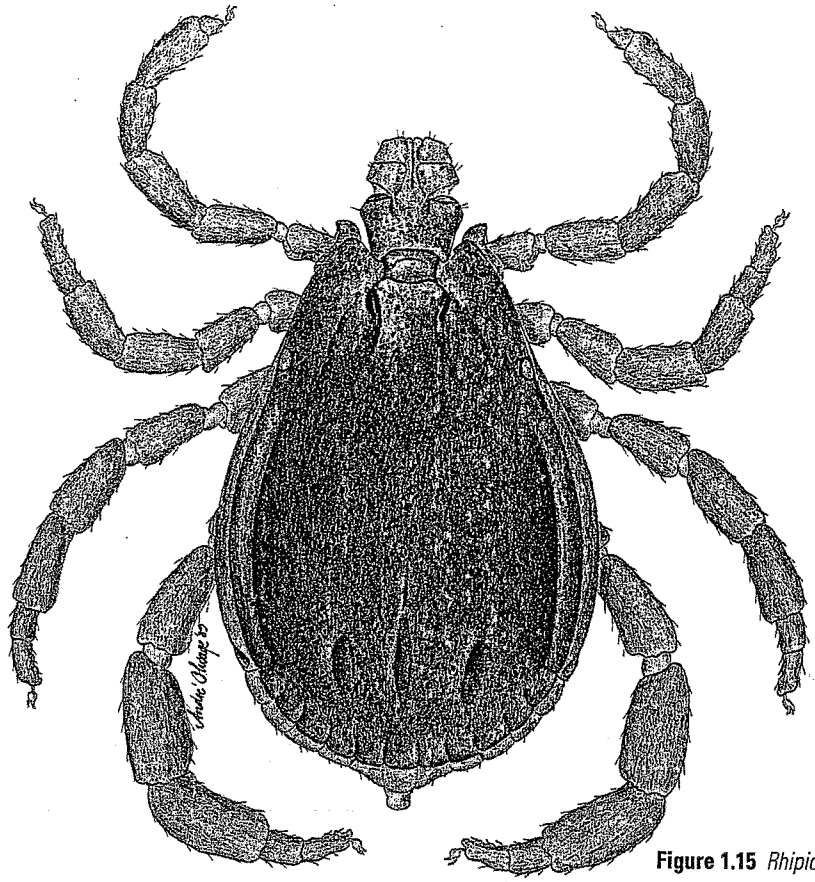

Figure 1.15 *Rhipicephalus appendiculatus* male

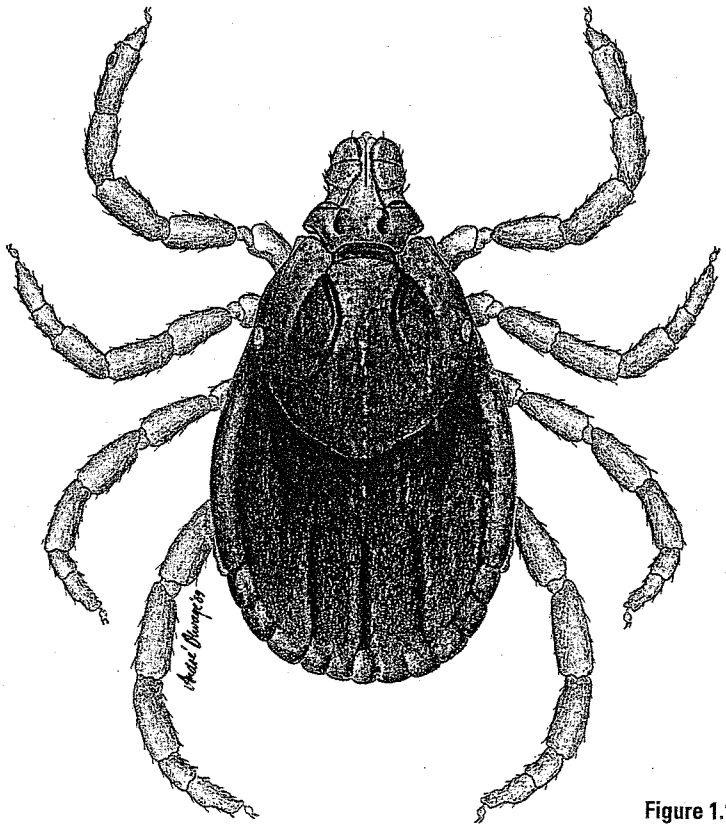

Figure 1.16 *Rhipicephalus appendiculatus* female

Distribution *Rhipicephalus appendiculatus* is an eastern, central and southern African tick.[130, 288] Its distribution extends from southern Sudan, Uganda, south-western Kenya, eastern Democratic Republic of the Congo, Rwanda and Burundi to northern, north-eastern, central and south-western Tanzania. Further south it is confined to the wetter areas, which include the highlands of Malawi, Zambia, Zimbabwe and the Angonia and Chimoio provinces of Mozambique. The extent of its distribution in the coastal areas of Mozambique is unknown. It is also present in eastern Botswana and in Swaziland. In South Africa it occurs in the Limpopo, North West, Gauteng and Mpumalanga provinces, along the east coast of KwaZulu-Natal and nearly throughout the southern Eastern Cape Province.

This tick survives best in woodland and woodland savannah regions with good vegetation cover. It tends to disappear if overgrazing occurs and it does not survive on open plains. Its distribution may vary with rainfall. It was introduced into the south-eastern lowveld of Zimbabwe during the commencement of a wet cycle in 1973, and by 1982 it was estimated that more than 1 million ha of the lowveld was infested.[181] The tick started to disappear from this region towards the end of a dry cycle in 1983 and by 1985 it could no longer be found.[186] In eastern Zambia, *R. appendiculatus* spread southwards between 1972 and 1982 and then westwards during the 1980s and 1990s.[11]

Disease transmission *Rhipicephalus appendiculatus* is the chief vector of strains of *Theileria parva* that cause East Coast fever; other strains of *T. parva* that cause Zimbabwe theileriosis; and yet others that cause Corridor disease. This tick also transmits *Theileria taurotragi,* the cause of benign bovine theileriosis; *Ehrlichia bovis,* the cause of bovine ehrlichiosis; the virus causing Nairobi (and Kisenye?) sheep disease; and when large numbers of ticks are present they may produce sufficient toxin to cause brown ear tick toxicosis. Infection with *T. taurotragi* may cause severe or even fatal disease in eland (**see Chapter 33: *Theileria taurotragi* infection**). Exotic *Bos taurus* cattle suffer serious production losses and can become secondarily infested with the larvae of the screw-worm fly if heavily infested with adult ticks. In small wildlife parks situated in high rainfall regions large infestations with *R. appendiculatus* can constitute a serious problem in several antelope species.[133]

Control Exotic cattle should receive acaricide protection throughout the summer months. Zebu (*Bos indicus*) cattle and indigenous Sanga breeds become fairly resistant to the tick and so require fewer acaricide treatments.[195, 231, 233] In the absence of theilerioses, adequate control of adults can usually be accomplished by localized application of acaricides to the ears or head. Larvae and nymphs are considerably less damaging to cattle than adults, and do not require treatment if adequate control of the adults is achieved. Heavy infestations with adult *R. appendiculatus* can also occur on horses, and these may require treatment with acaricides during the summer. Control on other domestic livestock species is unnecessary.

Regular acaricidal treatment of cattle on a mixed cattle and game ranch in Central Province, Zambia, resulted in a significant reduction in all stages of development of *R. appendiculatus* on sympatric impala and on the vegetation of the ranch.[309] Should infestation with adult *R. appendiculatus* become a problem on wildlife in small reserves, control can be achieved by various methods based on the principle of self-application of acaricide.[57, 249]

Rhipicephalus duttoni

Angolan brown ear tick

Identification, life cycle, hosts and distribution *Rhipicephalus duttoni* is an ear tick that closely resembles *R. appendiculatus* in appearance.[250] It is a three-host species of which the adults parasitize particularly domestic cattle and African buffalo.[59, 273] It occurs in the coastal and adjacent inland regions of Angola, particularly in the south. Its southern and northern distributions extend to the north-western border of Namibia and the western coast of the Democratic Republic of the Congo respectively.[288]

Disease transmission In Angola *R. duttoni* is considered to be the vector of strains of *Theileria parva* causing Corridor disease.[31]

Rhipicephalus zambeziensis

Lowveld brown ear tick, laeveldse bruinoorbosluis (Afrik.)

Identification *Rhipicephalus zambeziensis* and *R. appendiculatus* are morphologically very similar. The major difference between the adults of the two species is that those of *R. zambeziensis* have a more conspicuously punctate scutum.[291]

Hosts and life cycle Its host range, attachment sites, life cycle and pattern of seasonal abundance are also similar to those of *R. appendiculatus.*[109, 198, 288] However, on impala the vast majority of adult ticks attach around the muzzle as opposed to the ears,[150] and a larger proportion of nymphs attach to the lower legs of greater kudu than do those of *R. appendiculatus.*[198]

Distribution The distribution of *R. zambeziensis* differs from that of *R. appendiculatus.*[130, 288] It replaces the latter tick in the hot, dry river valley systems of south-eastern Africa (e.g. Luangwa, Kafue, Zambezi, Limpopo and Sabi rivers) which separate the major highland areas. In contrast to *R. appendiculatus,* it occurs in the fairly dry environments of northern Namibia and in the lowland areas of the Mozambique interior. It is also present in southern Angola, western and south-eastern Zambia, and in Tanzania north

of Lake Malawi.[288] The distributions of *R. zambeziensis* and *R. appendiculatus* overlap where there are gradual transitions between wet and dry areas. This occurs in parts of the Eastern and Southern provinces of Zambia bordering the Zambezi Valley, in eastern Botswana, and in the North West, Limpopo and Mpumalanga provinces of South Africa.[95, 130, 288] In these situations some interspecific hybridization may occur.[310] *Rhipicephalus zambeziensis* is absent from semi-desert and desert areas.

Disease transmission Strains of *Theileria parva* causing Corridor disease; strains of *Theileria parva* causing Zimbabwe theileriosis; *Theileria taurotragi,* the cause of benign bovine theileriosis; and *Ehrlichia bovis,* the cause of bovine ehrlichiosis. Although *R. zambeziensis* can, in the laboratory, transmit strains of *T. parva* associated with Zimbabwe theileriosis,[129] it is not associated with outbreaks of the disease in the field.[181] However, the presence of *T. parva* group antibodies in cattle in buffalo-free areas, in which the tick occurs in southern Zimbabwe, suggests that it does transmit subclinical infection.[181]

Control *Rhipicephalus zambeziensis* differs from *R. appendiculatus* in that its populations never build up to numbers that could be expected to cause significant production losses in cattle. For this reason there is little, if any, need to direct specific control measures against this tick species, other than to protect cattle from infection with the *T. parva* group of organisms where contact with buffalo occurs.

Rhipicephalus evertsi evertsi

Red-legged tick, rooipootbosluis (Afrik.)

Identification Adult *R. evertsi evertsi* are medium-sized ticks that are easily recognized by the dark-brown colour of their heavily punctate scuta, beady eyes and orange to red legs (**Figures 1.17 and 1.18**).

Hosts The preferred hosts of the adults are domestic and wild equids (horses, donkeys, mules and zebras) although cattle, sheep, goats and a number of antelope species, particularly eland, are also frequently parasitized.[86, 97, 100, 171] The adults attach in the peri-anal and inner thigh regions of their ungulate hosts.[8] Larvae and nymphs feed deep in the external ear canals,[8] and are found most commonly on the same ungulate hosts as the adults, as well as on hares.[109, 171]

Life cycle *Rhipicephalus evertsi evertsi* has a two-host life cycle in which the larvae moult to nymphs on the first host, the nymphs engorge, detach, fall off and moult, and the adults attach to the second host. With the possible exception of some of the colder regions the tick can complete more than one generation per year.[149] All stages may be present on hosts throughout the year, but their abundance can vary from season to season.

Distribution Of the 60-odd *Rhipicephalus* spp. present in sub-Saharan Africa, *R. evertsi evertsi* is the most widespread. It is most common in the eastern half of the continent, from Eritrea and Sudan in the north to South Africa in the south.[288] It tolerates a wide range of climatic conditions and in southern Africa the main factor limiting its distribution in the west is increasing aridity, with the critical rainfall level being about 250 to 280 mm per annum.[112]

Disease transmission *Anaplasma marginale,* the cause of bovine anaplasmosis; *Babesia caballi* and *Theileria equi,* the cause of equine piroplasmosis; *Theileria separata,* the cause of ovine theileriosis; *Borrelia theileri,* the cause of borreliosis or spirochaetosis; and the toxin causing spring lamb paralysis. This tick can also experimentally transmit *Babesia bigemina,* the cause of bovine babesiosis.[25] In the eastern highveld regions of the Mpumalanga and Free State provinces in South Africa, the synchronous moulting during spring of over-wintered nymphs gives rise to large numbers of adults,[111] and these may infest newly born lambs. As the females engorge they secrete a toxin which causes paralysis.[79] Locally this is known as spring lamb paralysis because of the season of its occurrence and the age of the animals affected.

Control Adult *R. evertsi evertsi* is easily controlled by localized application of acaricide to the peri-anal area. Usually no specific control measures are taken against the immature stages, but these could be controlled by the topical application of acaricides to the inner surface of the ears and to the ear canals. The danger of piroplasmosis in Thoroughbred racehorses often warrants the expense of treatment, in which case both the immature and adult ticks should be controlled.

Rhipicephalus evertsi mimeticus

Namibian red-legged tick, Namibiese rooipootbosluis (Afrik.)

Identification *Rhipicephalus evertsi mimeticus* looks like *R. evertsi evertsi,* but has red- and ivory-coloured banded legs similar to those of certain *Hyalomma* spp. However, the structure of its capitulum and its shorter mouthparts readily distinguish it from the *Hyalomma* spp.[250, 290]

Hosts, life cycle, distribution and control *Rhipicephalus evertsi mimeticus* would seem to have the same host preferences, predilection attachment sites and life cycle as *R. evertsi evertsi.*[288] The adults are most numerous from November to May, and the immature stages in February and March and from May to September.[16] This tick occurs in

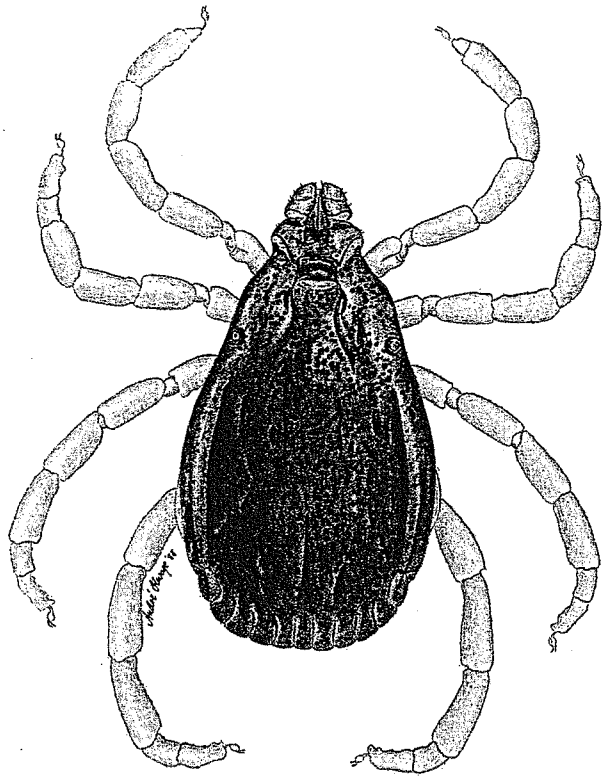

Figure 1.17 *Rhipicephalus evertsi evertsi* male

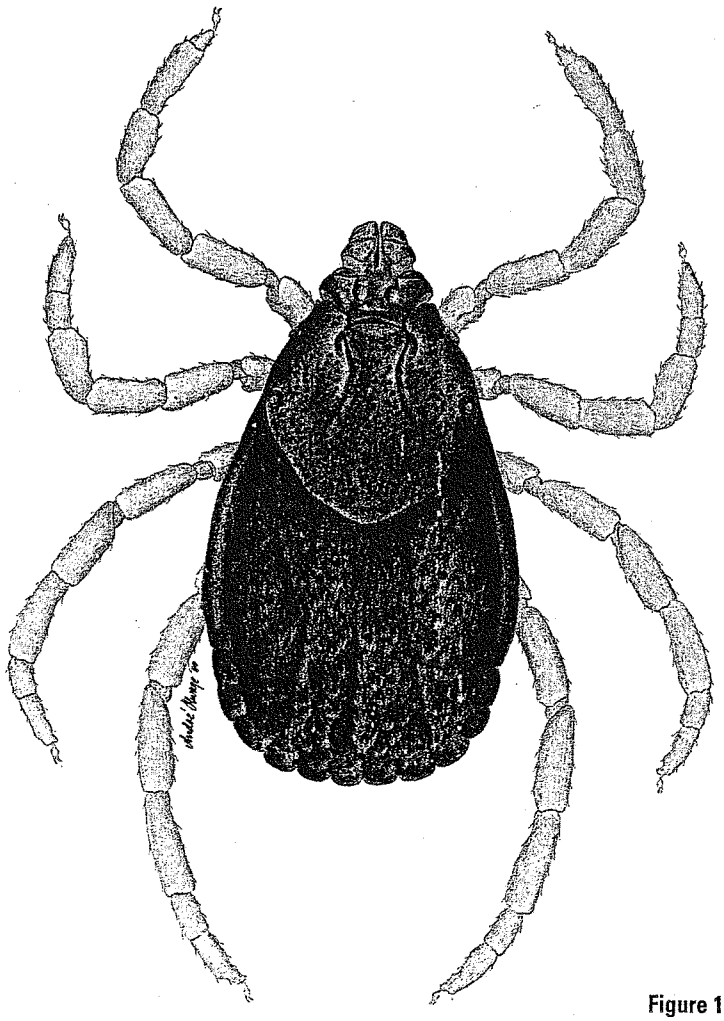

Figure 1.18 *Rhipicephalus evertsi evertsi* female

western Botswana, central and northern Namibia and southern and western Angola.[288, 290] Its control is the same as that of *R. evertsi evertsi.*

Disease transmission *Theileria equi,* the cause of equine piroplasmosis; and *Theileria separata,* the cause of ovine theileriosis.

Rhipicephalus bursa

Identification *Rhipicephalus bursa* is a large light-brown species. The scutum is covered with numerous fine punctations. In engorged males, the light tan body wall expands laterally and posteriorly beyond the darker scutal margins.

Hosts All stages of development feed on cattle, sheep, goats and camels.[288] Adult ticks attach mainly on the inner surface of the ears of sheep but can also attach on the dorsal outer surface, as well as in the perineal and inguinal regions of these animals.[288]

Life cycle *Rhipicephalus bursa* has a two-host life cycle that takes a year to complete. Adult ticks are most abundant on sheep during summer in the northern hemisphere (June and July).[288]

Distribution The Mediterranean, Adriatic and Aegean basins, and in Libya, Tunisia, Algeria and Morocco in North Africa. *Rhipicephalus bursa* is also present in some countries in southern Europe as well as in the Near East.[288]

Disease transmission *Babesia bigemina,* the cause of bovine babesiosis or African redwater; *Babesia caballi* (experimentally) and *Theileria equi,* the cause of equine piroplasmosis; *Ehrlichia ovina* (experimentally), the cause of ovine ehrlichiosis; *Anaplasma ovis,* the cause of ovine anaplasmosis; *Theileria separata,* the cause of ovine theileriosis; and the transmission of a toxin causing paralysis in sheep.

Control Acaricide can be applied to the ears of sheep during the summer months.

Rhipicephalus lunulatus

Identification, hosts and life cycle *Rhipicephalus lunulatus* is a small dark-brown tick. Its preferred domestic hosts are cattle, sheep, pigs and dogs, and its wild hosts are warthog, bushpig (*Potamochoerus* sp.) and African buffalo.[288, 289] On cattle it attaches on the legs, including the feet, and in the tail switch.[29] The hosts of the immature stages are certain rodent species and hares.[288] It is a three-host tick, and the adults appear to be most active during the rainy season.[29, 289]

Distribution It has an extensive distribution range, from Senegal in the west to Somalia in the east and thence southwards, mainly in the eastern half of the continent, to Kwa-Zulu-Natal, South Africa.[288]

Disease transmission *Babesia trautmanni* (suspected), the cause of porcine babesiosis. If *R. lunulatus* indeed is a vector of *B. trautmanni,* infection would have to be transmitted transovarially from the adults of one generation to the adults of the next generation because the immature stages do not feed on suids but on rodents and hares. Another possibility would be the migration of infected adult ticks from one host to another. This tick also produces a toxin causing paralysis in calves and lambs.

Rhipicephalus pulchellus

Zebra tick, yellow-backed tick

Identification Adult *R. pulchellus* are medium-sized to large ticks with a characteristic dark brown-and-ivory pattern on the scutum of the male, while the scutum of the female is predominantly ivory-coloured with anterior dark markings (**Figures 1.19 and 1.20**).

Hosts The adults prefer cattle, on which they may occur in large numbers, as well as camels, sheep and goats as hosts.[202, 287, 288] They attach primarily on the ears and the underside of the body, including the chest, belly, genital and peri-anal areas. Their preferred wild hosts are zebra, black rhinoceros, eland and gemsbok. The immature stages feed on these animals as well as on hares.[28, 287, 288]

Life cycle and distribution *Rhipicephalus pulchellus* has a three-host life cycle. The adults appear to be most active during the rainy season.[202] It is one of the most common ticks present in the Horn of Africa, as well as in and to the east of the Rift Valley from Eritrea in the north to north-eastern Tanzania in the south.[288]

Disease transmission *Theileria taurotragi,* the cause of benign bovine theileriosis; and the virus causing Nairobi sheep disease.

Control Strategic control of the adults can be achieved by acaricidal treatment during the rainy season.

Rhipicephalus simus

Glossy brown tick, blinkbruinbosluis (Afrik.)

Identification Adult *R. simus* are large, dark-brown ticks. The scutum has a glossy appearance and there are four longitudinal rows of large punctations on the scutum of the male.

Hosts The preferred domestic hosts of the adults are cattle, horses and dogs.[185, 208] The adults attach in the tail brush and around the feet of cattle and horses and around the head and

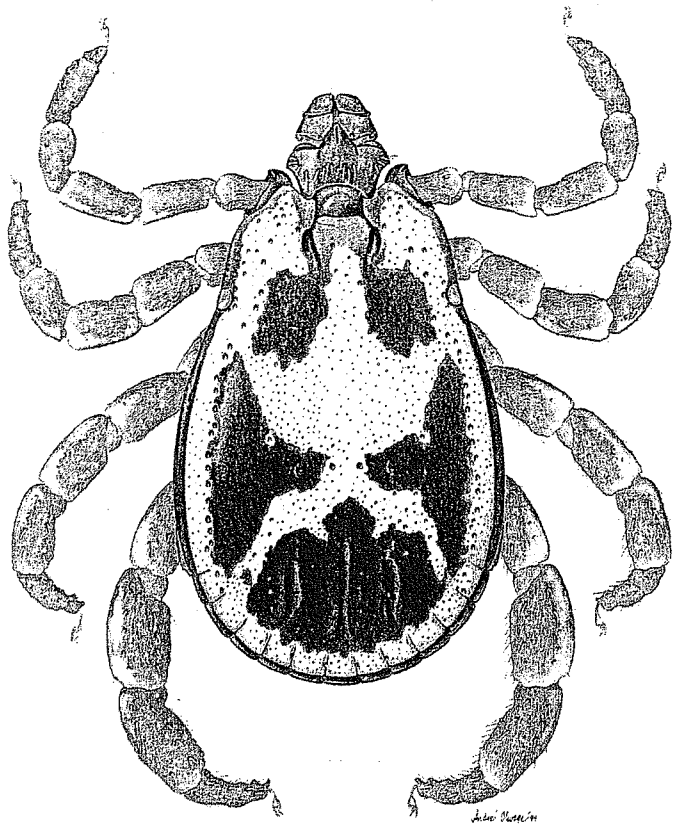

Figure 1.19 *Rhipicephalus pulchellus* male

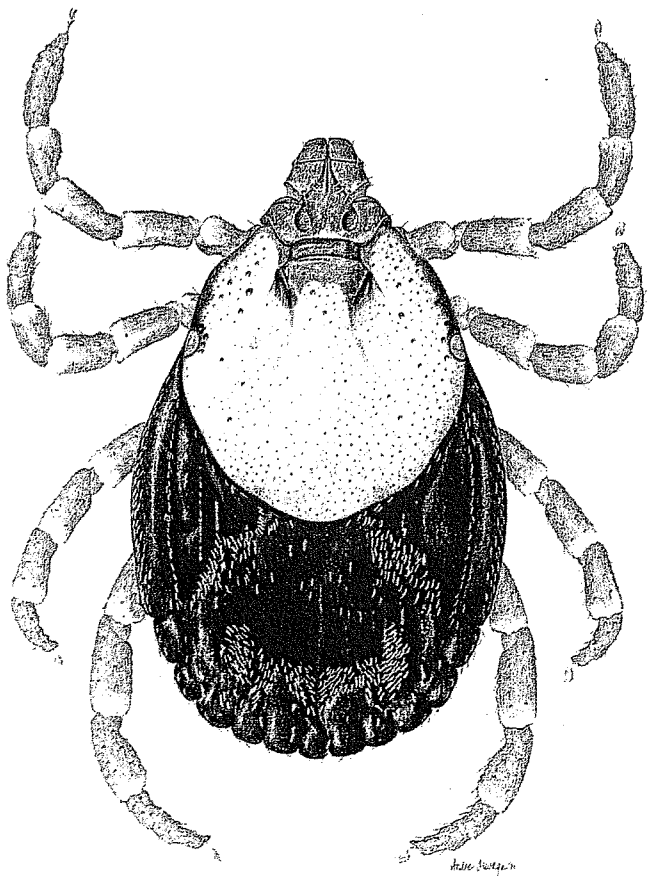

Figure 1.20 *Rhipicephalus pulchellus* female

neck of dogs.[8, 139, 288] Monogastric wild animals, such as the larger wild carnivores, zebra, rhinoceros, warthog and bush-pig, are particularly good hosts of the adults.[93, 97, 101, 185] The immature stages are parasitic on murid rodents.[19, 185, 230] Adult abundance appears to be limited by the availability of hosts for the immature stages.[108, 169]

Life cycle and distribution *Rhipicephalus simus* is a three-host tick of which the adults are most abundant during the warm, wet summer months, and the immature stages during the cooler, dry autumn to spring seasons.[19, 93, 139, 230] It is widely distributed in the moderate to high rainfall areas of Angola, Zambia, Zimbabwe, Malawi and Mozambique in the north to South Africa in the south,[288] but rarely occurs in large numbers. In the north-east of the continent it is replaced by *Rhipicephalus praetextatus* and in the north-west by *Rhipicephalus muhsammae*, both ticks that are very similar in appearance to *R. simus* and with which it has been confused in the past.[288]

Disease transmission *Anaplasma marginale*, the cause of bovine anaplasmosis; *Anaplasma centrale*, the cause of benign anaplasmosis; *Babesia trautmanni*, the cause of porcine babesiosis; and a toxin causing paralysis in calves and lambs.

Although transstadial transmission of *A. marginale* to cattle is possible,[221] this hardly seems likely to occur in the field as the immature stages feed virtually exclusively on rodents. Intrastadial transmission by infected adult ticks, and more particularly males, wandering from one host to another seems a more likely route of infection.[221] Infection of suids with *B. trautmanni* would seem to occur by the *Babesia* being passed transovarially from one generation of adult ticks to the next generation of adult ticks, which then feed on susceptible animals.[50]

Control Except as a measure to prevent anaplasmosis in susceptible cattle and occasionally to prevent paralysis in calves and lambs, acaricidal control of this species is probably not justified.[185]

Rhipicephalus turanicus

Identification *Rhipicephalus turanicus* is a moderate-sized, reddish-brown tick, which even under a stereoscopic microscope is difficult to differentiate from the kennel tick *Rhipicephalus sanguineus*, with which it has in the past been confused.[201] The latter tick virtually exclusively parasitizes domestic dogs.[288]

Hosts The domestic animals from which adult *R. turanicus* have most frequently been collected in sub-Saharan Africa are cattle, sheep and dogs, with no collections from pigs and only a few collections from horses. Its favoured wild hosts are the larger carnivores, hares and some of the larger ground-feeding birds, with a few collections from zebra and warthog.[201, 288] The hosts of the immature stages include hedgehogs, shrews, gerbils, murid rodents and hares.[288]

Life cycle and distribution *Rhipicephalus turanicus* is a three-host tick of which the adults generally are most numerous during the late rainy to early dry seasons.[109, 201]

In sub-Saharan Africa the majority of records originate from the eastern parts of the continent from Sudan, Ethiopia and Somalia in the north to South Africa in the south. However, several collections have also been made in northern Namibia. This tick occurs in several of the Mediterranean countries as well as in their immediate neighbours and also in Russia, India and Pakistan.[288]

Disease transmission *Babesia caballi* and *Theileria equi* (both suspected), the cause of equine piroplasmosis; and *Babesia trautmanni* (experimentally), the cause of porcine babesiosis.

Because *R. turanicus* has frequently been confused with *R. sanguineus*, reports of the transmission of equine piroplasmosis by *R. sanguineus* could have referred to *R. turanicus*.[60] However, attempts to transmit *B. caballi* and *T. equi* to horses transstadially from nymphs to adults with a South African strain of *R. turanicus* have been unsuccessful.[222] Transovarial transmission of *B. trautmanni* by adult *R. turanicus* seems the most likely possibility in the field,[134] because the immature stages of this tick do not normally feed on pigs.

Rhipicephalus spp.

Hosts, life cycle, distribution and disease transmission Two *Rhipicephalus* spp., other than those already mentioned, have been implicated as the cause of livestock paralysis (toxicosis). One is *Rhipicephalus warburtoni* (previously recorded as an undescribed species of the *R. pravus* group or as *R. punctatus*). The adults of *R. warburtoni* prefer domestic goats as hosts and the immature stages rock elephant shrews.[66, 70] However, all stages of development may be encountered on scrub hares and Cape hares (*Lepus capensis*).[98] On very young Angora goat kids adult ticks attach to the head and ears, while on older goats they attach here as well as on the neck and the brisket.[71] *Rhipicephalus warburtoni* is a three-host species of which the adults are most abundant on goats from September to February, and the larvae and nymphs on elephant shrews from December to July, and from April to October respectively.[66, 70] In South Africa, it is found only in the Free State and Northern Cape provinces.[288] Acaricide can be applied to the heads and ears of very young goat kids to prevent paralysis.

The other tick is *R. praetextatus* (previously recorded as *R. simus*), whose adults and immature stages have a host preference similar to that of *R. simus*.[208] On cattle the adults attach mainly to the tail brush and the feet. *Rhipicephalus praetextatus* is a three-host tick, and its adults are most abundant during the rainy season.[208] This tick is widespread

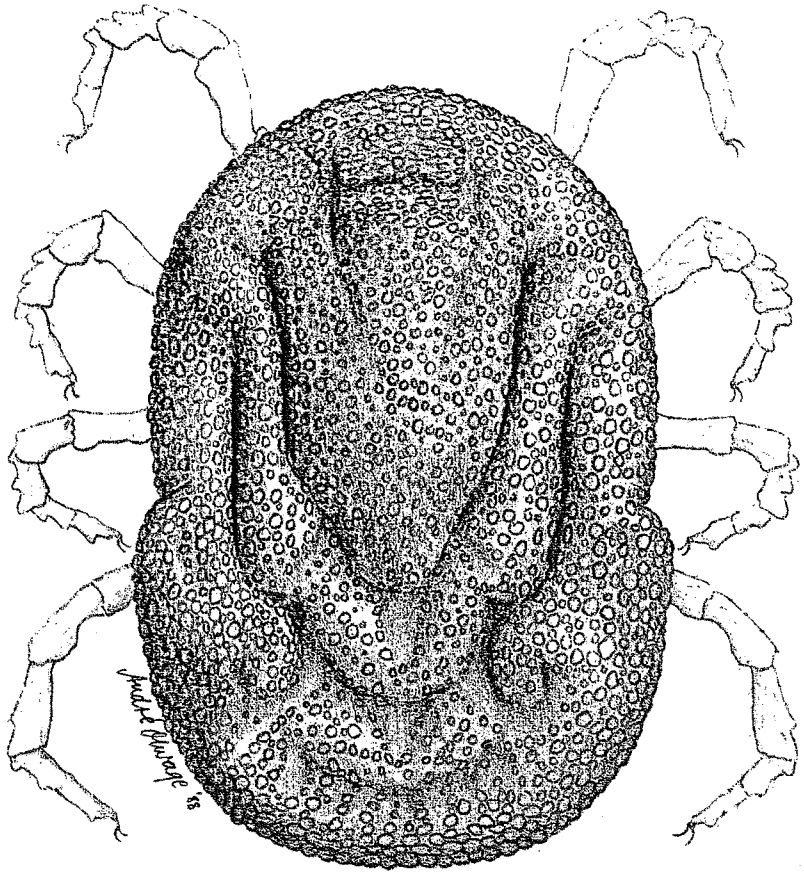

Figure 1.21 An adult tick of the *Ornithodoros moubata* complex

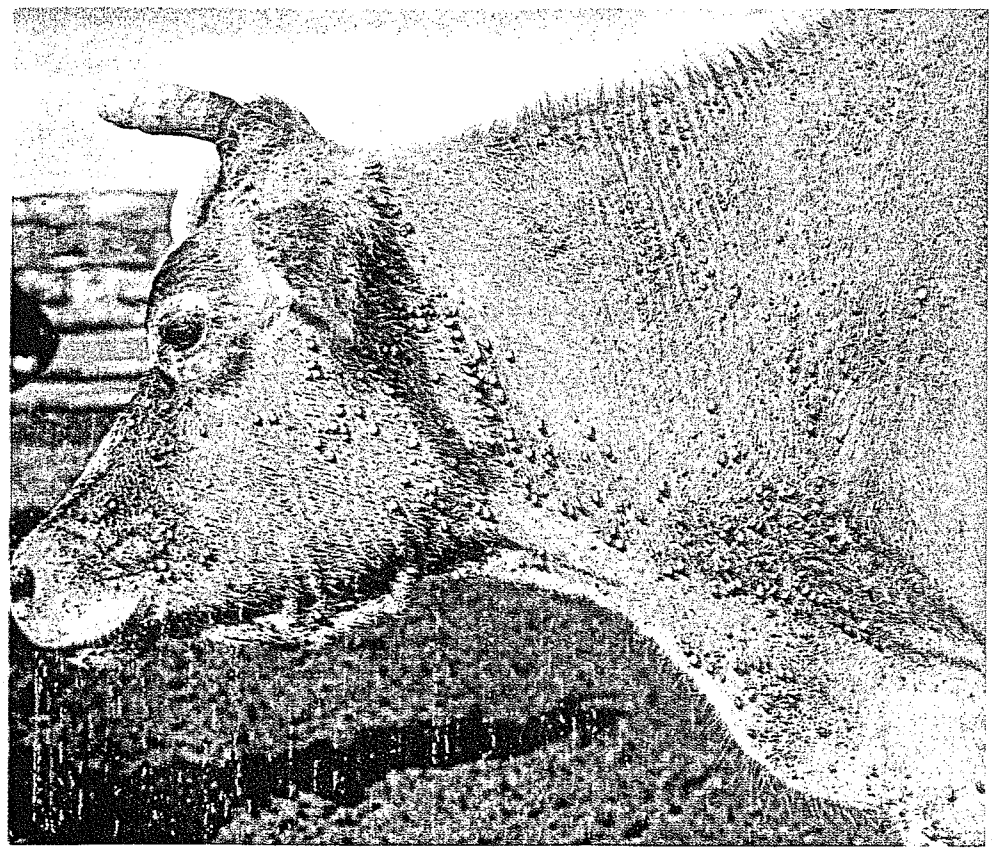

Figure 1.22 A typically heavy infestation of *Boophilus decoloratus*

in north-eastern Africa from Egypt to Tanzania.[208, 288] Not only can it cause paralysis, but it can also transmit the virus causing Nairobi sheep disease.[132]

Ornithodoros moubata complex

Eyeless tampan

Identification The eyeless tampans belonging to this complex lack the sclerotized dorsal scutum that characterizes the hard ticks, and their integument has a mammilated appearance (**Figure 1.21**). Male and female ticks can only be differentiated with certainty under a stereoscopic microscope.

Hosts and life cycle Ticks of the *O. moubata* complex are parasites of warthog, and complete their life cycle in warthog burrows. The adult female tick lays a batch of eggs in a sheltered locality in the burrow after each blood meal. After hatching the larvae do not feed, and they moult to the first nymph stage after one or two days. The first nymph stage seeks a warthog host on which it feeds briefly before moulting to the second nymph stage in the burrow. This process is repeated for each of the four or five nymph stages, with the last nymph stage moulting to an adult. The feeding periods of the various nymph stages and the adults are of short duration (approximately 30 minutes), and feeding takes place when the warthog hosts are at rest in their burrows. The nymphs can survive for two years without feeding and the adults even longer.

Distribution The distribution of ticks of the *O. moubata* complex that parasitize warthog follows that of their warthog hosts, which still occur in large areas of southern Africa (**see Chapter 98: African swine fever**). However, as the density of human habitation increases, these areas are decreasing in size and in number, and wildlife reserves are becoming the foci of warthog distribution. Locally the ticks are spread via their nymphal stages, which are commonly found on warthog foraging outside their burrows.[92, 93, 277]

Disease transmission The virus causing African swine fever is spread from male to female ticks by means of the spermatophore during mating.[217] It is transmitted transstadially and transovarially by the ticks.[218, 219]

Control No control measures need be taken against ticks in warthog burrows, but to prevent their spread warthog that are to be moved should be sprayed with an acaricide prior to translocation in order to kill tampans that may be present on their hides.

Control of ticks and tick-borne diseases

Cattle have been present in southern Africa for more than a thousand years,[83] and until the twentieth century survived without specific control measures against ticks and tick-borne diseases. It is now known that the indigenous Sanga and Zebu breeds can develop resistance to ticks,[17, 195, 231, 232, 233, 251] and will also acquire immunity to tick-borne diseases if exposed to them at an early age.[176, 304] Situations in which cattle acquire immunity to tick-borne diseases through natural exposure as calves are called endemically stable.[26] Most losses due to tick-borne diseases occur in endemically unstable situations where there are insufficient infected ticks to ensure that all calves receive challenge. Endemic instability exists in areas that are only marginally suitable for the survival of the tick vectors or where tick populations have been suppressed but not eradicated through the use of acaricides. Tick-borne diseases also cause losses if they are introduced, together with their vectors, to new regions and spread through susceptible livestock populations, or if susceptible animals, especially exotic breeds, are moved to endemic areas.

Historical perspective

Control measures against ticks and tick-borne diseases were only instituted on a large scale in southern Africa following the introduction of East Coast fever (caused by strains of *T. parva*) from East Africa. Prior to that, tick-borne diseases had not been reported as problematic in indigenous cattle, although losses caused by babesiosis and heartwater had been experienced in imported exotic cattle.[128] One of the most serious tick-borne disease problems of the nineteenth century was the spread of heartwater through the coastal areas of the Eastern Cape Province because of the spread of the vector *A. hebraeum*, introduced by cattle which had been taken to KwaZulu-Natal for winter grazing.[135] The other was the occurrence of babesiosis in cattle imported for restocking following the rinderpest pandemic of 1896.[128]

East Coast fever, which was introduced to Mozambique, Zimbabwe and South Africa in 1901/02, caused mortality of around 95 per cent in the herds of susceptible cattle (indigenous and exotic) to which it spread.[163] It caused serious economic losses, affecting agriculture, mining and commerce, all of which still used ox-drawn transport. Considerable effort was therefore devoted to the development of control measures. Early attempts at vaccination by the eminent microbiologist Robert Koch and later by Sir Arnold Theiler were largely unsuccessful. However, once it was shown by Lounsbury that the disease was transmitted by the brown ear tick, *R. appendiculatus*, [137] more successful control measures based on tick control, quarantine procedures, pasture spelling, slaughter, and dipping in arsenic solutions were instituted. Dipping proved to be the most practical and effective measure. It was widely adopted and later made compulsory. As a result the disease was brought under control fairly rapidly and then progressively eradicated. Complete eradication of East Coast fever from southern Africa was considered to have been achieved by 1960.

After the eradication of East Coast fever two options were open to southern African countries. They could either control the remaining major tick-borne diseases (babesiosis, anaplasmosis and heartwater) by vaccination and move towards reduced tick control and endemic stability, which had previously existed, or they could continue to control the diseases by intensive dipping. In South Africa compulsory dipping was first abolished on commercial cattle farms and the choice of control strategies was left to individual farmers. In the communal grazing regions of the Eastern Cape Province the management of the dipping service was handed over to the former homeland administrations during the 1970s. Although the service was maintained by these administrations, enforcement of the dipping programme was gradually relaxed and abolished after independence of the Transkei and Ciskei in 1975 and 1981 respectively. When these regions were reincorporated into South Africa in 1994 the Provincial Departments of Agriculture assumed responsibility for the dipping service and supplied both personnel and chemicals. Despite the relaxation of enforcement 98 per cent of livestock owners interviewed continued to partake in all dipping events, with disease control given as the main reason for participation.[146] Compulsory dipping has now been abolished throughout South Africa. However, the provinces of KwaZulu-Natal and Mpumalanga still provide personnel and chemicals in the communal grazing areas and report good attendance at each dipping event. In North West Province cattle owners utilizing a communal grazing area have been encouraged to participate in a research and extension project during which they were taught skills enabling them to make better informed decisions on the level of tick control they wished to achieve.[122]

The dipping policy in South Africa has had mixed results. Some progressive farmers took advantage of the availability of vaccines against babesiosis, anaplasmosis and heartwater; used them effectively, and were able to adopt flexible dipping regimes. Others, for reasons that were probably only partially understood, practised little or no tick control and contained tick-borne diseases through the maintenance of endemic stability. The majority, however, continued to treat cattle at regular intervals with acaricides. Few actually succeeded in eradicating ticks or tick-borne diseases,[44, 46, 47] and frequently the effect in endemic areas was to maintain instability where stability would otherwise have existed. In these circumstances losses due to tick-borne diseases commonly occurred if vaccines were not regularly used.

In Zimbabwe compulsory dipping continued to be enforced after the eradication of East Coast fever. However, it should be noted that Zimbabwe theileriosis caused by strains of *T. parva* persisted and it was partly for the control of this disease that compulsory dipping was continued. For 20 years after the eradication of East Coast fever, tick-borne diseases were effectively controlled in Zimbabwe by dipping. Control was particularly good in the communal farming areas, where dipping, together with overgrazing, which rendered the environment less suitable for tick survival, frequently resulted in the localized eradication of ticks.[167] However, this situation came to an end in the mid-1970s with the disruption of dipping in these areas during the pre-independence war. Large epidemics of tick-borne diseases occurred and losses over a five-year period amounted to more than a million head, which was one-third of the cattle owned by traditional farmers.[125, 170] These losses caused the Zimbabwe veterinary authorities to re-assess the national policy on tick and tick-borne disease control.[173] After independence in 1980, dipping was reintroduced in the traditional farming areas but was not strictly enforced. From 1985 a similar approach was adopted for commercial farmers, who were only required to have tick-free cattle if the animals were to be moved off their properties.

Intensive dipping is still practised in Swaziland, but is not as strictly enforced as in the past. In other countries in the region, including Namibia, Botswana and Angola, intensive dipping is not widely practised or enforced. It has been more extensively used in Malawi, Zambia and Mozambique for the control of theileriosis and heartwater, but not throughout each of these countries.

No movement away from intensive tick control can be made unless it is possible to control tick-borne diseases of cattle (and sometimes those of other livestock) by immunization, and then to manage the diseases to ensure continuing immunity. Management may involve regular immunization of calves or simply the maintenance of endemic stability through tick exposure. The requirements for tick-borne disease control are therefore reliable sources of vaccines, and knowledge of the epidemiology of the diseases. At present all vaccines against tick-borne diseases contain live organisms and for this reason either have a very short shelf-life (unfrozen blood vaccines) or must be stored at very low temperatures and transported in liquid nitrogen or on dry ice (frozen-blood vaccines or infected-tick stabilates). Vaccines against anaplasmosis, babesiosis and heartwater are currently available from Onderstepoort Biological Products, South Africa, and can be supplied to most parts of southern Africa.

Recent research

Debate in southern Africa on the role of acaricides for the control of tick-borne diseases was most intense in the early 1980s. By then there was considerable evidence from epidemiological studies that endemic stability was more widespread than previously believed and that intensive dipping frequently contributed to problems with tick-borne disease.[44, 46, 47, 116, 180, 181, 182] It was argued by many people that strict tick control was necessary to prevent large production losses, but no realistic information on the losses caused by African ticks was available although data existed on the effect of *B. microplus* on the productivity of cattle in Australia.[259, 265] In addition more quantitative information on the resistance of different breeds of cattle to African ticks was also required.

It was in response to these needs that experiments have been conducted in several African and other countries.

In Zimbabwe a project to determine the effects of *A. hebraeum* infestation on live-weight gain indicated that larvae and nymphs caused no detectable losses whereas adults did, the loss per female tick completing engorgement being approximately 10 g.[192] Estimated losses in live-weight gain for *A. variegatum* appear to be considerably more severe, amounting to 46 to 61 g per engorged female,[204] while those for *A. lepidum* amounted to 6 g.[268] In the lowveld of Zimbabwe the effects of infestation with adult *A. hebraeum* on the milk production of Sanga and Sanga x Brahman cows was measured over an 11-week period. Although the relationship between tick numbers and reduction in milk yield or calf live-weight gain during the observation period was poor, provided teats had not been damaged, an average loss in live-weight gain of approximately 6 g per calf for every engorged female tick was recorded.[193]

On a mixed bushveld farm in Mpumalanga Province, South Africa, the weaning weights of calves of which the dams were predominantly infested with *B. decoloratus*, were reduced by approximately 8 g for each engorged female present on the cows.[241] In Australia mid-lactation Holstein-Friesian cows were infested at weekly intervals with gradually increasing numbers of *B. microplus* larvae for a period of 15 weeks.[117] By week 15 uninfested control cows produced 2,86 litres more milk and 0,14 kg more butterfat per day and had gained 10,6 kg more live-weight than the infested cows. It was estimated that each engorging female tick was responsible for a loss of 8,9 ml in daily milk production and 1,0 g in body-weight gain over the trial period.

In Zimbabwe larvae and nymphs of *R. appendiculatus* caused no detectable losses in live-weight gain of Sanga and European breed cattle, whereas adult ticks caused losses which amounted to approximately 4 g for every female that completed feeding.[195] Under field conditions the weight losses caused by the adults were large in *Bos taurus* cattle (about 25 kg over one summer) as the animals had low resistance to the ticks. Losses in Sanga cattle which had high resistance, however, were small and frequently insignificant.[195] Despite severe ear damage in some animals, infestations averaging 20 engorging female *R. appendiculatus* per day had no significant effect on the milk yield of *B. taurus* dairy cows nor that of crossbred *B. taurus* x Sanga cattle kept on higher and lower planes of nutrition, respectively, under commercial management on the Zimbabwe highveld.[191] Infestation with adult *R. appendiculatus* of Sanga cows receiving nutritional supplement on the Zimbabwe highveld affected their milk yield, as judged by the weights of their calves before and after suckling, but had no significant effect on the live-weight gains of the calves compared with those of tick-free cows.[196] In Zambia tick infestations, comprising mainly *A. variegatum* and *R. appendiculatus*, on Sanga cows caused a significant decrease in the amount of milk produced.[203]

Because much of the information on the effects of ticks on their cattle hosts has been obtained using experimental single species infestations, it is of limited value under field conditions in Africa since in most regions of the continent animals are infested with several species simultaneously.[42] The effects of ticks are also often linked with those of tick-borne diseases and should be considered in conjunction with the latter. Furthermore, cattle herds contain animals of different ages, sexes and types, and experiments to determine the effects of ticks should be conducted on entire herds rather than on individual or selected age groups of animals.[42]

Two projects supported by the Food and Agriculture Organization of the United Nations have investigated the economic impact of ticks on cattle in Zambia with the aim of obtaining data on the cost-effectiveness of tick control in cattle herds maintained under management and environmental conditions similar to those in the traditional sector.[42, 203] In the first the tick-free herd performed significantly better than the tick-infested herd but the value of additional production in the form of increased milk yield, calf growth rate and fertility was less than the cost of the acaricide used. In the second project greater productivity was recorded for a herd sprayed with an acaricide once a week in the wet season and at two-weekly intervals in the dry season, compared to that of a herd sprayed every two weeks in the wet season only (October to March) and a herd receiving no treatment at all. When the costs of control were taken into account, the wet season treatment, which was designed to have the greatest impact on *A. variegatum*, but also reduced the numbers of *Hyalomma* spp. and *R. appendiculatus*, gave the best result followed by treatment throughout the year. Neither of the latter acaricidal treatment regimes prevented the transmission of East Coast fever when this was introduced into the area towards the end of the trial.[42]

On three cattle ranches in Zimbabwe regular weekly treatment proved to be economically justifiable in that it reduced *A. hebraeum* populations to imperceptible levels and eliminated mortality due to heartwater.[21] On many farms this approach would not be economically viable and farmers should select the best control options for their particular circumstances.

Tick resistance in various breeds of cattle has been compared in several countries in sub-Saharan Africa. These comparisons have demonstrated that Sanga and Zebu cattle are considerably more resistant to the commonly occurring tick species than are *B. taurus* cattle, and that crossbred cattle show intermediate resistance.[194, 231, 232, 233, 248, 251] Thus, as in Australia, the potential exists for the exploitation of genetic resistance to ticks in tick control programmes in sub-Saharan Africa.

Two new chemicals for the control of ticks have recently been tested on cattle. The one is a benzoyl phenyl urea compound, known as fluazuron, and is an acarine growth-

regulator, inhibiting the formation of chitin.[23] It is administered in a pour-on formulation, and female *B. microplus* present on animals at the time of treatment laid only a few non-viable eggs, while immature ticks died as they were unable to moult to the next stage. Protection after application lasted several weeks.[23] The efficacy of this or related compounds needs to be tested against other tick species to ensure their viability in Africa.

The second compound is a phenylpyrazone agent known as fipronil. This chemical has excellent therapeutic and persistent activity against fleas on both dogs and cats. Trials with pour-on formulations of fipronil on cattle indicate that it is effective against both *Boophilus annulatus* and *B. microplus*.[37, 38] Therapeutic and persistent efficacy are dose related and are increased by repeat treatments.

Biological control

Although several agents are effective or partially effective for the biological control of ticks it is unlikely that many of these will be commercially viable. Nevertheless, under natural conditions these agents may play a significant role in reducing tick numbers.

Domestic chickens are opportunistic predators of ticks. The indigenous varieties in particular, if allowed to scavenge amongst cattle, can consume considerable numbers of ticks, especially if the cattle are penned close to dwellings in the late afternoon and during the early morning.[55, 84, 85] Red- and yellow-billed oxpeckers (*Buphagus erythrorhynchus* and *Buphagus africanus*), which are virtually obligatory predators of ixodid ticks, take large numbers of these parasites from both domestic cattle and from several wildlife species.[7, 15, 258] The red-billed birds favour *B. decoloratus* and *R. appendiculatus* as food items,[15] whereas yellow-billed oxpeckers prefer the latter tick and *Amblyomma* spp.[286] As an aid to tick control on both wildlife and domestic cattle, red-billed oxpeckers have been reintroduced to several regions in which they originally occurred in South Africa, but from which they had in recent times disappeared.

Chalcid wasps of the genus *Ixodiphagus* are obligatory parasitoids of ixodid ticks and most species will oviposit and develop only in the nymphal stage of the ticks.[40] Several wasp larvae can successfully develop in a single engorged nymph, which is killed during this process.[40, 114] Two of the seven described species of these wasps occur in Africa, namely *Ixodiphagus hookeri* and *Ixodiphagus theilerae*.[30, 63] In Kenya adult *I. hookeri* were released over a period of one year into a field in which there were cattle naturally infested with *A. variegatum* and *R. appendiculatus*.[159] In addition the field was seeded with nymphs of both tick species. During the period of wasp release 51 per cent of *A. variegatum* nymphs but no *R. appendiculatus* nymphs collected from the cattle were infested with the parasitoid. There was also a significant decrease in the numbers of *A. variegatum* infesting the animals compared to the numbers of ticks prior to wasp release and compared to a control group of cattle.[159] In South Africa these wasps mainly parasitize the nymphs of ticks feeding on hares.[30] They can be found around the resting places of the hares and parasitize particularly the nymphs of *Hyalomma* spp.,[30] which by preference feed on these animals.[98, 109]

The infective juveniles of nematode species that are pathogenic for insects can also be pathogenic for ticks. In Guadeloupe the infective juveniles of various species of *Steinernema* and *Heterorhabditis* had no effect on any of the free-living stages of *A. variegatum* or *B. microplus* originating from the island, whereas an imported strain of *B. annulatus* was susceptible to all of them.[153] The infective juveniles of two species of *Steinernema* could kill ticks of all species tested within the genera *Amblyomma, Dermacentor* and *Rhipicephalus* in the USA.[123] However, it would appear that, unlike in insects, these nematodes are unable to multiply in ixodid ticks. The ticks are killed by bacteria of the genera *Xenorhabdus* and *Photorhabdus* that have a symbiotic association with the nematodes, and enter the ticks with the infective juveniles.[239]

Entomopathogenic fungi have been used in several countries for the control of agricultural pests and their use for the control of ticks is currently being investigated at various localities. In Kenya aqueous formulations of the spores of the fungi *Beauveria bassiana* and *Metarhizium anisopliae* induced a high mortality and reduced fecundity and egg hatchability in *R. appendiculatus* feeding on cattle.[118] These formulations also caused mortalities in all life stages of *A. variegatum* and *R. appendiculatus* in the vegetation. The comparative ease with which the spores of these fungi can be produced and artificially disseminated makes them promising potential agents for the control of ticks.

Various species of tropical pasture legumes in the genus *Stylosanthes* can trap and kill larvae of *B. microplus*.[62, 263, 266] However, more ticks are likely to settle and oviposit closer to the larger tussocks of grass plants than to the stems of the legumes.[300] Similarly, questing larvae are more likely to ascend a grass tussock than the stem of a legume and thus high legume to grass ratios are needed to ensure a useful level of tick control. A number of grasses also have anti-tick effects.[41, 276] The grasses *Melinis minutiflora* and *Brachiaria brizantha* both have a lethal effect on the free-living larvae of *B. microplus*, but *M. minutiflora* also has a repellent effect, thus making it likely that larvae will avoid it.[41]

A combination of biological and acaricidal control has been successfully incorporated in pheromone-acaricide-impregnated plastic tail tag decoys.[3, 190] These tags are more specifically designed for the control of adult *A. hebraeum* and *A. variegatum*, of which the feeding males exude a pheromone that is particularly attractive to other males, females and nymphs of the same species. The incorporation into such tags of squaline, a naturally abundant mammalian skin secretion that has a long-distance tick attractant effect on *Amblyomma americanum* may provide definite advantages.[303]

Tick and tick-borne disease models

A practical means of designing cost-effective tick control strategies is to use models.[228, 262] An ecological model was originally developed in Australia for the one-host tick, *B. microplus*.[261] It has subsequently been modified for three-host ticks and given the name T3HOST.[154] Ecological parameter values and the damage coefficient with respect to live-weight gain for *R. appendiculatus* have been fitted to T3HOST,[64] and it can now be used to simulate population dynamics and control strategies for this tick. These simulations allow the best strategies to be identified prior to the costly and time-consuming process of field-testing. For example, it has been estimated that the most cost-effective strategy for the control of *R. appendiculatus* on Zebu cattle at Lake McIlwaine in the highveld of Zimbabwe is intensive dipping for four months during the wet season (December to March).[64] The reason is that the adults, which cause losses in live-weight gain, are most abundant at this time. Extension of the dipping period could result in increased dipping costs progressively exceeding the value of increased live-weight gain. Shortening the dipping period could cause the value of decreased live-weight gain to progressively exceed the cost of dipping. Climate, geostatistics and satellite imagery have been used as predictive tools for the distribution and for the seasonal abundance of a number of economically important ticks.[61, 121, 187, 226, 227] As more data become available models will be refined and will undoubtedly become increasingly important tools for the design of tick control strategies.

Knowledge of the epidemiology of tick-borne diseases is steadily increasing and modelling is particularly useful in this respect.[32, 33, 305] Models have been developed for *E. ruminantium* transmission and its epidemiology,[43, 199] and for *B. bovis* transmission.[143, 144, 246] It should ultimately be possible to use epidemiological models to determine the best strategies for the control of tick-borne diseases in different situations.

Future control methods

It is likely that conventional live vaccines will be surpassed by a new generation of synthetic products. It is now well established that cattle and other hosts can be immunized against certain tick species by exposure to tick antigens, and considerable progress has been made in the characterization of these antigens.[294] At present the only tick against which vaccines are available commercially is *B. microplus*. This field was first pioneered by the Australians who realized that a 'concealed' antigen, which is located on the surface of the digest cells that line the gut of *B. microplus*, could be used to immunize animals against infestation with this tick.[120, 297, 299] Recombinant antigens derived from transformed cells were then incorporated in a vaccine commercially known as TickGard.[296, 298] Vaccination trials against *B. microplus* have now also been conducted on cattle in Cuba and Brazil with a commercially available recombinant antigen preparation known as Gavac.[237, 238] Both vaccines are also reported to be highly effective against *B. annulatus*.[296]

The discovery of a major gene, which infers resistance to *B. microplus*, now presents new prospects for tick control in both beef and dairy animals. This gene was found in a closed herd of the Adaptour line of cattle that results from the crossing of Hereford and Shorthorn animals, breeds that are normally highly susceptible to infestation. Homozygous carriers of this gene may acquire a stable total or nearly total resistance to *B. microplus* in early life.[76]

Many laboratories throughout the world are working on the isolation and characterization of immunizing antigens present in *Babesia*, *Anaplasma*, *Ehrlichia* and *Theileria* spp.[140, 200, 225] It seems that it is only a matter of time before some of these antigens are produced in commercial quantities, either by the application of biotechnology or by chemical synthesis. When these new generation vaccines are developed they could revolutionize our approach to the control of ticks and tick-borne diseases and have profound effects on cattle management and production throughout the tropical and subtropical regions of the world.

Integrated control

In conclusion, the control of ticks on domestic animals lies for the present in the integrated use of available technologies such as chemicals, the management of acaricide resistance, host resistance, tick vaccines, and tick-borne disease vaccines as it seems unlikely that any one of these is robust enough to stand alone.[295] The concept implies the rational use of acaricides in combination with other strategies to cost-effectively minimize production losses caused by ticks and tick-borne diseases. Such a programme could include any number of the components listed below.

Strategic control Acaricide is applied during strategic times of the year in order to control seasonal peaks in tick abundance. It is aimed mainly at adult ticks to decrease numbers to levels at which economic damage is less than the cost of control.

Opportunistic control Acaricide is applied only when tick numbers are considered to exceed the economic threshold. This strategy is effective when animals possess a high level of immunity to ticks or in regions where ticks are only sometimes a problem because of favourable climatic conditions.

Selective control Only those animals with tick burdens considered to be above the economic threshold are treated. This is more easily achieved with small herds of cattle and should reduce both treatment costs and delay the appearance of acaricide resistance. Individual animals, which continuously harbour very high tick burdens, should be culled as they are likely to pass this trait on to their offspring.

Alternation Acaricides from different chemical groups or combination formulations of acaricides are applied alternately. The inclusion of acarine growth regulators in this

regime may further help delay the development of acaricide resistance.

Management of acaricide resistance When resistance is already present, animals must not be treated with an acaricide from the chemical group to which resistance is evident before moving them to clean or rested pasture, as this will result in the new pasture becoming contaminated with resistant ticks only. An acaricide from a completely different group should be used in such an event.

Grazing strategies Avoid camps that are heavily infested with ticks during certain seasons. Thus sheep and goats must not be grazed in camps on the southern aspect of hills or mountains in the Karoo, South Africa, during autumn and winter. The Karoo paralysis tick, *I. rubicundus,* is most abundant in this type of habitat and is present only from late summer to spring. Goats and cattle can be grazed in sheep camps during summer to denude shrubs and keep the grass short, thus eliminating favourable breeding or questing sites for the tick.

With tick species that take a year to complete their life cycles, pastures can be rested from the end of the season of adult tick abundance until the commencement of the following year's season of adult abundance. Provided no hosts suitable for the immature stages are allowed on to the pastures during the intervening months, most of these ticks should have died and the numbers of adults present when the livestock are reintroduced should be minimal.

In much of southern Africa it is common practice to burn natural pastures once every two or three years during spring to control shrub invasion and remove dead plant material. These deliberate fires coincide with the post-winter synchronous hatching of *B. decoloratus* larvae and with their questing on the vegetation and consequently many are destroyed. However, the short-term effect on tick abundance does not compensate for the damage inflicted on some vegetation types by regular burning.

A high stock density may initially favour the propagation of ticks because of the abundance of hosts. However, should stock numbers become too large the habitat may be damaged to such an extent that it becomes unfavourable for the survival of some tick species. Human perturbation of the environment by chopping down trees for firewood or removing them in order to establish pastures can have the same effect.

Host resistance Sanga or Zebu cattle can be farmed with minimal tick control, ranging from none in dry areas to strategic wet-season control in higher rainfall areas, whereas *B. taurus* cattle require intensive tick control for the greater part of the year in all but dry regions. The amount of control required for crossbred cattle will be somewhere between these two extremes.

Predators Provided non-toxic acaricides are used, oxpeckers can be reintroduced into those regions in which they originally occurred. Where cattle are penned close to rural dwellings at night indigenous chickens can be encouraged to roost close to the enclosures as this will facilitate tick predation.

Immunization against ticks Recombinant vaccines are commercially available for the control of *B. microplus* with promising results against other species. The likelihood exists that more concealed immunizing antigens will be discovered and that vaccines against a multitude of tick species will ensue.

Immunization against tick-borne diseases Immunization can currently be accomplished by using blood vaccines containing virulent or attenuated organisms or using infected tick stabilates. These rather crude vaccines will undoubtedly be surpassed by recombinant antigens produced in transformed cells, or by chemically synthesized antigens.

Tick control on wildlife

Tick control on wildlife in nature reserves encompassing more than 20 000 ha should not be necessary, particularly if a sustainable number of large carnivores are present to remove stressed, weak, sick or injured animals. Problems with ticks usually occur in small wildlife reserves or on game farms, especially those under 1 000 ha in size, on which it is not practical also to keep the larger wild carnivores. Healthy wild antelopes and equids in Africa normally harbour tick burdens in excess of several thousand.[94, 95, 97] However, with the exception of large animals such as giraffe, African buffalo and eland, which may harbour large burdens of adult ticks, the majority of ticks parasitic on wildlife are usually larvae and nymphs.[77, 90, 104] Severe adult tick infestations on wildlife are therefore frequently an indication of some underlying management problem. This might be gross overstocking,[88, 133, 184] or overstocking with particular species such as eland, which are large animals that are highly susceptible to tick infestation.[100, 131] It could also be due to the introduction of wildlife species not indigenous to a region and hence not adapted to the local tick species. In the latter event these animals may not only acquire enormous tick burdens but could also succumb to diseases such as heartwater or one of the theilerioses.

Before control measures are instituted the underlying cause of the problem should be addressed. One of the first steps in this direction would be to remove any animals that are visually very heavily tick infested as well as any diseased or weak animals. The latter animals are normally severely stressed and consequently harbour large tick burdens that can lead to contamination of their surroundings. Thereafter stocking density should be examined and corrected for each wildlife species in the reserve or on the game farm. Wildlife species that historically did not occur in the region could also be removed.

Provided the habitat is suitable, the introduction of species such as blue wildebeest could be contemplated. These animals have an innate resistance to ticks and remarkably few adult ticks are found on them in their natural habitat.[90, 96] The introduction of oxpeckers can also be considered. This would only be feasible if the reserve or farm was located in a suitable habitat and was large enough to accommodate the birds, or if the surrounding cattle farmers use only acaricides that are not toxic to the oxpeckers. Although fire may kill large numbers of free-living ticks present on the vegetation at the time, its long-term effects seem to be limited, particularly if animals are not kept away from the burnt area once there is a flush of new vegetation.[158, 253]

Should chemical tick control be required, acaricide can be administered by means of a self-medicating applicator coupled to a bin containing licks or food concentrates to which the animals are attracted.[57, 249] In South Africa several wildlife species are more inclined to take supplementary feed in such bins during the winter months because of the seasonal shortage of grazing.[88] Consequently mainly immature ticks will be killed. Acaricide can be automatically applied to animals by constructing a single entrance to a watering point, thus forcing them to step on a pressure-plate or interrupt a light beam that will activate a jetting or pour-on device.[74, 157] Domestic cattle that are regularly treated with an acaricide, can also be used to control ticks on a small wildlife reserve. These animals can be introduced in the wet summer months when adult ticks are most abundant and can be herded during the day into those parts of the reserve where ticks are deemed to be most numerous. No new wildlife should be introduced on to a wildlife reserve or a game farm without having first been thoroughly treated with a reliable, broad-spectrum acaricide. This will reduce the risk of introducing ticks into a region in which they did not previously occur, as well as eliminating the stress of pre-existing tick burdens on the new introductions.

The regular treatment of domestic animals on mixed cattle and game farms can result in a significant reduction in tick numbers on the wildlife on the farm. Those tick species that use cattle as hosts for all their developmental stages, or that prefer cattle as hosts for their adults are particularly affected by this procedure.[102, 309]

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Ticks, toxins and tick resistance

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Abstract- Four tick species, namely *Ixodes rubicundus*, *Rhipicentor nuttalli*, *Rhipicephalus evertsi evertsi* and *Rhipicephalus warburtoni*, produce paralysis-inducing toxins. Two species, *Rhipicephalus appendiculatus* and *Rhipicephalus nitens*, produce immunosuppressing toxins, while *Hyalomma truncatum* produces an epitheliotropic toxin. Athough domestic animals appear to be most affected by these toxins, the ticks are primarily parasites of wildlife that, under specific circumstances, may also be affected. Wildlife may also exhibit resistance to ticks. African buffaloes acquire resistance to *Rhipicephalus* (*Boophilus*) *decoloratus*, whereas blue and black wildebeest appear to be innately resistant to most tick species.

INTRODUCTION

Rather than enemies, ticks and the diseases they transmit, should be regarded as the conservationist's friends, because they protect not only indigenous wildlife, but also the environment against human exploitation. Although most tick-induced toxicoses are reported in domestic animals, the principal hosts of the ticks responsible for these toxicoses are wildlife. Tick-induced toxicosis can, also occur in wildlife, however, but is then usually associated with some form of human interference[4]. In extensive conserved regions the visual presence of ticks in large numbers on any animal the size of a kudu and smaller is often an indication of an underlying stressful condition in the affected individual. In small conservancies the same phenomenon on animals of any size is usually symptomatic of incorrect management.

Because of the ancient association between wildlife and the ticks that infest them it is not surprising that some host species have developed resistance to infestation. This resistance may be acquired as in African buffaloes[32,37], or innate as in blue and black wildebeest[21,26].

THE TICKS AND THEIR TOXINS

Ixodes rubicundus

The Karoo paralysis tick, *Ixodes rubicundus*, is the most important cause of tick-induced paralysis in small domestic livestock and in wildlife in South Africa[4,41]. It is a three-host tick and the hosts of its adults are caracals and mountain reedbuck[23,24]. The hosts of its immature stages are rock elephant shrews, red rock rabbits and caracals[10,16,23,42]. Males rarely attach to host animals, but are frequently found attached to females. Domestic hosts of the adults are sheep, on which they attach in the ventral wool-line, and goats, cattle and dogs[6,8,11,31].

This tick is present in Karoo and Karoid regions of the Eastern, Western and Northern Cape Provinces and the southern and western Free State and in small foci at Bronkhorstspruit, Belfast and Heidelberg in Gauteng and Mpumalanga Provinces[33]. Hilly or mountainous rocky terrain with wild olive trees, *Olea africana*, the shrub, *Rhus erosa* and the grass species, *Merxmuellera disticha*, all contribute to an ideal habitat for the tick and for the small mammal hosts of its immature stages.

The life cycle of *I. rubicundus* takes two years to complete[13]. Female ticks are present on mountain reedbuck, sheep and other hosts from late autumn to early spring of the first year[6,13]. The eggs that they oviposit after detaching 'over-summer', and hatch synchronously the following autumn[13]. The resultant larvae are most abundant on rock elephant shrews and on red rock rabbits during late summer to winter, and nymphs during winter to spring. Peak detachment of engorged nymphs from their rock elephant shrew occurs about 1.5 hours after sunrise with a second peak at dusk[3]. The elephant shrews are active during these periods and this ensures that the nymphs that detach are widely dispersed and thus enhances the chances of the ensuing adults of finding a host[3]. The detached nymphs 'over-summer' and moult to adults the following autumn[13]. The grass, shrubs and wild olives afford protection for the red rock rabbits and shrews and the mat of leaves that forms under this vegetation supplies shelter to the ticks and their eggs. This mat also ensures the high relative humidity essential for the survival of the newly hatched larvae.

The lower the mean minimum temperature during the 2 months preceding the start of tick activity, the earlier it commences[14]. This can differ by 4 weeks from year to year on the same farm. Adult ticks quest on the grass at a height of *ca.* 40 cm[40], and more migrate onto the grass at lower temperatures than at higher. Most ticks can be collected from grass within 2 m of the canopy of wild olive trees. A greater proportion of ticks questing on the grass react to shadows and radiation heat or host odour at lower rather than at higher temperatures[12]. The majority also react to a single perturbation of the substrate, but constant perturbation results a progressive de-cline in the proportion of ticks reacting[12]. Adult ticks appear on host animals earlier in the autumn and winter in the south of the country than in the north, and peak numbers are present within 4 weeks of activity commencing[14,28].

Female ticks produce a toxin that causes paralysis in sheep and goats, but young calves and antelopes may also be affected. The occurrence of paralysis is dependent upon the number of female ticks per kg of host mass[7]. A large percentage of previously para-

lysed animals may become paralysed again during the same season[9]. If the ticks are removed timeously the symptoms are reversed within a few hours.

Fatal paralysis has been observed in springbok forced to graze in hilly terrain during winter because sheep have been moved into the plains to forestall paralysis[4]. It also occurs in young and subadult gemsbok in the southern Free State and plays a major role in deterring the introduction of foreign antelope species into regions where the tick is present.

Rhipicentor nuttalli

This a large brown tick superficially resembling ticks of the genus *Rhipicephalus*. It is a three-host species and the adults feed on hedgehogs and on leopards[38], and the immatures on elephant shrews[15]. It is probably present throughout the country, but is never encountered in large numbers. The adults can cause paralysis in domestic dogs[38,39].

Rhipicephalus evertsi evertsi

The red-legged tick, *R. e. evertsi* is easily recognisable because of its orange legs and very dark brown dorsal scutum. The preferred hosts of the adults are zebras, eland, horses, sheep, goats and cattle[44]. The larvae and nymphs infest the same hosts as the adults and also smaller antelopes and scrub hares[44]. The immature stages attach deep in the ear canals, while the adults are found on the hairless area around the anus as well on the inner thighs and adjacent belly.

With the exception of the Northern Cape Province it is present throughout South Africa[44]. This is a two-host tick. It is active mainly during the summer on the Highveld, and throughout the year in warm areas[25]. More than one life cycle can be completed in a year.

The saliva of engorging female ticks weighing between 15 and 21 mg contains a toxin that causes paralysis in lambs[17,18], known as spring lamb paralysis. This paralysis occurs due to a congruence of circumstances. In the Highveld regions of South Africa over-wintering nymphs synchronously moult to adults in spring[25], and the male and female ticks attach simultaneously resulting in a slow-down in the engorgement of females, which consequently remain in the toxic phase for a longer time[17]. The occurrence and severity of this paralysis is dependent upon the number of female ticks simultaneously reaching an engorgement weight between 15 and 21 mg in relation to the weight of spring lambs born at this time[19,20].

Rhipicephalus warburtoni

The adults of the brown paralysis tick, *R. warburtoni*, can cause paralysis in goat kids, to which they attach on the head and ears[5]. Whether they can or do cause paralysis in the young of antelopes is unknown. The wildlife hosts of the adults are antelopes and Cape and scrub hares, and the domestic hosts goats, sheep and cattle[44]. The adults are hunters and quest for their hosts from the soil surface. They respond to CO_2 and host odour, and depending on wind direction will react to a CO_2 source at a distance of 15 m[12]. They are thus attracted to very young kids that are hidden by their dams. The imamture stages parasitize rock elephant shrews and Cape and scrub hares[10,16,44].

The tick is present in south-west Free State Province, particularly in hilly terrain[44]. It is a three-host tick and the life cycle takes a year to complete. Adults infest goats from spring to late summer[8], and larvae infest rock elephant shrews and hares in the greatest numbers from late summer to winter, and nymphs from winter to spring[10].

Rhipicephalus appendiculatus* and *R. nitens

Severe infestations with the brown ear ticks may result in immuno-suppression[35,43]. *Rhipicephalus appendiculatus* is present in the northern and eastern bushveld regions of the country and *R. nitens* occurs in the fynbos regions of the Western and Eastern Cape Provinces[44]. Eland seem to be the most severely affected by the toxins produced by these ticks[34] (Horak 1992, unpublished data), but springbok in the Western Cape Province can also be affected (Horak 1992, unpublished data). Severe infestations of wildlife are usually due to overstocking.

These are both three-host ticks, completing only one lifecycle annually. The adults are present from mid to late summer and attach to the ears and heads of their hosts[22,44].

Hyalomma truncatum

The adults are easily recognisable by their red-brown and ivory-coloured banded legs, dark scutum and long mouthparts. The adults prefer large wild herbivores, particularly giraffes and eland, and the immature stages scrub hares and rodents[26]. The adults attach around the hooves, in the axillary region, perianally, the lower perineum and in the tail brush. The adults are hunters and are attracted by vibrations and large dark objects. This is a two-host tick and the life cycle takes a year to complete. The adults are active mainly during the summer months and the immature stages are present on hares from autumn to spring[26]. With the exception of the Eastern Cape Province, the eastern half of the Free State, south-eastern Gauteng and Mpumalanga and southern KwaZulu-Natal provinces, *H. truncatum* is present throughout South Africa[33].

The females of certain strains of *Hyalomma truncatum* contain a toxin in their saliva which causes sweating sickness, an acute dermatitis, in cattle, particularly calves[1,36]. When the ticks infest dogs they tend to cluster at one site and can cause severe penetrating necrosis[2].

TICK RESISTANCE

In domestic cattle bulls usually harbour greater numbers of ticks than cows, and the indigenous breeds of cattle are capable of acquiring resistance to ticks provided they are challenged as calves. It is thus not surprising that some of the larger wild ruminants demonstrate the same traits. Kudu bulls are invariably more heavily infested with the adults of *Amblyomma hebraeum* and of *Rhipicephalus* (*Boophilus*) *decoloratus* than kudu cows[27], and nyala bulls are more heavily infested with the adults of *R.* (*B.*) *decoloratus*, *R. appendiculatus*, *Rhipicephalus maculatus* and *Rhipicephalus muehlensi* than nyala ewes[29] (Table 1).

African buffaloes, provided they are challenged as calves, would seem to develop a strong immunity to infestation with *R.* (*B.*) *decoloratus* by the time they reach one year of age[32,37] (Table 2). Blue wildebeest are innately resistant to infestation with a

variety of tick species virtually from birth[21,30] (Tables 3, 4), and the same seems to apply to black wildebeest[26] (Table 5). However, this resistance can be broken down by stress, most notably if the animals are diseased, injured or very old, or if they are translocated to foreign habitats[21] (Tables 4, 5).

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TABLE 1 Average numbers of ticks collected from male and female kudus and nyalas examined in pairs

Tick species	Average number of adult ticks collected			
	Kudus (number examined)		Nyalas (number examined)	
	Males (15)	Females (15)	Males (24)	Females (24)
Amblyomma hebraeum	33	3	3	2
R. (Boophilus) decoloratus	806	492	105	29
Rhipicephalus appendiculatus	39	18	345	7
Rhipicephalus maculates	-	-	10	1
Rhipicephalus muehlensi	-	-	646	292

TABLE 2 *Rhipicephalus* (*Boophilus*) *decoloratus* collected from African buffaloes in KwaZulu-Natal nature reserves

Hosts (No. examined)	Total number of *R.* (*B.*) *decoloratus* collected				
	Larvae	Nymphs	Males	Females	Total
Adult African buffaloes (9)	1 442	112	62	40	1 656
Ratio	**36.0**	**2.8**	**1.6**	**1.0**	
African buffalo calf (1)	234	178	186	120	718
Ratio	**1.9**	**1.5**	**1.5**	**1.0**	

TABLE 3 *Rhipicephalus* (*Boophilus*) *decoloratus* collected from blue wildebeest, impalas and kudus in the Kruger National Park

Hosts (No. examined)	Total number of *R.* (*B.*) *decoloratus* collected				
	Larvae	Nymphs	Males	Females	Total
Blue wildebeest (47)	19 722	3 805	1 271	940	25 738
Ratio	**21.0**	**4.0**	**1.4**	**1.0**	
Impalas (135)	226 612	101 981	37 724	18 024	384 341
Ratio	**12.6**	**5.7**	**2.1**	**1.0**	
Kudus (95)	161 815	107 711	35 959	18 140	323 625
Ratio	**8.9**	**5.9**	**2.0**	**1.0**	

TABLE 4 Average numbers of ticks collected from Burchell's zebras, impalas, kudus and blue wildebeest in the Kruger National Park

Host	Number examined	Average number of ticks
Burchell's zebras	33	3 432
Kudus	95	4 543
Impalas	135	4 205
Blue wildebeest	47	812
Blue wildebeest calf with broken leg	1	2 732

TABLE 5 Average numbers of ticks collected from mountain zebras, eland and black wildebeest in the Mountain Zebra National Park

Host	Number examined	Average number of ticks
Mountain zebras	14	8 348
Eland	11	3 616
Black wildebeest	9	156
Very old black wildebeest	1	13 019

CHAPTER 10

APPRAISAL

Presentation of data

I was faced with three possibilities for the format in which the data constituting the body of this treatise could be presented. Firstly, by tick species, this would, however, have been virtually impossible as the majority of my publications include findings relating to several tick species, and to follow this route would have led to fragmentation of the publications and frequent repetition. The second choice was to present the data according to the provinces in which the studies had been conducted. Although this would have been possible, duplication of data would have been inevitable for those surveys conducted across provincial borders. The third option, which I have chosen, was to link the various publications to a particular topic or to the host species investigated. This has resulted in a minimum of repetition and hopefully a more readable document.

The role of ticks

In large ecosystems, free from human interference, ticks and other parasites as well as predators fulfil an important role in the selection of host populations for fitness. Young animals, usually until the age of 12 to 18 months, and before they develop resistance, are often heavily infested with parasites. Weaker individuals and those that do not develop an effective immune response often succumb, and are caught by predators before they can contribute towards the gene pool. Diseased, injured, stressed or maladapted young or older animals as well as very old animals frequently have compromised immune systems. They become heavily infested with ticks and other parasites (Horak 2006) resulting in a further deterioration in their condition and thence rapid removal from the environment by predators. Between the parasites and the predators the population is thus continuously screened for fitness.

In smaller systems, the indigenous ticks and the diseases they transmit, protect the *status quo*. Wildlife that is trans-located into such a system often become severely infested with ticks and either die from the infestation or from diseases transmitted by the ticks. Examples of this are numerous in, that with the exception of the indigenous domesticated species, cattle, sheep, goats and dogs must be considered as historical introductions of foreign species into a wildlife habitat. The tick infestations and tick-borne diseases from which they suffer are processes by which nature's balance is restored.

Biodiversity

One of the advantages of tick infestation is that it maintains the species diversity of the various hosts indigenous to a region by preventing swamping of resident hosts by non-resident introductions. However, the species diversity of indigenous ticks is also in danger. The survey by Nyangiwe & Horak (2007), conducted in the eastern region of the Eastern Cape Province, clearly indicates that the introduced Asiatic blue tick *Rhipicephalus* (*Boophilus*) *microplus* has spread throughout the region, compared to the more limited distribution mapped for it by Howell, Walker & Nevill (1978) a few years ago. A similar occurrence has been reported in Limpopo Province (Tønnesen, Penzhorn, Bryson, Stoltsz & Masibigiri 2004), while in southern Mozambique the displacement of the indigenous *Rhipicephalus* (*Boophilus*) *decoloratus* by *R.* (*B.*) *microplus* is virtually complete with only a few isolated pockets remaining (Matos, Neves & Horak 2007, unpublished data). However, although the distribution range of *R.* (*B.*) *decoloratus* in southern Africa might be waning, the tick is unlikely to disappear. This is because of the numerous wildlife species that it utilizes as hosts, whereas *R.* (*B.*) *microplus* is a tick of domestic cattle, and perhaps goats, and has not adapted to wildlife.

Host preference

The large variety of tick species recovered in my studies and the large number of host species examined, particularly sympatric host species examined during the same time frame, make it possible to determine trends in host preference. With a few notable

exceptions, the adult ticks that infest domestic and wild ruminants show few host preferences. The ticks that comprise the exceptions are, however, not necessarily species specific, but infest host species that are closely related. Some of these exceptions are *Amblyomma exornatum*, a tick of varanid lizards, *Varanus* spp. (Walker 1991; Horak, McKay, Henen, Heyne, Hofmeyr & De Villiers 2006d); *Amblyomma sylvaticum*, a tick of angulate tortoises, *Chersina angulata* (Horak *et al*. 2006d); *Dermacentor rhinocerinus*, a tick of black and white rhinoceroses, *Diceros bicornis* and *Ceratotherium simum* (Keirans 1993); *Haemaphysalis hyracophila* and *Rhipicephalus distinctus*, both ticks of rock dassies, *Procavia capensis* (Horak & Fourie 1986; Walker 1991; Walker, Keirans & Horak 2000); *Ixodes matopi* and *Rhipicephalus oreotragi*, ticks of klipspringers, *Oreotragus oreotragus* (Spickett, Keirans, Norval & Clifford 1981; Walker *et al.* 2000); *Rhipicephalus arnoldi*, a tick of Smith's red rock rabbits, *Pronolagus rupestris* (Horak, Fourie, Novellie & Williams 1991b); and *Rhipicephalus oculatus*, a tick of Cape and scrub hares, *Lepus capensis* and *Lepus saxatilis* (Horak & Fourie 1991; Walker *et al*. 2000). It is perhaps significant that rock dassies, red rock rabbits and klipspringers, all known for their rocky habitat preferences, and hence patchy distributions, harbour tick species that are peculiar to them.

The presence of a large number of easily visible adult ticks, belonging to a single species, on a large animal is often construed as evidence that the particular animal is a host species favoured by that tick. The large number of ticks may, however, only be a function of size, in that as a general rule the larger the host species the larger the number of adult ticks it is likely to harbour (Horak, MacIvor, Petney & De Vos 1987; Gallivan & Horak 1997).

The immature stages of most tick species are more catholic than the adults in their choice of hosts, but some associations are noteworthy, particularly because of their implications for the transmission of disease. The immature stages of three of the paralysis-inducing ticks, namely *Ixodes rubicundus*, *Rhipicentor nuttalli* and *Rhipicephalus warburtoni* all prefer elephant shrews, and particularly rock elephant shrews, *Elephantulus myurus*, as hosts (Fourie, Horak & Woodall 2005). The immature stages of *Hyalomma marginatum rufipes*, the tick implicated as a vector in most

instances of Crimean-Congo haemorrhagic fever in people in South Africa, prefer Cape hares and scrub hares and ground frequenting birds as hosts (Horak & Fourie 1991; Van Niekerk, Fourie & Horak 2006).

Seasonal abundance

During the various longer-term studies, in which regular monthly collections of ticks were made, the seasonal abundance of two one-host ticks, five two-host ticks and 24 three-host ticks were determined. *Margaropus winthemi*, a one-host tick, was most numerous on Cape Mountain zebras, *Equus zebra zebra*, and eland, *Taurotragus oryx* in the Mountain Zebra National Park during winter and was very nearly absent on these animals during summer (Horak *et al.* 1991b). Peak numbers of questing larvae of *R.* (*B.*) *decoloratus*, another one-host species, collected from the vegetation in the Kruger National Park during the spring and early summer months (Spickett, Horak, Van Niekerk & Braack 1992), are reflected in the peak tick burdens of greater kudus, *Tragelaphus strepsiceros* (Horak, Boomker, Spickett & De Vos 1992b), and impalas, *Aepyceros melampus* (Horak, Gallivan, Braack, Boomker & De Vos 2003), in the park during the same months.

The immature stages of *Hyalomma glabrum*, *H. marginatum rufipes* and *Hyalomma truncatum*, all two-host ticks, use ground-frequenting birds, hares, or rodents as hosts, on which they are present in peak numbers from autumn to spring (Horak *et al.* 1991b; Horak & Fourie 1991; Horak, Spickett, Braack & Penzhorn 1993). The adults utilize large ungulates, on which they are most numerous during summer (Horak *et al.* 1991b). Only one life cycle is completed annually. The immature stages of development of *Rhipicephalus evertsi evertsi* and *Rhipicephalus glabroscutatum*, both of which are two-host ticks, use the same host species as the adults. These include small to large antelopes and domestic ruminants. *R. evertsi evertsi*, however, can complete more than one life cycle annually, and thus displays more than one peak in abundance of both the adult and immature stages during the course of a year (Horak, Williams & Van Schalkwyk 1991a). *R. glabroscutatum*, on the other hand, completes only one life cycle

per annum, with its immature stages present from late summer to spring and adults from spring to late summer (Horak *et al*. 1991a).

The immature stages of nine of the 24 three-host ticks for which seasonal abundances were determined, namely *Haemaphysalis elliptica*, *I. rubicundus*, *R. nuttalli*, *Rhipicephalus exophthalmos*, *Rhipicephalus follis*, *Rhipicephalus gertrudae*, *Rhipicephalus simus*, *Rhipicephalus turanicus* and *R. warburtoni*, utilize small mammals to complete their life cycles, and the adults larger mammals. Depending on the tick species these larger mammals may include zebras, *Equus* spp., warthogs, *Phacochoerus africanus*, domestic and wild carnivores, and domestic and wild ruminants. However, the adults of three of the abovementioned nine species, to wit *R. exophthalmos*, *R. turanicus* and *R. warburtoni*, utilize scrub hares, *Lepus saxatilis*, along with larger animals as hosts. The seasonal abundance of all stages of development of six of the nine tick species as well as that of the adults of the remaining three species has been determined, namely that of all stages of development of *H. elliptica* (Fourie, Horak, & Van Den Heever 1992; Horak, Emslie & Spickett 2001), *I. rubicundus* (Horak *et al*. 1991b), *R. nuttalli* (Fourie *et al*. 2005), adults of *R. exophthalmos* (Horak 1999), all stages of *R. follis* (Horak *et al*. 1991b; Petney, Horak, Howell & Meyer 2004), adults of *R. gertrudae* (Horak & Matthee 2003), all stages of *R. simus* (Horak, Boomker, De Vos & Potgieter 1988; Petney *et al*. 2004), adults of *R. turanicus* (Horak, Spickett & Braack 2000), and all stages of *R. warburtoni* (Fourie & Horak 1991; Fourie *et al*. 2005).

The larvae and nymphs of the remaining 15 tick species usually, or might, infest the same hosts as the adults to complete their life cycles. The seasonal abundance of several of these species, but not all, are fairly similar, with larvae most numerous from autumn to winter, nymphs from winter to spring and adults at some period between spring and late summer. The species for which patterns of seasonal abundance for all stages of development have been determined are *Amblyomma hebraeum* (Horak *et al.* 1992b; Horak 1999), *Amblyomma marmoreum* (Horak, McKay, Heyne & Spickett 2006a), *A. sylvaticum* (Horak *et al*. 2006d), *H. hyracophila* (Horak *et al.* 1991b), *Haemaphysalis silacea* (Horak *et al.* 1991a, 1992b; Horak 1999), ticks of the *Ixodes pilosus* group

(Horak, Keep, Spickett & Boomker 1989), *Rhipicephalus appendiculatus* (Horak *et al.* 1992b, 2003; Horak 1999), *R. arnoldi* (Horak *et al.* 1991b), *R. distinctus* (Horak *et al.* 1991b), *Rhipicephalus kochi* (Horak *et al.* 2003), *Rhipicephalus maculatus* (Horak, Boomker & Flamand 1995), *Rhipicephalus muehlensi* (Horak *et al.* 1995), *Rhipicephalus nitens* (Horak *et al.* 1991a), *R. oculatus* (Horak *et al.* 1991b; Horak & Fourie 1991), ticks of the *Rhipicephalus pravus* group (Horak *et al.* 1993), and *Rhipicephalus zambeziensis* (Horak *et al.* 1992b, 2003). The life cycles of 23 of these ticks take one year to complete, while the life cycle of *I. rubicundus* takes 2 years to complete. Its larvae are most numerous from autumn to winter, and nymphs from winter to spring of the first year, while the adults are most abundant during autumn to spring of the following year (Horak *et al.* 1991b; Fourie *et al.* 1992). It is quite probable that some cohorts of the tortoise ticks *A. marmoreum* and *A. sylvaticum* also take more than one year to complete their life cycles.

Geographic distribution

Although none of my collections were made with the specific intention of determining the geographic distribution of particular tick species, the fact that the sites at which the collections were made were nearly always recorded, and that I collected ticks at a multitude of localities, have made a considerable contribution to our knowledge in this field, particularly where some of the more rare species are concerned. The ability to identify all stages of development of the large number of tick species frequently collected at a single site in southern Africa also meant that locality data were simultaneously collected for more than one species. My data, added to the large amount of data previously collected, provided the basis for many of the maps illustrating the geographic distributions of nearly all species of the genus *Rhipicephalus* in southern Africa (Walker *et al*. 2000). This is even more applicable to the maps drawn for five of the ixodid tick species and the single argasid tick that infest reptiles (Horak *et al.* 2006d).

Accurate data on the geographic distribution of ticks in southern Africa will become increasingly more relevant in the future in light of global warming, and with the large

scale movement and conservation of wildlife in some regions and its total destruction in others. Certain species, like the rhinoceros tick *D. rhinocerinus*, has, and will, with its rhinoceros hosts become extinct in large tracts of Africa, while others will expand their ranges.

Control

The control of ticks can be achieved in several manners, the most common, and particularly in the case of wildlife, the most undesirable, is the application of chemicals directly to host animals. Chemical control applied to domestic animals has resulted in selection for acaricide resistance in several of the tick species targeted. The difficulty with which acaricides can be applied at accurate dosages levels to wildlife, or even at all, is perchance a blessing in disguise. Poor control will ensure that the wild hosts of ticks that also infest domestic livestock will serve as refugia for acaricide-susceptible strains of these arthropods. They will thus act as an essential reservoir of susceptible ticks in any control programme designed to counteract acaricide resistance in ticks on sympatric domestic stock. This may sound paradoxical, but while acaricide resistant ticks on domestic stock are being eradicated it is essential that they are replaced with acaricide susceptible ticks. This will assist in maintaining immunity in the domestic stock to both the ticks and the diseases that they may transmit. What better source of susceptible ticks than sympatric wildlife?

The need for chemical control of ticks on wildlife is often indicative of bad management. This may be overstocking, particularly with large host species, or because wildlife that are not indigenous to the region have been introduced. Overstocking with eland is especially common. These large animals have little inherent resistance to ticks, and hence harbour huge loads of adult ticks (Horak, Golezardy & Uys 2007), resulting in pollution of an already inadequate area with enormous numbers of tick larvae and nymphs. Regular chemical treatment of wildlife also carries with it the possibility of the loss of resistance in the treated wildlife both to the ticks that infest them and the tick-borne diseases transmitted by these arthropods.

A reduction in tick numbers on wildlife can indirectly be achieved by treating sympatric domestic animals, particularly cattle, with acaricides. Because of the cattle's large size most adult ticks will attach to them, and not to the wildlife, and can then be eradicated by treating the cattle (Horak & Knight 1986; Zieger, Horak, Cauldwell, Uys & Bothma 1998c). If cattle are not already present on a property, their introduction and treatment during the summer months, when most adult ticks are present, can be considered. This management strategy will also assist in maintaining refugia of chemically susceptible ticks on their wildlife hosts.

Control can also be achieved by the introduction of predators, of which oxpeckers are the most efficient (Bezuidenhout & Stutterheim 1980). Other species of birds can also act as opportunistic predators (Penzhorn & Horak 1989). Certain host species, notably blue and black wildebeest are innately resistant to ticks (Horak, De Vos & Brown 1983; Horak *et al*. 1991b) and can be used for this purpose in a mix with other more susceptible wildlife species. African buffaloes, *Syncerus caffer*, provided they have previously been challenged with ticks, acquire resistance to reinfestation with *R.* (*B.*) *decoloratus* (Norval 1984; Horak, Golezardy & Uys 2006c). This attribute could possibly be used to advantage on properties on which buffaloes are farmed with greater kudus and impalas, both of which are highly susceptible to infestation with this tick (Horak *et al*. 1992b; 2003).

Fire as a means of reducing the numbers of free-living ticks questing for hosts on the vegetation (Spickett *et al*. 1992; Horak, Gallivan, Spickett & Potgieter 2006b), is only effective if animals are kept off the recently burnt area until the majority of ticks that have survived the fire have died.

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CHAPTER 11

PRODUCTS

Nearly all the research that has gone into the papers comprising the substance of this thesis has been descriptive or observational in character, and hence the knowledge value of any of my findings reside more in their uniqueness compared to older descriptive works rather than any discoveries made by scientific experimentation. Many of the observations may also have future historical importance as they could serve as base-line data to be used for mapping or predicting tick distributions, particularly in view of global warming. They may also supply ammunition to those arguing for or against the concept of host specificity or preference.

Unique or important findings

1. The description of two new ixodid tick species, namely *Rhipicephalus oreotragi* Walker & Horak 2000, and *Rhipicephalus warburtoni* Walker & Horak 2000.
2. The re-establishment of the old taxon *Hyalomma glabrum* Delpy 1949, as a valid species. This tick was previously thought to be identical to *Hyalomma marginatum turanicum* of Asia, and had been identified as such in South Africa.
3. The re-establishment of the old taxon *Haemaphysalis elliptica* (Koch 1844), as a valid species. This tick was previously thought to be identical to *Haemaphysalis leachi* of north-east Africa, and had been identified as such in South Africa.
4. Larger animal species are more important hosts for adult ticks than smaller species, while the intensity of infestation with nymphs and larvae is proportional to the surface area of the host.
5. Male animals, notably greater kudus, *Tragelaphus strepsiceros*, and nyalas, *Tragelaphus angasii*, are likely to harbour significantly more adult ticks of a variety of species than their female counterparts.
6. Within their preferred habitat black wildebeest, *Connochaetes gnou*, are innately resistant to infestation with a multitude of tick species present in the same habitat.

7. African buffaloes, *Syncerus caffer*, acquire resistance to reinfestation with *Rhipicephalus* (*Boophilus*) *decoloratus* after approximately one year of age.
8. Goats are important hosts of not only the immature stages, but also the adults of tick species that normally infest cattle. The latter include *Rhipicephalus* (*Boophilus*) *microplus*, which hitherto has been considered a cattle tick.
9. The species composition of the tick burdens of sympatric hosts belonging to different species may differ markedly.
10. The species composition of the tick burdens of the same host species examined in geographically different localities may differ markedly.
11. The hosts of the larvae and nymphs of the rhinoceros tick, *Dermacentor rhinocerinos*, have been discovered.
12. The hosts of the immature stages of *Rhipicentor nuttalli* have been discovered, and the tick's life cycle has been determined in the laboratory.
13. Although no, or perhaps very few ticks are completely host specific, a number of species exhibit clear host preferences in their adult or immature stages, or in both.
14. The geographic distributions of all *Rhipicephalus* spp. that occur in South Africa have been determined and most have been mapped.
15. The geographic distributions in South Africa of five tick species that infest reptiles have been plotted.
16. The geographic distribution of *Hyalomma marginatum rufipes* more closely corresponds to that of human instances of Crimean-Congo haemorrhagic fever in South Africa than that of any other tick species, thus supporting its pre-eminence as the vector of the virus responsible for the disease in this country.
17. The seasonal abundances of all stages of development of two one-host tick species, five two-host tick species, and of the adults, and generally also of the immature stages, of 23 three-host tick species have been determined.
18. During a period of 11 consecutive years, in which the vegetation of a landscape zone in the Kruger National Park was sampled for questing ticks at monthly intervals, an above average warm winter in 1998 appeared to result in *R.* (*B.*) *decoloratus* completing an additional life cycle within that year.
19. In the same sampling period and in the same locality as item 18 above, a rodent explosion resulted in a ten-fold increase in the numbers of questing adult

Rhipicephalus simus collected from the vegetation the following year, and in a five-fold increase in the numbers of adult *Rhipicephalus turanicus*. The immature stages of both these ticks use rodents as hosts.

20. During the same sampling period and in the same locality as item 18 above, a drought in 1991/92, followed by a generally dry cycle and warm winters, resulted in a decline in the annual total numbers of questing *Rhipicephalus appendiculatus* collected from the vegetation from more than 9 000 ticks in both 1990/91 and 1991/92 to less than 120 ticks in 1995/96, and a total of only 76 ticks in 1996/97.

Publications of postgraduate students and of a postdoctoral fellow

Since 1989 I have acted as a supervisor or co-supervisor of the Master's degree research projects of a number of postgraduate students. In chronological sequence of our association they are E.J. Visagie, J.S. Du Toit, S. Matthee, U. Zieger, N.R. Bryson, H. Golezardy and N. Nyangiwe. I was also privileged to host Dr D.A. Apanaskevich of the Russian Academy of Sciences, St Petersburg, as a postdoctoral fellow in my laboratory during 2005 and 2006. The publications, of which I was a co-author, emanating from the research of these postgraduate students and from my association with Dr Apanaskevich are listed below. Some of these publications have been incorporated in this thesis, others, in which I feel I had a lesser part, have not, while a third group are unrelated to the topic of my treatise.

Visagie, Elize J., Horak, I.G. & Boomker, J. 1992. The louse fly *Lipoptena paradoxa* Newstead, 1907 (Diptera: Hippoboscidae): description of its adult and puparium and biology in South Africa. *Onderstepoort Journal of Veterinary Research*, 59: 303-314.

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Bryson, N.R., Horak, I.G., Venter, E.H., Mahan, S.M., Simbi, B. & Peter, T.F. 2002. The prevalence of *Cowdria ruminantium* in free-living adult *Amblyomma hebraeum* collected at a communal grazing area and in 2 wildlife reserves in South Africa. *Journal of the South African Veterinary Association*, 73: 131-132.

Golezardy, H. & Horak, I.G. 2006. Ticks (Acari: Ixodidae) of small antelopes: steenbok, *Raphicerus campestris* and suni, *Neotragus moschatus*. *Onderstepoort Journal of Veterinary Research*, 73: 233-236.

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Haemaphysalis (*Rhipistoma*) *leachi* group from East and southern Africa, and of *Haemaphysalis* (*Rhipistoma*) *leachi* (Audouin, 1826) (Ixodida, Ixodidae). *Onderstepoort Journal of Veterinary Research*, 74: 181-207.

VALEDICTION

The closing paragraph of the DVSc thesis that I completed during 1989 read, 'In the many years I have spent working as a parasitologist I have had the privilege of collaborating with a large number of extraordinarily nice people. I am greatly indebted to them for their assistance, constructive criticism and friendship.' But for 'the many years' that have now progressed to '47 years', I see no reason to change the sentiments I expressed then.

CHAPTER 10

APPRAISAL

Presentation of data

I was faced with three possibilities for the format in which the data constituting the body of this treatise could be presented. Firstly, by tick species, this would, however, have been virtually impossible as the majority of my publications include findings relating to several tick species, and to follow this route would have led to fragmentation of the publications and frequent repetition. The second choice was to present the data according to the provinces in which the studies had been conducted. Although this would have been possible, duplication of data would have been inevitable for those surveys conducted across provincial borders. The third option, which I have chosen, was to link the various publications to a particular topic or to the host species investigated. This has resulted in a minimum of repetition and hopefully a more readable document.

The role of ticks

In large ecosystems, free from human interference, ticks and other parasites as well as predators fulfil an important role in the selection of host populations for fitness. Young animals, usually until the age of 12 to 18 months, and before they develop resistance, are often heavily infested with parasites. Weaker individuals and those that do not develop an effective immune response often succumb, and are caught by predators before they can contribute towards the gene pool. Diseased, injured, stressed or maladapted young or older animals as well as very old animals frequently have compromised immune systems. They become heavily infested with ticks and other parasites (Horak 2006) resulting in a further deterioration in their condition and thence rapid removal from the environment by predators. Between the parasites and the predators the population is thus continuously screened for fitness.

In smaller systems, the indigenous ticks and the diseases they transmit, protect the *status quo*. Wildlife that is trans-located into such a system often become severely infested with ticks and either die from the infestation or from diseases transmitted by the ticks. Examples of this are numerous in, that with the exception of the indigenous domesticated species, cattle, sheep, goats and dogs must be considered as historical introductions of foreign species into a wildlife habitat. The tick infestations and tick-borne diseases from which they suffer are processes by which nature's balance is restored.

Biodiversity

One of the advantages of tick infestation is that it maintains the species diversity of the various hosts indigenous to a region by preventing swamping of resident hosts by non-resident introductions. However, the species diversity of indigenous ticks is also in danger. The survey by Nyangiwe & Horak (2007), conducted in the eastern region of the Eastern Cape Province, clearly indicates that the introduced Asiatic blue tick *Rhipicephalus* (*Boophilus*) *microplus* has spread throughout the region, compared to the more limited distribution mapped for it by Howell, Walker & Nevill (1978) a few years ago. A similar occurrence has been reported in Limpopo Province (Tønnesen, Penzhorn, Bryson, Stoltsz & Masibigiri 2004), while in southern Mozambique the displacement of the indigenous *Rhipicephalus* (*Boophilus*) *decoloratus* by *R.* (*B.*) *microplus* is virtually complete with only a few isolated pockets remaining (Matos, Neves & Horak 2007, unpublished data). However, although the distribution range of *R.* (*B.*) *decoloratus* in southern Africa might be waning, the tick is unlikely to disappear. This is because of the numerous wildlife species that it utilizes as hosts, whereas *R.* (*B.*) *microplus* is a tick of domestic cattle, and perhaps goats, and has not adapted to wildlife.

Host preference

The large variety of tick species recovered in my studies and the large number of host species examined, particularly sympatric host species examined during the same time frame, make it possible to determine trends in host preference. With a few notable

exceptions, the adult ticks that infest domestic and wild ruminants show few host preferences. The ticks that comprise the exceptions are, however, not necessarily species specific, but infest host species that are closely related. Some of these exceptions are *Amblyomma exornatum*, a tick of varanid lizards, *Varanus* spp. (Walker 1991; Horak, McKay, Henen, Heyne, Hofmeyr & De Villiers 2006d); *Amblyomma sylvaticum*, a tick of angulate tortoises, *Chersina angulata* (Horak *et al*. 2006d); *Dermacentor rhinocerinus*, a tick of black and white rhinoceroses, *Diceros bicornis* and *Ceratotherium simum* (Keirans 1993); *Haemaphysalis hyracophila* and *Rhipicephalus distinctus*, both ticks of rock dassies, *Procavia capensis* (Horak & Fourie 1986; Walker 1991; Walker, Keirans & Horak 2000); *Ixodes matopi* and *Rhipicephalus oreotragi*, ticks of klipspringers, *Oreotragus oreotragus* (Spickett, Keirans, Norval & Clifford 1981; Walker *et al.* 2000); *Rhipicephalus arnoldi*, a tick of Smith's red rock rabbits, *Pronolagus rupestris* (Horak, Fourie, Novellie & Williams 1991b); and *Rhipicephalus oculatus*, a tick of Cape and scrub hares, *Lepus capensis* and *Lepus saxatilis* (Horak & Fourie 1991; Walker *et al*. 2000). It is perhaps significant that rock dassies, red rock rabbits and klipspringers, all known for their rocky habitat preferences, and hence patchy distributions, harbour tick species that are peculiar to them.

The presence of a large number of easily visible adult ticks, belonging to a single species, on a large animal is often construed as evidence that the particular animal is a host species favoured by that tick. The large number of ticks may, however, only be a function of size, in that as a general rule the larger the host species the larger the number of adult ticks it is likely to harbour (Horak, MacIvor, Petney & De Vos 1987; Gallivan & Horak 1997).

The immature stages of most tick species are more catholic than the adults in their choice of hosts, but some associations are noteworthy, particularly because of their implications for the transmission of disease. The immature stages of three of the paralysis-inducing ticks, namely *Ixodes rubicundus*, *Rhipicentor nuttalli* and *Rhipicephalus warburtoni* all prefer elephant shrews, and particularly rock elephant shrews, *Elephantulus myurus*, as hosts (Fourie, Horak & Woodall 2005). The immature stages of *Hyalomma marginatum rufipes*, the tick implicated as a vector in most

instances of Crimean-Congo haemorrhagic fever in people in South Africa, prefer Cape hares and scrub hares and ground frequenting birds as hosts (Horak & Fourie 1991; Van Niekerk, Fourie & Horak 2006).

Seasonal abundance

During the various longer-term studies, in which regular monthly collections of ticks were made, the seasonal abundance of two one-host ticks, five two-host ticks and 24 three-host ticks were determined. *Margaropus winthemi*, a one-host tick, was most numerous on Cape Mountain zebras, *Equus zebra zebra*, and eland, *Taurotragus oryx* in the Mountain Zebra National Park during winter and was very nearly absent on these animals during summer (Horak *et al.* 1991b). Peak numbers of questing larvae of *R.* (*B.*) *decoloratus*, another one-host species, collected from the vegetation in the Kruger National Park during the spring and early summer months (Spickett, Horak, Van Niekerk & Braack 1992), are reflected in the peak tick burdens of greater kudus, *Tragelaphus strepsiceros* (Horak, Boomker, Spickett & De Vos 1992b), and impalas, *Aepyceros melampus* (Horak, Gallivan, Braack, Boomker & De Vos 2003), in the park during the same months.

The immature stages of *Hyalomma glabrum*, *H. marginatum rufipes* and *Hyalomma truncatum*, all two-host ticks, use ground-frequenting birds, hares, or rodents as hosts, on which they are present in peak numbers from autumn to spring (Horak *et al.* 1991b; Horak & Fourie 1991; Horak, Spickett, Braack & Penzhorn 1993). The adults utilize large ungulates, on which they are most numerous during summer (Horak *et al.* 1991b). Only one life cycle is completed annually. The immature stages of development of *Rhipicephalus evertsi evertsi* and *Rhipicephalus glabroscutatum*, both of which are two-host ticks, use the same host species as the adults. These include small to large antelopes and domestic ruminants. *R. evertsi evertsi*, however, can complete more than one life cycle annually, and thus displays more than one peak in abundance of both the adult and immature stages during the course of a year (Horak, Williams & Van Schalkwyk 1991a). *R. glabroscutatum*, on the other hand, completes only one life cycle

per annum, with its immature stages present from late summer to spring and adults from spring to late summer (Horak *et al*. 1991a).

The immature stages of nine of the 24 three-host ticks for which seasonal abundances were determined, namely *Haemaphysalis elliptica*, *I. rubicundus*, *R. nuttalli*, *Rhipicephalus exophthalmos*, *Rhipicephalus follis*, *Rhipicephalus gertrudae*, *Rhipicephalus simus*, *Rhipicephalus turanicus* and *R. warburtoni*, utilize small mammals to complete their life cycles, and the adults larger mammals. Depending on the tick species these larger mammals may include zebras, *Equus* spp., warthogs, *Phacochoerus africanus*, domestic and wild carnivores, and domestic and wild ruminants. However, the adults of three of the abovementioned nine species, to wit *R. exophthalmos*, *R. turanicus* and *R. warburtoni*, utilize scrub hares, *Lepus saxatilis*, along with larger animals as hosts. The seasonal abundance of all stages of development of six of the nine tick species as well as that of the adults of the remaining three species has been determined, namely that of all stages of development of *H. elliptica* (Fourie, Horak, & Van Den Heever 1992; Horak, Emslie & Spickett 2001), *I. rubicundus* (Horak *et al*. 1991b), *R. nuttalli* (Fourie *et al*. 2005), adults of *R. exophthalmos* (Horak 1999), all stages of *R. follis* (Horak *et al*. 1991b; Petney, Horak, Howell & Meyer 2004), adults of *R. gertrudae* (Horak & Matthee 2003), all stages of *R. simus* (Horak, Boomker, De Vos & Potgieter 1988; Petney *et al*. 2004), adults of *R. turanicus* (Horak, Spickett & Braack 2000), and all stages of *R. warburtoni* (Fourie & Horak 1991; Fourie *et al*. 2005).

The larvae and nymphs of the remaining 15 tick species usually, or might, infest the same hosts as the adults to complete their life cycles. The seasonal abundance of several of these species, but not all, are fairly similar, with larvae most numerous from autumn to winter, nymphs from winter to spring and adults at some period between spring and late summer. The species for which patterns of seasonal abundance for all stages of development have been determined are *Amblyomma hebraeum* (Horak *et al.* 1992b; Horak 1999), *Amblyomma marmoreum* (Horak, McKay, Heyne & Spickett 2006a), *A. sylvaticum* (Horak *et al*. 2006d), *H. hyracophila* (Horak *et al.* 1991b), *Haemaphysalis silacea* (Horak *et al.* 1991a, 1992b; Horak 1999), ticks of the *Ixodes pilosus* group

(Horak, Keep, Spickett & Boomker 1989), *Rhipicephalus appendiculatus* (Horak *et al.* 1992b, 2003; Horak 1999), *R. arnoldi* (Horak *et al.* 1991b), *R. distinctus* (Horak *et al.* 1991b), *Rhipicephalus kochi* (Horak *et al.* 2003), *Rhipicephalus maculatus* (Horak, Boomker & Flamand 1995), *Rhipicephalus muehlensi* (Horak *et al.* 1995), *Rhipicephalus nitens* (Horak *et al.* 1991a), *R. oculatus* (Horak *et al.* 1991b; Horak & Fourie 1991), ticks of the *Rhipicephalus pravus* group (Horak *et al.* 1993), and *Rhipicephalus zambeziensis* (Horak *et al.* 1992b, 2003). The life cycles of 23 of these ticks take one year to complete, while the life cycle of *I. rubicundus* takes 2 years to complete. Its larvae are most numerous from autumn to winter, and nymphs from winter to spring of the first year, while the adults are most abundant during autumn to spring of the following year (Horak *et al.* 1991b; Fourie *et al.* 1992). It is quite probable that some cohorts of the tortoise ticks *A. marmoreum* and *A. sylvaticum* also take more than one year to complete their life cycles.

Geographic distribution

Although none of my collections were made with the specific intention of determining the geographic distribution of particular tick species, the fact that the sites at which the collections were made were nearly always recorded, and that I collected ticks at a multitude of localities, have made a considerable contribution to our knowledge in this field, particularly where some of the more rare species are concerned. The ability to identify all stages of development of the large number of tick species frequently collected at a single site in southern Africa also meant that locality data were simultaneously collected for more than one species. My data, added to the large amount of data previously collected, provided the basis for many of the maps illustrating the geographic distributions of nearly all species of the genus *Rhipicephalus* in southern Africa (Walker *et al*. 2000). This is even more applicable to the maps drawn for five of the ixodid tick species and the single argasid tick that infest reptiles (Horak *et al.* 2006d).

Accurate data on the geographic distribution of ticks in southern Africa will become increasingly more relevant in the future in light of global warming, and with the large

scale movement and conservation of wildlife in some regions and its total destruction in others. Certain species, like the rhinoceros tick *D. rhinocerinus*, has, and will, with its rhinoceros hosts become extinct in large tracts of Africa, while others will expand their ranges.

Control

The control of ticks can be achieved in several manners, the most common, and particularly in the case of wildlife, the most undesirable, is the application of chemicals directly to host animals. Chemical control applied to domestic animals has resulted in selection for acaricide resistance in several of the tick species targeted. The difficulty with which acaricides can be applied at accurate dosages levels to wildlife, or even at all, is perchance a blessing in disguise. Poor control will ensure that the wild hosts of ticks that also infest domestic livestock will serve as refugia for acaricide-susceptible strains of these arthropods. They will thus act as an essential reservoir of susceptible ticks in any control programme designed to counteract acaricide resistance in ticks on sympatric domestic stock. This may sound paradoxical, but while acaricide resistant ticks on domestic stock are being eradicated it is essential that they are replaced with acaricide susceptible ticks. This will assist in maintaining immunity in the domestic stock to both the ticks and the diseases that they may transmit. What better source of susceptible ticks than sympatric wildlife?

The need for chemical control of ticks on wildlife is often indicative of bad management. This may be overstocking, particularly with large host species, or because wildlife that are not indigenous to the region have been introduced. Overstocking with eland is especially common. These large animals have little inherent resistance to ticks, and hence harbour huge loads of adult ticks (Horak, Golezardy & Uys 2007), resulting in pollution of an already inadequate area with enormous numbers of tick larvae and nymphs. Regular chemical treatment of wildlife also carries with it the possibility of the loss of resistance in the treated wildlife both to the ticks that infest them and the tick-borne diseases transmitted by these arthropods.

A reduction in tick numbers on wildlife can indirectly be achieved by treating sympatric domestic animals, particularly cattle, with acaricides. Because of the cattle's large size most adult ticks will attach to them, and not to the wildlife, and can then be eradicated by treating the cattle (Horak & Knight 1986; Zieger, Horak, Cauldwell, Uys & Bothma 1998c). If cattle are not already present on a property, their introduction and treatment during the summer months, when most adult ticks are present, can be considered. This management strategy will also assist in maintaining refugia of chemically susceptible ticks on their wildlife hosts.

Control can also be achieved by the introduction of predators, of which oxpeckers are the most efficient (Bezuidenhout & Stutterheim 1980). Other species of birds can also act as opportunistic predators (Penzhorn & Horak 1989). Certain host species, notably blue and black wildebeest are innately resistant to ticks (Horak, De Vos & Brown 1983; Horak *et al*. 1991b) and can be used for this purpose in a mix with other more susceptible wildlife species. African buffaloes, *Syncerus caffer*, provided they have previously been challenged with ticks, acquire resistance to reinfestation with *R.* (*B.*) *decoloratus* (Norval 1984; Horak, Golezardy & Uys 2006c). This attribute could possibly be used to advantage on properties on which buffaloes are farmed with greater kudus and impalas, both of which are highly susceptible to infestation with this tick (Horak *et al*. 1992b; 2003).

Fire as a means of reducing the numbers of free-living ticks questing for hosts on the vegetation (Spickett *et al*. 1992; Horak, Gallivan, Spickett & Potgieter 2006b), is only effective if animals are kept off the recently burnt area until the majority of ticks that have survived the fire have died.

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CHAPTER 11

PRODUCTS

Nearly all the research that has gone into the papers comprising the substance of this thesis has been descriptive or observational in character, and hence the knowledge value of any of my findings reside more in their uniqueness compared to older descriptive works rather than any discoveries made by scientific experimentation. Many of the observations may also have future historical importance as they could serve as base-line data to be used for mapping or predicting tick distributions, particularly in view of global warming. They may also supply ammunition to those arguing for or against the concept of host specificity or preference.

Unique or important findings

1. The description of two new ixodid tick species, namely *Rhipicephalus oreotragi* Walker & Horak 2000, and *Rhipicephalus warburtoni* Walker & Horak 2000.
2. The re-establishment of the old taxon *Hyalomma glabrum* Delpy 1949, as a valid species. This tick was previously thought to be identical to *Hyalomma marginatum turanicum* of Asia, and had been identified as such in South Africa.
3. The re-establishment of the old taxon *Haemaphysalis elliptica* (Koch 1844), as a valid species. This tick was previously thought to be identical to *Haemaphysalis leachi* of north-east Africa, and had been identified as such in South Africa.
4. Larger animal species are more important hosts for adult ticks than smaller species, while the intensity of infestation with nymphs and larvae is proportional to the surface area of the host.
5. Male animals, notably greater kudus, *Tragelaphus strepsiceros*, and nyalas, *Tragelaphus angasii*, are likely to harbour significantly more adult ticks of a variety of species than their female counterparts.
6. Within their preferred habitat black wildebeest, *Connochaetes gnou*, are innately resistant to infestation with a multitude of tick species present in the same habitat.

7. African buffaloes, *Syncerus caffer*, acquire resistance to reinfestation with *Rhipicephalus* (*Boophilus*) *decoloratus* after approximately one year of age.
8. Goats are important hosts of not only the immature stages, but also the adults of tick species that normally infest cattle. The latter include *Rhipicephalus* (*Boophilus*) *microplus*, which hitherto has been considered a cattle tick.
9. The species composition of the tick burdens of sympatric hosts belonging to different species may differ markedly.
10. The species composition of the tick burdens of the same host species examined in geographically different localities may differ markedly.
11. The hosts of the larvae and nymphs of the rhinoceros tick, *Dermacentor rhinocerinos*, have been discovered.
12. The hosts of the immature stages of *Rhipicentor nuttalli* have been discovered, and the tick's life cycle has been determined in the laboratory.
13. Although no, or perhaps very few ticks are completely host specific, a number of species exhibit clear host preferences in their adult or immature stages, or in both.
14. The geographic distributions of all *Rhipicephalus* spp. that occur in South Africa have been determined and most have been mapped.
15. The geographic distributions in South Africa of five tick species that infest reptiles have been plotted.
16. The geographic distribution of *Hyalomma marginatum rufipes* more closely corresponds to that of human instances of Crimean-Congo haemorrhagic fever in South Africa than that of any other tick species, thus supporting its pre-eminence as the vector of the virus responsible for the disease in this country.
17. The seasonal abundances of all stages of development of two one-host tick species, five two-host tick species, and of the adults, and generally also of the immature stages, of 23 three-host tick species have been determined.
18. During a period of 11 consecutive years, in which the vegetation of a landscape zone in the Kruger National Park was sampled for questing ticks at monthly intervals, an above average warm winter in 1998 appeared to result in *R.* (*B.*) *decoloratus* completing an additional life cycle within that year.
19. In the same sampling period and in the same locality as item 18 above, a rodent explosion resulted in a ten-fold increase in the numbers of questing adult

Rhipicephalus simus collected from the vegetation the following year, and in a five-fold increase in the numbers of adult *Rhipicephalus turanicus*. The immature stages of both these ticks use rodents as hosts.

20. During the same sampling period and in the same locality as item 18 above, a drought in 1991/92, followed by a generally dry cycle and warm winters, resulted in a decline in the annual total numbers of questing *Rhipicephalus appendiculatus* collected from the vegetation from more than 9 000 ticks in both 1990/91 and 1991/92 to less than 120 ticks in 1995/96, and a total of only 76 ticks in 1996/97.

Publications of postgraduate students and of a postdoctoral fellow

Since 1989 I have acted as a supervisor or co-supervisor of the Master's degree research projects of a number of postgraduate students. In chronological sequence of our association they are E.J. Visagie, J.S. Du Toit, S. Matthee, U. Zieger, N.R. Bryson, H. Golezardy and N. Nyangiwe. I was also privileged to host Dr D.A. Apanaskevich of the Russian Academy of Sciences, St Petersburg, as a postdoctoral fellow in my laboratory during 2005 and 2006. The publications, of which I was a co-author, emanating from the research of these postgraduate students and from my association with Dr Apanaskevich are listed below. Some of these publications have been incorporated in this thesis, others, in which I feel I had a lesser part, have not, while a third group are unrelated to the topic of my treatise.

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VALEDICTION

The closing paragraph of the DVSc thesis that I completed during 1989 read, 'In the many years I have spent working as a parasitologist I have had the privilege of collaborating with a large number of extraordinarily nice people. I am greatly indebted to them for their assistance, constructive criticism and friendship.' But for 'the many years' that have now progressed to '47 years', I see no reason to change the sentiments I expressed then.