THE DIET OF CARACAL (*CARACAL CARACAL*) IN THE SOUTHERN FREE STATE

by

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A THESIS

Submitted in accordance with the academic requirements for the degree

MAGISTER SCIENTIAE (ZOOLOGY)

in the Department of Zoology & Entomology,

Faculty of Natural & Agricultural Sciences

at the University of the Free State

December 2015

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DECLARATION

"I hereby declare that this thesis submitted by me to the University of the Free State for the degree MAGISTER SCIENTIAE (M.Sc. Zoology) is my own independent work and has not previously been submitted by me to any other university. I furthermore cede copyright of the thesis in favour of the University of the Free State."

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ACKNOWLEDGEMENTS

I firstly would like to thank my heavenly Father, my parents, Adv. Louis Pohl and Elna Pohl, my brother Le Roux Pohl and other family and friends for both supporting me as a person and for financial provision.

My supervisors, Doctors Nico Avenant and Alexander Sliwa are greatly thanked for supervising this research. Their guidance during this research and additional research opportunities they provided are greatly appreciated. The farmers of the Bethulie district, particularly Harm Grobbelaar, his wife Letitia Grobbelaar as well as Gen. Abel Grobbelaar and Martiens Le Roux, are thanked for their hospitality and for allowing research to be conducted on their properties. I would also like to thank the numerous anonymous farm labourers who aided in carnivore scat collection.

The National Museum, Bloemfontein is thanked for their assistance in the field, specifically regarding small mammal research, but also for aiding with numerous other research methodologies that was used in this study. Doctors Ashley Kirk-Spriggs and Leon Lotz are thanked for helping identify fragmented insect remains in carnivore scats. Doctor Mike Bates is thanked for aiding with identification of fragmented reptile remains in carnivore scat and for reviewing species lists, included in the appendix section.

Numerous people from the University of the Free State are given credit for their aid in this project. A few specific people that I would like to mention are the following: Kalego Msindo from the Geography Department and Roe Wiid from the Zoology and Entomology Department for providing voluntary research assistance in the field. Roe Wiid, who specialises in problem hyrax in urban areas, also provided valuable insight into the availability of hyrax in the study area. Vivian Butler form the Department of Game and Grassland Sciences is thanked for his help with identifying insects collected from pitfall traps. Advice on literature management from Hennie Butler at the Zoology and Entomology Department is greatly appreciated. Doctor Charles Barker is thanked for his advice on GIS maps.

The bulk of financial support for this project was received from the National Research Foundation (NRF). The Free State Department of Environmental Affairs and Tourism are thanked for issuing general research permits to the National Museum, under which this study was conducted.

Research for this project was cleared by the University of the Free State Animal Ethics Committee (NR 05/2011).

Climate data was acquired from the South African Weather Service, while caracal distribution data was acquired and used with permission from the IUCN.

SUMMARY

Caracal *Caracal caracal* is a damage-causing predator in rangeland ecosystems of southern Africa, with the southern Free State being one of the most severely impacted small stock areas. Available literature indicate that these cats usually prey on the most abundant prey groups, but are also opportunistic and take small stock, especially during lambing seasons. The aim of this study was to define the diet of caracal over a 13 month period through scat analysis in a small stock area and to discuss its prey-niche overlap and sharing with the three most common sympatric carnivores-black backed jackal *Canis mesomelas*, Cape grey mongoose *Galerella pulverulenta* and yellow mongoose *Cynictis penicillata*. The study site was described as a productive ecosystem and characterised by a diverse number of prey species. Prey availability was determined on a number of transects (driven and walked) and through numerous observations of birth peaks/the presence of young.

Results show that caracal fed predominantly on Mammalia prey (94.74 percentage occurrence, %Occ.; 93.40 percentage volume, %Vol.). Prey items that made the most notable contributions to caracal diet were Lagomorpha (28.5%Occ.; 28.0%Vol.), rock hyrax *Procavia capensis* (17.5%Occ.; 17.3%Vol.), and springhare *Pedetes capensis* (15.2%Occ.; 15.2%Vol.) and domestic sheep *Ovis aries* (13.6%Occ.; 13.6%Vol.). Prey items that made the most notable contributions to black-backed jackal diet were Muridae (34.43%Occ.; 9.83%Vol.), Lagomorpha (19.94%Occ.; 16.98%Vol.), springbok *Antidorcas marsupialis* (13.92%Occ.; 12.92%Vol.), sheep *Ovis aries* (9.09%Occ.; 8.24%Vol.) and mountain reedbuck *Redunca fulvorufula* (9.82%Occ.; 9.42%Vol.).

The current study showed that caracal was more of a specialist than black-backed jackal, with the latter utilizing the widest prey spectrum. Both caracal and black-backed jackal fed opportunistically in this study, and their diets included a large proportion of natural prey. The diet of caracal and black-backed jackal included more mammal and less invertebrate prey than that of Cape grey mongoose and yellow mongoose.

Of the four predators studied, black-backed jackal diet was the most diverse (widest niche breadth), followed by Cape grey mongoose, caracal, and yellow mongoose diet the least diverse. The two larger carnivores, caracal and black-backed jackal, utilised their prey items with higher evenness than the two mongoose species.

Highest niche overlap was observed between caracal and black-backed jackal (1.0), and between Cape grey mongoose and yellow mongoose (0.9). Moderate niche overlap was observed between caracal and Cape grey mongoose, and between black-backed jackal and Cape grey mongoose (both 0.6; smallest overlaps were between caracal and yellow mongoose (0.3), and black-backed jackal and yellow mongoose (<0.1).

Springhare remains in caracal scats correlated with monthly springhare abundance (r=0.8; p=0.004), which in turn correlated with humidity (r=-0.7; p=0.03). Hare *Lepus* spp. remains in caracal scats did not correlate with hare monthly abundance (r=0.6; p=0.09), but followed the same general trend. The results suggest that caracal fed on the most abundant prey and opportunistically exploited peaks in prey abundance.

Both caracal and black-backed jackal preyed markedly on sheep during the two lambing seasons (March to April and September to October). Black-backed jackal predated less on this prey item than caracal, but predated, more than caracal, on (also economically important) springbok. Both caracal and black-backed jackal were, therefore, damage-causing predators in the study area, but also played an intricate role in the ecosystem in that they regulate prey populations and may benefit syntopic carnivores through, for example, carrion provision. Caracal and black-backed jackal may also serve as regulators of prey species that are also potential damage-causing animals (e.g. rodents destroying crops and carrying disease, hyrax competing for forage with sheep, and molerat tunnels causing damage to tractors and plows).

Although the current research was a descriptive ecological study of caracal diet in a rangeland ecosystem, and not a management focused project, it nevertheless provided information that can benefit farmers, conservation authorities and the government sector in the quest to address the sensitive issues of predator control and ecosystem conservation on rangelands characterised by major small stock losses.

Key words: *Caracal caracal*, damage-causing predators, diet, major prey, minor prey, niche breadth, niche overlap, predator-prey interactions, small stock, syntopic carnivores.

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LIST OF KEY TERMS AND ABBREVIATIONS

Acetone* (C_3H_6O)*: medium used to remove DPX mounting medium ($C_{18}H_{18}Br_2N_2$) and Entellan ($C_{13}H_{22}O_4$) from microscope slides.

Apex predator/carnivore: a predator/carnivore that occupies the top trophic level in a community of species (Ritchie & Johnson 2009).

Breeding season: Context specific, but usually refer to a period when a specific (or a number) of prey species breed or have new young with them.

Damage-causing animal/predator/carnivore: a wild vertebrate animal/predator/ carnivore that, when interacting with humans or interfering with human activities, there is substantial proof that it

- causes losses to stock or to other wild specimens;
- causes damage to cultivated trees, crops, natural flora or other property;
- presents a threat to human life; or
- is present in such numbers that agricultural grazing is materially depleted (National Environmental Management Biodiversity Act, 2004: Act no. 10 of 2004).

Diet category: similar to prey groups

Dietary items: used in the context of the diet of a carnivore, is a collective term that includes both Animalia and Plantae components.

100579 | DPX (non-aqueous mounting medium for microscopy- $C_{18}H_{18}Br_2N_2$): medium used to make cuticular scale imprints of hair (see Entellan).

107961 | Entellan® new (rapid mounting medium for microscopy- $C_{13}H_{22}O_4$): medium used to make cuticular scale imprints of hair (similar to DPX mounting medium).

Field signs (sometimes indirect or secondary field signs): refers to a number of field signs, such as tracks, scats, animal markings, carcass bite marks, etc., that gives an indication of the presence and sometimes whereabouts of animals (Stuart & Stuart 2000; Chame 2003; Hodkinson *et al.* 2007; Smuts 2008; Walker 2009; Murray 2011).

GIS map: map created using Geographic Information Systems (GIS) software.

Hair imprint/cuticular scale imprint: a "cast" that is made by placing a strand of hair on a medium such as Entellan ($C_{13}H_{22}O_4$) or DPX mounting medium ($C_{18}H_{18}Br_2N_2$) and later removing it, leaving an imprint of the cuticular scales of the hair on the medium. This imprint is then placed under a light microscope and serves as an identification aid when compared to a published collection of photographic keys (Keogh 1983, 1985) and/or self-compiled hair imprint references (e.g. hares, springhares, carnivores).

Importance value (IV.): calculated as percentage occurrence x percentage volume / 100 (following Mealey 1980; Avenant 1993).

Lambing season (s): context specific, but usually refers to the periods when sheep (*Ovis aries*) have lambs, between zero and two months old, with them (Strauss 2009).

Main prey: context specific and varies among studies, but may be defined as prey that is represented in a notable high number of scats and contributes to a large proportion of the volume in most of the scats in which it is present (>40%, following Avenant & Nel 1997, 2002).

Mean/average monthly: used in the overall representation of the diet of a carnivore. To determine the overall percentage occurrence, volumetric contribution or importance value of specific prey groups, where data from the sampled months are not simply pooled together, but averaged.

Meso-predator/carnivore: related to "meso-predator release", which refers to an increase of middle-ranked predator populations as a result of the removal of Apex predators from an ecosystem (Prugh *et al.* 2009; Brassine & Parker 2011). Meso-predators/carnivores occupy trophic positions under Apex predators/carnivores (Ritchie & Johnson 2009).

Minor prey: context specific and varies among studies, but may be defined as prey that is represented in a small number of scats and or contributes to a small proportion of the volume in those scats (<4%, following Avenant & Nel 1997).

Niche breadth/width (e.g. food niche breadth/width): the diversity of resources used by a species (Putman & Wratten 1984).

Niche overlap/sharing (e.g. food niche overlap/sharing): the shared use of (food) resources used by two or more species (Colwell & Futuyma 1971; Capello *et al.* 2012).

Percentage occurrence (%Occ.): defined as the percentage of scats containing a particular prey item, following Lockie (1959), Corbett (1989), Nel *et al.* (1997) and Bizani (2013)

Percentage volume (%Vol.): defined as the percentage volume that a specific prey type comprise in scats (Mealey 1980; Sillero-Zubiri & Gottelli 1995) .

Photographic reference collection: a collection of published (e.g. in Keogh 1983, 1985) and self-compiled (e.g. photographs taken from a reference collection) identification aids used in scat analysis.

Prey abundance: refers to prey quantity (prey numbers).

Prey availability: broad term that may be used in an annual or monthly/seasonal context. Prey availability may be influenced by special and temporal factors and includes aspects of prey abundance, prey density, the ability of a predator to capture and kill prey, and the ability of prey to avoid being captured.

Prey densities: related to prey abundance and refers to prey quantity per surface area.

Prey group size: refers to agglomerations of individuals belonging to a specific prey species.

Prey groups: collective term that includes a number of Animalia prey species, categorised into taxonomically defined prey groups (e.g. Muridae, Lagomorpha, Ruminantia, etc.).

Rangeland: land used for grazing/browsing by livestock and or game.

Reference collection: is used to identify undigested remains from faecal (scat) samples. A reference collection consists of catalogued museum skins, hair from such skins, hair imprints, whole skeletons, parts of skeletons (e.g. teeth) and hair sampled from clearly identifiable live specimens and carcasses found in the study area. Photographs of pre-identified reference material may also be included.

Relative importance value (Rel.IV): similar to *Importance value (IV.)*, but calculated from relative percentage occurrence and relative percentage volume. The value is expressed as a percentage.

Relative percentage occurrence (Rel.%Occ.): calculated by dividing the number of incidences of a particular prey item in scats by the number of incidences of all prey items in the larger prey group to which the particular prey item belongs (multiply by 100 to convert to a percentage value).

Relative percentage volume (Rel.%Vol.): calculated by dividing the volumetric contribution of a particular prey item in scats by the volumetric contribution of all prey items in the larger prey group to which the particular prey item belongs, multiplied by 100 (to convert to a percentage value).

Relative values: includes relative percentage occurrence, relative percentage volume and relative importance value. These values are affected by the number of occurrences of a specific prey item in relation to the total number of occurrences of all other prey items in the larger prey group to which the particular prey item belongs, and not by the total sample size.

Road transect/drive count: driven transect used for game counts (e.g. *Lepus* spp. and *Pedetes capensis* in this study). Transect methodology acquired from Rudran *et al.* (1996), Avenant & Nel (1997), Avenant & Nel (2002), Bothma (2002) and Stenkewitz *et al*. (2010).

Scat analysis: analysis of faecal samples.

Scat(s): faecal sample.

Small stock: domesticated sheep and goats; in the current study area, only sheep.

Species pair (s): used in the context of niche overlap and refers to the diets of two species that are combined in a calculation to determine a proportion or percentage of niche overlap.

Sympatric predator/carnivore: a predator/carnivore that occurs together with other predators/carnivores in the same geographical area (Rivas 1964).

Syntopic predator/carnivore: a predator/carnivore that occurs together with other predators/carnivores in the same general habitat.

Two-monthly pool: a representation of the diet of a carnivore that creates a certain degree of overlap between monthly scat samples, calculated from the first day of the first month to the last day of the second month.

Walked transects/strip counts: Walked transects used for scat collection and field observations, specifically density and presence/absence calculations. Transect methodology acquired from Avenant & Nel (1997), Avenant & Nel (2002) and Bothma (2002).

1. General Introduction and background

1.1. Caracal conservation status and general ecology

The caracal, *Caracal caracal* (Schreber, 1776) is currently listed as “least concern” on the IUCN red data list of threatened species. It has a wide distribution (Appendix 1) which spans beyond the African continent (IUCN 2013; Stuart & Stuart 2013). Major threats to caracal are persecution and habitat destruction through desertification and agriculture (IUCN 2013). The latter is a substantial threat to caracal populations, specifically in central, west, north and northeast Africa; the former is a marked threat in South Africa & Namibia where especially small stock farmers hold them responsible for considerable losses in their flocks. Despite extensive damage control practices, caracal are still very common in farming areas in South Africa and Namibia (Avenant & Du Plessis 2008; Van Niekerk 2010; Du Plessis 2013). This suggests that caracal have adapted extremely well to direct anthropogenic pressures by land owners.

Although described as generally solitary nocturnal feeders (Stuart & Stuart 2013), caracal have been found to be commonly active during cooler winter days in the West Coast National Park (Avenant & Nel 1998). The bulk of their diet usually includes small to medium sized prey, such as small rodents, hyrax, hares, springhares, birds and the young of some antelope species (Skinner & Chimimba 2005; Stuart & Stuart 2013). Home ranges may differ among studies and is mostly influenced by prey availability (Avenant & Nel 1998). In terms of reproduction caracal are considered to have varying birth peaks. Bernard & Stuart (1987) and Stuart & Wilson (1988) lists the birth peaks between October and February; Stuart (1982) similarly found births to concentrate in the summer months, but mentioned that births could occur at any time of the year.

1.2. Ecological role of the caracal

In this study, the ecological role of caracal is predominantly described through location specific data (see Study area, Chapter 2). It is related to “ecological niche”, which includes all physical, chemical, and biological conditions that a species needs to live and reproduce in an ecosystem (Miller 2007). Avenant (1993) indicated this role for opportunistic caracal, which consumed specific prey species when they were most abundant, and switched to other species when their relative frequencies (availability) changed. As such they play an intricate role in conserving the biodiversity of prey species and therefore fulfill a vital role in healthy ecosystem functioning.

Avenant (1993) argued that caracal play an important role in limiting prey species numbers, including rock hyrax, molerats and rodents. Three hyraxes, for example, may eat as much as one adult sheep, which makes them competitive grazers, especially at high densities (see Avenant 1993). Other prey species, such as molerats (their tunnel systems) can cause serious axle damage to tractors and wagons in the soft West Coast Strandveld soil (Avenant 1993) while rodents are well known pests on agricultural crops but also vectors of disease (Singleton *et al.* 2003; Mukherjee *et al.* 2004). Extermination of caracal could, therefore, potentially result in prey species population outbreaks and sickness. For instance: it was calculated that each adult caracal consumed approximately 5427 muroid rodents per year in the Postberg section of the West Coast National Park (Postberg Nature Reserve, PNR), and 5502 on the surrounding farms (Avenant & Nel 2002). There is, therefore, an economic trade-off between the value of caracal as biological control agent and the financial loss from caracal predation on small stock. According to Palmer & Fairall (1988) caracal play an important role in regulating hyrax *Procavia capensis* numbers. They (Palmer & Fairall 1988) identified hyrax as the second most common prey item occurring in caracal scats in the Karoo National Park (22% occurrence). It was calculated that each of the 28 caracal in their study area consume approximately 16 hyrax per annum, whilst Avenant & Nel (2002) calculated that 5.4 hyrax were caught by each caracal in the Postberg Nature Reserve (PNR) per year. It was also calculated that, together, the caracal in the Karoo National Park could be responsible for consuming 30% of the hyrax population increase per year. Extermination of caracal may therefore cause a considerable increase in hyrax numbers, resulting in indirect financial loss due to a dearth of forage availability. Increasing hyrax populations would eventually directly compete with small stock for food. It, therefore, calls for a management plan that recognises that small stock loss need not only be limited, but caracal populations, ecosystem functioning and biodiversity should be managed and protected. Such a plan would also need to recognise the potential impact that caracal and black-backed jackal (*Schreber, 1775*) have on each other's numbers (Avenant & Du Plessis 2008).

Although previous studies have indicated caracal to be strictly carnivorous, the following should also be considered in the present study: Goldenberg *et al*. (2010), Kaunda & Skinner (2003) and Rosalino *et al*. (2010) highlighted the role of some carnivores in seed dispersal and germination . This ecological function depends on seed structure, seed size, behavioural factors of the specific carnivore involved, as well as carnivore abundance in the area where the fruits originate.

1.3. Caracal diet and most eminent theories

Theoretical topics relevant to this thesis include the optimal foraging theory, generalist versus specialist feeding, prey switching, meso-predator trophic interactions, intra-guilt predation and niche overlap and breadth. These theories form a valuable background framework for a comprehensive understanding of carnivore diet.

1.3.1. Optimal prey theory

The strengths and weaknesses of this theory are discussed by Sih & Christensen (2001). In general the optimal prey theory has the following three predictions: 1, prey that provides the most energy per unit handling time is selected; 2, increased abundance of higher value prey in the diet of the predator should cause lower value prey to occur less frequently; 3, there is a quantitative threshold that determines when certain prey items are included or excluded in the diet of a predator. They (Sih & Christensen 2001) found that diet preferences for immobile prey often fit the predictions of the optimal diet theory, whereas diet preferences for mobile prey often contradict the predictions. Accordingly the following points should receive special attention when dealing with caracal diet and foraging behaviour: firstly, factors such as encounter rates and capture success should be accounted for when explaining non-random predator diets based on the optimal diet theory; and secondly, prey in a predator's diet is not merely a function of prey availability, but is determined by numerous factors, such as microhabitat use, anti-predator behaviour and prey mobility. From a summary of Goldenberg *et al*. (2010)'s illustration of the optimal foraging theory, it can be reasoned that energy rich food will be taken at a constant rate, whilst less nutritional food will be taken on a variable basis that corresponds to the availability of that prey (and thus, encounter rates). However, prey choice is also influenced by the costs of searching, handling and consuming a specific prey (Sih & Christensen 2001). Diet choice is therefore not clear cut, but involves numerous underlying and interrelated factors. In the simplest explanation for diet choice, it can be argued that the selection of a prey item is determined by a trade-off between prey energetic/nutritional value and prey accessibility in terms of ecosystem structure in time and space, where ecosystem structure refers to microhabitats within an ecosystem, species diversity, species abundance and trophic arrangement of different predator and prey species. Prey accessibility in this explanation would also include the ability of the predator to catch and kill a specific prey, the ability of the predator to consume and protect the carcass while consuming it, and the anti-predator response of the prey species or individual.

1.3.2. Specialist vs. generalist

A feeding specialist may be defined, traditionally, as a species that feeds on a narrow spectrum of food, irrespective of how this food resource fluctuates over time (Azevedo *et al.* 2006). In contrast, a generalist species would be a species that feeds on a wide spectrum of food, irrespective of food fluctuations over time. The term “feeding specialist” also implies that this species has a reduced, narrower, dietary breath than the usual. Theory then predicts that the niche overlap of this species should decline in comparison with that of other species in the community. Azevedo *et al*. (2006) argues that specialization may also be system specific and/or may be characteristic of individuals within a population. A population may, for example, show generalised feeding patterns, but within the larger population certain individuals could be more specialised than others in terms of feeding. The exact generalist-specialist nature of caracal is also not always clear cut. Avenant & Nel (2002) argued that, although caracal are specialists of small rodents, they are also opportunistic generalists. Caracal, furthermore, seem to feed on the prey that is most abundant, may occasionally scavenge (Avenant 1993), and their diet will also be affected by prey availability in the specific area under study.

1.3.3. Prey switching

Some studies have found that caracal do not select for specific prey species, but rather opportunistically select for the most common prey (Avenant & Nel 1997, 2002): when the common prey item decreases, caracals change their diet and make use of a different prey and/or increase the diversity of prey types they utilise. Prey groups such as rodents and birds increase and decline over months and seasons, and it has been questioned whether caracals in farming areas will be more prone to switch to livestock during times when their natural prey species decrease (Avenant 1993; Avenant & Du Plessis 2008). Research done in the West Coast National Park, the only study that correlated caracal home range use with diet and with prey abundance in specific plant communities and on various contours and slopes (Avenant 1993), found that predation on small stock increased during times of seasonal decrease in rodent density, their most utilised prey in that study area (Avenant & Nel 1997, 1998, 2002). In this instance the increase in depredation also co-occurred with the lambing season. This raised another question: Does poor ecological management practices, such as overgrazing of farmland and the unselected taking out of predators add to the lowering of natural prey diversity and availability, and indirectly force caracals to take small stock (Avenant & Du Plessis 2008)?

There are also indicators that individual caracal may switch prey to suit specific needs, not related to the prey fluctuations mentioned above (e.g. females taking more large prey when lactating and or caring for young; Avenant 1993; Avenant & Nel 1998).

Being an opportunistic and fairly generalist feeder (Avenant & Nel 1997, 2002; Melville *et al.* 2004; Kok & Nel 2004), it can be argued that these females may exploit small stock as an easy prey item when they lactate or have young with them (e.g. Avenant & Nel 1998). They (Avenant & Nel 1998) found that raised energetic requirements, due to lactation, corresponded with the time of seasonal decrease in rodent abundance and biomass, increased predation on adult springbok *Antidorcas marsupialis* in the reserve, with the small stock lambing season, and when predation on livestock in farm areas increased. In the West Coast National Park study small stock remains were also only found in scats collected on the farms (never well-inside the reserve; i.e. areas > 1km from the Park fence), which indicated that only caracal with direct access to farming areas are responsible for killing sheep (and territorial animals well-inside the reserve probably only foraged inside their territories). Avenant & Nel (1998) suggested that prey switching may occur under natural conditions and in farm areas. The question nevertheless arises whether caracal, especially females with young, may be motivated by energetic demands to leave conservation areas to kill small stock outside the reserve. Another important question is whether or not male caracal, especially displaced males and young males who have not yet established a territory, also leave reserves to hunt outside the reserve on farms, but return to the safety of the reserve during resting periods. This is a common accusation among farmers on peripheral small stock areas, and is currently being investigated within a larger research programme (Avenant pers. comm.). Only one study (Moolman 1986) has documented the ranging behaviour and territories of caracal in and outside a nature reserve. That specific study has shown that caracal utilise nature reserves and peripheral farming areas in different degrees; for example, some caracal never left the reserve, some only occasionally ventured onto nearby farming areas, some utilised both nature reserves and farming areas when part of their home range, whilst others utilised mostly farming areas. No connection was made with females and higher energy needs.

1.3.4. Meso-predator trophic interactions and intra-guild predation

Both caracal and black-backed jackal are currently implicated as the major culprits in the damage-causing animal / livestock industry conundrum in South Africa. The latest estimates are that these two animals are, together, responsible for losses up to R1.4 billion per annum (Van Niekerk 2010). These two species do not only share natural and domestic prey species, but are considered to impact on each other's densities amongst others through predation on each other's young (Ferreira 1988; Kaunda 2001; Melville *et al.* 2004). Numerous farmers, damage-causing animal hunters and conservation officials has remarked how strategies to decrease numbers of one of them has led to the increase in numbers of the others (e.g. S. Hanekom, R. Wilke, C. Stegman, L. Goosen), and proposed the collective management of both species (instead of focusing on only one - Du Plessis 2013).

Interspecific killing can take one of two forms: symmetrical killing refers to cases where both species kill individuals of the other; asymmetrical killing refers to cases where only one species kills individuals of the other species (Palomares & Caro 1999). In the current study, where the two meso-predators caracal and black-backed jackal are able to kill each other, the predation can be described as symmetrical.

Relative body mass plays an important role in this matter, since there is a certain threshold above which a successful kill is unlikely (Palomares & Caro 1999). Woodward & Hildrew (2002) write about a size-refugium, whereby the young of some animals become less vulnerable to predation as their relative body size (to that of the predator) increases. Smaller species in the community would, according to this theory, be more vulnerable to predation than larger species, while individuals of larger species would be able to outgrow a certain vulnerability size. This concept may be best displayed by observing certain carnivores that are only able to kill the young of other carnivores, whereas some carnivores kill both young and adults. Donadio & Buskirk (2006) indicated that when the body sizes of two carnivores are too similar, interspecific killing may be avoided; there is a certain risk involved, and the benefits of interspecific killing should outweigh the potential cost of sustaining injury during attack. They also suggest that interspecific killing is more likely to occur between species that are taxonomically closer related, especially at family level. Similar ecological needs and trophic status are also major determinants of interspecific killings. Other authors, e.g. Kamler *et al*. (2012), argued that sympatric carnivore competition may still exist despite sufficient niche sharing in terms of body size and resource overlap, because carnivores may kill for territorial purposes. Group forming behaviour may also overwrite body size limitations, affecting interspecific killing; carnivores that form groups may kill larger competing carnivores with more ease, or compete more effectively for food (Palomares & Caro 1999). Intra-guild predation can, therefore, also be seen as a form of size driven interference competition (Woodward & Hildrew 2002).

Reports that caracal prey on the young of black-backed jackal (Lynch 1983) have been used as possible evidence to explain the increase of black-backed jackal in areas where caracal has been eradicated. It has been speculated that caracal play an important ecological role in keeping black-backed jackal numbers low, which in effect may decrease predation on small stock by the latter. However, one would still need to manage for caracal predation on small stock. The degree of predation on black-backed jackal cubs in a sympatric area can partly be resolved by determining what proportion of caracal scats comprises black-backed jackal remains, if any, and at what time of the year this peaks. Whether lower numbers of black-backed jackal in some areas are due to direct predation on them by caracal, or as a result of competition for natural prey and space, remains an open research question.

The occurrence of other sympatric carnivore remains in caracal scats is not unusual. Palmer & Fairall (1988) found the remains of two carnivores, suricate *Suricata suricatta* and striped polecat *Ictonyx striatus,* in caracal scats in the Karoo, and mentioned that genet *Genetta* spp. may also be included in the diet of caracal. In the Kgalagadi Transfrontier Park five carnivore species collectively contributed 10.7% of the total number of prey identified in scats (Melville *et al*. 2004); these carnivores were African wild cat *Felis silvestris*, black backed jackal *Canis mesomelas*, bat eared fox *Otocyon megalotis*, Cape fox *Vulpes chama*, striped polecat and yellow mongoose *Cynictis penicillata*. In the West Coast Strandveld water mongoose *Atilax paludinosus*, Cape grey mongoose *Galerella pulverulenta* and striped polecat were also taken in small quantities (collectiveley 1.9% mean monthly occurrence; Avenant & Nel 1997, 2002). Melville *et al*. (2004) argued that a low density of smaller artiodactyls, together with the low density of larger apex carnivores such as leopards *Panthera pardus* and cheetahs *Acinonyx jubatus*, may be partly responsible for smaller carnivores filling in the diet of caracal. Results from the Kalahari, Karoo and the West Coast Strandveld may not be directly comparable with the current study as these locations are subjected to different prey compositions and ecological regimes, but do support the fact that caracal are highly opportunistic.

Scavenging behaviour is another aspect that relates to meso-predator trophic interactions. Devault *et al*. (2011) in the USA, found that carnivores may compete differently in agricultural habitats compared to more pristine habitats. They (Devault *et al*. 2011) described how some meso-predators may dominate carrion resources (= monopolisation), thus, excluding other meso-predators from carcasses. There is some evidence from Mills *et al*. (1984) that caracal may be at an advantage when it comes to interference competition with black-backed jackal (a single caracal was observed to drive away three black-backed jackal from a springhare kill in the Kgalagadi Transfrontier Park). Although evidence exists that caracal may scavenge opportunistically (Grobler 1981; Mills *et al.* 1984; Stuart & Hickman 1991; Avenant & Nel 1998), black-backed jackal are recognised as the more specialised scavenger of the two (Kok & Nel 2004; Loveridge & Nel 2013). Avenant (1993) found that it was non-territorial caracal that made use of carcasses (springbok, not killed by caracal), and that no scavenging by radio-collared territorial caracal could be detected. Females with their young revisited larger prey killed (e.g. springbok and duiker *Sylvicapra grimmia*) for up to four nights in a row.

1.3.5. Niche breadth and overlap in the context of intra-guild predation

Azevedo *et al*. (2006) stresses the importance of community-level analysis during diet studies, whereby the diet of more than two sympatric carnivore species are compared and food niche overlap discussed. Carnivore species referred to as “sympatric”, are those species that occupy the same area (Rivas 1964), while “food niche overlap” can be defined as the shared use of food resources by two or more species (Capello *et al.* 2012). Defining the dietary breadth of a carnivore in relation to that of sympatric carnivores, should, in theory, produce a more accurate description of the ecology of a carnivore. Niche overlap is expected to also have an effect on the rate of interference competition and inter-specific killing. Donadio & Buskirk (2006), for example, presents evidence that high dietary overlap is associated with frequent inter-specific killing events, while low overlap relates to less killing.

It can also be argued that exploitation competition, as a result of high niche overlap (two or more carnivores competitively utilizing the same prey resource), is reduced by intraguild predation (Polis *et al.* 1989; Donadio & Buskirk 2006). It would, thus, be advantageous for farmers if interference and exploitative competition is allowed to naturally occur on rangelands, as a reduced predator population may potentially result in less small stock being killed. In addition to allowing predators to naturally control each other's numbers, however, farmers may still need to curb predator populations (see Chapter 6).

In recent years there has been a hot debate between farmers, conservation and management authorities on how the removal of one meso-predator (e.g. caracal) causes the other meso-predator in the ecosystem (e.g. black-backed jackal) to increase in numbers. This is but one of the arguments why blanket control practices may not be the answer to the stock loss problem. Both these predators also seem to recover rapidly after unselective control practices (see Avenant & Du Plessis 2008).

1.4. The management of damage-causing caracal in southern Africa

The livestock industry in southern Africa is suffering excessive loss due to both caracal and black-backed jackal predating on commercialised farm animals (Strauss 2009; Van Niekerk 2010; Du Plessis 2013). These animals are recognised and defined as “damage-causing animals” in official government legislation (DEAT 2010). The National Woolgrowers Association (NWKV) has identified the southern Free State as one of the areas where the risk of exorbitant losses are the highest (Deacon 2010; Van Niekerk 2010). Throughout South Africa current blanket control, and poisoning practices in some cases, are ineffective and pose a serious threat to biodiversity and ecosystem integrity in these areas (Avenant & Du Plessis 2008; Du Plessis 2013), the methods employed are mostly unselective for the species, and those that are selective for the species are to a large extent non-selective in getting rid of the specific problem individual. These control methods also ignore the social behaviour aspect of the damage-causing species (Avenant & Du Plessis 2008). Social behaviour influence where and how these animals establish territories, at what time of the year breeding occurs, and which (and how many) individuals are involved - which in turn affects population numbers, as well as prey species numbers, diversity and evenness. The result is that farmers experience continuous loss, whilst biodiversity is expected to be degraded.

Du Plessis (2013) stresses the points that few holistic field studies have been conducted in southern Africa, and that scientific literature on the ecology of these damage-causing animals is limited. For example, only 22 field studies have been conducted on caracal ecology, from which stemmed only 28 publications. Fifteen publications emerged up until 1990; six were published since 2001, while between 2006 and 2012 only three publications appeared (average publication age = 21 years). The fact that they are spatially and temporally isolated further limits our knowledge on their ecology, which in turn limits our ability to formulate a sustainable management plan (Du Plessis 2013). In terms of the number of studies conducted, the different biomes are unequally represented, and throughout little is known about caracal ecology in farming areas (a mere eight studies focused exclusively on farming areas). The grassland biome, in which the current study was conducted, is only represented in three caracal diet related publications. Without adequate background, such as feeding behaviour, ecological knowledge is impaired and it is impossible to predict how caracals will respond to changing management interventions. There is a dire need for a sustainable management strategy to reduce predation on livestock. On the other hand, biodiversity conservation and the role that these damage-causing animals play in healthy ecosystem functioning, should not be ignored.

1.5. Aims and objectives

The ecological role of caracal is expected to vary geographically as prey species composition, trophic structure and potential competition with black-backed jackal are not the same across habitats/geographical areas and differently managed entities (Avenant 1993; Avenant & Du Plessis 2008). Different forms of human intervention and disturbance is also expected to influence the role of caracal in the ecosystem (Du Plessis 2013). Although the limited number of previous studies give valuable insight into caracal ecology, it is, thus, inaccurate to generalise and make statements that caracal behave in a certain way. Specific characteristics of each location under discussion must be considered.

This study forms part of a larger study that addresses the lack of knowledge regarding caracal ecology and the problem of excessive stock loss on farms as a result of caracal and sympatric black-backed jackal predation (Avenant pers. comm.). Comparing prey abundance, diversity, density and group size with the prey consumed, will contribute towards caracal preferences and behaviour, and prey niche sharing and overlap with sympatric carnivores (see Appendix 6). Although the caracal is the main animal under study here, the diet of three of the other carnivores in Appendix 6 were co-investigated: black-backed jackal, Cape grey mongoose and yellow mongoose.

Using scat analysis, prey availability methodology and existing literature information (Grobler 1981; Moolman 1984; Palmer & Fairall 1988; Stuart & Hickman 1991; Avenant & Nel 1997, 2002), this study aims to address some of the key questions asked today when considering damage causing animal management:

- “what percentage of these species’ prey constitute small stock?”,
- “what are the relationships between natural and livestock prey in caracal diet?”,
- “does the conservation of high integrity natural habitat in small stock farming areas play a role in limiting predation on live stock?”,
- “does caracal and black-backed jackal have an influence on each other’s numbers?”,
- “could the conservation of natural prey and syntopic predators limit predation on live stock?”,
- “how does the reproduction and territorial aspect of caracal (and black-backed jackal) relate to prey availability and prey use?”.

One of the strong points of the larger study is that diet, prey availability and activity and ranging behaviour is addressed together at the same location, in a holistic approach. These components are each undertaken by a specific group of researchers. However, cooperation and fieldwork assistance between researchers is joined, in such a way that the individual studies can stand alone; at the same time cross referencing and stimulation benefits the bigger programme. This specific project focused on the diet and prey availability aspects.

The following objectives are discussed in this study:

1. Area specific characteristics of caracal diet and the relative importance of different prey items (Chapter 3)
2. Prey niche overlap and breadth of syntopic carnivores (Chapter 4)
3. Predator-prey interactions of caracal (Chapter 5)
4. Implications of this study for management of damage-causing caracal (Chapter 6)

2. Study Area, Materials & Methods

2.1. Study area

The study area is situated in a *c.* 40 000 ha, predominantly small stock, farming area (centered at 30°30'S, 26°07'E), in the southern Free State (Fig. 2.1), approximately 20 km north of both Bethulie and the confluence of the Orange and Caledon rivers (Fig. 2.2). This group of farms constitutes the Tafelberg Hunting Club. The area falls within the Dry Grassland subgroup of the Grassland Biome (Mucina *et al.* 2006).

On local scale the study area can be described as a heterogeneous, hilly landscape, consisting of a variety of vegetation types, representative of the larger area in which it lies (Fig. 2.3). Open grassland (Xhariep Karroid Grassland, Gh3) characterises most of the flat areas, whereas thick shrubby vegetation (Besemkaree Koppies Shrubland, Gh4) covers the sloping parts and valleys (Mucina *et al.* 2006). The open grassland areas falls within the Permian Adelaide (soil) Subgroup of the Beaufort Group, Karoo Supergroup, and grows on interchanging layers of mudstone and sandstone (Mucina *et al.* 2006). Vegetation of the Besemkaree Koppies Shrubland grows on dolerite dykes and sills, and intermittently on a mixed geologic substrate (Ecca and Beaufort Groups) consisting of sandstones, mudstones and dolerite. Numerous rocky outcrops are present throughout the hilly parts of the study area. A number of valleys, ephemeral streams and ground water aquifers support wildlife and the local agriculture activities.

Altitude ranges between 1 350 m and 1 650 m above sea level. The mean minimum and maximum monthly temperatures in this summer rainfall area range between -2 and 19˚C in July, and between 15 and 33˚C in January, respectively (Data Source: South African Weather Service). The average precipitation for the past ten years was calculated as 393 mm/year, which is slightly less than the 98-year long term mean of 444 mm/year (Data Source: South African Weather Service). Following Walter & Breckle (1985, 2002) and Juvik *et al.* (2008), a Walter Lieth climate diagram was constructed with historic climate data from 2004 to 2014 (Fig. 2.4). The diagram shows the dry season to be from April to November and the wet season from December to April. During the period of May 2011 to May 2012 (≈ the study period) the study area received 343 mm of rain (dry season = 108 mm; wet season = 235 mm) (Fig. 2.5). Overall the study area was very dry. Only during the months of December 2011, February 2012 and March 2012 did the study area receive more than 40mm of rain (Fig. 2.5 A). The average humidity was lowest in October 2011 (41%) and highest (between 70% and 87%) in the mid-autumn to mid-winter (April – July) months (Fig. 2.5. B). During the study period the highest average wind speeds (above 13km/h) were recorded in the summer months, November to January (Fig. 2.5 C). The study area received light snowfall during the coldest days in June and July. Frost commonly occurs from mid-May to end-July (Data source: South African Weather Service).

Veld fires are common in the study area as a result of dry vegetation, and usually peaks in November (H. Grobbelaar, farmer and chair, Tafelberg Hunting Club, pers. comm.), at the end of the dry season when wind speed and temperatures are high and humidity low (Fig. 2.5). In ideal conditions veld fires can spread rapidly, causing large scale loss in agricultural assets, such as land, structures, livestock and game animals. The majority of veld fires in the area is caused by lightning strikes (H. Grobbelaar pers. comm.) and is considered a natural ecological phenomenon (Mucina *et al.* 2006). The area receives approximately between two and six ground lightning strikes per km^2/year; considered a moderate amount when compared to other areas of the Southern African sub-region, such as certain parts of Lesotho that receive more than 12 ground lightning strikes per km^2/year (Schulze 1997).

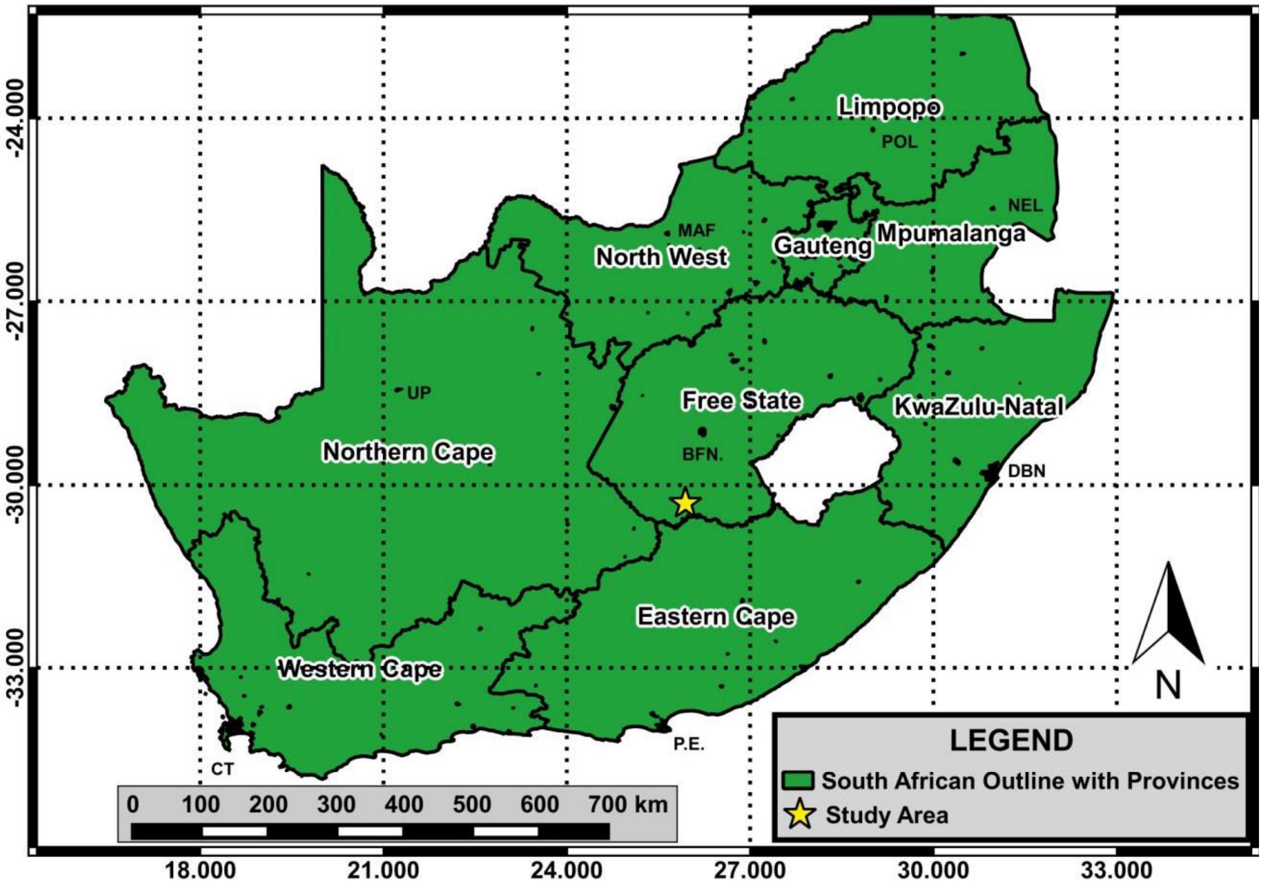

Fig. 2.1. Location of the study area in the southern Free State, central South Africa.

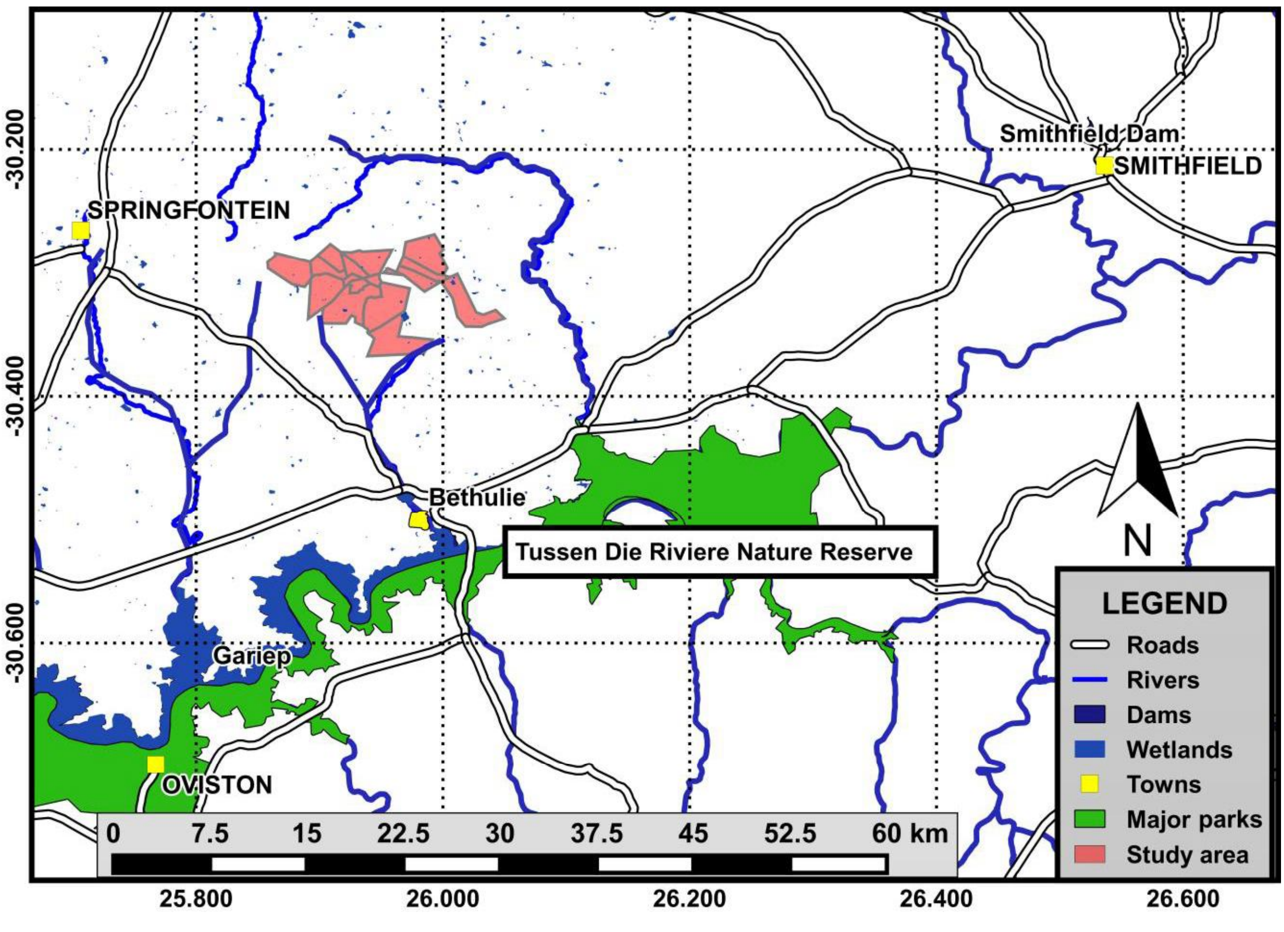

Fig. 2.2. Location of the study area, *c*. 20 km north of Bethulie in the southern Free State.

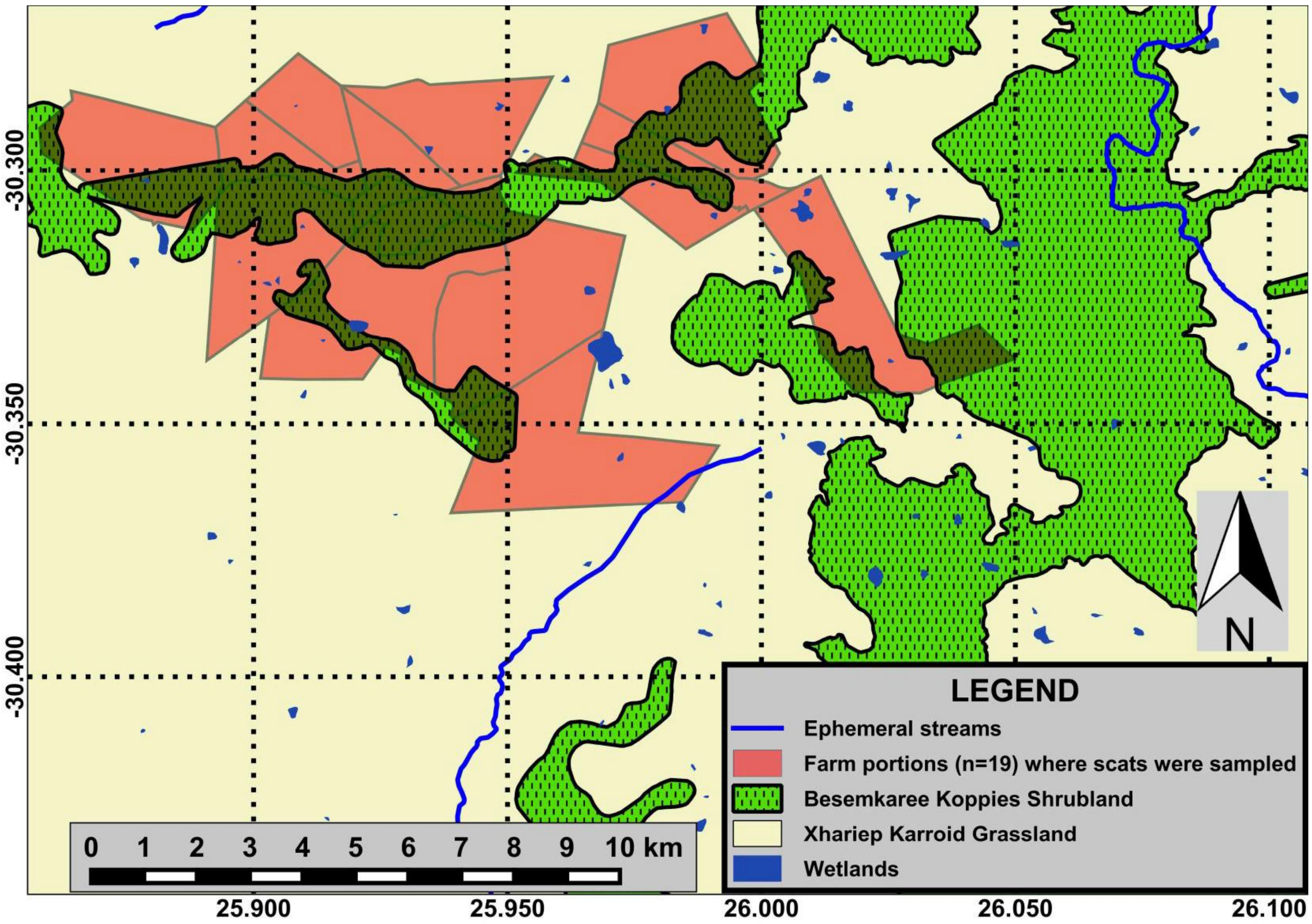

Fig. 2.3. Study area vegetation (following Mucina & Rutherford 2006) and surface water availability.

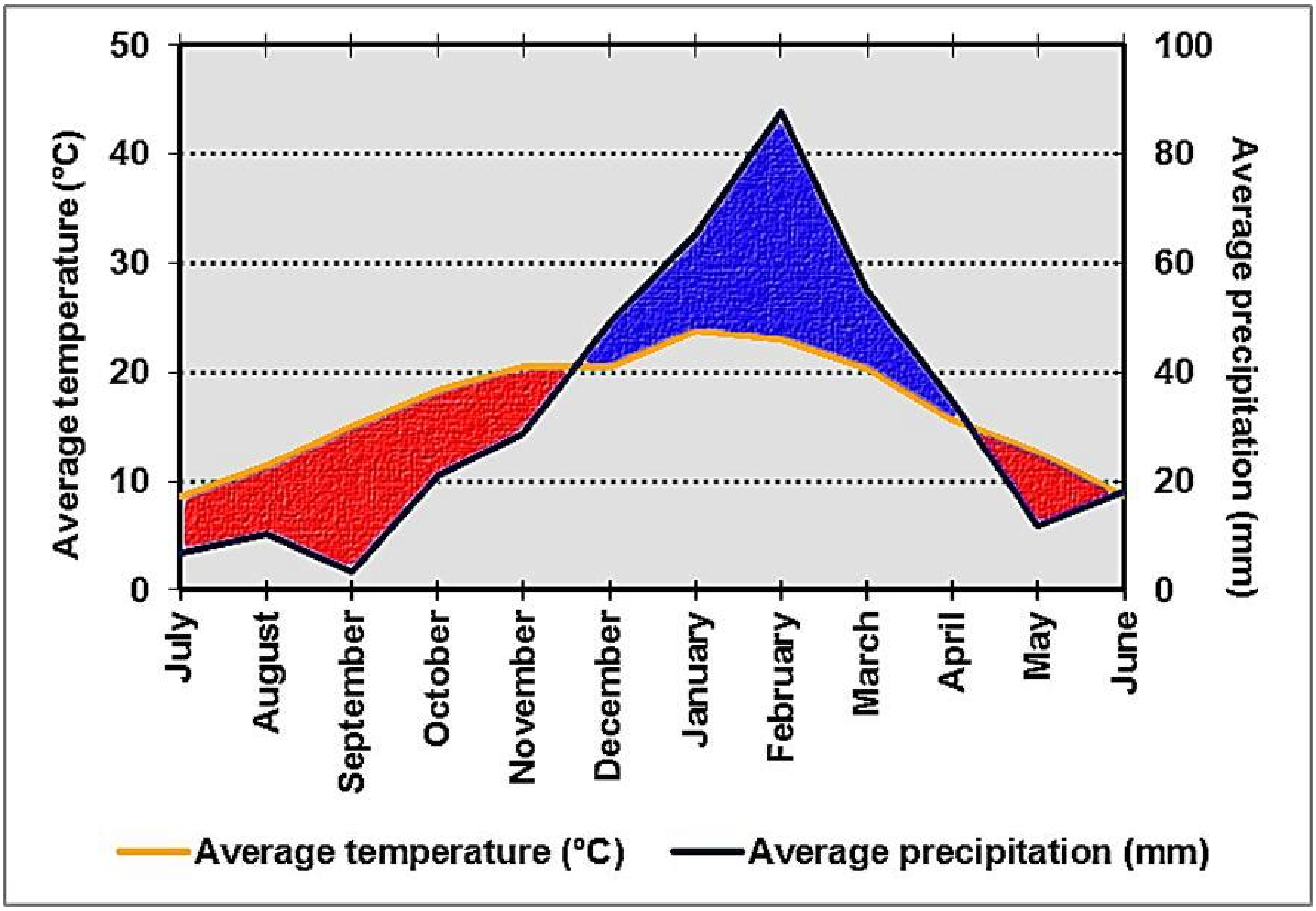

Fig. 2.4. General dry (red) and wet (blue) seasons in the study area, calculated for the period 2004 - 2014 (Data source: South African Weather Service and www.wunderground.com).

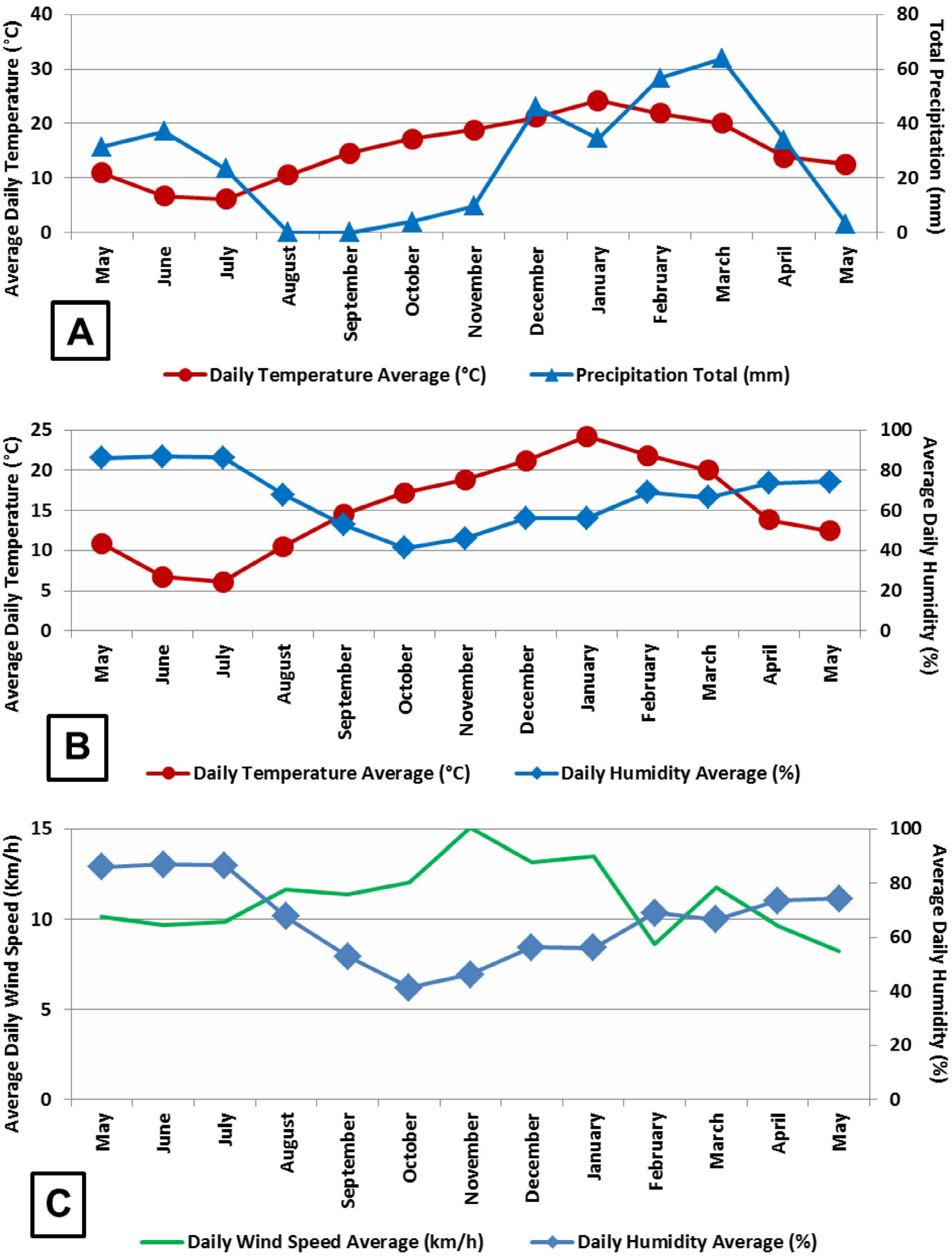

Fig. 2.5. Climate statistics for the study area, May 2011-May 2012. **A.** Temperature and rainfall, **B.** temperature and humidity, and **C.** humidity and wind speed (Data source: South African Weather Service).

In addition to drought, veld fires and damage-causing animals, stock theft also threatens the livelihood of farmers in the Bethulie area. Since landlines are underdeveloped and cell phone reception is limited, farmers are obliged to make use of two-way hand-held and vehicle radios for communication (H. Grobbelaar pers. comm.). Most famers in the area are committed towards an integrated network of anti-stock theft patrols, locally organised fire combating regimes and damage-causing predator management procedures.

Damage-causing predator control procedures in the larger southern African context include the placing of cage traps, gin traps, poison, hunting with dogs, and large scale exterminations of caracal and jackal (e.g. hunting caracal and black-backed jackal via helicopter). For the purpose of this thesis, these management methods have to be taken note of, but are not discussed in further detail (as this research is specifically aimed at the diet and niche overlap of caracal with that of sympatric carnivores). These and other management methods, and the varying impacts thereof, are comprehensively described by Du Plessis (2013). In the specific study area the farmers are comparatively selective in terms of killing damage-causing species, and mostly caracal and black-backed jackal individuals directly linked to small stock losses are killed.

As in many areas of the Free State, the habitat is fragmented and at places degraded by agriculture. Overall, however, the habitat is considered in a relatively good ecological condition. This may be ascribed to the topography and hard soil types of especially the sloping parts, which makes it difficult to fully utilise the natural habitat for agricultural purposes, and the presence of the full complement of small to medium-sized predators and their prey. Nonetheless, the high impacts of unsustainable grazing practices have to be considered as a potential threat, with the "fence-line effect" observed at places in the larger area. Fair grazing pressure is typically maintained throughout the year by providing small stock and herds of cattle with supplementary fodder. Mucina *et al*. (2006) also highlights the degradation of the grassland biome as a result of overgrazing, which leads to spread of karroid shrubland into grassland.

Many farmers in the area have game inside the perimeter of their farms. Some of these game animals (e.g. springbok, gemsbok, blesbok and black wildebeest) are contained with their livestock within normal 4-strand barbed wire fences, whilst others are free roaming natural populations (e.g. kudu, mountain reedbuck, duiker and steenbok). For a list of mammals and other animals present in the study area, see Appendix 6. The observed impact of agriculture on biodiversity is expected to vary greatly among groups of animals found in the area. From the work of Eccard *et al*. (2000), O' Farrell *et al*. (2008) and Avenant & Du Plessis (2008) it can be argued that certain groups, such as small mammals, may be used as indicators of ecosystem integrity as they are vulnerable to disturbance of agricultural practices, and usually make up a large proportion of carnivore diets. O' Farrell *et al*. (2008) argues that small mammals may play an important role as an alternative prey resource that could potentially inhibit predation on small stock by caracal and black-backed jackal. O' Farrell *et al*. (2008) also argued that small mammal diversity may be determined by a certain minimum level of vegetation cover. Intensive agricultural land transformation therefore not only decreases food resources, but also intensifies predation risk by destroying natural shelter – and as such can have a significant impact on the ecological integrity of an area.

2.2. Materials and methods

2.2.1. Fieldwork and study schedule

A *c.* 30-day pilot study, stretching between February and March 2011, was conducted in order to test research methods. Outcomes from the pilot study showed that all methods, including adequate scat collection and prey counts were possible in the study area, achievable within a 10-day period per month (≈ adequate to address the research aims and objectives). It also indicated that wind speed, precipitation and moonlight had a marked effect on the activity patterns and nighttime observations of animals in the study area (especially applicable to prey counts).

Transects and focus areas were selected, and fieldwork was planned to coincide with the time period between the three quarter moon phase and new moon, since many nocturnal animals (e.g. springhare *Pedetes capensis*, Cape hare *Lepus capensis* and scrub hare *Lepus saxatilis*) in the study area are more active when the moon is darker (see Stenkewitz *et al*. 2010).

The calendar year was divided into winter (June–August), spring (September-November), summer (December–February) and autumn (March–May).

2.2.2. Scat collection and analyses

The current study used scat analysis, a non-invasive method of carnivore diet estimation (rather than stomach content analysis or isotope studies that may limit a holistic detailed analysis of diet). Scat analysis, however, is not without its own set of problems. Due to different passage rates of prey types and relative body size differences of prey (also relative to the carnivore), there is potential bias in scat analysis methodology, most notably, under- and over-estimation (Bowland & Bowland 1991). Some dietary items, such as soft bodied insects and seedless fruit for example, may even be completely digested (see Forbes 2011). Additionally, bias may arise when sequentially passed scats are collected along frequently used paths, latrines (Bowland & Bowland 1991) and kill sites (Marucco *et al.* 2008). Brassine (2011) lists decomposition rates, manipulation and coprophagy of scats (Livingston *et al.* 2005) by invertebrates and other animals as additional sources of bias. The method also does not reveal much about the age, sex, territorial status or the number of individuals from which the sample came. Scat analysis also does not discern which prey (or food) items were killed by the predator, and which were scavenged. Scat analysis does, however, have a number of benefits that sets it apart from other methods of diet estimation. These include the detection of species in the area which are difficult to find using methods such as through observations, finding carcasses, isotope studies and identifying in limited samples of stomachs - Palmer & Fairall 1988).

As a result of potential biases the sampling method and laboratory procedure of the current study was carefully planned in order to give reliable diet estimates. Scats of caracal and sympatric carnivores were sampled over a 13 month period, from April 2011 to May 2012. GIS software was used to make maps of scat locations (scat plots) which were instrumental for increasing scat sample size (Appendices 2-5). These monthly updated scat plots made it possible to identify which areas caracal frequently defecated in. Locations on scat plots were used to construct transects (*c.* 5 km long), which were thoroughly searched for scats each month. At the end of the study the four carnivores included in this study all had reasonable numbers of positively identified mean monthly scat sample sizes (caracal 11.2 ± 4.3; black-backed jackal 13.2 ± 7.0; Cape grey mongoose 20.5 ± 12.4; and yellow mongoose 25.1 ± 19.6; see Chapters 3 and 4). Judging from the number of caracal caught in cage traps by farmers in the study area (6-12 caracal per annum) and the number of black-backed jackal and caracal hunted during the study period (4-6 black-backed jackal; 1 caracal), it was estimated that the scat sample sizes are from between 6 and 12 individuals from each damage-causing species. Moreover, fresh caracal and black-backed jackal scats were still found almost immediately after some of these animals were removed from the ecosystem.

All sampled scats were placed in separate paper bags, labeled with the necessary information such as date and location (see Palmer & Fairall 1988; Avenant 1993), and analysed separately in the laboratory. Only relatively fresh scats were collected during fieldwork (see Avenant 1993). A scat was labeled “fresh” when they had no visible cracks on the outer surface, were not brittle when picked up, were relatively unfaded, and or were not present at a specific recognised place the previous month.

From descriptions by Stuart & Stuart (2000), Chame (2003), Walker (2009) and Murray (2011), the following criteria were used when identifying scats in the field: scat and segment length, width, form, smell, color, locality and habitat. Scats were then further identified in the laboratory based on the following criteria: presence of the carnivore's hair in the scat, metadata on the labeled envelope, a closer look at the form (e.g. segmentation is usually characteristic of the cat family), shape of the edges (e.g. pointed, round or sudden), precise length and width (in mm), and location on the GIS map. A small cotton thread was used to measure the length, whilst a digital caliper was used to record the width of scats to the second decimal.
In this study a total of 1607 carnivore scats (including: caracal, black-backed jackal, Cape grey mongoose, yellow mongoose, suricate and unidentified scats) were collected over the 13 month study period (±124 scats/month). Scats were excluded from analysis if the identity of a scat could not be verified based on factors such as, external appearance (e.g. width, length, shape), scat content, location and the hair of a carnivore in the scat. Of the 670 scats that were excluded (42% of all collected scats) 33 belonged to either caracal or black-backed jackal; 480 of the scats possibly belonged to Cape grey mongoose, five to yellow mongoose, and 152 scats belonged to either yellow mongoose or suricate. The diet of suricate was not described in this study as the sample size was too small (only 81 scats could be positively identified as from suricate).

Laboratory methodology of scat analysis followed that of Avenant & Nel (1997, 2002). Caracal and sympatric carnivore diet was determined by examining the contents of their scats collected from various plant communities, habitats, contours and slopes identified in the study area. Large, diagnostic fragments of prey were macroscopically identified while hair, teeth, feathers and reptilian scales were identified by means of a stereo dissection microscope at 25x or 50x magnification. Prey items in undigested remains were identified to species level where possible by comparing the latter with a reference collection of material from the National Museum, Bloemfontein, and with remains from clearly identifiable carcasses found in the study area. Prey fragments were also compared with published diagnostic features, such as scales on hair imprints (Keogh 1983, 1985) and tooth form (De Graaff 1981). DPX ($C_{18}H_{18}Br_2N_2$) mounting medium, Entellan ($C_{13}H_{22}O_4$) and commercial nail polish were all tested for making hair imprints on microscope slides.

Transparent nail polish produced the quickest imprints, but with occasional disappointments (sometimes failed to show the small detail of cuticular scales on mammal hair). DPX mounting medium produced the slowest imprints, but with better results (well defined cuticular scales of mammal hair). At the end of the trial phase, Entellan was preferred over DPX and nail polish, because it produced relatively fast, but good quality imprints similar to DPX. Acetone was used for cleaning microscope slides. With some practice, dried Entellan could be “recycled” by applying a small amount of acetone, just enough to make the Entellan viscous again. This was useful, since Entellan is expensive. However, care should be taken to ensure that a sufficient amount of the semi-dried Entellan is available on microscope slides when recycling it. Entellan was not recycled when completely dried, as an ideal viscous state for hair imprints could not be achieved. Only hair imprints that clearly displayed the cuticular scale patterns and edges were used in analyses.

2.2.3. Prey availability

Prey availability studies also included scientific and casual observations of antelope (e.g. mountain reedbuck *Redunca fulvorufula*, springbok *Antidorcas marsupialis* and steenbok *Raphicerus campestris*), Cape hare *Lepus capensis* scrub hare *Lepus saxatilis*, springhares *Pedetes capensis*, rock hyrax *Procavia capensis* and ground living birds, such as Orange River francolin *Scleroptila levaillantoides*, northern black korhaan *Afrotis afraoides* and helmeted guineafowl *Numida meleagris* in the study area. Data on antelope, hares, springhares and birds were gathered from transects laid out in all major plant communities. Two kinds of transects were used: walk transects and drive transects. Standard count methodology followed that of Rudran *et al.* (1996) and Bothma (2002). Since the study area contained a mosaic of plant communities, the length of transects varied in each (see Avenant & Nel 1997).

The three walked transects were designed for scat collection, game counts and casual observations (on e.g. breeding seasons, presence of young and group sizes of various prey). These transects followed each of the three major broadly defined habitats: (1) on the relatively dense, shrubby, southern slope, (2) on the open, flat grassland plateau, and (3) on the rocky plateau. Their lengths were approximately 10 km each, and they were walked on separate days. They were walked using a GPS, twice every month, in the early morning, always in the same direction, when it was not raining, and when wind speed was less than 4 m/s (see Avenant & Nel 2002). The position of all transects therefore remained constant throughout the study period. The width or mean diameter over which prey can be positively identified differed between plant communities, and was taken as the maximum distance from the midline of the transect that animals can be clearly identified. Animals outside this predetermined width were ignored (see Avenant & Nel 1997).

Drive counts followed the same methodology as walked transects, except that they differed in terms of time of the day started, and they did not cover the same habitat types. The reason for this different coverage was inaccessibility of certain parts of the study area, especially during heavy rains. This was, however, no setback as the drive counts were primarily designed for counting hares and springhares at night and before sunrise, to serve as an indication of density fluctuations over months and seasons. Both hares (*Lepus* spp., expected to be mostly Cape hare *L. capensis*) and springhares seemed to prefer the open, flat, grassland (Xhariep Karroid Grassland) which comprised the overwhelmingly largest proportion of the drive count transect (Fig. 2.6). This transect consisted of a 17 km stretch of farm road. Animals were counted on both sides of the road using Pentax UCFX II 8x25 binoculars, a Celestron 80 mm spotting scope, and a Lightforce (240 mm diameter, 1000000 candlelight, 1000 m beam range) spotlight. Hares were counted up until 60 m from the vehicle (i.e. the distance over which it was estimated that >90% of hares present would have been sighted) whilst springhares *Pedetes capensis* were counted up until 300 m from the vehicle. Drive counts, at 25 km/hour, were repeated three to four times per month and the average values were calculated to be used in the further analyses.

Arthropod sampling were done in the summer months (Dec-Feb) on three transects, each ± 50 m long and consisting of 11 pitfall traps each. These transects were laid out in three locations in the study area (Fig. 2.7). The primary purpose of this was to aid in the identification of arthropod prey in Cape grey mongoose and yellow mongoose scats (this list of Arthropoda prey is listed in Appendix 9), and not to compare densities between sites or seasons.

Densities of two rock hyrax colonies were determined using standard count and catch-mark-release methods (see Wiid & Butler 2014; Fig. 2.7). Population data was inferred using the Lincoln-Peterson and Robson–Whitlock technique indices (Wiid & Butler 2014).

Date, GPS locality and habitat description of all freshly killed antelope and sheep carcasses found were noted. The identity of the carnivore responsible for killing a carcass was assessed based on the killing pattern or descriptions of carcasses and secondary field signs (Stuart & Stuart 2000; Chame 2003; Hodkinson *et al.* 2007; Smuts 2008; Walker 2009; Murray 2011). Some of the carcass characteristics and signs that were investigated include: the position and size of bite marks, body area eaten (e.g. hind quarters, front quarters, abdominal area, etc.), carcass location (e.g. in the open or dragged under a bush), nearby scats (e.g. shape, length, width, colouration, position) and footprints. This information were thought to be useful to correlate with the scat contents of caracal, but also with that of black-backed jackal and that of the smaller carnivores Cape grey mongoose and yellow mongoose (who might have scavenged on the carcass).

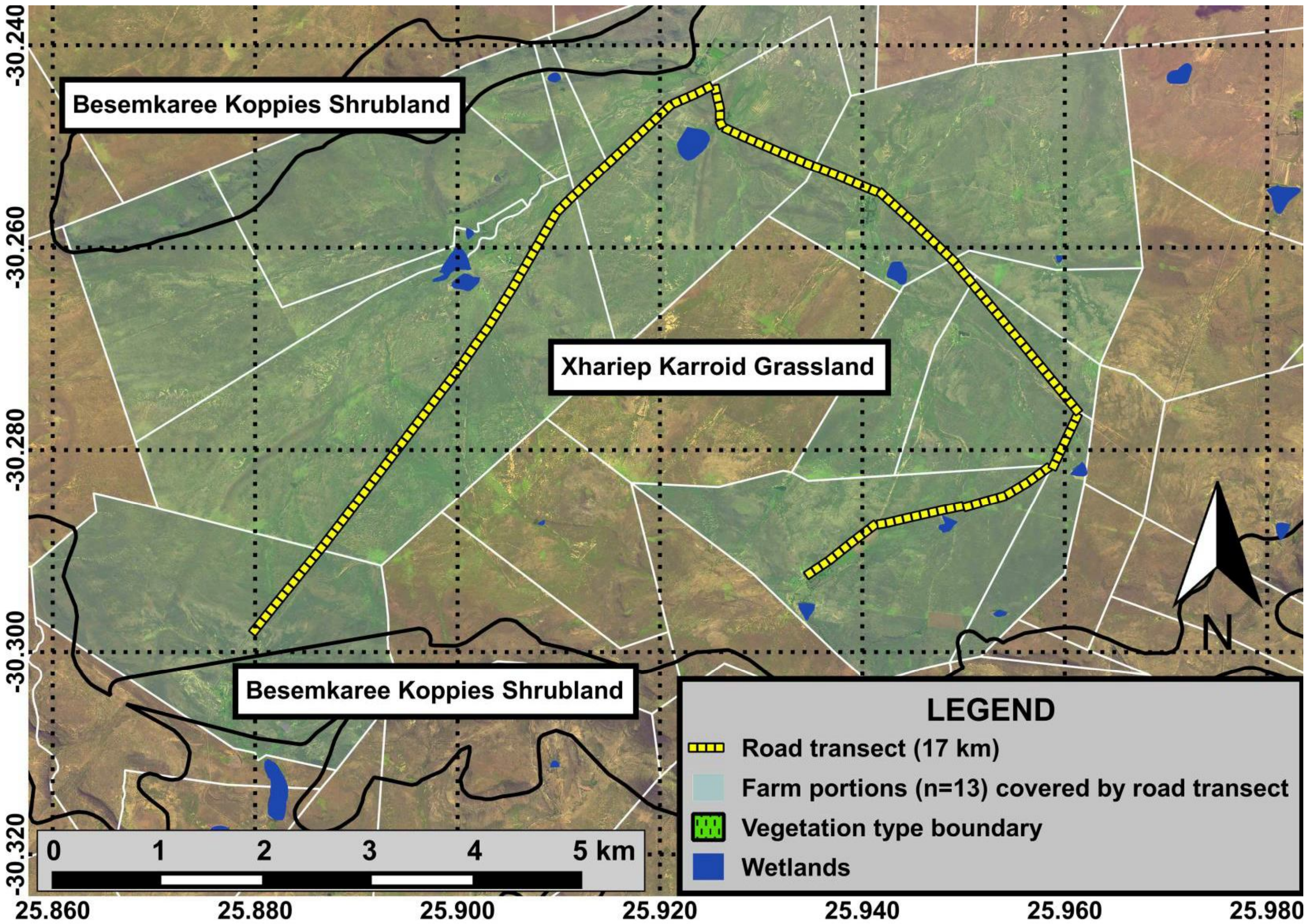

Fig. 2.6. Road transect in the study area, southern Free State (vegetation types from Mucina & Rutherford 2006).

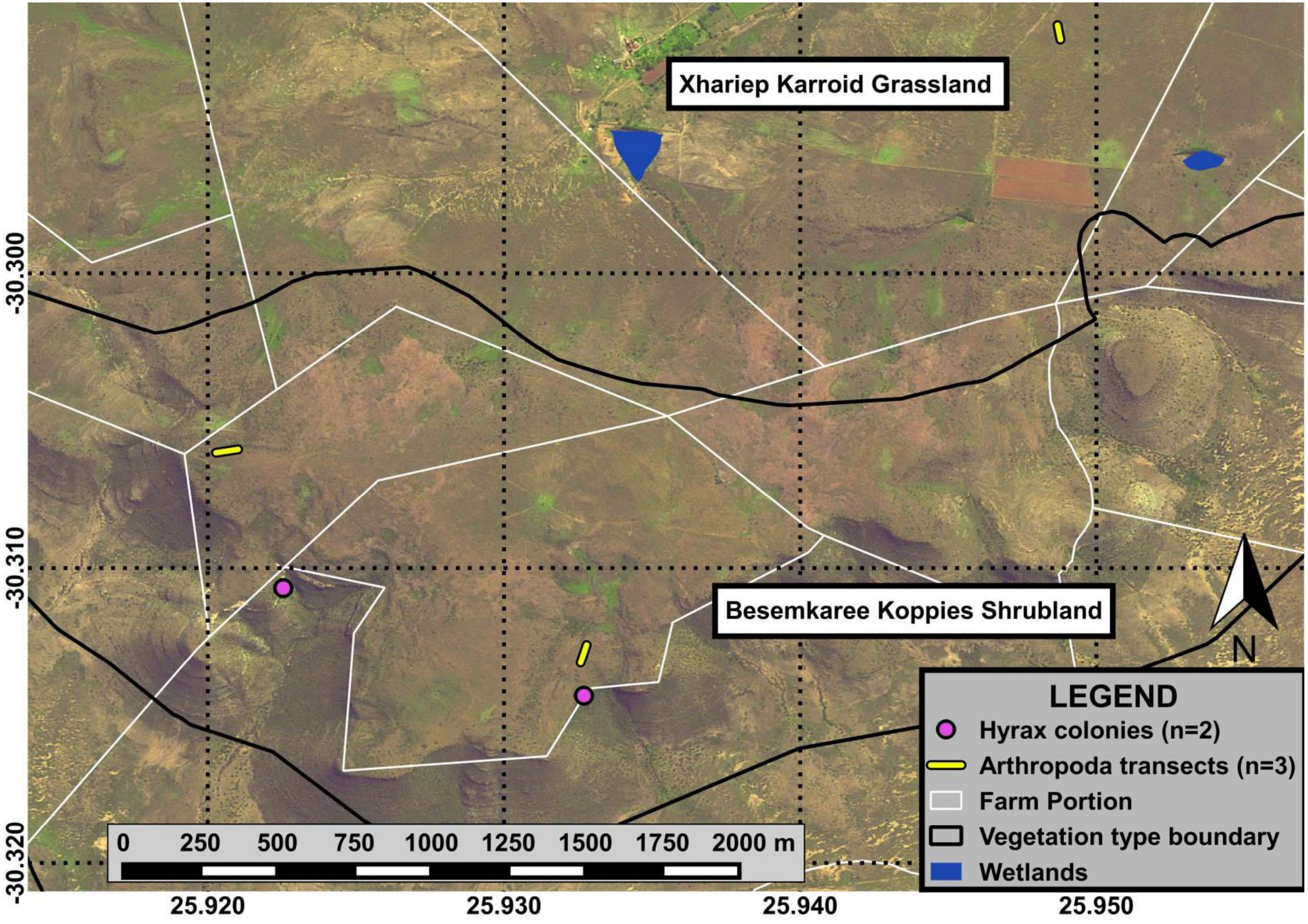

Fig. 2.7. The location of three Arthropod transects and two rock hyrax populations in the study area, southern Free State (vegetation types from Mucina & Rutherford 2006).

2.2.4. Data analysis

In order to eliminate some of the bias of scat analysis described in section 2.2.2, both the percentage of occurrence (%Occ.) and percentage of volume (%Vol.) methods were used to describe the predator species' diet. Numerous authors recognised that both percentage occurrence and percentage volume indices should be used together, since neither by itself can define the diet of a carnivore accurately (see Putman 1984, Bowland & Bowland 1991, Avenant & Nel 2002, Klare *et al*. 2011). Using both methods also allows for comparisons with other, especially older, studies where only one of the methods were used (see Avenant & Nel 2002 and Klare *et al*. 2011). Percentage of occurrence (following Lockie 1959, Corbett 1989, Nel *et al.* 1997 and Bizani 2013) is simply defined as the percentage of scats containing a particular prey item (number of scats with prey item / total number of scats in the specified period X 100/1). This expression, including relative percentage occurrence (see below), was handy to express how many times a specific prey type was, relatively, taken and is for example useful when addressing the frequency with which even very small items are utilised. The percentage volume was calculated as the sum of volumetric contributions of a particular prey item in scats, divided by the total number of scats in the specified period (following Mealey 1980, Sillero-Zubiri *et al.* 1995). The percentage volume, including the relative volumetric contribution (see below), was useful to express the relative quantitative contribution of specific prey items in the carnivore's diet.

From the percentage occurrence and percentage volume an importance value (IV.), a relative percentage occurrence (Rel.%Occ.), relative percentage volume (Rel.%Vol.) and relative importance value (Rel.IV.) was also calculated. The importance value (IV.) was calculated as percentage occurrence x percentage volume / 100 (following Mealey 1980, Raine & Kansas 1990 and Avenant & Nel 2002). The relative percentage of occurrence was expressed as the number of incidences of a particular prey type in scats, divided by the number of incidences of all prey types in scats, multiplied by 100. The relative percentage volume was calculated as the volumetric contribution of a particular prey item in a specified period / total volume of all prey in that period. The relative importance value (Rel.IV.) is similar to the Importance value (IV.), but is calculated using the relative percentage occurrence (Rel.%Occ.) and relative percentage volume (Rel.%Vol.) instead of the percentage occurrence (%Occ.) and percentage volume (%Vol.).

Scat analysis may be used to identify main prey items. Avenant & Nel (1997, 2002), for example, referred to main prey as those prey items that clearly dominated the mean monthly diet of a carnivore in terms of volumetric contribution (>40%). In this study, however, "main prey" contributed less than 40% to the volume of scats. This study defined two new terms, namely minor and major prey. "Minor prey" were those prey categories with an importance value of less than five in all two-monthly periods (see chapter 3), while the rest fell under the "major prey" category (IV. > 5).

The number of prey killed or preyed on by caracal were calculated following Grobler (1981) and Avenant & Nel (2002): the relative percentage occurrence (Rel.%Occ.) of prey (converted to proportions) was multiplied by the average weight that a 10kg adult caracal can consume in one year (~365 kg; see Grobler 1981) or on a monthly basis (~30 kg), divided by the weight of the specific prey that was consumed. Weights of rodent and other prey species (= the average of male and female weights) are from areas closest to the study area, as listed in Skinner & Chimimba (2005) and Hockey *et al*. (2005).

A number of additional indices were also used to describe dietary data (see formulas in (Table 2.1). Food niche overlap and niche width were calculated following Pielou (1972), Loveridge & Macdonald (2003), Maude & Mills (2005) and Varela *et al*. (2008). Both the Shannon and Simpson's indices were used to measure the seasonal diversity of prey items utilised by predators (Magurran 2004). The evenness with which prey were taken during specific time periods were calculated using Evar (Smith & Wilson 1996). The Shannon-Wiener index is a measure of species diversity which takes into account both the number of prey species as well as the evenness with which individuals are distributed among prey species (Putman & Wratten 1984; Magurran 2004; Avenant 2005). The Simpson's index takes these two variables (= species richness and species evenness) into account, but is also closely related to the Levin's index and commonly functions as a measure of niche breadth and diversity in carnivore diet studies (Chuang & Lee 1997; Loveridge & Macdonald 2003). Although Simpson's index is now thought to be a more robust, and therefore a more acceptable, measure than Shannon's index, the latter has been used commonly in older literature (e.g. Massei *et al.* 1996 and Nel *et al.* 1997). For comparative reasons, therefore, both Simpson's and Shannon's indices are used in this chapter. The Evar evenness index (Smith & Wilson 1996) served as a useful, complementing, addition in this study, the reasoning being that the highest diversity index is found at high species numbers utilised with high evenness. When diversity is high and evenness low, however, this is then an indication of an even higher number of species utilised.

Table 2.1. Formulas used in the dietary analysis.

Index	Formula	Description of formula components
Pianka's index of niche overlap (***O_{jk}***)	$O_{jk} = \sum_{i=1}^{n} p_{ij}\, p_{ik} / \sqrt{\left(\sum_{i=1}^{n} p_{ij}^{2} \sum_{i=1}^{n} p_{ik}\right)}$	***p_{ij}*** (or ***p_{ik}***) is the proportion of food category ***i*** recorded in diet of the species ***j*** (or ***k***)
Levins index of niche breadth (***B***)	$B = \left(\sum_{i=1}^{n} p_i^{2}\right)^{-1}$	***n*** is the number of food categories and ***p*** is the proportion of records in each food category (***i***)
Shannon-Wiener index (***H'***)	$H' = -\sum p_i \ln(p_i)$	***p_i*** is the relative abundance of food category ***i*** in the diet of species ***p***
Simpson index (***D***)	$D = \sum_{i=1}^{s} p_i^2$	***p_i*** is the relative abundance of food category ***i*** in the diet of species ***p***
E_{var}	$E_{var} = 1 - 2 / (\pi \times \arctan(\sum_i \{\log(n_i) - \sum_j \{\log(n_j)\}\}^2/S))$	***n_i*** and ***n_j*** are the number of individuals in species *i* and ***j*** respectively, and ***S*** is the total number of species

Scat analysis data was tested for normality using the Shapiro-Wilks' W test. To investigate any differences in prey items utilised, Friedman Anovas were used. For a comparison of food niche breadth t-tests for independent samples were used, and Spearman rank order for correlations. Statistical analyses were done with Statistica for Windows (Statsoft Inc., Tulsa, OK), and the 95% level ($p<0.05$) was regarded as statistically significant for all tests.

All GIS maps (e.g. count transects, vegetation types and latrine sites) were created with QGIS desktop version 2.4.0. Spot images and farm boundary data was acquired from the Geography Department, University of the Free State, while wetland and river shape files were acquired from SANBI (http://bgis.sanbi.org/index.asp?screenwidth=1366). Vegetation type shape files and major towns is from Mucina & Rutherford (2006).

3. The Diet of Caracal on Small Stock Farms in the southern Free State

Caracal *Caracal caracal* is considered a damage-causing predator in many rangeland ecosystems in southern Africa. This study aimed to define the diet of this opportunistic cat over a 13 month period in one of the most severely impacted small stock areas in South Africa; to (1) differentiate between major (IV.>5) and minor (IV.<5) prey items, (2) to determine their impact on small stock in the 40 000 ha study area, and (3) to determine their possible role in this agri-ecosystem. The diet was described in terms of various prey species and groups' presence (≈ percentage occurrence, %Occ.) in scats, their volumetric contribution (percentage volume, %Vol.), importance value (IV.), and the relative values Rel.%Occ., Rel.%Vol. and Rel.IV. Results indicated that caracal fed predominantly on mammalian prey (94.74%Occ.; 93.40%Vol.; Rel.IV. 99.4%). The major prey items were Lagomorpha (hare *Lepus* spp. and Smith's red rock rabbit *Pronolagus rupestris*: 28.5%Occ.; 28.0%Vol.; Rel.IV. 38.2%), rock hyrax *Procavia capensis* (17.5%Occ.; 17.3%Vol.; Rel.IV. 19.6%), springhare *Pedetes capensis* (15.2%Occ.; 15.2%Vol.; Rel.IV. 16.7%) and sheep *Ovis aries* (13.6%Occ.; 13.6%Vol.; Rel.IV. 10.2%). Minor prey included endemic antelopes springbok *Antidorcas marsupialis*, mountain reedbuck *Redunca fulverufula* and steenbok *Raphicerus campestris* (Rel.IV. 3.8%), a number of bird species (Rel.IV. 2.9%), small carnivores (Rel.IV. 1.1%), vlei rat *Otomys* spp., Namaqua rock mouse *Micaelamys namaquensis* and gerbil *Gerbilliscus leucogaster* (Rel.IV. 1.0%) and invertebrates (Rel.IV. 0.3%). Plant material (Rel.IV. 0.5%) was ingested opportunistically and in small quantities. The ingestion of most prey groups, including small stock, fluctuated over months and showed different peaks and troughs. Most of these peaks could be correlated with higher prey densities within that prey group in the study area. A number of (mostly negative) correlations could also be found between the IV. and Rel.IV. of especially the major prey groups, clearly indicating prey switching during specific periods. Opportunistic feeding behaviour was, further, evident from the observation of utilising an increased diversity of prey during lean times, when minor prey items became more important in caracal diet. Caracal fed markedly more on small stock during and immediately following the two lambing seasons, March to April and September to October, reaching Rel.IV.s of up to 35%. Both these periods were associated with at least low major prey densities, and high prey species diversity and numbers in scats. It was estimated that a single caracal in the study area may kill approximately 20 sheep lambs annually, which is expected to have substantial financial and socio-economic

implications in the long run. On the other hand, one adult caracal was also estimated to consume >70 hares and rabbits, >50 hyraxes, >20 springhares, >230 mice, c. 10 small carnivores and c. 30 birds per annum; an indication that caracal has a valuable role to play in this agri-ecosystem.

Key words: *Caracal caracal*, scat analysis, diet, small stock, major prey, minor prey.

3.1. Introduction

The caracal *Caracal caracal* is a major predator of small stock losses in southern Africa (Avenant & Du Plessis 2008; Van Niekerk 2010; McManus *et al*. 2014). Nevertheless, existing literature on rangeland ecology of caracal is scarce – a major drawback in the search to formulate a sustainable management plan for caracal (and black-backed jackal *Canis mesomelas* on rangeland (Du Plessis 2013). Overall, studies that focussed on caracal diet indicated that caracal do take more of certain prey groups (e.g. hyrax, hares, birds and small antelope) in certain areas/habitats (probably because of their relatively high availability). For instance, in the Karoo National Park their main prey was springhare, antelope and hyrax (Palmer & Fairall 1988), in the Mountain Zebra National Park it was hyrax, hares and antelopes (Grobler 1981; Moolman 1984), on the farms around the Mountain Zebra National Park it was hyrax, domestic stock and antelopes, in the southwestern and Eastern Cape it was rodents and domestic stock (Stuart & Hickman 1991), in the Kgalagadi Transfrontier Park it was rodents and small carnivores, and in the West Coast National Park it was mice and birds (Avenant & Nel 1997). Caracal are, however, also opportunistic, feed on prey that is most abundant at any specific time (Skinner 1979; Grobler 1981; Moolman 1984; Palmer & Fairall 1988; Stuart & Hickman 1991; Avenant & Nel 1997, 2002; Melville *et al*. 2004; Braczkowski *et al*. 2012; Stuart & Stuart 2013). Their opportunistic feeding behaviour is also clear from the presence of even 1g insects to >30 kg antelope (see Moolman 1986; Avenant & Nel 2002). The purpose of this chapter is to report on caracal diet in a rangeland ecosystem of the southern Free State, to see how it change over months/seasons, and to compare it with caracal diet observed elsewhere in the sub-region.

3.2. Materials and methods

Caracal diet was analysed over a 13 month period, from May 2011 to May 2012, using scat analysis. A subset of 145 fresh scats, or 11.2 ± 4.3 per month, out of the initial 1607 carnivore scats collected, were with high confidence selected and used for analyses in this chapter. Nine percent of possible caracal scats were discarded due to a measure of uncertainty. To increase scat sample sizes, they were pooled (stacked) for two-monthly periods (e.g. May-Jun, Jun-Jul, Jul-Aug, etc.); accordingly, sample size was increased to 22.1 ± 6.0 per two-month period. Fluctuations in prey usage now had to be carefully considered (and relatively fast prey switching would understandably not be picked up so clearly), but a higher confidence in more scats outweighed the latter. Data for 12 two-monthly periods could now be calculated, and the results used to determine mean percentage occurrence (%Occ.), percentage volume (%Vol.) and importance value (IV.) scores (see Chapter 2). Using relative contribution values, prey items were ranked according to their relative importance within the larger taxonomic group under discussion. All prey were identified to species level where possible (Chapter 2)

The two-monthly values were therefore used to illustrate fluctuations in prey utilised, and to split the prey items into major and minor prey categories. Minor prey were prey with an importance value never exceeding five in any two-monthly period, and Major prey were those with an IV. exceeding five for at least one two-monthly period.

A list of potential caracal prey (indigenous, introduced and domestic) present in the study area, according to field observations and literature (Estes 1991, 1999; Skinner & Chimimba 2005; Watson 2006; Stuart & Stuart 2007), is shown in Appendix 6-10.

Both the Shannon-Wiener and Simpson's diversity indices (Magurran 2004) were calculated from the two-monthly relative %Occ. and relative %Vol. values. The Evar evenness index (Smith & Wilson 1996) served as a useful, complementing, addition in this study, the reasoning being that the highest diversity index is found at high species numbers utilised with high evenness. When diversity is high and evenness low, however, this is then an indication of an even higher number of species utilised.

The number of prey items killed/consumed by caracal were calculated following Grobler (1981) and Avenant & Nel (2002): the relative percentage occurrence (Rel.%Occ.) of the specific prey (converted to proportions) was multiplied by the average weight that a 10 kg adult caracal can consume on a monthly basis (± 30 kg), and in one year (± 365 kg), divided by the assumed weight that was consumed. Prey weights (averages of males and females) were taken from Skinner & Chimimba (2005) and Hockey *et al*. (2005) (also following Grobler 1981 and Avenant & Nel 2002). Since caracal can only consume a limited amount of meat per day (*c.* 10% of its body weight per day; or 20% if eaten every second day; Grobler 1981), it was assumed that caracal would wholly consume small prey (≤1 kg) such as Muridae, while larger prey (>1 kg), such as sheep, would only be consumed partially. Prey weights consumed for some of the larger prey species (*Redunca fulvorufula*, *Antidorcas marsupialis*, *Raphicerus campestris*, *Ovis aries* and *Proteles cristatus*) was taken as 2 kg, the maximum amount of meat that an adult caracal can consume at a time (Grobler 1981). Weights for bird prey was taken as 0.838 kg (≈ the average of three species of ground living birds, Helmeted guineafowl *Numida meleagris*, Orange River francolin *Scleroptila levaillantoides* and Northern black korhaan *Afrotis afraoides*.

3.3. Results

Animalia were the major dietary component, with Vertebrata present in a mean of 99.76% (and a volumetric contribution of 98.01%) of scats stacked for the 12 two-monthly periods (Table 3.1). Plantae (≈ grass) occurred in a mean of 11.45% of scats, but with less than 1% volumetric contribution. Mammal remains were present in 94.74% of scats and contributed 93.40% to the average volume. Bird remains occurred in 6.03% (volumetric contribution = 4.62%), and invertebrates in 2.78% (volumetric contribution = 1.35%). No remains of reptiles were found.

Table 3.1. Summary of caracal diet (absolute values) in the study area, May 2011 to May 2012.

Taxonomic group	%Occ.	%Vol.	IV.
ANIMALIA	100.00	99.36	99.36
Vertebrata	99.76	98.01	97.80
Mammalia	94.74	93.40	88.49
Aves	6.03	4.62	0.28
Invertebrata	2.78	1.35	0.04
PLANTAE	11.45	0.64	0.07

Mammals, therefore, were by far the most important prey, with a mean IV. of >88%, and a Rel.IV. (of all vertebrate prey) of >99% (Table 3.2). Although plants were present in a considerable number of scats (mean Rel.%Occ. >10%), it was ingested in small quantities, and had a Rel.IV. of 0.1% only.

Table 3.2. Summary of caracal diet (relative values) in the study area, May 2011 to May 2012.

Prey group	Rel.%Occ.	Rel.%Vol.	Rel.IV.
ANIMALIA	89.6	99.3	99.9
Vertebrata	96.5	98.4	98.4
Mammalia	92.1	93.9	99.4
Aves	7.9	6.1	0.6
Invertebrata	3.5	1.6	1.6
PLANTAE	10.4	0.7	0.1

3.3.1. Major and minor dietary items

Following the frequency of occurrence and volumetric contributions, Lagomorpha (hares and rock rabbit), Ruminantia (sheep *Ovis aries* and endemic antelopes), Hyracoidea (rock hyrax) and Rodentia (springhares and mice) were the dominant prey items in caracal scats (Fig. 3.1 - Fig. 3.2). Using the definition mentioned in section 3.2 (Materials & Methods), however, the following groups and/or subsections of groups were classified as major prey items: Lagomorpha, sheep, rock hyrax and springhare. Aves (guineafowl, francolin, korhaan and some unidentified birds), Ruminantia (antelope, excluding small stock), Muridae (mice), Carnivora (mongoose and aardwolf), Invertebrata (insects and Diplopoda) and Plantae (grass) were minor items. Figure 3.2 also indicated that most prey items fluctuated over months with clear peaks and troughs observed over the two-monthly stacked periods. These fluctuations became even more evident when expressed as relative values (Fig. 3.3).

Spearman Rank correlations performed on IV.s (Fig. 3.2) between different combinations of minor and major prey produced a number of associations (at 95% confidence). Within the major prey category, Lagomorpha-*Ovis aries* (r=-0.66; p=0.02), and *Pedetes capensis*-*Procavia capensis* (r=-0.64; p=0.02) correlated significantly; interestingly, no positive correlations were found. Within the minor prey category, carnivores increased when both birds (r=-0.80; p=0.002) and springhares (r=-0.76; p=0.004) decreased (and *vice versa*), and invertebrates increased when antelopes (sheep excluded) decreased (r=-0.63; p=0.03) and when rock hyrax increased (r=0.59; p=0.04).

Correlations on the Rel.IV.s produced similar results (Fig. 3.3; Table 3.3): hares/rabbits and sheep, springhare and rock hyrax, springhare and carnivores, and carnivores and birds were all negatively related. Within the endemic Ruminantia group, springbok *Antidorcas marsupialis* usage decreased with an increase in hares/rabbits (-0.64), but was positively related to rock hyrax (r=0.65) usage. Other antelope (mountain reedbuck *Redunca fulverufula* and steenbok *Raphicerus campestris*) was negatively related to rock hyrax (r=-0.62), but positively with hares/rabbits (r=0.62). The correlation between springbok and the other antelopes were strong (p<0.005) and negative (r=-0.75).

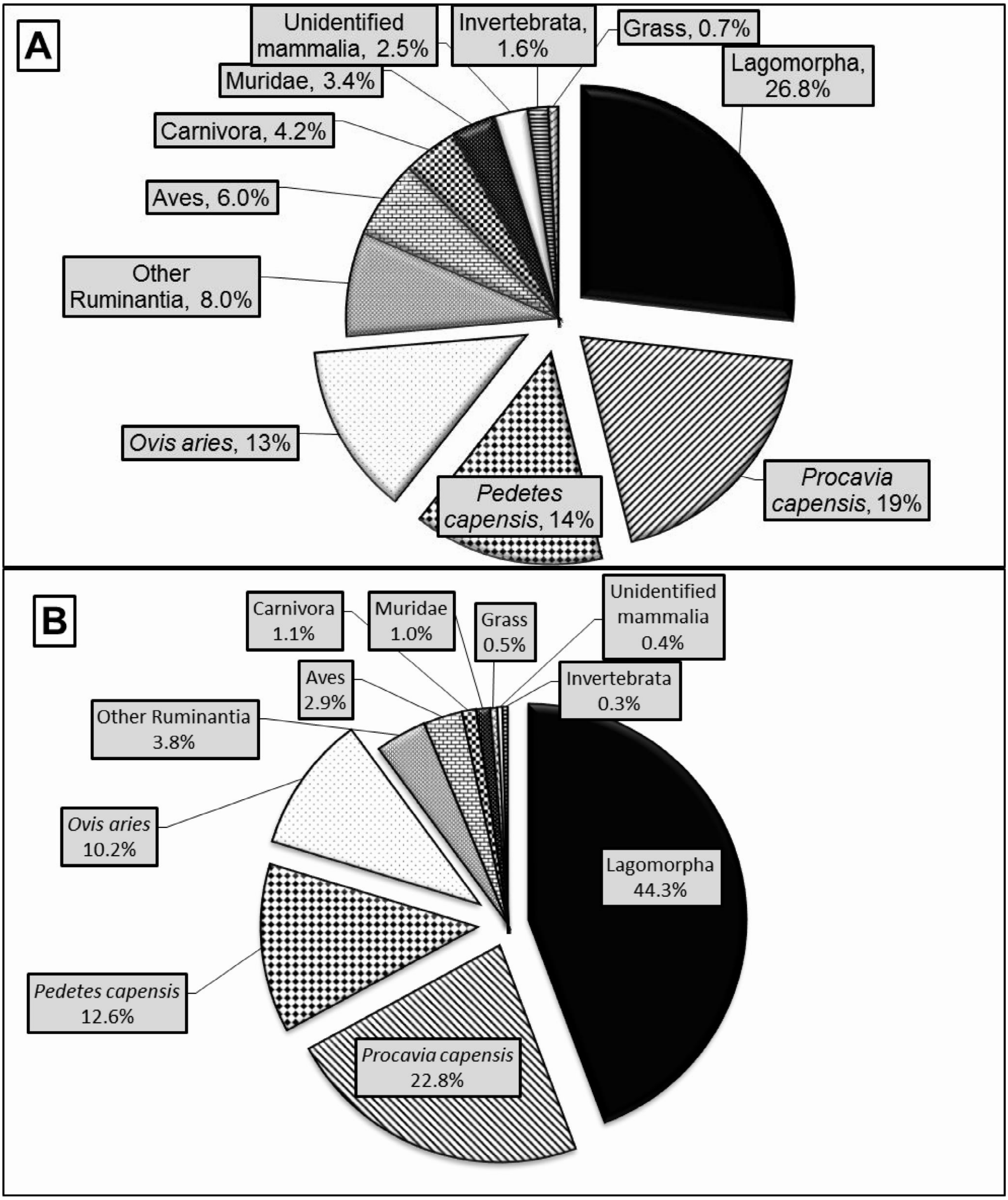

Fig. 3.1. Mean two-monthly volumetric contribution, **A**, and Importance Value (expressed as relative percentage), **B**, of all diet categories in caracal diet, May 2011 to May 2012.

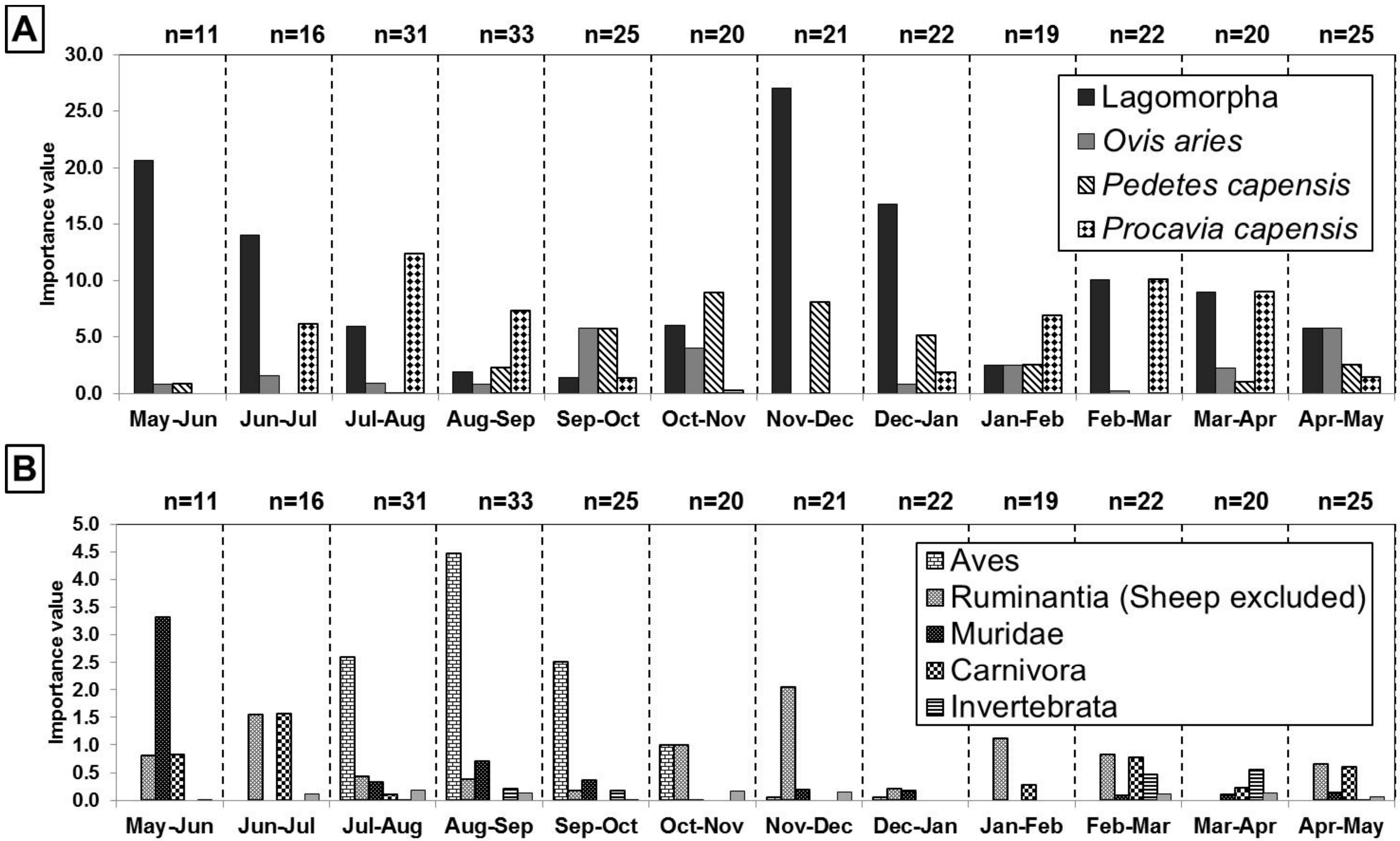

Fig. 3.2. Importance value of major **(A)** and minor **(B)** dietary items in caracal diet in the study area, May 2011 to May 2012.

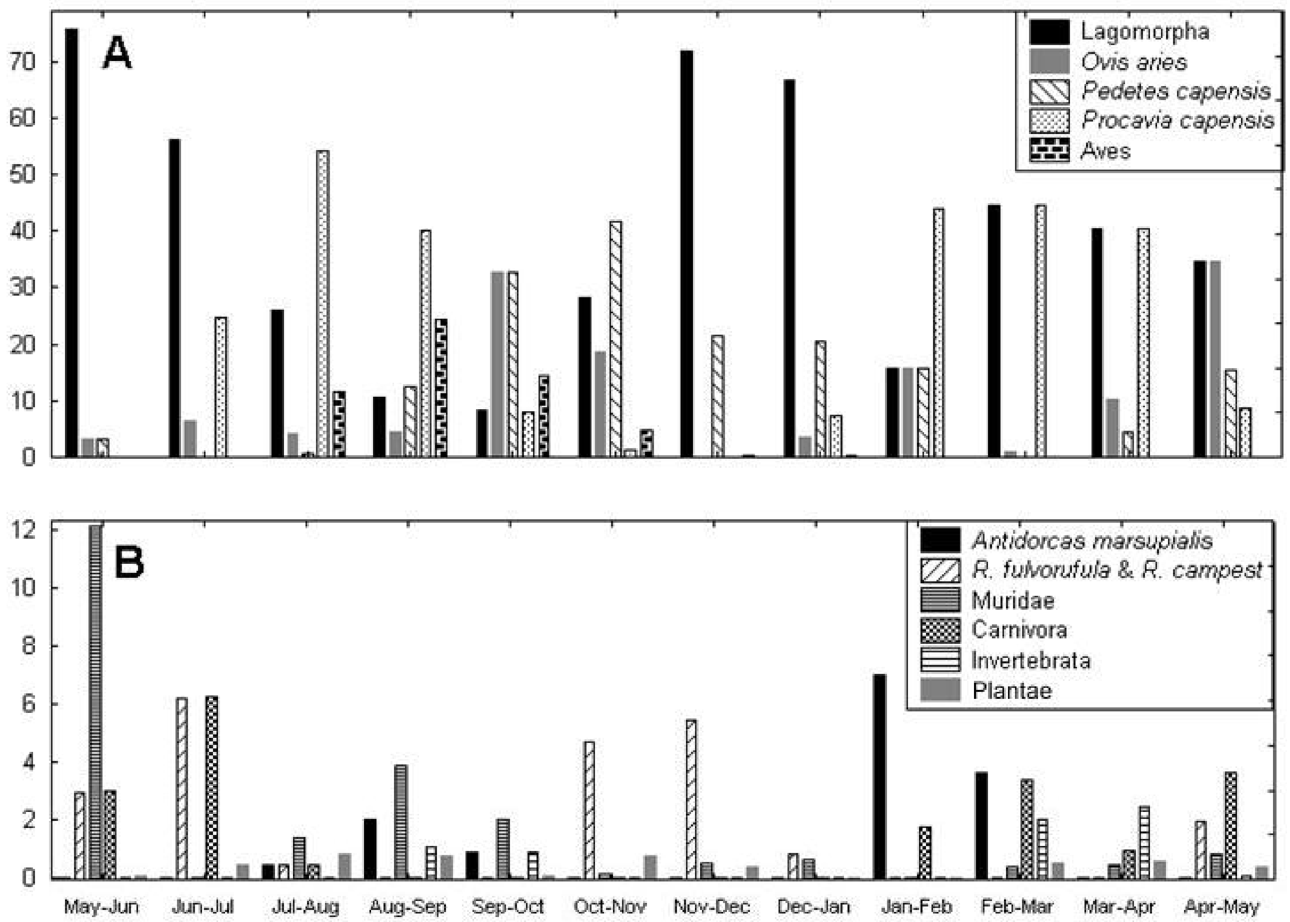

Fig. 3.3. Relative importance value of major **(A)** and minor **(B)** dietary items in caracal scats, May 2011 to May 2012.

Table 3.3. Spearman R correlation values of the relative importance value (Rel.IV.) of prey groups in caracal diet in the study area, May 2011 to May 2012. *, p<0.05; **, p<0.005; NS, p>0.05.

	Lagomorpha	*Ovis aries*	*Antidorcas marsupialis*	Ruminantia, excl. sheep & springbok	*Pedetes capensis*	*Procavia capensis*	Aves	Muridae	Carnivora	Invertebrata
Lagomorpha	-	-0.65*	-0.64*	0.62*	NS	NS	NS	NS	NS	NS
Ovis aries	-0.65*	-	NS	NS	NS	NS	NS	NS	NS	NS
Antidorcas marsupialis	-0.64*	NS	-	-0.75**	NS	0.65*	NS	NS	NS	NS
Ruminantia, excl. sheep & springbok	0.62*	NS	-0.75**	-	NS	-0.62*	NS	NS		-0.72*
Pedetes capensis	NS	NS	NS	NS	-	-0.57*	NS	NS	-0.76*	NS
Procavia capensis	NS	NS	0.65*	-0.62*	-0.57*	-	NS	NS	NS	NS
Aves	NS	NS	NS	NS	NS	NS	-	NS	-0.82**	NS
Muridae	NS	NS	NS	NS	NS	NS	NS	-	NS	NS
Carnivora	NS	NS	NS	NS	-0.76*	NS	-0.82**	NS	-	NS
Invertebrata	NS	NS	NS	-0.72*	NS	NS	NS	NS	NS	-

3.3.2. Mammal prey

Five mammalian prey groups were identified in caracal diet with an additional sixth unidentified category (Table 3.4).

3.3.2.1. Lagomorpha

Lagomorpha was the dominant prey group during the period late-autumn 2011 to mid-winter 2011 (50-64% relative importance value) and from the following late-spring to mid-summer (60-68% relative importance value) (Fig. 3.5). The group also had a high relative importance value of *c.* 40% during the period late-summer to mid-autumn. The lowest relative importance value of Lagomorpha was observed during the period late-winter to mid-spring 2011 (7-11%) before increasing again during the warm summer months. From May 2011 to October 2011 the Lagomorpha component gradually declined. Another notable decline of the Lagomorpha component was observed from early- to late-summer (Nov 2011-Feb 2012; a drop from >65% to 12% relative importance value).

Two Lagomorpha prey categories were identified in caracal diet, *Lepus* spp. (both *L. capensis* and *L. saxatillis* are presumeably taken, but could not be distinguished macro or microscopically) and *Pronolagus rupestris* (Table 3.5). *Lepus* spp. Contributed on average 71% to volumetric contribution, and was approximately four times as important a prey unit as *P.rupestris* (Rel.%Vol. = 29%) (Fig. 3.6 A-B).

Lepus spp. was well represented in the caracal's diet throughout most of the study period (Fig. 3.7) with its Rel.IV. rarely dropping below 60%. Only in two of the two-monthly stacked periods was *P. rupestris* more prevalent than *Lepus* spp. (August-September and September-October); then with a Rel.IV. of 77% and 80%, respectively.

Table 3.4. Average monthly contributions of mammal prey groups in caracal diet, southern Free State, May 2011 to May 2012.

Taxonomic group	%Occ.	%Vol.	IV.
Lagomorpha	28.5	28.0	8.0
Ruminantia (Sheep included)	22.7	22.7	5.2
Rodentia	19.3	17.7	3.4
Hyracoidea	17.5	17.3	3.0
Carnivora	5.3	5.1	0.3
Unidentified mammalia	2.9	2.5	0.1

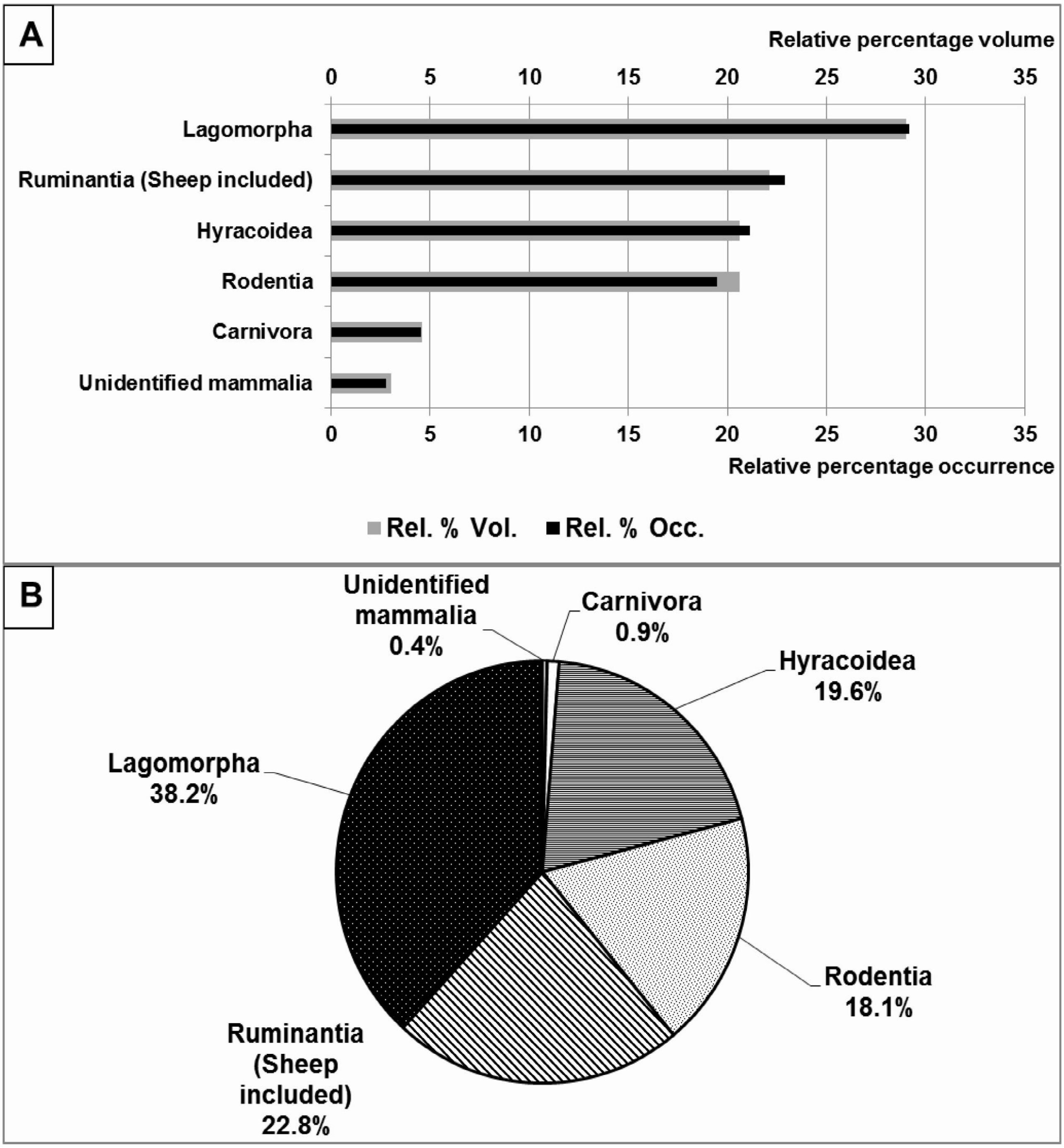

Fig. 3.4. Mean two-monthly relative percentage occurrence and volume hierarchy, **A**, and relative importance value hierarchy, **B**, of mammal prey groups in caracal diet, May 2011 to May 2012.

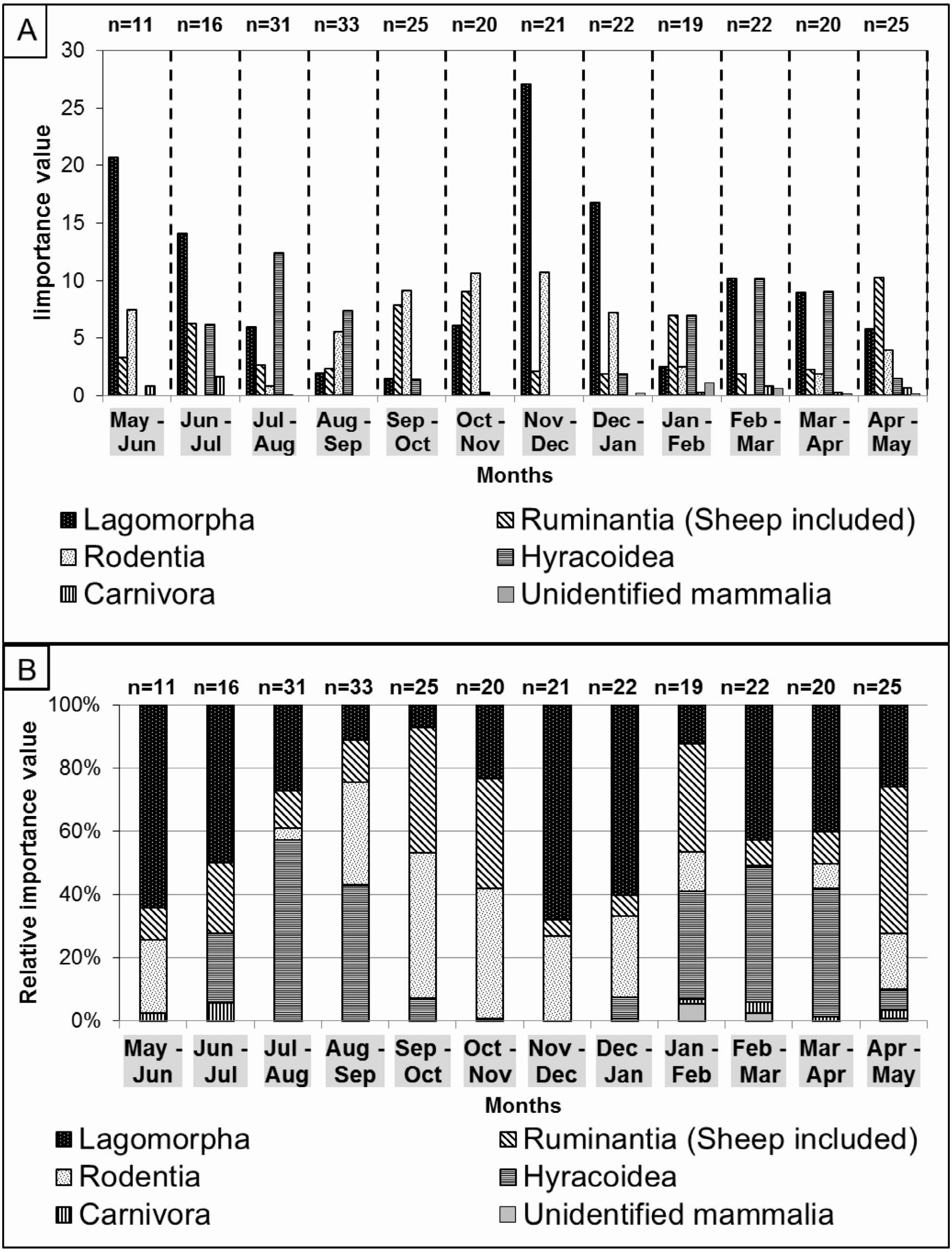

Fig. 3.5. Two-monthly Importance, **A**, and relative importance, **B**, values of mammal prey in caracal diet, May 2011 to May 2012.

Table 3.5. Average two-monthly stacked contributions (absolute values) of Lagomorpha prey species in caracal diet, southern Free State, May 2011 to May 2012.

Taxonomic group	%Occ.	%Vol.	IV.
Lepus spp.	20	19	4
Pronolagus rupestris	9	9	1

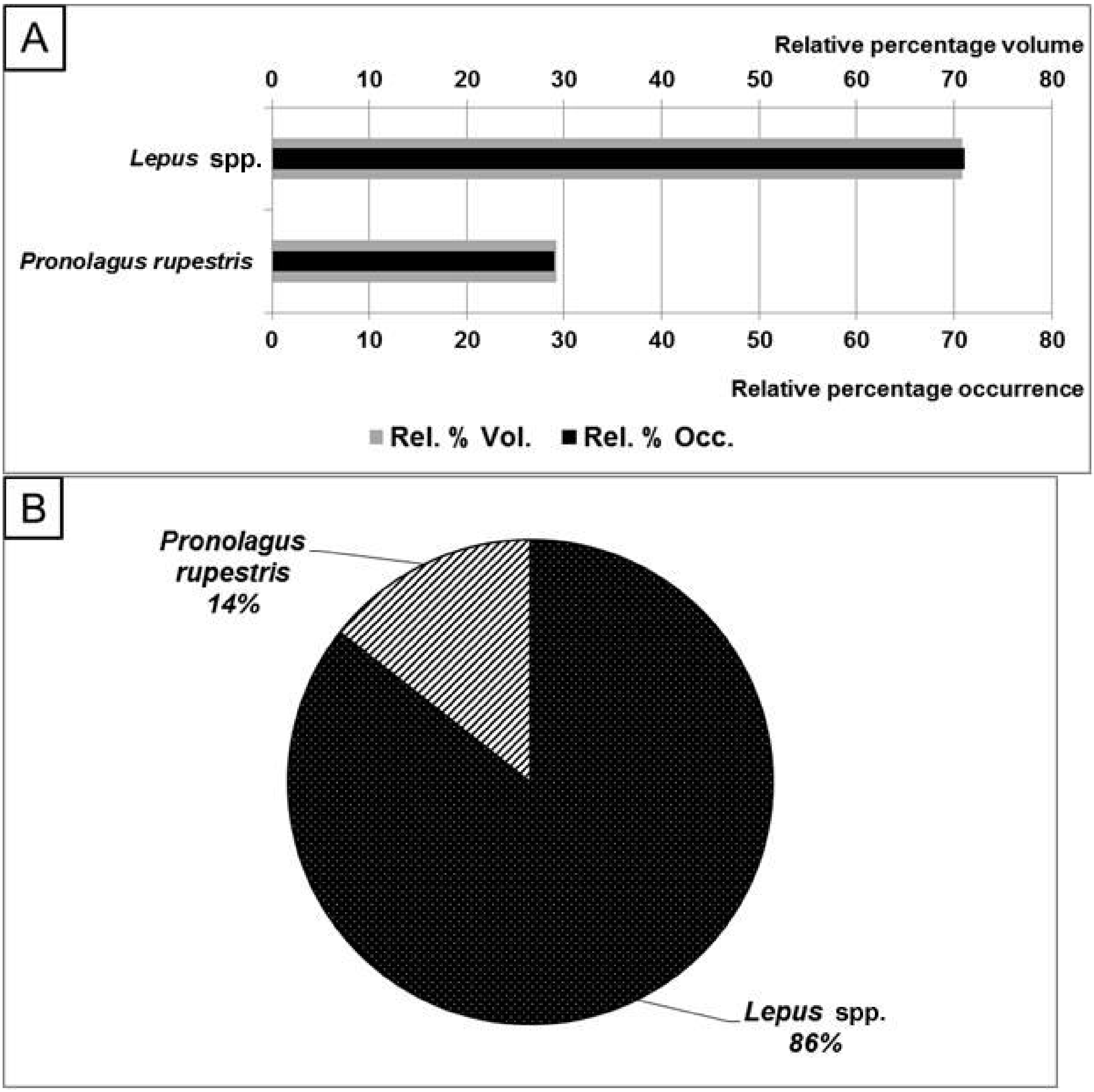

Fig. 3.6 Relative percentage occurrence and volume hierarchy, **A**, and average importance value contribution, **B**, of Lagomorpha prey in caracal diet (May 2011-May 2012).

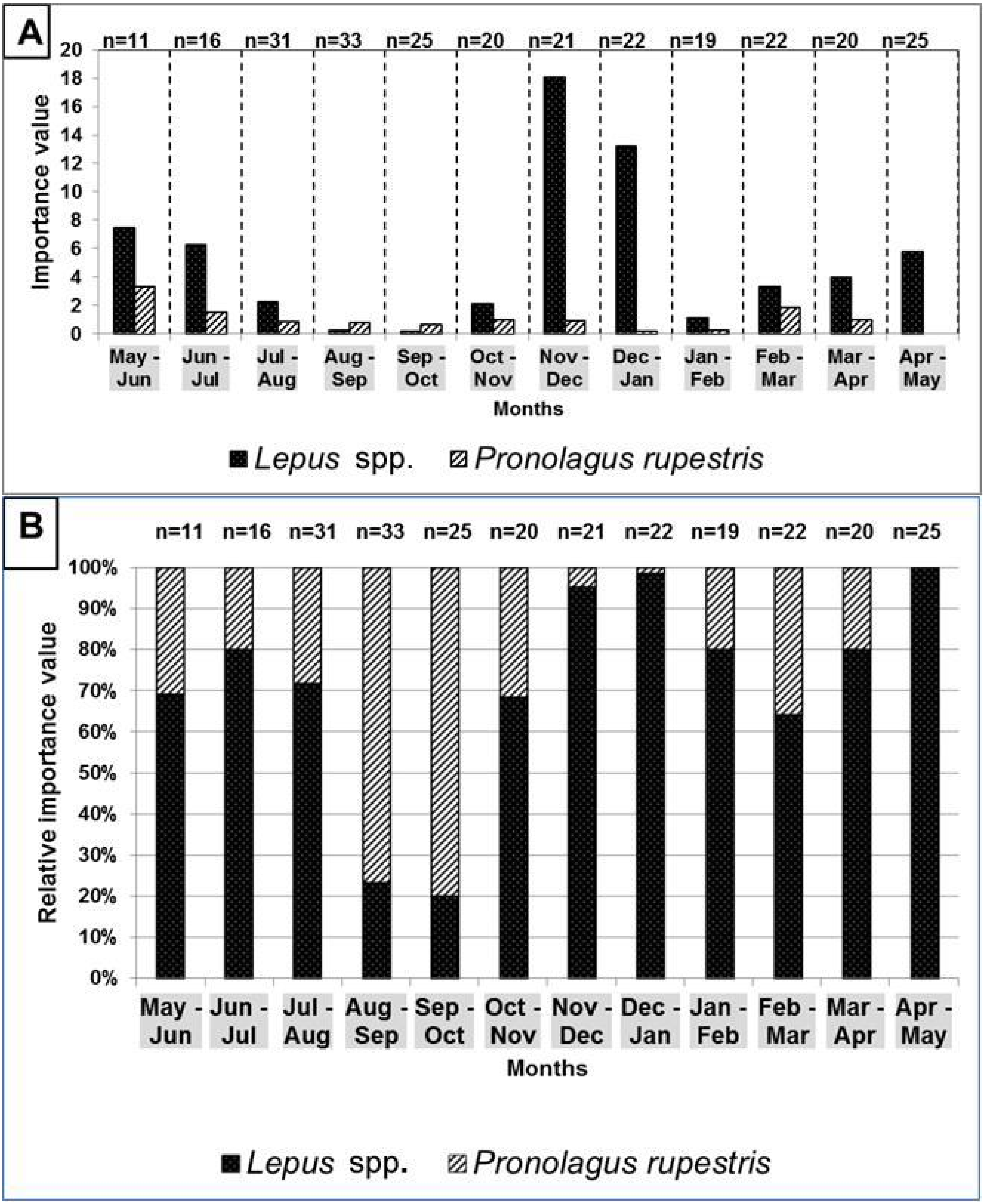

Fig. 3.7. Two-monthly importance **(A)** and relative importance **(B)** values of Lagomorpha prey categories in caracal diet, May 2011 to May 2012.

3.3.2.2. Ruminantia

The Ruminantia (including sheep) prey category was represented throughout the study period (Fig. 3.5). Peaks were observed in September-November (35-40% relative importance value), January-February (34% relative importance value) and April-May (46% relative importance value). Four Ruminantia species were identified in the caracal scats (Table 3.6; Fig 3.8). Sheep remains were identified in most months (Fig. 3.9), except in November and December 2011. Two marked peaks were observed, in September-October 2011, and in March to May 2012. Mountain reedbuck was present in relatively large proportions from May to July 2011 (Rel.IV. ± 50%), and in November-December 2011 (Rel.IV. 100%). Smaller relative importance values were found in July-August 2011 (9%), October-November 2011 (20%), December-January (20%) and April-May 2012 (3%). Steenbok was only found in one month, May 2012 (3%).

Table 3.6. Average monthly contributions (absolute values) of Ruminantia prey species in caracal diet, southern Free State, June 2011 to May 2012.

Taxonomic group	%Occ.	%Vol.	IV.
Ovis aries	13.601	13.601	1.850
Redunca fulvorufula	5.787	5.745	0.332
Antidorcas marsupialis	2.886	2.886	0.083
Raphicerus campestris	0.463	0.463	0.002

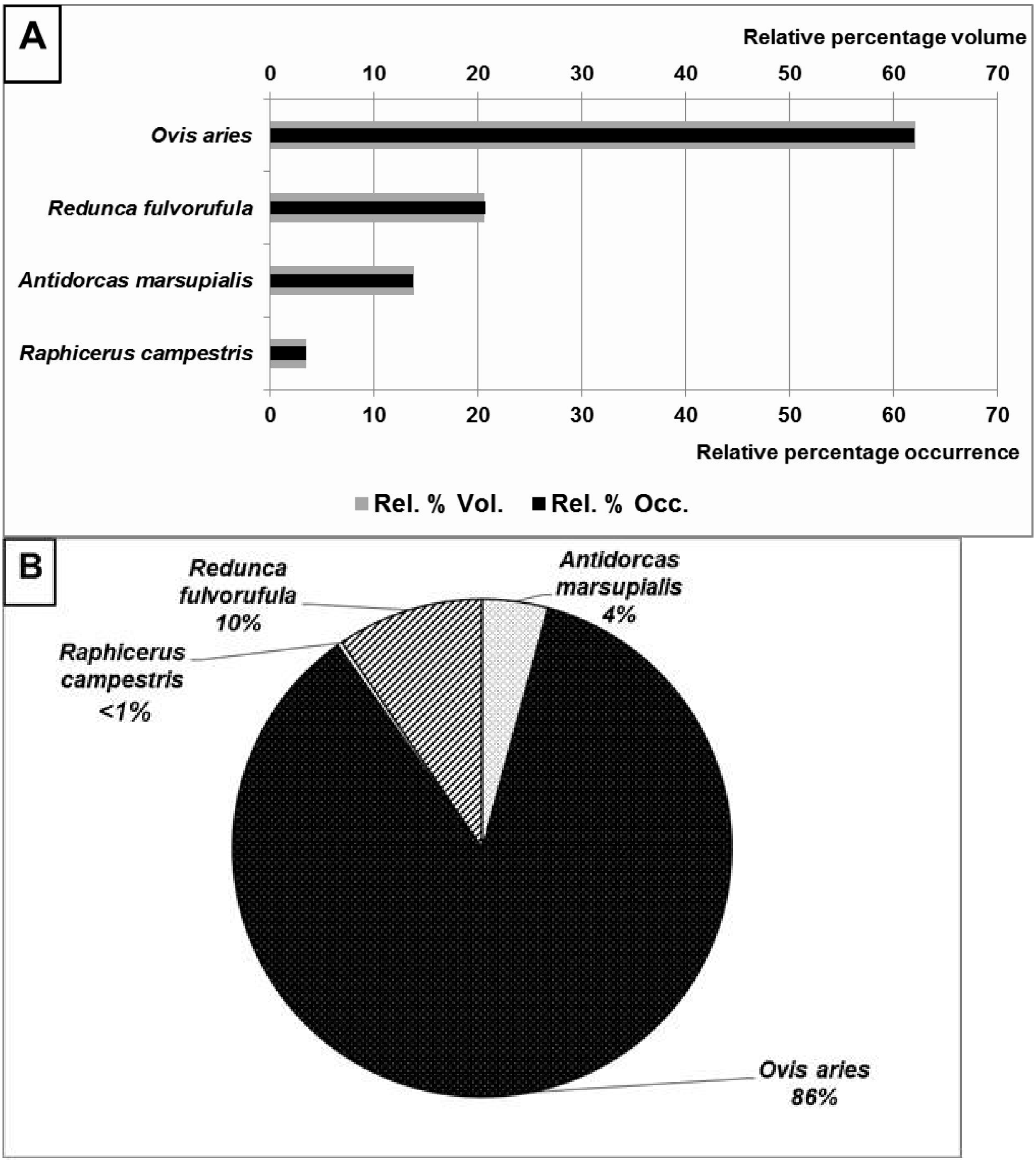

Fig. 3.8. Mean two-monthly relative percentage occurrence and volume hierarchy, **A**, and importance value, **B**, of Ruminantia prey in caracal diet, May 2011-May 2012.

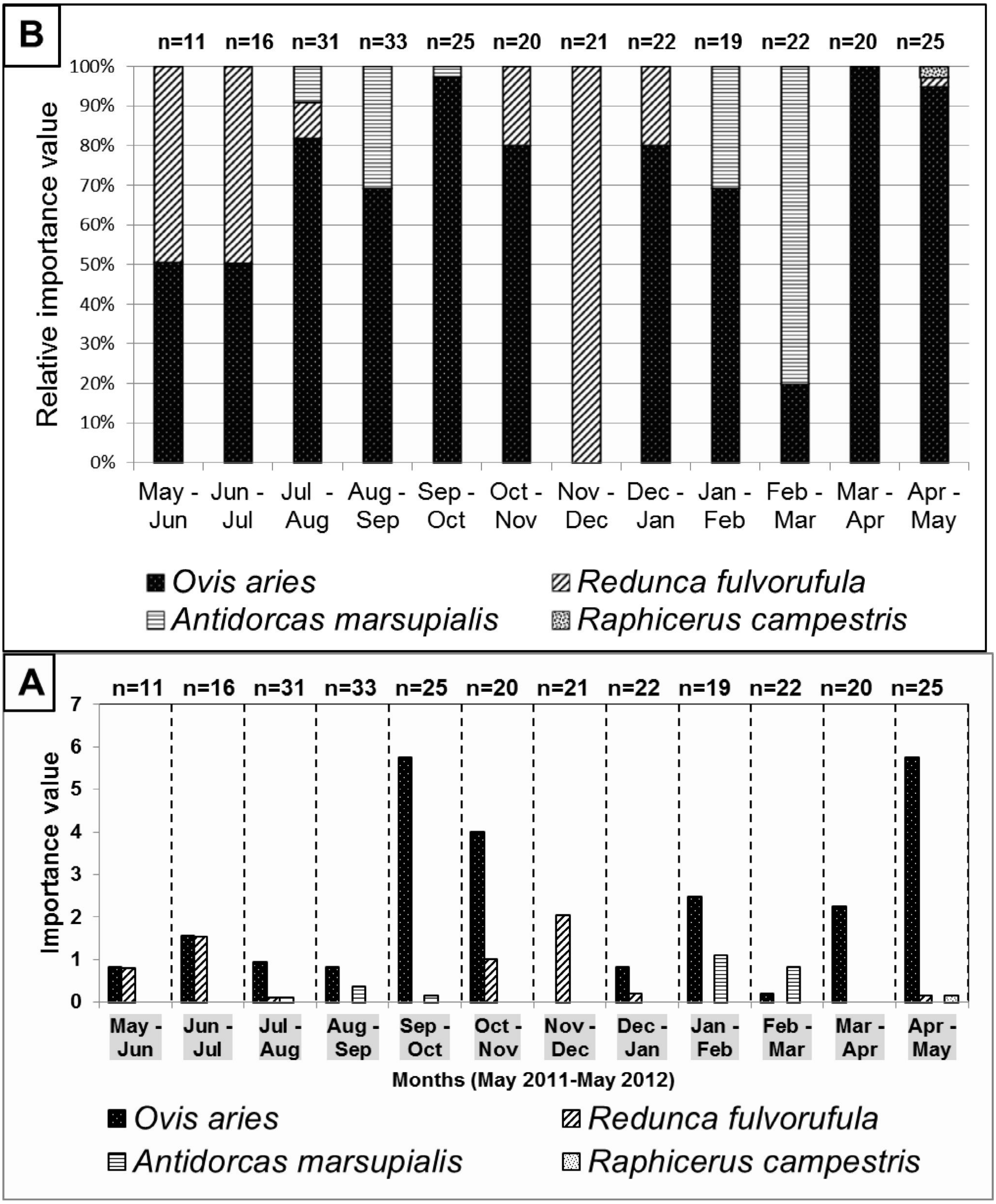

Fig. 3.9. Two-monthly importance **(A)** and relative importance **(B)** values of Ruminantia prey in caracal scats, May 2011 to May 2012.

3.3.2.3. Hyracoidea

Hyracoidea was represented in most months, except in the periods May-June 2011 and November-December 2011. Two peaks were observed, from July to September 2011 (Rel.IV. 43-57%), and from January to April 2012 (Rel.IV. 34-43%).

3.3.2.4. Rodentia

Rodentia was utilised as prey throughout the study period, except in June and July 2011 (Fig 3.5). It was a prevailing prey group in the period September to November 2011 (42-46% relative importance value). Rodent presence in scats decreased gradually from September 2011 to March 2012, before starting to increase again from March to May.

Two Rodentia families were identified in caracal diet, Pedetidae and Muridae (Table 3.7) with relative importance values in this group 92% and 8% respectively (Fig 3.10). Pedetidae (= springhare *Pedetes capensis*) peaks were observed from early-spring to mid-summer, and an increase again from early-autumn. During these times their relative importance in the group ranged between 77% and 100%, with a relatively high importance value of above six (6) in the period September-December 2011 (Fig. 3.11). Murids on the other hand had a low importance value, higher than 1 only in late-autumn/early-winter. They dominated the relative rodent contribution during three of the 12 two-monthly periods, but only during the above-mentioned period (late-autumn/early-winter) did they make any marked overall contribution. Species from three genera could be identified in the scats, these being *Micaelamys namaquensis* (Rel.IV. 38%), *Gerbilliscus leucogaster* (Rel.IV. 11%), and *Otomys* spp. (Rel.IV. 51%; both vlei rats *O. auratus* and *O. karoensis* are present in the larger study area and could have been taken - but could not be distinguished between during the scat analyses). *Otomys* spp. was the dominant taxa taken during all the months when murids were consumed (Rel.IV.s then always >40%). This group (*Otomys* spp.) contributed also 51% to the total murid volumetric contribution. *M. namaquensis* was present in scats from July 2011 to January 2012, but their relative importance increased slightly during the period October 2011 to January 2012. *G. leucogaster* was only observed in August/September and September/October 2011 (Rel.IV. in the murid group then 14% and 45%, respectively).

Table 3.7. Average two-monthly stacked contributions of Rodentia families to caracal scats in the study area, southern Free State, May 2011 to May 2012.

Taxonomic group	%Occ.	%Vol.	IV.
Pedetidae	15.2	15.2	2.3
Muridae	4.0	2.6	0.1

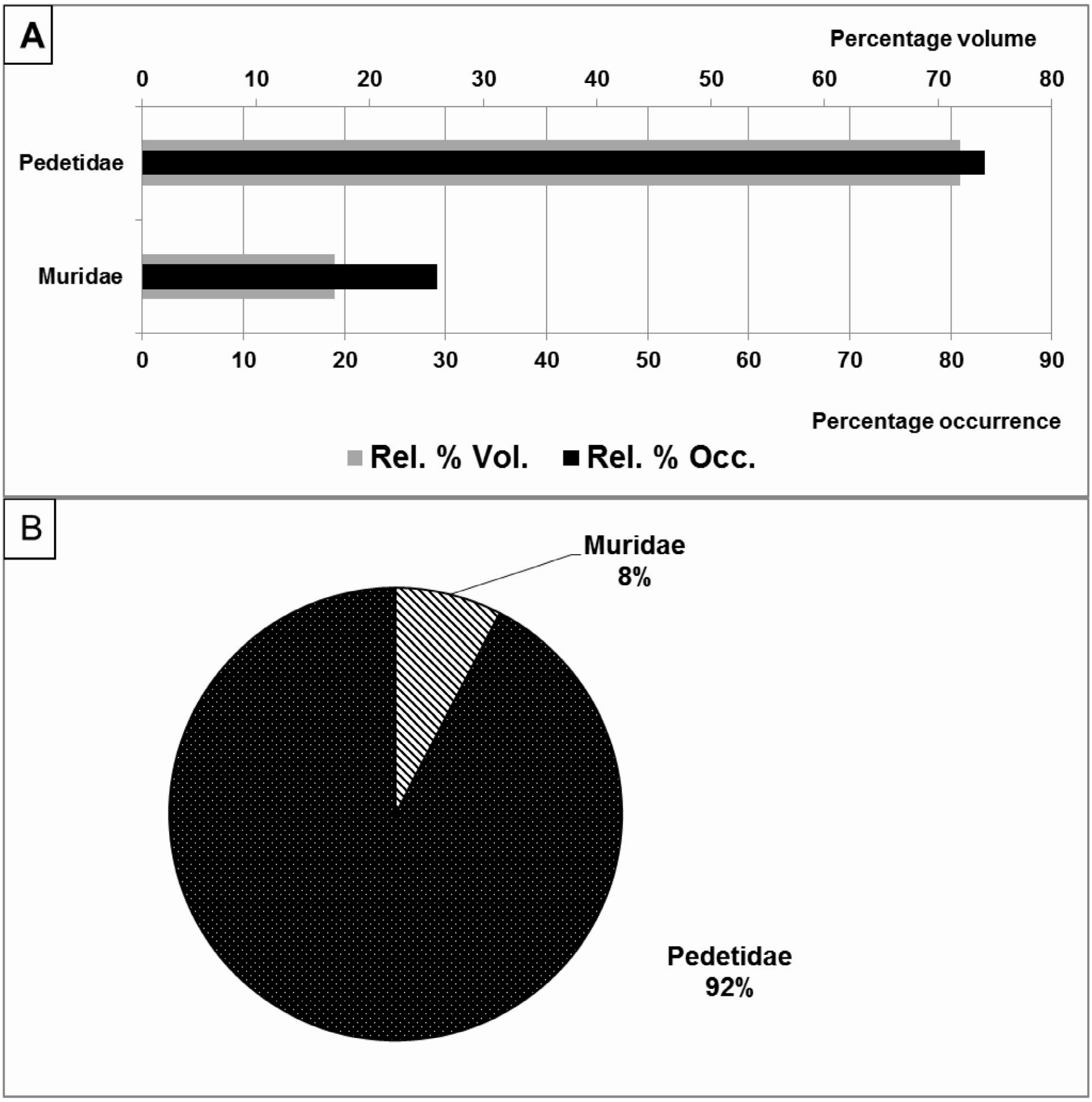

Fig. 3.10. Mean relative percentage occurrence and volume hierarchy, **A**, and relative importance value, **B**, of Rodentia families in caracal scats, May 2011 to May 2012.

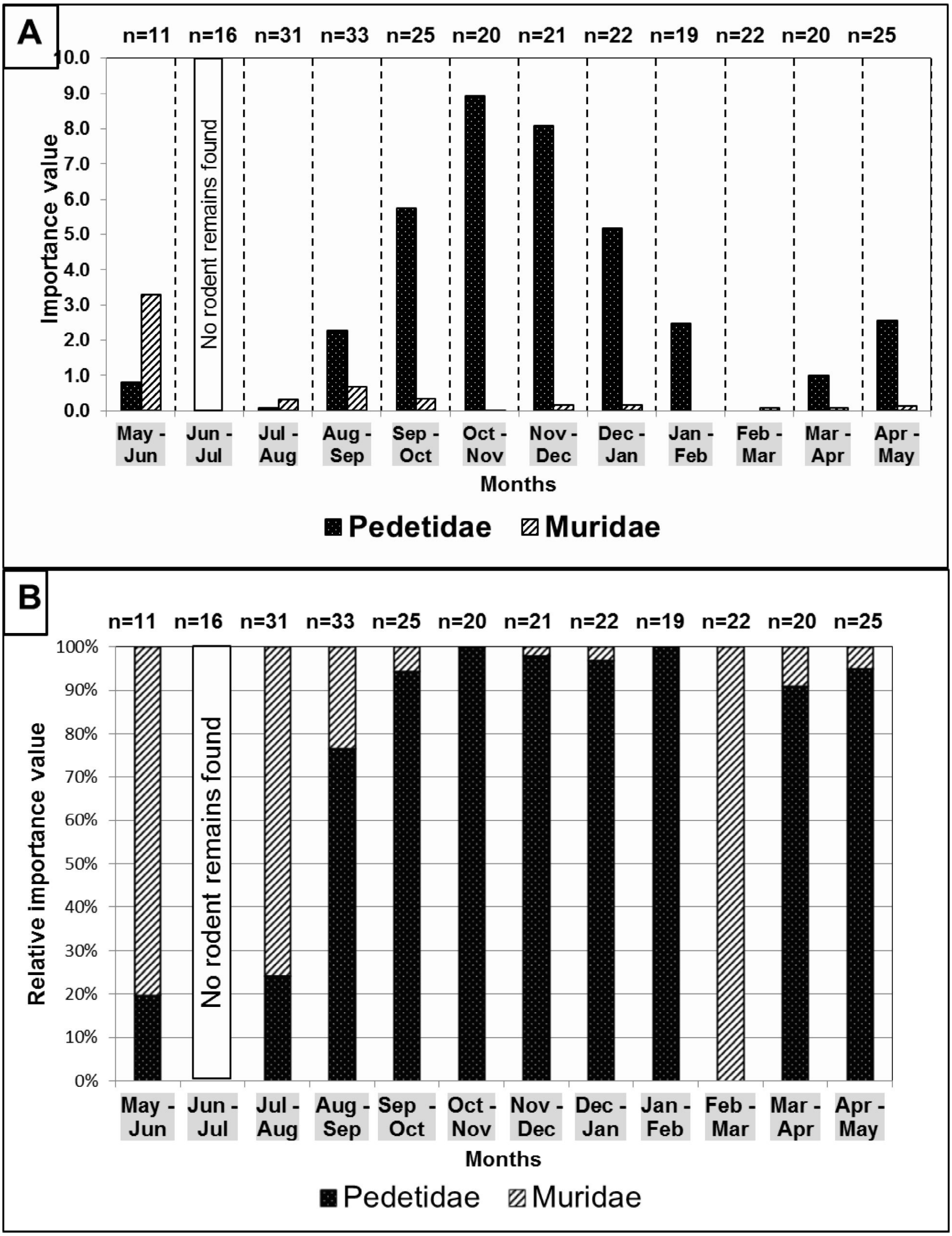

Fig. 3.11 Two-monthly importance **(A)** and relative importance **(B)** values of rodent families in caracal scats, May 2011 to May 2012.

3.3.2.5. Carnivora

Carnivores were utilised in small amounts (<1% to 6% relative importance value), and only in May and June 2011, and from February to May 2012 (Fig. 3.5). This component consisted of two species, yellow mongoose *Cynictis penicillata* (Herpestidae) and aardwolf *Proteles cristatus* (Hyaenidae). *C. penicillata* occurred in scats in June 2011 and in April-May 2012; *P. cristatus* occurred more frequently and in larger volumes in scats, in May and June 2011, and throughout in the period February to May 2012 (then between 53% and 100% Rel.IV. in the group).

3.3.3. Invertebrate prey

Arthropod remains consisted of Diplopoda (millipedes) and four Insecta orders (Coleoptera, Orthoptera, Isoptera and Lepidoptera) (Table 3.8). These prey remains were only found in small quantities in scats in September and October 2011 and in March and April 2012, and became relatively more prominent in the autumn months March and April. Coleoptera was present in the highest relative number of scats and had the highest mean importance value (<0.02). Diplopoda was found in trace amounts in September and October 2011 (Rel.IV. <1% in the group) and in March and April 2012 (then in larger relative amounts, and Rel.IV. 77%).

Table 3.8 Average two-monthly stacked contributions of arthropods present in caracal scats form the study site, southern Free State, May 2011 to May 2012.

Taxonomic group	%Occ.	%Vol.	IV.
Coleoptera	2.138	0.566	0.012
Orthoptera	1.699	0.141	0.002
Isoptera	0.641	0.064	0.0004
Lepidoptera	0.463	0.005	0.00002
Diplopoda	1.236	0.570	0.007

3.3.4. Prey diversity and evenness

Shannon-Wiener and Simpson's diversity indices, based on relative percentage occurrence and relative percentage volume values, ranged between *c*. 1.4 and 2.4, and 3.8 and 8.3, respectively (Fig. 3.12 A-B). Although the respective values differed when based on relative percentage occurrence and relative percentage volume values, fluctuations over months (≈ two-monthly stacked periods) were similar. Both showed a steady increase from mid-winter to early-spring, then decreased until early-summer, increased again until mid- to late-summer, and then remained relatively constant until late-autumn. Peeks were observed in late-winter/early-spring and in autumn. The lowest diversity was observed in late-spring/early-summer. The evenness with which prey groups were ingested also differed depending in whether relative percentage occurrence or relative percentage volume values were used, and fluctuated more or less in synergy over the year Fig. 3.12 C). These fluctuations differed, however, from those of the two diversity indices.

When diversity and evenness indices were calculated from relative importance values (Fig. 3.13), some clear differences in peaks and troughs between the two indices became evident. Diversity scores were (still) highest in the periods late-autumn/early winter and late-winter to mid-spring, and lowest in mid-winter and in late-spring/early-summer. The evenness score (on the other hand) was low and decreased further from late-summer to late-autumn/early-winter, and late-winter to mid-spring (= the time when diversity scores were high). During two specific times of the year both diversity and evenness scores decreased considerably and was low, in July-August, and in November and December; both diversity and evenness values also peaked sharply in January -February.

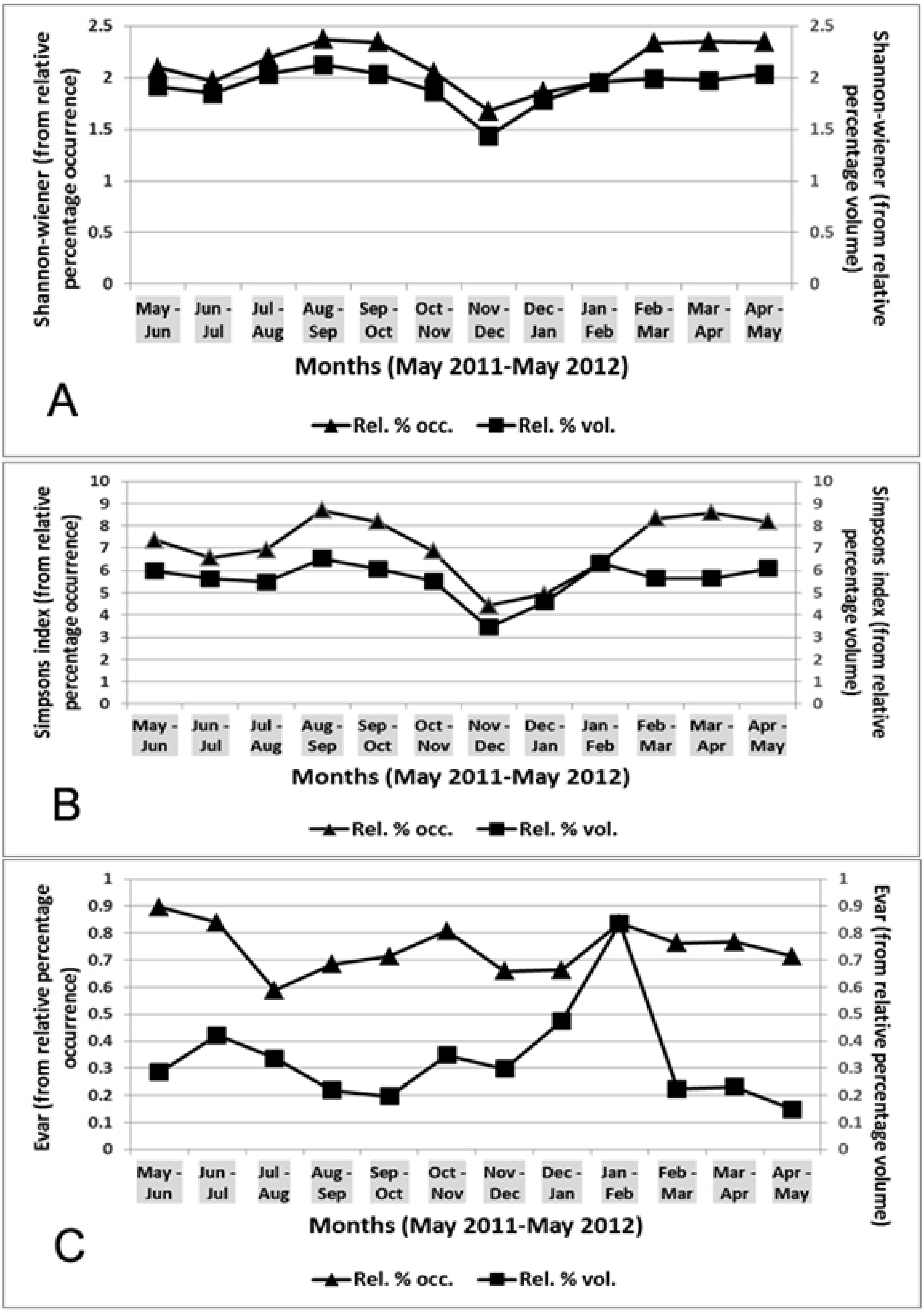

Fig. 3.12. A. Shannon-wiener two-monthly diversity index and **B.**, Simpson's two-monthly diversity index and **C.** Evar two-monthly diversity index.

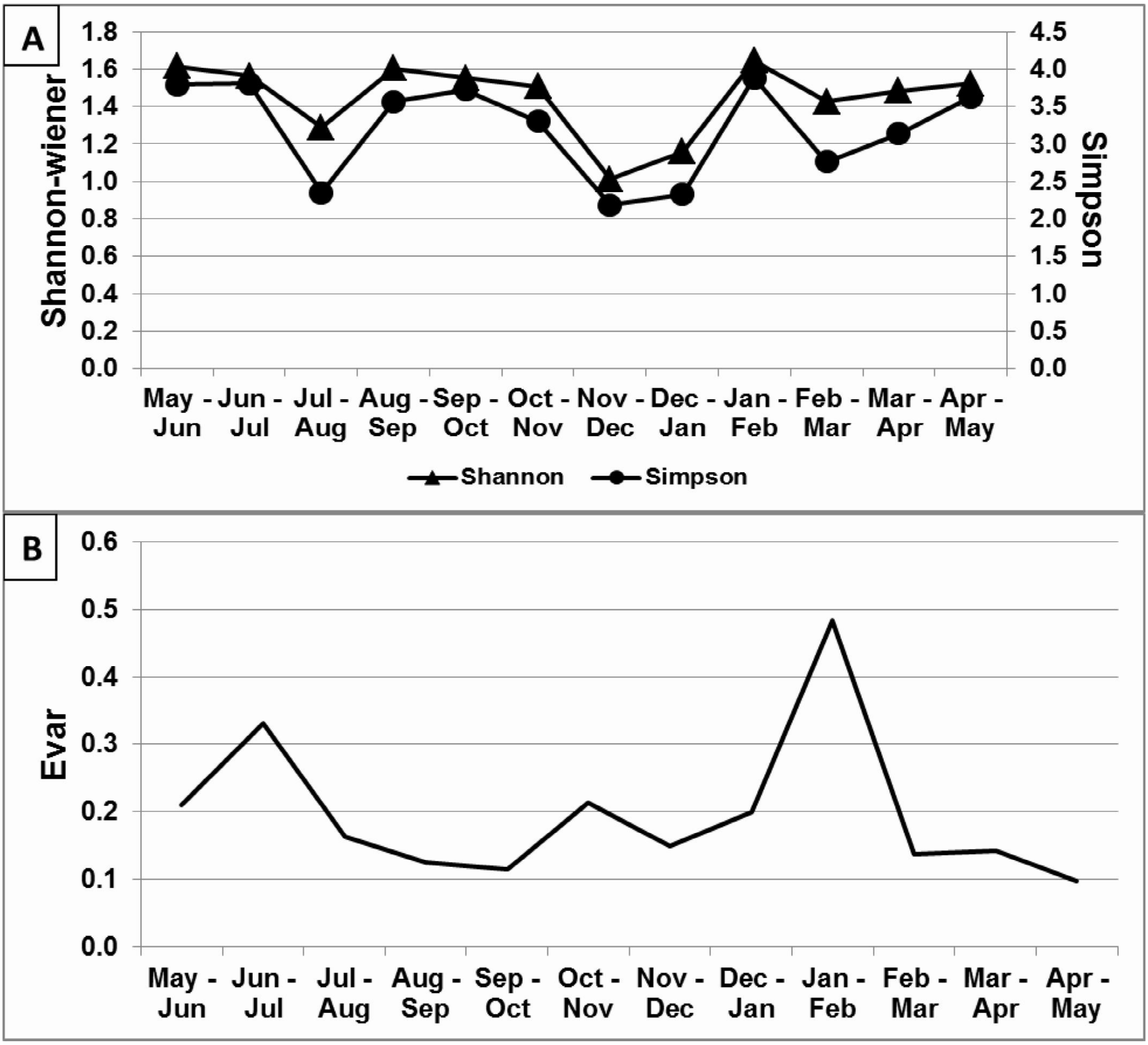

Fig. 3.13. Shannon-Wiener and Simpsons diversity **(A)** and evenness **(B)** two-monthly indices of prey present in caracal scats as determined from relative importance values, May 2011 to May 2012.

3.4. Discussion

Caracal have been described as opportunistic in their feeding behaviour and usually feed on prey that is most abundant (Skinner 1979; Grobler 1981; Moolman 1984; Palmer & Fairall 1988; Stuart & Hickman 1991; Avenant & Nel 1997, 2002; Melville *et al.* 2004; Braczkowski *et al.* 2012). Caracal have also been described as being specialists or generalists, depending on the circumstances under which they find themselves (Avenant & Nel 1997, 2002; Nel & Kok 2004; Braczkowski *et al*. 2012). Literature further states that caracal does not necessarily select for any specific prey species, but for prey groups (Avenant & Nel 2002). The current study, for instance, showed that some mammalian groups (e.g. Lagomorpha and *Ovis aries*) are utilised throughout the year while specific species, such as *Gerbilliscus leucogaster* and *Raphicerus campestris*, were only ingested during certain times of the year (August to October and April to May, respectively). Moreover, the major prey items (*Lagomorpha*, *Procavia capensis*, *Pedetes capensis* and *Ovis aries*) peaked at different times of the year, indicating a switch of prey (see section 3.5.1). Compared to other studies (Grobler 1981; Moolman 1984; Palmer & Fairall 1988; Stuart & Hickman 1991; Avenant & Nel 1997; Melville *et al.* 2004), this study accede in that caracal's diet included many of the same prey categories and species, and preyed mostly on mammals throughout the study period (Table 3.9). The show of opportunistic behaviour observed here has also been described throughout. The caracal's overall usage of the different prey groups and species ingested over the year is, however, different in the current study area (as expected, as this depends the differences of what prey is present and differences is the relative densities/diversity of prey taxa – Avenant & Nel 2002). For example: In this study caracal utilised a markedly higher proportion of Lagomorpha prey compared to all the other studies, and similar to in the Mountain Zebra National Park the Rodentia category (particularly Muridae) was less represented than in five of the other study areas (Table 3.9). None of the other prey groups were used particularly more or less in the current study area than in the other, comparable, study areas.

Table 3.9. Relative percentage contributions of categories in caracal scats, compared to other studies (Table adapted from Melville *et al.* 2004). **A.** farmland in the southern Free State (present study), **B.** farmland in the eastern Cape (Moolman 1984), **C.** Kgalagadi Transfrontier Park (Melville *et al.* 2004), **D.** West Coast National Park (Avenant & Nel 1997), **E.** southwestern and Eastern Cape (Stuart & Hickman 1991), **F.** Karoo National Park (Palmer & Fairall 1988), **G.** Mountain Zebra National Park (Moolman 1984) and **H.** Mountain Zebra National Park (Grobler 1981).

Diet category	A	B	C	D	E	F	G	H
Mammals	89.0	96.9	81.3	69.8	94.8	85.2	94.9	93.7
Lagomorpha	26.6	9.4	4.9	1.3	5.2	14.7	15.3	10.6
Rodentia	18.9	24.0	60.9	57.4	50.0	30.2	8.5	5.3
Hyracoidea	18.9	30.3	none	1.2	9.0	17.1	52.5	53.3
Carnivora	4.2	none	10.7	1.2	2.9	1.6	5.1	0.9
Ruminantia (Artiodactyla)	7.7	10.3	1.3	4.2	10.9	21.7	13.5	23.6
Eulipotyphla (Insectivora)	none	none	none	4.5	none	none	none	none
Domestic stock	12.6	22.9	3.6	none	16.8	none	none	none
Birds	7.7	2.1	6.7	11.5	5.2	1.6	4.3	5.3
Reptiles	none	1.0	none	7.9	none	none	0.8	0.9
Invertebrates	3.5	none	12.0	10.8	none	13.2	none	none

Note: Refer to the original publications for percentage occurrence and percentage volume statistics.

Lagomorpha prey remains in scats displayed a strong seasonal pattern, reflecting their availability (see Chapter 5). Following Skinner & Chimimba (2005) *Lepus* spp. may breed throughout the year, with the main breeding season during the warm, wet summer months (e.g. *Lepus capensis* breeding peaks from July to December and *Pronolagus rupestris* breeding peaks from September to February; this corresponds with both counts and field observations on numbers of latrines in use and sightings of young – Chapter 5). The large proportion of Lagomorpha prey in caracal diet may be explained by this group's relative abundance and availability throughout the year.

The Ruminantia component was prominent in a high percentage of scats (22.7%) and contributed, on average, >20% to the volume of scats. Sheep contributed by far the most to the Ruminantia component (mean Rel.IV. in the group = 86%), with 62%Occ. and an average monthly volumetric contribution of (also) 62%. Caracal are known to kill the young of larger prey species, but may also kill animals more than twice their own weight; e.g. adult mountain reedbuck up to 59kg (Moolman 1986) and adult sheep (Marker & Dickman 2005; Gunter 2008; Strauss 2009). In this study peaks in small stock remains were observed in scats during the two small stock lambing seasons, March/April and September/October. This falls within the period when farmers in the study area report the most small stock losses - August to October and March to May (Deacon 2010). Domestic animals such as sheep have very little (if any) anti-predatory mechanisms, thus, making them easy prey for predators (Sillero-Zubiri & Switzer 2004). Young lambs are especially vulnerable to small and medium-sized predators, including caracal and black-backed jackal (Strauss 2009). The predation situation is worsened when the natural prey density is low (late-autumn to mid-spring; see Chapter 5), and when energy demands of predators are high during such "vulnerable" (≈ lambing) times; such as when females lactate (energetically one of the most stressful times for females – Avenant 1993) or when caracal females care for young that start to eat meat or learn to hunt (Avenant 1993). He (Avenant 1993) recorded an increase in larger prey kills, as well as the repeated return to carcasses during such times. Caracal birth peaks and the presence of young caracal as a cause for increased small stock utilisation could, however, not be addressed in this study as no such data were recorded.

Mountain reedbuck was the second most frequent (21%) and also the second largest ruminant component in terms of relative volumetric contribution in the caracal's diet (21%). Peaks in mountain reedbuck remains (during November/December 2011) can also be explained by the presence of juveniles in the field (Chapter 5). Similarly, the peak in springbok remains in scats from January to March can be associated with a peak in springbok births in January and February (Chapter 5). Steenbok were utilised in comparatively small numbers, and their presence in scats (in April-May 2012) can probably be attributed to the opportunistic nature of caracal during this time when natural prey densities were low (Chapter 5), and the diversity of prey was high while evenness was low (Fig. 3.13).

The utilisation of Rodentia, specifically from the Muridae family, delivered unexpected low overall results as caracal are known to prey heavily on small mammals (Avenant & Nel 2002; Braczkowski *et al.* 2012; see also Table 3.9). This study therefore agrees with Melville *et al*. (2004) that Rodentia may vary considerably among different studies. Some of the main influencing factors are the relative densities, and the seasonal availability (in the current study area murid rodent densities are known to decrease drastically from early/mid-winter, starts reproduction again in spring, and only reach fairly high densities in mid-autumn – Avenant & Cavallini 2007; Avenant 2011). The frequency with which prey is encountered, as well as the prey size, therefore plays a major role in its presence in the carnivore's diet (Avenant & Nel 2002). Even though the frequency of occurrence of the Rodentia group was much smaller in this study compared to the study in the Kalahari (Melville *et al*. 2004; 21% vs. 60.9%), the results is similar in that the Rodentia component comprised a considerably larger proportion of springhare than mice. The opportunistic feeding behaviour of caracal when feeding on the rodent group was clear when peaks in murids (end-autumn/early winter) and springhare (mid-spring to mid-summer) (Fig. 3.3) could be correlated with their density (Chapter 5).

The relatively high mean presence of *Procavia capensis* remains in caracal scats, and its presence in most months, suggest that this food resource was available throughout the year. It can be argued that the peak in *P. capensis* remains between January and April may have been as a result of a birth peak in the summer months (see Skinner & Chimimba 2005), but this could not be confirmed in the study area (Chapter 5). Lynch (1983) also remarked that births may occur throughout the year in the Free State. The high predation on rock hyrax during the winter and early-spring months could, therefore, also not be coupled to an increase in rock hyrax numbers or an increase in easier to catch and subdue individuals. From Fig. 3.13 it is clear that this was a time when a higher diversity of prey were taken, most probably as less prey were available (see e.g. Chapter 5, and the comments on mouse densities, above); therefore, even if rock hyrax densities did not increase in winter/early-spring, it is not impossible that their relative density was high during this time of year.

The mean presence of bird remains found in scats in this study falls within the range reported by other studies (Table 3.9). The occurrence was also similar to that found by Melville *et al*. (2004; between 2.6 and 6% in the Kalahari), Moolman (1984) and Grobler (1981) in the Mountain Zebra National Park (5% and 5.3%, respectively), and Stuart & Hickman (1991; 5.2%) in the south western and Eastern Cape.

The small amount of invertebrate (arthropod) remains in caracal scats may be attributed to opportunistic supplementary feeding [Fig. 3.3 and Fig. 3.13; most pronounced in the periods when more prey groups were utilised (diversity high and evenness low)]. Similar to Melville *et al*. (2004), Coleoptera made the largest contribution to the ingested arthropod remains. The significance thereof, however, could not be quantified.

Grass that was detected in scat analysis was probably consumed accidentally, and its relative contribution was highest in the months when more prey groups, including small invertebrates, were preyed upon. The purposeful ingestion of grass can, however, not be excluded as this can potentially aid in keeping the digestive system functional during times of starvation and can act as a vitamin C supplement and to clear the digestive tract of endoparasites (Palmer & Fairall 1988). It may also help to assist digestion or, as domestic cats and dogs commonly do, be taken when they are not well (see Avenant 1993; Avenant & Nel 2002).

The two carnivore species *Cynictis penicillata* and *Proteles cristatus* that were found in scats may also reflect the caracal's opportunistic feeding behaviour (as their intake increased in times when prey diversity was highest - Fig. 3.3 and Fig. 3.13). Literature shows that the occurrence of carnivores in caracal diet is not uncommon (Avenant & Nel 2002; Melville *et al.* 2004; Braczkowski *et al.* 2012). *Ad hoc* observations suggest that these carnivores occur in high densities in the study area, supported by reasonably high densities of termites (which is one of the major prey items of both *C. penicillata* and *P. cristatus* - Nel & Kok 1999; De Vries *et al*. 2011; Chapter 4).

3.4.1. Major and minor dietary items

The largest prey category, Lagomorpha, made a mean relative volumetric contribution of 26.8% to scat remains, and had a mean relative importance value of 44.3%. The other major prey items were rock hyrax (mean Rel.IV. = 22.8%), springhare (Rel.IV. 12.6%) and sheep (Rel.IV. 10.2%). Minor prey items were birds, endemic antelopes, mice, carnivores and invertebrates. Significant, and mostly negative, correlations between a number of these prey items are testimony to the caracal's opportunistic feeding behaviour in the study area. It is also an indication of the fluctuations in density and availability of these prey items throughout the year, and emphasise the importance of both minor and major prey in caracal diet (i.e. minor prey is not necessarily less important than major prey, and may also act as an important substitute during lean times and or times of increased energy requirements). The correlations also point to the potential of especially major prey (e.g. Lagomorpha) to influence the utilisation of domestic sheep as prey; the conservation of which may have implications on a management strategy for damage-causing caracal. It also confirms the caracal's role in, amongst others, ensuring high prey groups (and species) diversity. This role presumably also include the predation on (≈ removal of) weak or sick prey individuals, as it is assumed that, especially during the lean times, these individuals will be taken out of the system (inferred from the high diversity and nature of prey taxa utilised during these times).

3.4.2. Monthly prey diversity

Both the diversity of prey ingested and the evenness with which they were utilised fluctuated over the course of the study period. Important differences between diversity and evenness highs and lows were found. Where diversity scores were highest in the periods late-autumn/early winter and late-winter to mid-spring, and lowest in mid-winter and in late-spring/early-summer, the evenness score was low and decreased further from late-summer to late-autumn/early-winter, and late-winter to mid-spring. These times of contrast were typically before or at the start of the general breeding season (Chapter 5), and at the end of the breeding season. Prey availability were then relatively low, and caracal responded by utilising a wider prey base. The fact that diversity scores were high during these times while evenness scores were low, indicates that caracal were taking an even higher number of prey taxa than during e.g. January-February or November-December and December-January; an indicating of highest relative energy need and less of the preferred prey available. The times when both diversity and evenness scores were low (during the two-monthly periods November-December, December-January, July-August and February-March) indicates that less prey taxa were taken, and with a higher evenness; an indication that more of the preferred prey items was available, and energy needs could be more readily met.

3.4.3. Number of prey consumed

The number of prey consumed by one caracal, as indicated in Table 3.10. Approximate number of prey individuals consumed by a single adult caracal in the southern Free State., is expected to be a fair reflection of what is caught and eaten by caracal in the study area. Caracal rarely scavenge, and usually eat what natural prey they catch themselves (Avenant 1993; Skinner & Chimimba 2005; Stuart & Stuart 2013). The position of sheep/lambs killed vs. scavenged (if any) has not been studied in any area, and also this study can unfortunately not elaborate on it. The information contained in Table 3.10 is also useful for comparison with past (Grobler 1981; Avenant & Nel 2002) and future studies that use the same calculation methods.

Ranked from most to least consumed, were mice *Micaelamys namaquensis* (141 individuals/year) and *Otomys* spp. (59 individuals/year), hares *Lepus* spp. (57 individuals/year), rock hyrax *Procavia capensis* (55 individuals/year), gerbil *G. leucogaster* (32 individuals/year), birds (29 individuals/year), springhare *Pedetes* *capensis* (22 individuals/year), sheep *Ovis aries* (20 individuals/year), red rock rabbit *Pronolagus rupestris* (15 individuals per year), mountain reedbuck *Redunca fulvorufula* (6 individuals/year), yellow mongoose *Cynictis penicillata* (5 individuals/year), aardwolf *Proteles cristatus* (5 individuals/year), springbok *Antidorcas marsupialis* (5 individuals/year) and steenbok *Raphicerus campestris* (1 individual/year). Although the number of prey consumed per month is also indicated in Table 3.10. Approximate number of prey individuals consumed by a single adult caracal in the southern Free State., this is a mean and will differ from month to month. Compared with Avenant & Nel (2002), a lot less mice is eaten in the southern Free State study area (e.g. 141 *M. namaquensis* in this in this study vs. >5000 in the Postberg section of the West Coast National Park, PNR). The current study also showed that fewer birds were consumed (29 in this study vs. 80 in PNR), but more larger mammals, such as hares, springhares, rock hyrax and small stock. Although these numbers should be viewed as broad indications of the intensity of predation on different prey species, they do suggest that caracal play an intricate role in the ecosystem. They also indicate that the yet unknown number of territorial, roaming and dispersing caracal have a marked impact on small stock farming in the study area.

Table 3.10. Approximate number of prey individuals consumed by a single adult caracal in the southern Free State.

Prey group/species utilized		Number consumed by an adult caracal in one year	Number consumed by an adult caracal per month
Muridae	*Micaelamys namaquensis (0.047 kg)*	140.7	11.7
	Otomys spp. (0.151 kg)	59.1	4.9
	Tatera leucogaster (0.07 kg)	31.9	2.7
**Pedetes capensis (2 kg)*		22.3	1.9
**Procavia capensis (1.1 kg)*		54.6	4.6
*Lagomorpha	*Lepus spp. (1.05 kg)*	57.2	4.8
	Pronolagus rupestris (1.62 kg)	15.1	1.3
Carnivora	Cynictis penicillata (0.83 kg)	5.4	0.4
	Proteles cristatus (2 kg)	4.5	0.4
Ruminantia (2 kg)	**Ovis aries*	20.0	1.7
	Redunca fulvorufula	6.7	0.6
	Antidorcas marsupialis	4.5	0.4
	Raphicerus campestris	1.1	0.1
Aves (0.838 kg)		29.2	2.4

* = major prey (Importance value in most “two-monthly” periods > 5)

4. Prey niche overlap of syntopic carnivores in a small stock area, southern Free State

This chapter describes the diets of four syntopic carnivores, caracal *Caracal caracal*, black-backed jackal *Canis mesomelas*, Cape grey mongoose *Galerella pulverulenta* and yellow mongoose *Cynictis penicillata*, in terms of niche overlap and niche breadth over a 12 month period (June 2011-May 2012). Two of these carnivores are well-known damage-causing animals in the study area, impacting on the sheep farming industry. Niche breadth (Levin's index) and niche overlap (Pianka's index) was calculated from the relative percentage occurrence (Rel.%Occ.), relative volumetric contribution (Rel.%Vol.) and relative importance values (Rel.IV.). Black-backed jackal fed on the largest spectrum of prey species. Caracal and yellow mongoose had the narrowest niche breadths, while that of the Cape grey mongoose was intermediate. Highest niche overlap, calculated from Rel.IV., was observed between caracal and black-backed jackal (1.0), and between Cape grey mongoose and yellow mongoose (0.9). Moderate niche overlap was observed between caracal and Cape grey mongoose, and between black-backed jackal and Cape grey mongoose (both 0.6), and smallest overlaps between caracal and yellow mongoose (0.3), and black-backed jackal and yellow mongoose (<0.1). All four carnivores displayed fluctuations in the monthly niche overlap and breadth over the 12 month period. Both damage-causing predators utilised small stock throughout the year, but more notably during the lambing seasons (March/April and September/October). Although both these predators are opportunistic and considered generalists, caracal was more of a specialist than black-backed jackal.

Key words: carnivore, damage-causing, meso-predator, insectivorous, niche overlap, niche breadth, syntopic.

4.1. Introduction

The niche concept in community ecology refers to the interaction of an individual within a specific species, with all aspects of the environment (Ricklefs 1990). It therefore refers to the functional role and position of a species in a community of species, and has both behavioural and distributional properties (Pianka 1974; Poole 1974). On a finer scale “food niche overlap” can be defined as the shared use of food resources by two or more organisms (Colwell & Futuyma 1971; Capello *et al.* 2012), whereas, “food niche breadth” is simply the diversity of resources used by organisms (Putman & Wratten 1984). Studies that incorporated the concepts of niche overlap and breadth are common in a southern African context (Avenant & Nel 1997; Loveridge & Macdonald 2003; Van der Merwe *et al.* 2009; Kamler *et al.* 2012). Measures of niche overlap and breadth are frequently used to describe and compare the diets of syntopic small to medium sized carnivores in totality and/or over seasons and months. This chapter describes the diets of four syntopic carnivores, caracal *Caracal caracal*, black-backed jackal *Canis mesomelas*, Cape grey mongoose *Galerella pulverulenta* and yellow mongoose *Cynictis penicillata* in terms of niche overlap and niche breadth.

Both caracal and black-backed jackal are well-known damage-causing meso-predators in the study area (Deacon 2010). Caracal are mostly solitary and nocturnal, but may be active and feeding on cooler winter days (Avenant & Nel 1998; Stuart & Stuart 2013). Black-backed jackal are both diurnal and nocturnal with their activity pattern being determined by the availability of specific food items (e.g. by predominantly crepuscular vlei rats) and damage-causing predator control practices (Deacon 2010; Du Plessis 2013; Loveridge & Nel 2013). Cape grey mongoose *G. pulverulenta* is a predominantly solitary, diurnal and terrestrial species (Cavallini 2013). In the Free State region they select for rocky habitat with adequate grass cover, trees and shrubs (Lynch 1983; Skinner & Chimimba 2005). Yellow mongoose *Cynictis penicillata* is predominantly diurnal and may be spotted singly or in pairs. These terrestrial carnivores prefer open habitat with a sandy substrate (Skinner & Chimimba 2005; Taylor 2013). Unlike the Cape grey mongoose, these mongoose species are able to dig their own burrows, but also share burrows with suricates *Suricata suricatta* and ground squirrel *Xerus inauris*. Avenant & Nel (1997) listed predator relative body size, predator habitat selection, prey size selected, and seasonal changes in diets of syntopic carnivores, in relation to seasonal prey availability, as factors that may allow syntopic carnivores to co-exist. The hypothesis of this study was that larger niche overlap would exist between those carnivores with similar body size and trophic status, while less overlap would exist between those carnivores that differ in this regard. The purpose is, further, to alleviate a dearth of information that address the diet of caracal and black-backed jackal, especially at the same time and in the same farming area (Du Plessis 2013).

4.2. Material and methods

In this study scats of Cape grey mongoose were commonly found in rocky habitat, specifically near crevices, and areas of thick vegetation. Similar to Cavallini & Nel (1990), scats were also scarcely found in large groups like that of yellow mongoose *Cynictis penicillata* and suricates *Suricata suricatta*. Both caracal and black-backed jackal scats were found in quantities of no more than one, seldom two, scats per location and in a variety of habitat types. Only fresh scats were collected (see Chapter 2). The monthly sample sizes achieved in the study varied over the June 2011 to May 2012 study period, with the monthly averages as follows: caracal 11.2 ± 4.3, black-backed jackal 13.2 ± 7.0, Cape grey mongoose 20.5 ± 12.4, and yellow mongoose 25.1 ± 19.6. Where contributions were expressed as seasonal values, they comprised the means of the following months: winter = June to August; spring = September to November; summer = December to February; and autumn = March to May

The prey utilised was expressed as percentage occurrence (%Occ.), percentage volume (%Vol.), importance value (IV.; = %Occ. x %Vol. / 100), and their relative values Rel.%Occ., Rel.%Vol. and Rel.IV. Relative importance values were used to indicate overall relative contributions of prey groups and species. Shannon and Simpson’s diversity and Evar evenness indices were calculated from the mean relative percentage occurrences. Niche overlap was calculated using Pianka’s index (Chuang & Lee 1997; Fedriani *et al.* 2000; Loveridge & Macdonald 2003; Zielinski & Duncan 2004; Van der Merwe *et al.* 2009; Remonti *et al.* 2012) while niche breadth was calculated using Levin’s index (Fedriani *et al.* 2000; Zielinski & Duncan 2004;

Castillo *et al.* 2011; Remonti *et al.* 2012). These indices were calculated using the mean monthly relative percentage occurrence, mean monthly relative percentage volume and mean monthly relative importance values. The Levin's index (≈ niche breadth) is an indication of the versatility of a carnivore's diet (Marti *et al.* 2013) and varies from zero to infinity, with zero being the minimum niche breadth. The niche overlap index has an upper limit of one (maximum overlap), with zero as the lower limit, an indication of no overlap (Barrientos & Virgós 2006).

Data were tested for normality using a Shapiro-Wilks' W test. To investigate any differences in prey items utilised, Friedman Anovas were used. Wilcoxon matched pairs tests then indicated between which groups the differences lay. For a comparison of food niche breadth t-tests for independent samples were used. Statistical analyses were done with Statistica for Windows (Statsoft Inc., Tulsa, OK), and the 95% level ($p<0.05$) was regarded as statistically significant for all tests.

4.3. Results

4.3.1. Prey items utilised

Many of the same food items were utilised by all of the four syntopic carnivores (Table 4.1). Appendix 11 to Appendix 15 shows a calculation of these values, relative to all prey ingested) Prey items that made the most notable contributions (Rel.IV.) in caracal diet were Lagomorpha (44%; mostly *Lepus* spp., but also *Pronolagus rupestris*), Hyracoidea (23%; *Procavia capensis*), Pedetidae (13%; *Pedetes capensis*) and Ruminantia (mostly sheep *Ovis aries*, 10%) (Fig. 4.1 A). The diet of black-backed jackal was characterised by the dominance of Muridae (47.96%; mostly *Micaelamys namaquensis* and *Otomys* spp. – see also Appendix 11 for mean monthly values, relative to all prey ingested), Lagomorpha (23%; mostly *Lepus* spp., but also *Pronolagus rupestris*) and Ruminantia (mostly *Antidorcas marsupialis,* 7.94%, *Ovis aries,* 5.14%, and *Redunca fulvorufula,* 4.71%) (Fig. 4.1 B and Appendix 12). Prey items most prominent in Cape grey mongoose scats were Insecta (Isoptera = 50.41%, Orthoptera = 14.77%, Coleoptera 5.74% - see also Appendix 14) and Muridae (15.75%; mostly *Rhabdomys pumilio*, *Otomys* spp. and *Micaelamys namaquensis*) (Fig. 4.2 A). The diet of yellow mongoose was almost completely dominated by Insecta (Isoptera = 55.47%, Coleoptera = 31.12%) (Fig. 4.2 A and also Appendix 14).

The diet of caracal and black-backed jackal therefore included more mammal and less invertebrate (Arthropoda) prey species/taxa than of Cape grey mongoose and yellow mongoose (Fig. 4.1; Table 4.2). Black-backed jackal diet was the most diverse (Shannon-Wiener = 3.1; Simpson's = 18.1), followed by Cape grey mongoose (Shannon-Wiener = 2.7; Simpson's = 10.6), caracal (Shannon-Wiener = 2.6; Simpson's = 10.2) and yellow mongoose (Shannon-Wiener = 2.5; Simpson's = 8.6 - Table 4.3). The two larger carnivores caracal and black-backed jackal utilised their prey items with higher evenness than the two mongoose species (Evar = 0.45 and 0.42 vs. 0.24 and 0.18, respectively - Table 4.3).

Table 4.1. Mean monthly contributions (%Occ., %Vol. and IV. values) of prey groups in caracal **(A)**, black-backed jackal **(B)**, Cape grey mongoose **(C)** and yellow mongoose **(D)** diet in the study area, southern Free State (June 2011-May 2012). Letters in superscript refer to homologous groupings within rows, derived from Wilcoxon matched pairs tests.

		A	B	C	D
Animalia	%Occ.	100.00	99.18	98.96	100.00
	%Vol.	99.36	96.62	91.38	98.00
	IV.	99.36 [a]	95.82 [b]	90.43 [bc]	98.00 [c]
Vertebrata	%Occ.	98.76	98.51	65.34	56.57
	%Vol.	98.01	95.25	37.06	10.54
	IV.	96.80 [a]	93.83 [b]	24.21 [c]	5.96 [d]
Mammalia	%Occ.	94.74	96.34	56.03	46.97
	%Vol.	93.40	91.89	31.17	8.44
	IV.	88.49 [a]	88.53[a]	17.46 [b]	3.97 [b]
Muridae	%Occ.	4.03	34.43	37.63	37.67
	%Vol.	2.56	28.55	17.81	5.37
	IV.	0.10 [a]	9.83 [b]	6.70 [b]	2.02 [b]
Pedetidae	%Occ.	15.23	3.36	0.26	00.00
	%Vol.	15.19	3.30	0.26	0.00
	IV.	2.31 [a]	0.11 [b]	0.00 [b]	0.00 [b]
Sciuridae	%Occ.	0.00	0.00	0.00	0.93
	%Vol.	0.00	0.00	0.00	0.14
	IV.	0.00 [a]	0.00 [a]	0.00 [a]	0.00 [a]
Macroscelidea	%Occ.	0.00	3.55	6.46	2.86
	%Vol.	0.00	2.10	4.22	0.32
	IV.	0.00 [a]	0.07 [b]	0.27 [b]	0.01 [b]
Eulipotyphla	%Occ.	0.00	1.70	1.13	1.06
	%Vol.	0.00	0.83	0.72	0.10
	IV.	0.00 [a]	0.01 [a]	0.01 [a]	0.00 [a]
Lagomorpha	%Occ.	28.54	19.94	16.80	11.37
	%Vol.	27.99	16.98	6.15	1.65
	IV.	7.99 [a]	3.39 [ab]	1.03 [b]	0.19 [b]
Hyracoidea	%Occ.	17.47	2.16	0.00	0.00
	%Vol.	17.31	2.16	0.00	0.00
	IV.	3.02 [a]	0.05 [b]	0.00 [b]	0.00 [b]
Ruminantia (Sheep included)	%Occ.	22.74	32.66	2.69	2.30
	%Vol.	22.70	31.17	1.27	0.87
	IV.	5.16 [a]	10.18 [a]	0.03 [b]	0.02 [b]

Table 4.1. continued…

Carnivora	%Occ.	5.27	1.71	0.38	0.00
	%Vol.	5.12	1.71	0.23	0.00
	IV.	0.27^{a}	0.03^{a}	0.00^{a}	0.00^{a}
Reptilia	%Occ.	0.00	0.00	6.33	1.62
	%Vol.	0.00	0.00	1.24	0.41
	IV.	0.00^{a}	0.00^{a}	0.08^{b}	0.01^{b}
Aves	%Occ.	6.03	7.98	10.41	21.04
	%Vol.	4.62	3.37	4.65	1.68
	IV.	0.28^{a}	0.27^{a}	0.48^{ab}	0.35^{b}
Invertebrata	%Occ.	2.78	16.08	90.16	99.65
	%Vol.	1.35	1.37	54.32	87.46
	IV.	0.04^{a}	0.22^{b}	48.97^{c}	87.16^{d}
Plantae	%Occ.	11.45	21.85	34.75	54.48
	%Vol.	0.64	3.38	8.62	2.10
	IV.	0.07^{a}	0.74^{b}	3.00^{c}	1.14^{bc}

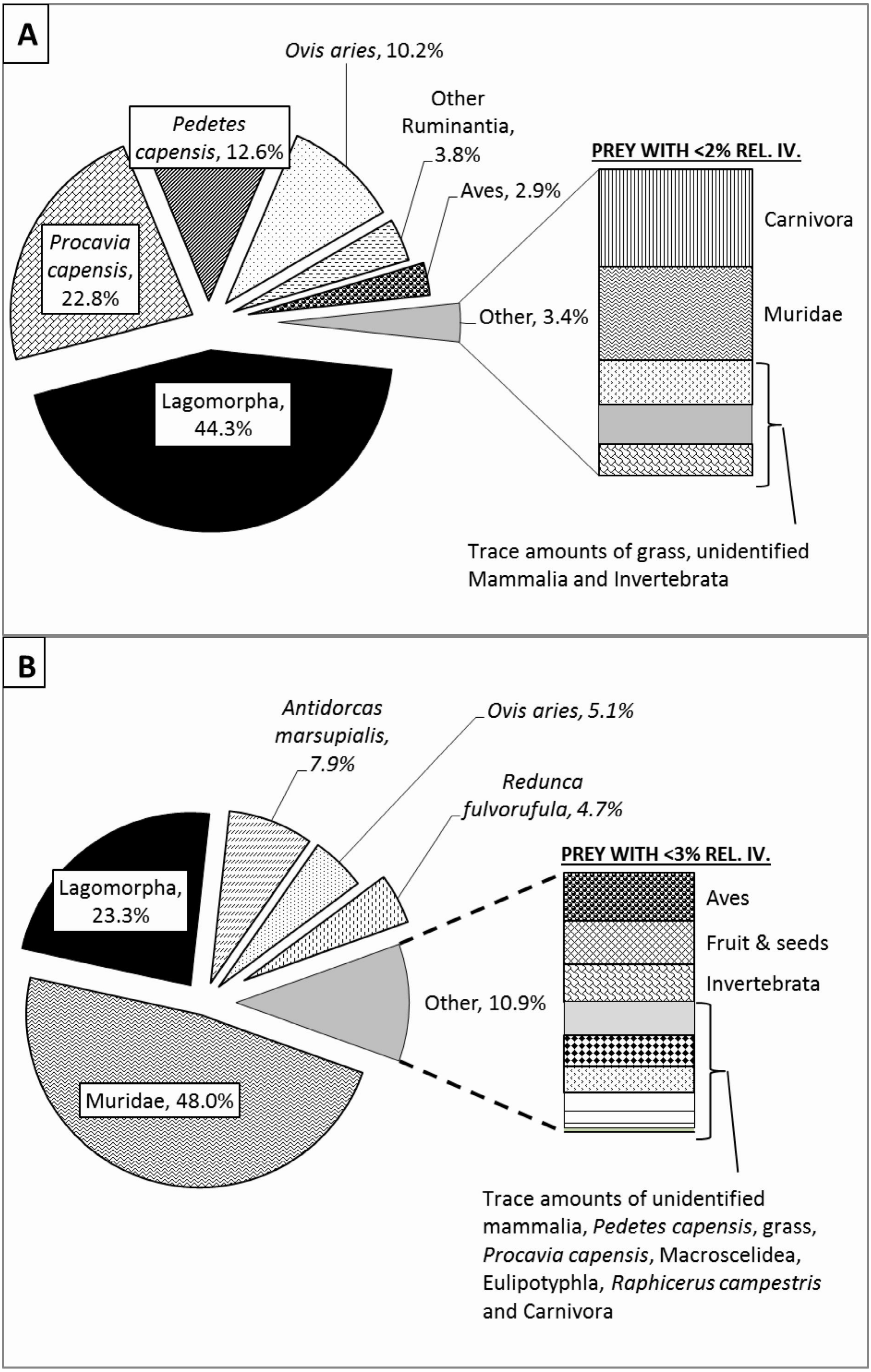

Fig. 4.1. Mean monthly importance value of prey in caracal **(A)** and black-backed jackal **(B)** diet in the study area, southern Free State.

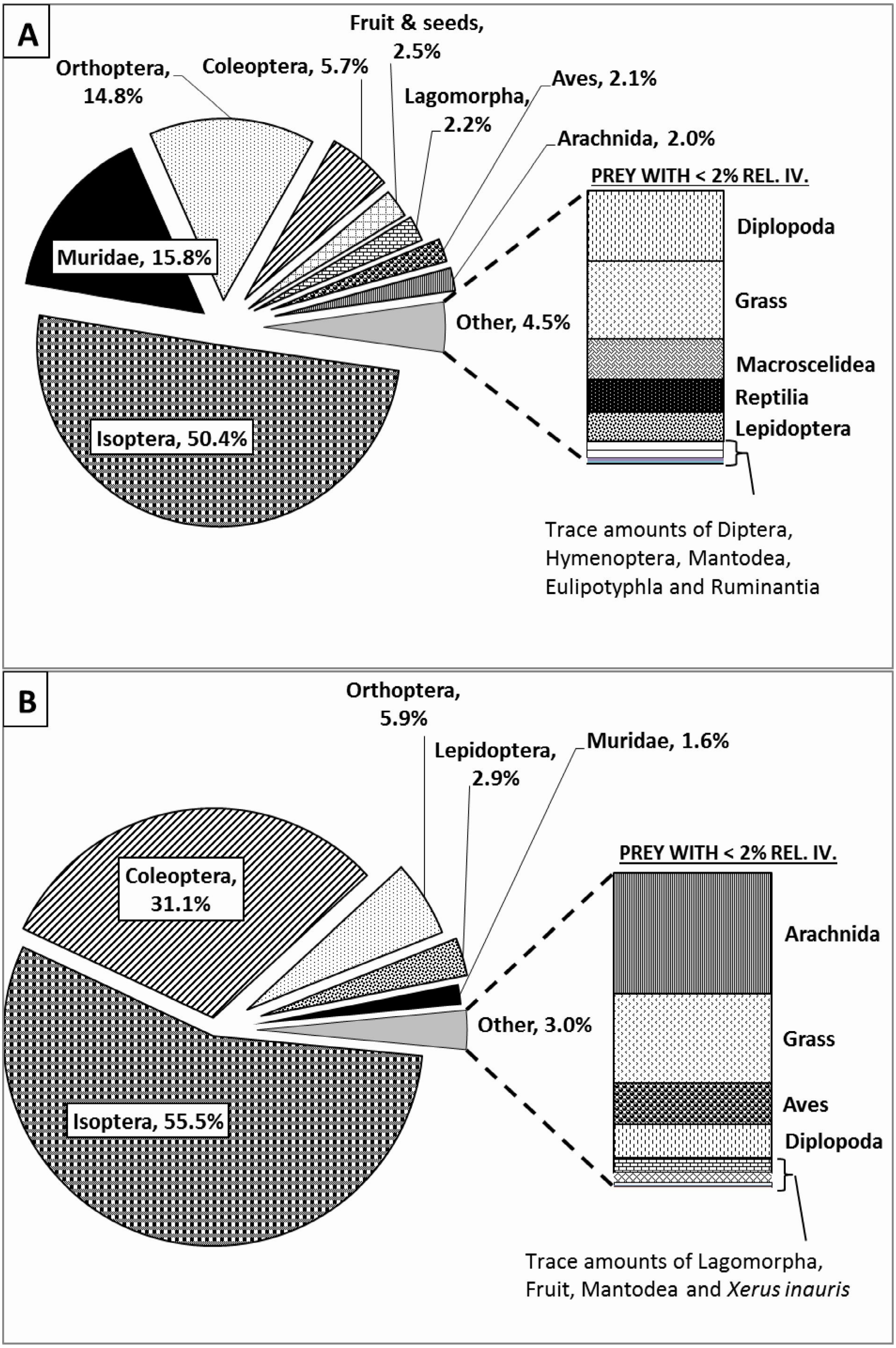

Fig. 4.2. Mean monthly relative importance value of prey in Cape grey mongoose **(A)** and yellow mongoose **(B)** diet in the study area, southern Free State.

Table 4.2. Number of prey items included in the diet of four syntopic carnivores in the study area, southern Free State. **A**, caracal; **B**, black-backed jackal; **C**, Cape grey mongoose; **D**, yellow mongoose. Mammals indicated to species level; Aves, pooled, indicated as one group; Reptilia, pooled and indicated as one group; grass, one group; fruit, one group; Insecta, to order level.

Diet category	**Carnivore**			
	A	**B**	**C**	**D**
All (Vertebrata, Invertebrata, grass and fruit)	21	31	30	29
Vertebrata (Mammalia, Aves and Reptilia)	15	21	17	16
MAMMALIA	14	20	15	14
Rodentia species (Muridae, Sciuridae, Pedetidae)	5	7	7	7
Lagomorpha species	2	2	2	2
Muridae species	4	6	6	6
Carnivora species	2	3	1	0
Ruminantia species (sheep included)	4	4	3	3
Invertebrata prey (Insecta, Aranea and Scorpiones)	5	8	11	11
INSECTA	4	5	7	8

Table 4.3. Shannon and Simpson diversity and Evar evenness indices, calculated for all prey categories of syntopic carnivores in the study area, southern Free State. Indices were determined using the prey items' mean monthly relative percentage occurrence in scats.

	Shannon	**Simpson**	**Evar**
Caracal	2.58	10.23	0.45
Black-backed jackal	3.09	18.14	0.42
Cape grey mongoose	2.72	10.56	0.24
Yellow mongoose	2.47	8.64	0.18

4.3.2. Seasonal variation in diet

The relative contributions (Rel.IV.s) of prey items fluctuated over seasons in the diets of all four carnivores, with varying peaks and throughs evident Fig. 4.3 - Fig. 4.4). Some destinct results, for each carnivore, are highlighted below:

4.3.2.1. Caracal

In the dominant prey group, Lagomorpha, *Lepus* spp. contributed most to caracal's diet in summer (Rel.IV. 50.94%) and autumn (Rel.IV. 36.15%). *Procavia capensis* contributed its most in winter (Rel.IV. 54.30%), autumn (28.57%) and summer (15.72%). *Pedetes capensis* was the prey item that contributed the most to caracal diet in spring (Rel.IV. 52.16%); it contributed 15.72% in summer, <5% in autumn, and only a trace in winter. *Ovis aries* was present in all four seasons, but made notable contributions in spring (Rel.IV. 18.87%) and autumn (16.07%) (see also section 4.3.3). Bird remains were mostly present in scats in winter (Rel.IV. *c*.10%) and spring (Rel.IV. >5%). Carnivores (*Cynictis penicillata* and *Proteles cristatus*) were found in trace amounts throughout, but most notably in autumn and winter.

4.3.2.2. Black-backed jackal

Murids in total contributed most to black-backed jackal diet in summer (78.54%), then spring (Rel.IV.=48.01%), and then autumn (Rel.IV.=37.77%) and winter (22.73%). Here, *Micaelamys namaquensis* was present in all seasons, but made the most notable contributions in spring and summer. *Otomys* spp. made a relative contribution of 25.75% in summer, and marked contributions also in spring and autumn. *Antidorcas marsupialis* contributed 45.87% (Rel.IV.) in winter and 24.25% in spring. Lagomorpha (*Lepus* spp.) made its largest contribution in summer (Rel.IV. 22.20%) and autumn (19.46%), however, *Pronolagus rupestris* was most and least prominent in winter and summer respectively. *Ovis aries* were most prominent in spring and autumn (Rel.IV.=11.70% and 5.69% respectively) (see also section 4.3.3), *Redunca fulverufula* made its highest contribution in winter and spring (Rel.IV.=14.28% and 9.43% respectively), birds were most present in spring (Rel.IV.=3.36%) and summer (Rel.IV.=3.01), and fruit contributed most (Rel.IV. >15%) in autumn. *Suricata suricatta* and *Otocyon megalotis* were found in trace amounts in winter and spring.

4.3.2.3. Cape grey mongoose

Invertebrates were the dominant prey group throughout the year (Fig. 4.4 A). Isoptera contributed 27.08% (Rel.IV.) in winter, 63.64% in spring, 16.19% in summer and 35.83% in autumn 2012; Orthoptera contributed 23.69% in winter and 17.79% in autumn; and Coleoptera >15% in summer and >5% in autumn and winter. Muridae made its largest contribution (Rel.IV. 21.18%) in autumn, 14.80% in winter, and 12.38% in spring. The following prey items were found in trace amounts: *Crocidura sp*. (autumn and spring), Hymenoptera (autumn, spring and winter), Diptera (autumn, spring and winter), Mantodea (autumn, spring and winter), Ruminantia (autumn, spring and winter), unidentified mammalia (summer), *Pedetes capensis* (winter), *Pronolagus rupestris* (autumn, summer, spring and winter), and Carnivora (autumn).

4.3.2.4. Yellow mongoose

Insects, especially Isoptera, dominated scat remains throughout the year Fig. 4.4 B). Isoptera alone contributed 69.02% (Rel.IV.) in winter, 78.09% in spring, 36.99% in summer, and 31.69% in autumn. Coleoptera was present in all seasons, but made the most notable contributions in summer (Rel.IV. 52.75%) and in autumn (46.49%). Prey items that were found in trace amounts included *Crocidura sp*. (spring and winter), sengi *Elephantulus myurus* (winter), Hymenoptera (autumn, spring and winter), Diptera (autumn, spring and winter), Mantodea (autumn, spring and winter), Blattodea (autumn and spring), Ruminantia (summer, winter and spring).

4.3.3. Prey species of economic importance (sheep and springbok)

Domestic sheep *Ovis aries* and springbok *Antidorcas marsupialis* are two of the species confined to specific camps and farmed with in the study area (others are black wildebeest *Connochaetes gnou*, blesbok *Damaliscus pygargus* and red hartebeest *Alcelaphus buselaphus*.

In caracal diet *Ovis aries* made the highest mean percentage occurrence, percentage volume and importance value contributions in spring (e.g. 17.6%Occ.) and autumn (15.8%Occ.) (Table 4.4). In black-backed jackal diet *Ovis aries* also had a high presence, especially in spring (15.6%Occ.) and autumn (9.0). In both meso-predators sheep remains mostly filled the whole scat when present, resulting in mean volumetric contributions much similar to sheep occurrence contributions (Table 4.4). Accordingly, importance values followed the same pattern: most important in spring months, then autumn months, followed by summer and winter months. Throughout, sheep had a higher prey importance value in caracal diet (mean IV. = 1.78 ± 1.15) than in black-backed jackal diet (mean IV. = 0.85 ± 0.81).

Antidorcas marsupialis was utilised by both caracal and black-backed jackal (Table 4.5). In black-backed jackal, *Antidorcas marsupialis* was represented mostly in winter and spring, with percentage occurrences of 28.0% and 17.8% respectively. Caracal fed most intensely (although to a lesser degree than black-backed jackal) on *Antidorcas marsupialis* during summer, then present in 6.5% of scats; springbok were less utilised in winter and spring, and no springbok remains were found in caracal scats collected in autumn. Again, similar percentage occurrence and volume values were observed in caracal scats, hinting that these prey were killed by the caracal, and eaten. The same were observed in caracal-sheep association (Table 4.5). In black-backed jackal this phenomenon was more or less observed in its relationship with sheep, but not with springbok. In the latter the percentage volume values were lower than the percentage occurrence values, indicating that scavenging on springbok were more pronounced than on sheep.

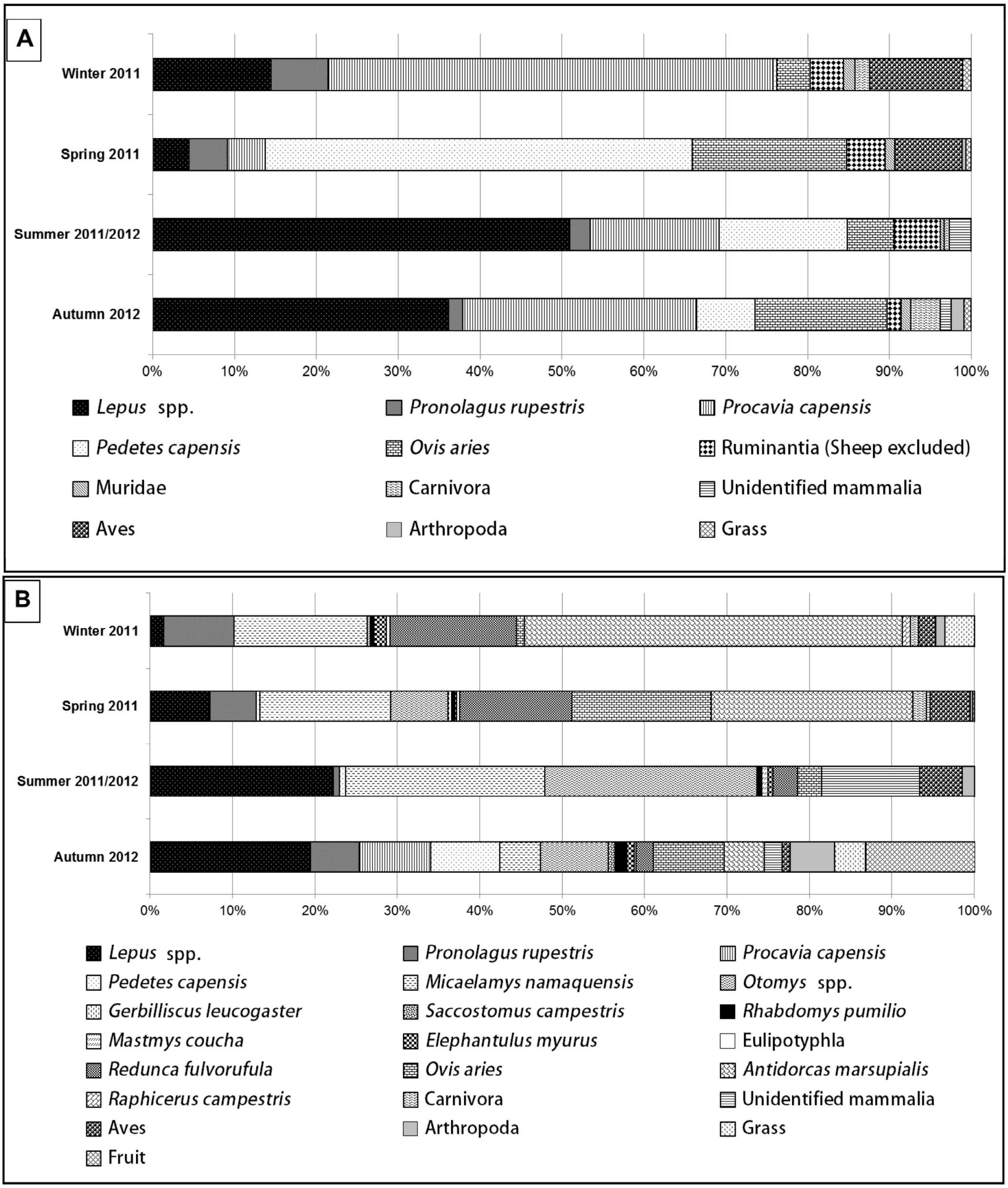

Fig. 4.3. Seasonal variation in the contributions of prey items in caracal **(A)** and black-backed jackal **(B)** scats in the southern Free State study area. Mean monthly relative importance values are indicated. Winter, June - August; Spring, September - November; Summer, December - February; Autumn, March – May.

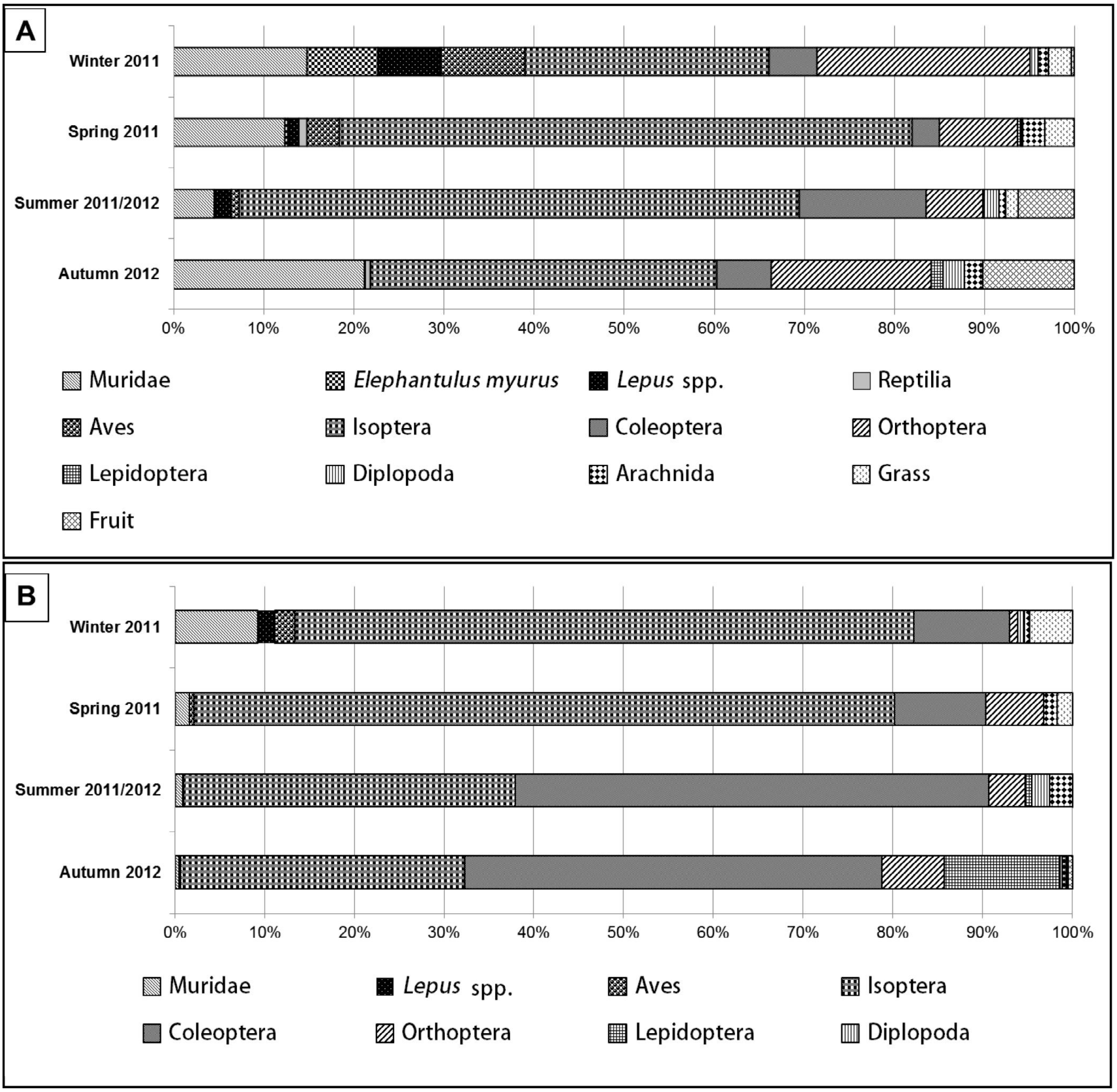

Fig. 4.4. Seasonal variation in the contributions of prey items in Cape grey mongoose **(A)** and yellow mongoose **(B)** scats in the southern Free State study area. Mean monthly relative importance values are indicated. Winter, June - August; Spring, September - November; Summer, December - February; Autumn, March – May.

Table 4.4. Mean monthly contributions of domestic sheep *Ovis aries* in caracal *Caracal caracal* and black-backed jackal *Canis mesomelas* scats in the study area, southern Free State. *****, significant difference between carnivores (Wilcoxon matched pairs test).

	Caracal caracal	***Canis mesomelas***
Percentage occurrence		
Winter	8.57	4.00
Spring	17.65	15.56
Summer	9.68	6.45
Autumn	15.79	8.96
Mean	**12.93 ± 4.44***	**8.78 ± 4.97**
Percentage volume		
Winter	8.57	4.00
Spring	17.14	13.00
Summer	9.68	6.45
Autumn	15.79	8.88
Mean	**12.80 ± 4.27***	**8.10 ± 3.83**
Importance value		
Winter	0.73	0.16
Spring	3.03	2.02
Summer	0.94	0.42
Autumn	2.49	0.80
Mean	**1.78 ± 1.15***	**0.85 ± 0.81**

Table 4.5. Mean monthly contributions of springbok *Antidorcas marsupialis* in caracal *Caracal caracal* and black-backed jackal *Canis mesomelas* scats in the study area, southern Free State. ^{NS}, no significant difference between carnivores (Wilcoxon matched pairs test).

	Caracal caracal	***Canis mesomelas***
Percentage occurrence		
Winter	8.57	4.00
Spring	17.65	15.56
Summer	9.68	6.45
Autumn	15.79	8.96
Mean	**3.08 ± 2.66** ^{NS}	**13.33 ± 12.20**
Percentage volume		
Winter	8.57	4.00
Spring	17.14	13.00
Summer	9.68	6.45
Autumn	15.79	8.88
Mean	**3.08 ± 2.66** ^{NS}	**12.43 ± 12.01**
Importance value		
Winter	0.73	0.16
Spring	3.03	2.02
Summer	0.94	0.42
Autumn	2.49	0.80
Mean	**0.15 ± 0.17** ^{NS}	**2.73 ± 3.49**

4.3.4. Food niche breadth

For each of the four carnivores the food niche breadth values differed markedly depending on whether relative percentage occurrence (Rel.%Occ.) or relative percentage volume (Rel.%Vol.) contribution values were used in the calculations (Fig. 4.5); especially for yellow mongoose whose main diet consist of invertebrates. Black-backed jackal and Cape grey mongoose had the widest niche breadths when using both the Rel.%Occ. and Rel.%Vol. data; caracal had the narrowest niche breadth when using the Rel.%Occ. information, and yellow mongoose when using the Rel.%Vol. information. For the two larger carnivores, who consumes larger quantities of larger prey, the seasonal variation in niche breadth were more similar (when using Rel.%Occ. and Rel.%Vol. data). In contrast, considerable differences were observed for yellow mongoose, who consumes the largest quantities of the smallest prey (insects). In Cape grey mongoose these differences were intermediate.

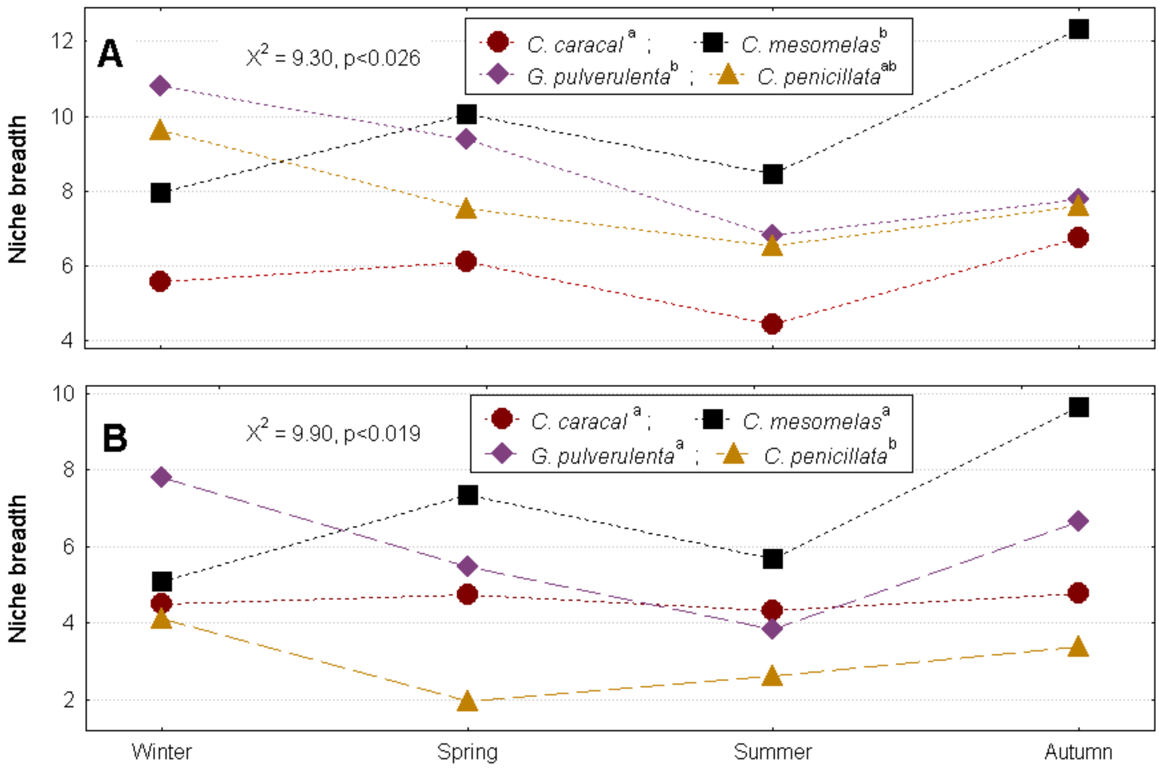

Fig. 4.5. Seasonal niche breadth, as determined from relative percentage occurrence **(A)** and relative percentage volume **(B)** values of prey in scats of four carnivores in the study area, southern Free State. Letters in superscript refer to homologous groupings derived from t-tests for independent samples.

When food nich breadths were calculated from relative importance values (Fig. 4.6), black-backed jackal had the largest overall niche breadth, followed by Cape grey mongoose. Caracal and yellow mongoose had the narrowest food niche breadths with no overall differences between these two species (Fig. 4.6).

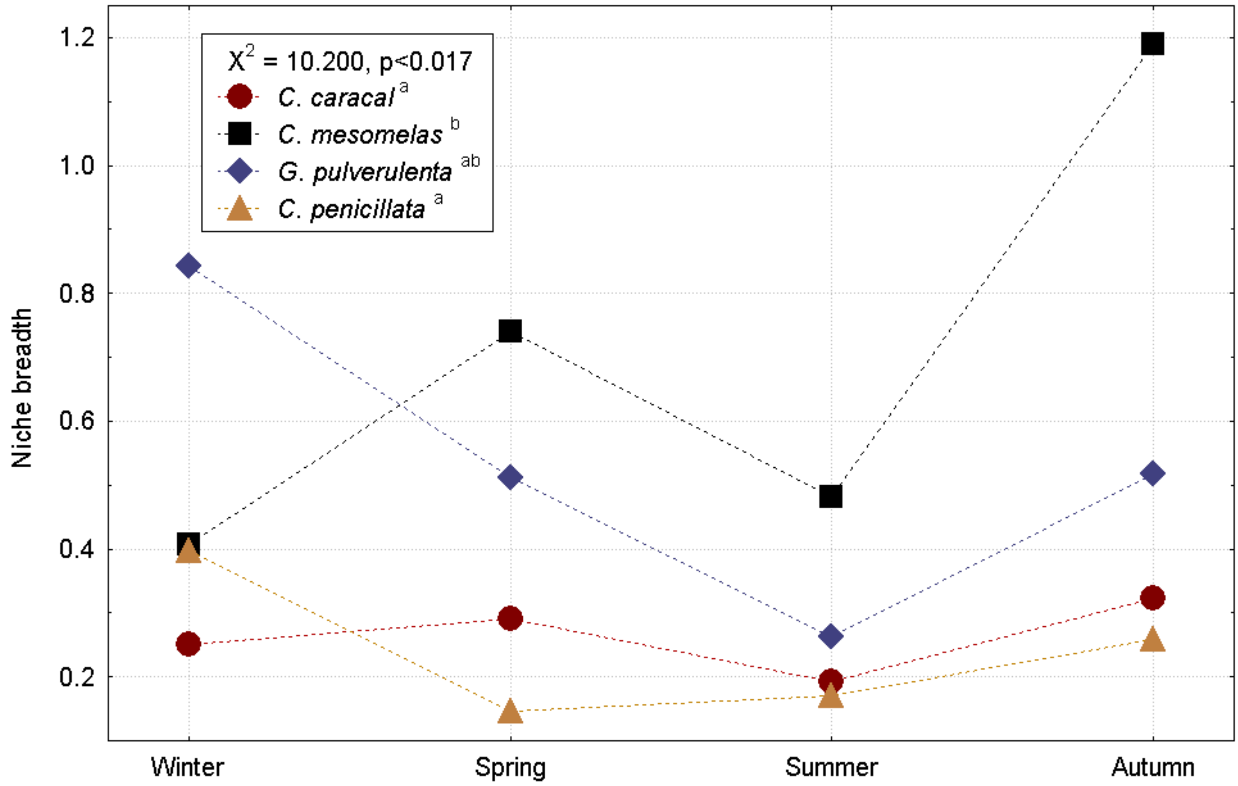

Fig. 4.6. Seasonal niche breadth, as determined from relative importance values of prey in scats of four carnivores in the study area, southern Free State. Letters in superscript refer to homologous groupings derived from t-tests for independent samples.

4.3.5. Food niche overlap

Food niche overlap calculations, using the relative percentage occurrence and relative percentage volume data (Fig. 4.7 A) yielded the following ranking, from highest overlap to lowest: 1) caracal-black-backed jackal, 2) Cape grey mongoose-yellow mongoose, 3) black-backed jackal-Cape grey mongoose, 4) caracal-Cape grey mongoose, 5) black-backed jackal-yellow mongoose and 6) caracal-yellow mongoose. Within species pairs, differences were detected between values calculated from Rel.%Occ. and Rel.%Vol. data, especially where yellow mongoose was involved.

Food niche overlap calculations using the relative importance values (≈ a combination of %Occ. and %Vol. values; Fig. 4.7 B) confirmed that caracal and black-backed jackal had the largest (overall) niche overlap in the study area, followed by Cape grey mongoose-yellow mongoose, caracal-Cape grey mongoose and black-backed jackal-Cape grey mongoose, caracal-yellow mongoose, and black-backed jackal-yellow mongoose.

Food niche overlap values, however, changed markedly over seasons (Fig. 4.8). The seasonal food niche overlap between caracal and black-backed jackal (Fig. 4.8 A) was lowest (0.1) in winter, after which it gradually increased until autumn (0.8). The seasonal niche overlap between Cape grey mongoose and yellow mongoose (Fig. 4.8 B) was relatively high for all seasons (winter=0.7, spring=1, summer=0.7 and autumn=0.6).

Although the overall seasonal niche overlap was low between caracal and Cape grey mongoose (<0.1; Fig. 4.8 C), a higher overlap was observed during winter (0.09), and lowest overlaps during spring and autumn (0.01). The overall seasonal niche overlap between caracal and yellow mongoose (Fig. 4.8 D) was, in comparison with the other overlaps studied, very low. As with the caracal-Cape grey mongoose overlap, a definite higher overlap was observed during winter (0.014); in this instance, however, the lowest overlap was found in summer (0.0001).

Between black-backed jackal and Cape grey mongoose (Fig. 4.8) the niche overlap was lowest in winter (0.03), spring (0.03) and summer (0.03), and highest in autumn (0.16). As with the caracal and yellow mongoose, the overlap between black-backed jackal and yellow mongoose was also very low (Fig. 4.8). It fluctuated from winter to autumn, with lowest overlap in spring (0.003) and highest in autumn (0.020).

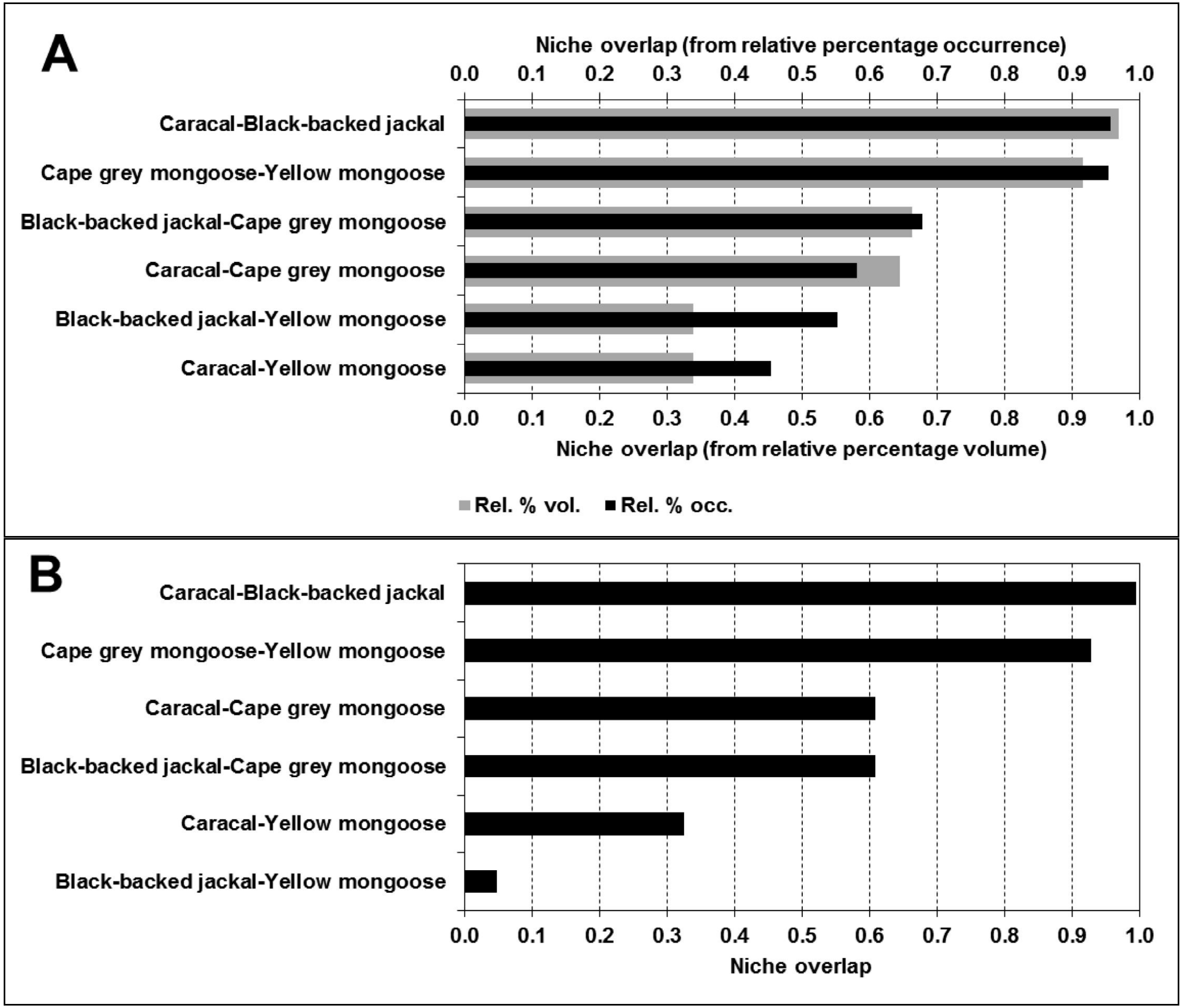

Fig. 4.7. Food niche overlap hierarchy calculated from relative percentage occurrence and relative percentage volume **(A)**, and relative importance value **(B)**, of caracal, black-backed jackal, Cape grey mongoose and yellow mongoose in the study area, southern Free State.

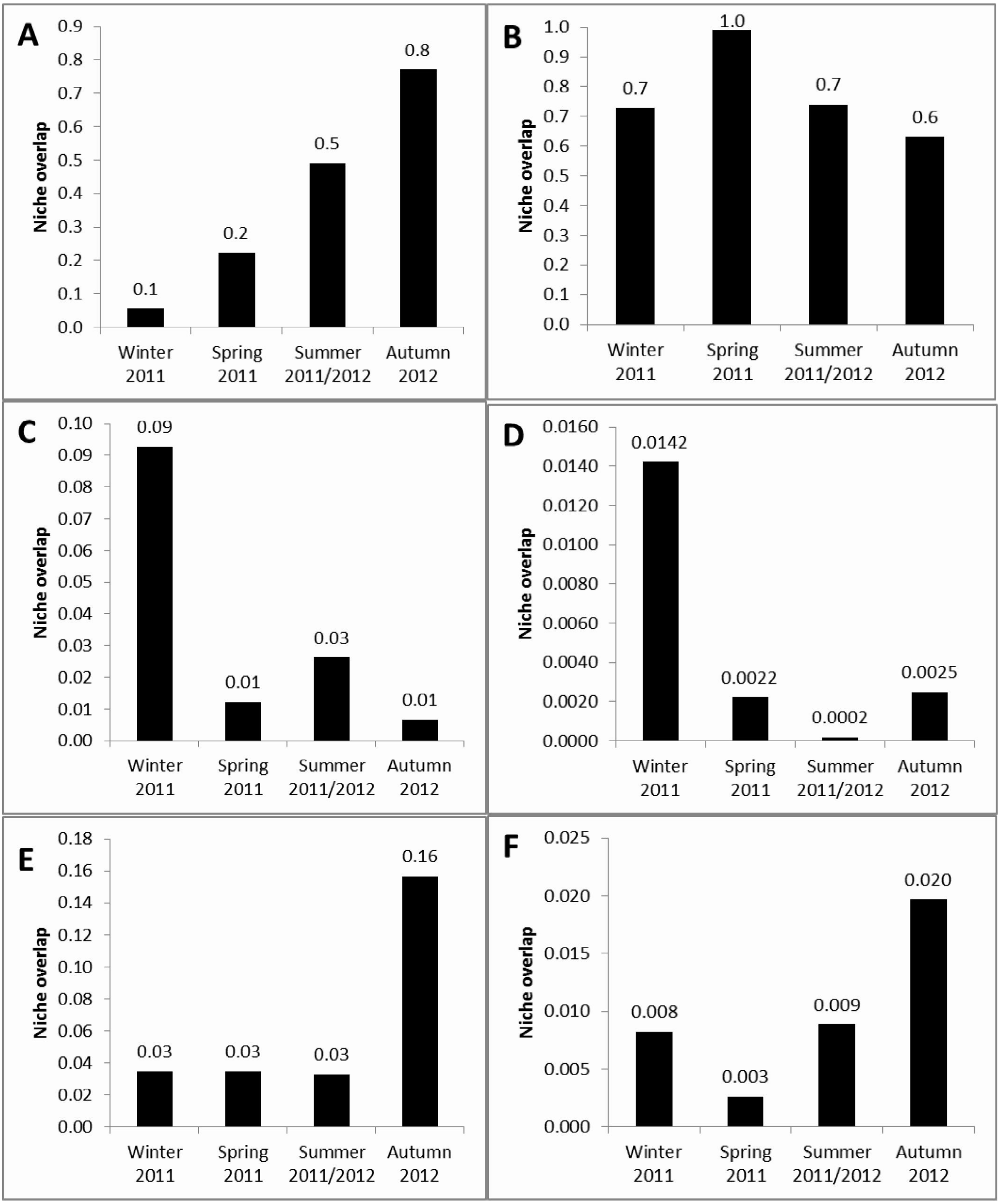

Fig. 4.8. Seasonal niche overlap of species pairs, calculated using monthly relative importance values of prey items. **A**, caracal and black-backed jackal; **B**, Cape grey mongoose and yellow mongoose; **C**, caracal and Cape grey mongoose; **D**, caracal and yellow mongoose; **E**, black-backed jackal and Cape grey mongoose; and **F**, black-backed jackal and yellow mongoose.

4.4. Discussion

4.4.1. Prey utilised

More than 30 different prey items were used by the four syntopic carnivores. Of these, a large number were shared, in different proportions. These proportions also differed between seasons, most probably as the relative availability of these species and groups change. It is understandable that the two larger carnivores, caracal and black-backed jackal, utilised more larger prey items than the two mongoose species. Caracal, for example, consumed mostly hares and rabbits, rock hyrax, springhares and antelope, including domestic sheep. The diet of black-backed jackal was dominated by a smaller prey, mice, but it also utilised fairly large proportions of hares and rabbits, and ungulates (including sheep and springbok). Prey items most prominent in Cape grey mongoose scats were insects and mice, and the diet of yellow mongoose was almost completely dominated by insects (mainly of the orders Isoptera and Coleoptera).

The diet of caracal and black-backed jackal therefore included more mammal and less invertebrate prey than that of Cape grey mongoose and yellow mongoose. Black-backed jackal diet was the most diverse, followed by Cape grey mongoose, caracal, and yellow mongoose diet the least diverse. The two larger carnivores, caracal and black-backed jackal, utilised their prey items with higher evenness than the two mongoose species.

The presence and domination of the main prey items in the carnivores' diet fluctuated, and the same prey species or group were not always utilised by the different carnivores in the same pattern. For example, Lagomorpha (the main prey group of caracal) were, used by both caracal and black-backed jackal mostly in summer and autumn. Sheep also peaked in both these carnivores' diet at the same times (spring and autumn). Rock hyrax on the other hand was consumed by caracal mostly in winter, after which its importance value dropped significantly and reached a second high in autumn (with usage still 50% less than in winter); in black-backed jackal rock hyrax was basically only found in autumn scats. Springhare remains also peaked in caracal scats in winter, and in black-backed jackal scats in autumn; bird remains peaked in caracal scats in winter and spring, and in black-backed jackal scats in spring and summer; and rodents peaked in black-backed jackal diet in summer, and in Cape grey mongoose in autumn and winter. While general theory is that an opportunistic carnivore will uitilse more of a specific prey item when it is more available, this study therefore has shown that there is more at stake. *Caracal caracal*, *Canis mesomelas* and *Galerella pulverulenta* have all being described as opportunistic, but still their usage of the same prey item varied markedly over the year. Together with behavioural differences such as time of activity and habitat preferences, the intricate way and differences in which syntopic carnivores utilise their prey spectrums therefore may also play a major role in their co-existance.

4.4.2. Prey niche breadth and overlap

Black-backed jackal had the largest overall food niche breadth, Cape grey mongoose the second largest (or intermediate), and caracal and yellow mongoose had the narrowest breadths. This is in agreement with (Kok & Nel 2004) which that stated, although both feed opportunistically, caracal is more of a specialist than black-backed jackal. Niche breadths changed over seasons, with autumn the time of year when caracal and black-backed jackal had highest niche breadths, and winter the time when Cape grey and yellow moongoose had their highest niche breadth. All four carnivores had lowest niche breadth in summer. This is a general reflection of high and low prey density/availability times during the year: warm and wet summer and autumn is the main breeding seasons for a number of mammal, bird and reptile species in the study area (= increased densities and more vulnerable young present in the prey populations), while dry and cold late-autumn and winter is usually a time when densities drastically decline, also in relation to cessation of primary growth (Van der Westhuizen 2006; Avenant 2011; Chapter 5). Therefore, it is possible that when the preferred prey is more available (= summer), basically all of these carnivores showed a narrower niche breadth; and when the animals are under energy (cold) stress and the preferred prey is less available (= end-autumn/early-winter), carnivores utilise a wider prey spectrum and food niche breadth increase.

Food niche overlap calculations indicated that caracal and black-backed jackal had the largest niche overlap of the four most numerous carnivores in the study area. This high overlap value is closely followed by that of Cape grey mongoose-yellow mongoose; also the combination of a relative generalist (Cape grey mongoose, with relative high niche breadth) and a more specialist (yellow mongoose, narrow niche breadth) carnivore. Caracal-Cape grey mongoose and black-backed jackal-Cape grey mongoose had intermediate food nich overlaps, and the caracal-yellow mongoose and black-backed jackal-yellow mongoose had much smaller overlaps. These remained the pattern over al four seasons, despite the fact that niche overlap values changed markedly over seasons.

The seasonal fluctuations in food niche overlap can also be an indication of when competition for food is expected to be highest between two carnivores. Caracal and black-backed jackal overlap was highest in autumn, when both species were forced to forage outside their preferred prey (see also highest food niche breadth). On the other hand, winter and spring (= lowest lowest overlap) was the period when the diets of these two animals showed major differences, with caracal taking high volumes of rock hyrax and springhare, while black-backed jackal consumed more antelope, rodents, red rock rabbit and sheep. The seasonal niche overlap between Cape grey mongoose and yellow mongoose was almost the opposite, with overlap highest in spring and lowest in autumn. As in the winter and spring with caracal-black-backed jackal comparison, autumn was the time of year where the main prey contributions of Cape grey and yellow mongoose differed the most: yellow mongoose mostly ingested Isoptera and Coleoptera, while Cape grey mongoose consumed large quantities of mice, Isoptera, Orthoptera and fruit.

4.4.3. Caracal and black-backed jackal niche overlap and breadth

It is clear that both damage-causing meso-predators caracal and black-backed jackal play an intricate part of the ecosystem in the study area. A large proportion of natural prey was utilised and prey usage was observed to fluctuate with availability (Chapter 5). It is also clear why these species are regarded as damage-causing predators in the study area. In this study small stock was one of the major prey items for both caracal and black-backed jackal. While both damage-causing carnivores have been termed "specialist" and " generalist" in literature (Avenant & Nel 2002), these terms should be used in context of relative diets. Caracal, for example, usually has a narrower overall niche breadth than black-backed jackal, but cannot be regarded as a "specialist". The diet of black-backed jackal in this study included numerous prey not found in the diet of caracal (Muridae species *Saccostomus campestris*, *Rhabdomys pumilio*, *Mastomys coucha*; a Macroscelidea species, *Elephantulus myurus*; two Eulipotyphla species, *Crocidura cyanea* and *Atelerix frontalis*; two Carnivora species, *Suricata suricatta* and *Otocyon megalotis*). Black-backed jackal also utilised fruit, which was not found in any caracal scats. The occurrence of fruit, especially in autumn is similar to that found by Brassine (2011). The relatively high occurrence of Muridae in the diet of *Canis mesomelas* is similar to that found by Rowe-Rowe (1983) (more than 50%). Rowe-Rowe (1983) also found antelope remains peaking in late-winter and early-spring, which is very similar to this study. In this study niche breadths of both carnivores expand and contract over seasons; however, they have different peaks and troughs, an indication that specialised (and general) feeding behaviour is displayed at different times of the year. Both niche breadth as well as overlap was found to be markedly impacted by the availability of specific prey items, namely: small stock (lambs), springbok (lambs) and rodents (mice and springhare). Highest niche overlap also coincided with the lambing seasons. Though both caracal and black-backed jackal had a high predation impact on small stock during the lambing seasons, it should be noted that small stock made up a larger proportion of the Ruminantia prey group in the caracal's diet (mean monthly Rel.%Vol. = 62% vs the 31% of black-backed jackal).

The results of this study suggests that although caracal and black-backed jackal feed on many of the same food resources, natural and small stock prey are utilised in different relative proportions, which may eliminate a large degree of interference competition. Caracal, for example, preyed relatively more on Lagomorpha, *Procavia capensis* and *Pedetes capensis* than black-backed jackal. Black-backed jackal also preyed on Lagomorpha and *Ovis aries*, but relatively less than caracal. In addition to the many species not preyed upon by caracal (see above), black-backed jackal preyed more on Muridae species and other antelope species (*Antidorcas marsupialis* and *Redunca fulvorufula*). The current study, however, does not propose that no competition exists between caracal and black-backed jackal (see niche overlap), but that the two carnivores may have developed feeding strategies to coexist in the same farming area. The study area, furthermore, is characterised by a high availability of natural prey (Chapter 5). Interference competition between caracal and black-backed jackal will probably be more conspicuous in ecosystems of low availability of natural prey.

4.4.4. Cape grey mongoose and yellow mongoose niche overlap and breadth

The high prey niche overlap between Cape grey mongoose and yellow mongoose (0.9) is similar to that reported by MacDonald & Nel (1986) and Avenant & Nel (1997) (>0.8 and ± 0.9, respectively). The results of MacDonald & Nel (1986) and this study are in agreement that insect prey is the main reason for this high overlap. Despite this high overlap, the current study also indicates that prey items are utilised in different proportions. Cape grey mongoose, for example, fed more on Muridae and Orthoptera than yellow mongoose. The diet of yellow mongoose, on the other hand, included more Coleoptera than the diet of Cape grey mongoose. Following the results of MacDonald & Nel (1986) it can also be argued that there would be some food niche overlap (± 0.6 or higher) between bat-eared fox *Otocyon megalotis* and each of these two carnivores in the present study area (*O. megalotis* was frequently spotted in the study area during drive counts). This assumption, however, could not be tested in the current study as no *O. megalotis* scats were collected. Although niche overlap between Cape grey mongoose and yellow mongoose is high, Avenant & Nel (1997) suggests that different habitat preferences would allow these carnivores to co-exist despite high niche overlap. The notion of contrasting habitat preferences of these two syntopic carnivores is supported by the results of Cavallini & Nel (1995) and MacDonald & Nel (1986) where yellow mongoose preferred open fields while Cape grey mongoose preferred bush habitat. In this study latrine sites of yellow mongoose were almost never found in bushy vegetation, but in flat, open grassland. Cape grey mongoose scats, on the other hand, were concentrated in areas of bushy vegetation, often on the sloping terrain. According to Cavallini & Nel (1995), these habitat preferences are associated with differing prey (insect and rodent) densities in these contrasting habitats. Moreover, *Galerella pulverulenta* is typically more carnivorous than *Cynictis penicillata*, which will determine how these species select microhabitats. Open habitat may contain high densities of Arthropoda prey (favoured by yellow mongoose), but low densities of rodent prey, whereas, bushy habitat may contain high densities of rodent prey (favoured by Cape grey mongoose), but lower densities of insect prey. Differences in anti-predator behaviour and social structure may contribute to these habitat preference differences (Cavallini & Nel 1995).

4.4.5. Other interactions

Differences in relative body size, activity rhythms and habitat preference are factors that may allow the two smaller species (Cape grey mongoose and yellow mongoose) to successfully co-exist with the two larger meso-carnivores (caracal and black-backed jackal) in the study area (Avenant & Nel 1997). Caracal and black-backed jackal, for example, are primarily nocturnal, whilst Cape grey mongoose and yellow mongoose are diurnal. These carnivores not only display temporal specialisation, but also effectively utilise a different prey spectrum. Both smaller species also utilised insects to a larger extent than the two larger meso-carnivores, caracal and black-backed jackal, in the study area. This explains why large overlap was observed between caracal and black-backed jackal, between Cape grey mongoose and yellow mongoose, but significantly less between the meso-carnivores and the two smaller carnivores. Another notable find was that the diet of Cape grey mongoose was not limited to invertebrate insect prey, but included many of the prey items also utilised by caracal and black-backed jackal, whereas yellow mongoose fed primarily on invertebrate prey. Invertebrate prey was probably consumed accidentally and/or opportunistically by caracal and black-backed jackal.

Since there were major differences in terms of intensity of predation on vertebrate and invertebrate prey (see Table 4.1), these indices, although not shown in this chapter, will differ when calculated at different taxonomic levels (e.g. Mammalia and Insecta).

5. Predator-prey interactions of caracal in a small stock farming area

The aim of this chapter was to describe caracal predator-prey interactions in a small stock farming area of the southern Free State. Caracal diet was analysed over a 13 month period through scat analysis, whilst prey availability (monthly abundance and density) was determined with standardised transect methodology. Spearman-rank correlations were used to draw correlations between caracal diet (importance values) and prey availability, between prey availability and climatic factors (rainfall, temperature and humidity), and between climatic factors and the overall breeding season. Springhare remains in scats correlated strongly with monthly springhare abundance (r=0.8; p=0.004), which in turn correlated with humidity (r=-0.7; p=0.03). Hare *Lepus* spp. remains in scats did not correlate with hare monthly abundance (r=0.6; p=0.09). The overall breeding season showed a positive correlation with temperature (r=0.8; p=0.001). The study established that many prey species that caracal fed on were affected by climatic factors (correlates with the breeding season and presence of young), another indirect cue that caracal in the study area were found to be opportunistic and consume more of a specific prey as it becomes more available. Caracal fed on a variety of prey, of which Lagomorpha (especially *Lepus* spp.), springhare *Pedetes capensis* and small stock (sheep *Ovis aries*) were main prey. The results suggest that caracal fed on the most abundant prey and opportunistically exploited peaks in prey abundance. As such, it is proposed that caracal play an intricate role in this specific ecosystem, that they regulate prey populations, and that they may benefit other syntopic carnivores also directly through carrion provision.

Key words: breeding times, diet, meso-predator, predator-prey interactions, prey abundance.

5.1. Introduction

Understanding predator-prey interactions (fluctuations in prey availability and use) is key to the management of damage-causing meso-predators, such as caracal and black-backed jackal. According to (Du Plessis 2013) there is currently limited published material available on both caracal's and black-backed jackal's predator-prey interactions, and little on the inter-species interaction between these two predators (five studies: Ferreira 1988; Kuanda 2001; Melville *et al.* 2004; Kok & Nel 2004; Blaum *et al.* 2009). The effects of predator-prey interactions are also not limited to an interaction between a predator and its prey species, but may also impact on a shared predator of a specific prey source (Arthur & Prugh 2010). The community of prey species may be affected variably, depending on the nature of the predator-prey interactions (Arthur & Prugh 2010). In the context of the current study, it should be noted that the traditional four level trophic interaction model (apex predator-meso-predator-herbivores-plants) (Mukherjee *et al.* 2009) is not appropriate, as apex predators have been eradicated in the area. The result is that meso-predator populations increase in density and/or range as they would only compete with other meso-predators and are no longer suppressed by apex predators (Prugh *et al.* 2009; Russell *et al.* 2009). Furthermore, the behaviour of meso-predators, particularly microhabitat use, would be different in this context compared to areas where apex predators are present (Mukherjee *et al.* 2009). It can also be argued that the prey communities that meso-predators feed on would be structured in a different manner than in areas where meso-predators are suppressed by apex predators. Potential competition as a result of prey niche overlap and breadth is discussed in more detail in Chapter 4. The habitat heterogeneity characteristic of the study area (see Chapter 2) would, in theory, allow for a variety of prey species to exist. Vegetation rich and rocky, sloping, areas in the study area could provide a food source consisting of *Procavia capensis*, *Pronolagus rupestris*, mountain reedbuck, scrub hare and numerous small mammal species, while the open grassland is suitable habitat for species such as *Pedetes capensis*, *Lepus* spp. and aardwolf. The specific aim of this chapter is to discuss the interactions of caracal with its main prey groups *Lepus* spp., *Pedetes capensis* and *Ovis aries* in a rangeland ecosystem, characterised by diverse habitats.

5.2. Materials & methods

5.2.1. Scat analysis

Methodology of scat analysis followed that of (Avenant & Nel 1997, 2002). Both the percentage of occurrence (%Occ.) and percentage of volume (%Vol.) methods were used to describe caracal diet, since this allows for comparisons with other studies where, for example, only one of these methods was applied (see Avenant & Nel 2002; Klare *et al.* 2011). Percentage of occurrence can be defined as the percentage of scats containing a particular prey item, whereas percentage volume is the mean percentage volume that a specific prey type comprises in all scats. An importance value for main prey items was calculated as percentage occurrence x percentage volume / 100 (following Mealey 1980; Raine & Kansas 1990; Avenant & Nel 2002).

5.2.2. Prey availability

5.2.2.1. Drive counts

A drive count, following the methodology of Stenkewitz *et al.* (2010) and Bothma (2002) over a 17 km stretch of farm road, was used to determine monthly densities of hares *Lepus* spp. and springhares *Pedetes capensis*. Individuals were counted on both sides of the road using Pentax UCFX II 8x25 binoculars, a Celestron 80 mm spotting scope, and a Lightforce (240 mm diameter, 1.000.000 candlelight, 1.000 m beam range) spotlight (see chapter 2). Hares *Lepus* spp. were counted up until 60 m from the vehicle whilst springhares *Pedetes capensis* were counted up until 300 m from the vehicle. To eliminate bias, these counts were done always at the same time of day, in the same direction and when no wind, or at most a little breeze, was present. Drive counts were repeated three to four times per month and an average count per kilometre calculated, as an indication of density. Although other animals, such as springbok *Antidorcas marsupialis*, steenbok *Raphicerus campestris*, aardwolf *Proteles cristatus* and mountain reedbuck *Redunca fulvorufula*, were also counted during the drives, their small monthly sample sizes prohibited their inclusion in estimates. These species all have large home ranges that the current count method did not account for.

5.2.2.2. Strip counts (walked)

Freshly used *Pronolagus rupestris* latrine sites were counted in April 2012 on a number of bottom slope and plateau transects (Fig. 5.6). These two walked transects (each ± 4 km long) followed standardised methodology outlined in Bothma (2002).

5.2.2.3. Rock hyrax

The population sizes of two rock hyrax colonies were estimated during March 2012 using the Lincoln index (a catch-mark-release-recapture method) and the Robson–Whitlock index (comprising direct observations) (Wiid & Butler 2014).

5.2.2.4. GIS maps

Count transects, vegetation types and latrine sites were indicated on GIS maps created with QGIS desktop version 2.4.0.

Spot images and farm boundary data was acquired from the Geography Department, University of the Free State. Wetlands and rivers shape files were acquired from SANBI (http://bgis.sanbi.org/index.asp?screenwidth=1366). All other shape files, such as vegetation type and major towns, is from Mucina & Rutherford (2006).

5.2.2.5. Statistical analysis

Relationships between caracal prey usage and prey densities, between prey densities and climatic data, and between the overall breeding season and climatic data was tested using Spearman rank correlations (Magurran 2004).

5.3. Results

5.3.1. Primary productivity and prey availability

In the current study the observed breeding season of most of the caracal prey species stretched from September 2011 to April 2012. These species include *Lepus saxatilis* and *Lepus capensis*, *Pronolagus rupestris*, *Pedetes capensis*, game birds, *Antidorcas marsupialis*, *Redunca fulvorufula*, and *Raphicerus campestris*. Using data from Van der Westhuizen (2006), strong significant correlations were found between primary productivity of vegetation (from two locations within the province: Fauresmith and Phuthaditjhaba) and climatic data. These correlations (Fig. 5.1 A-B) were as follows: Fauresmith-Temperature (r=0.8; p=0.01), Fauresmith-rainfall (r=0.9, p=0.0003), Phuthaditjhaba-temperature (r=0.9, p=0.0001), Phuthaditjhaba-rainfall (r=0.9, p=0.0002).

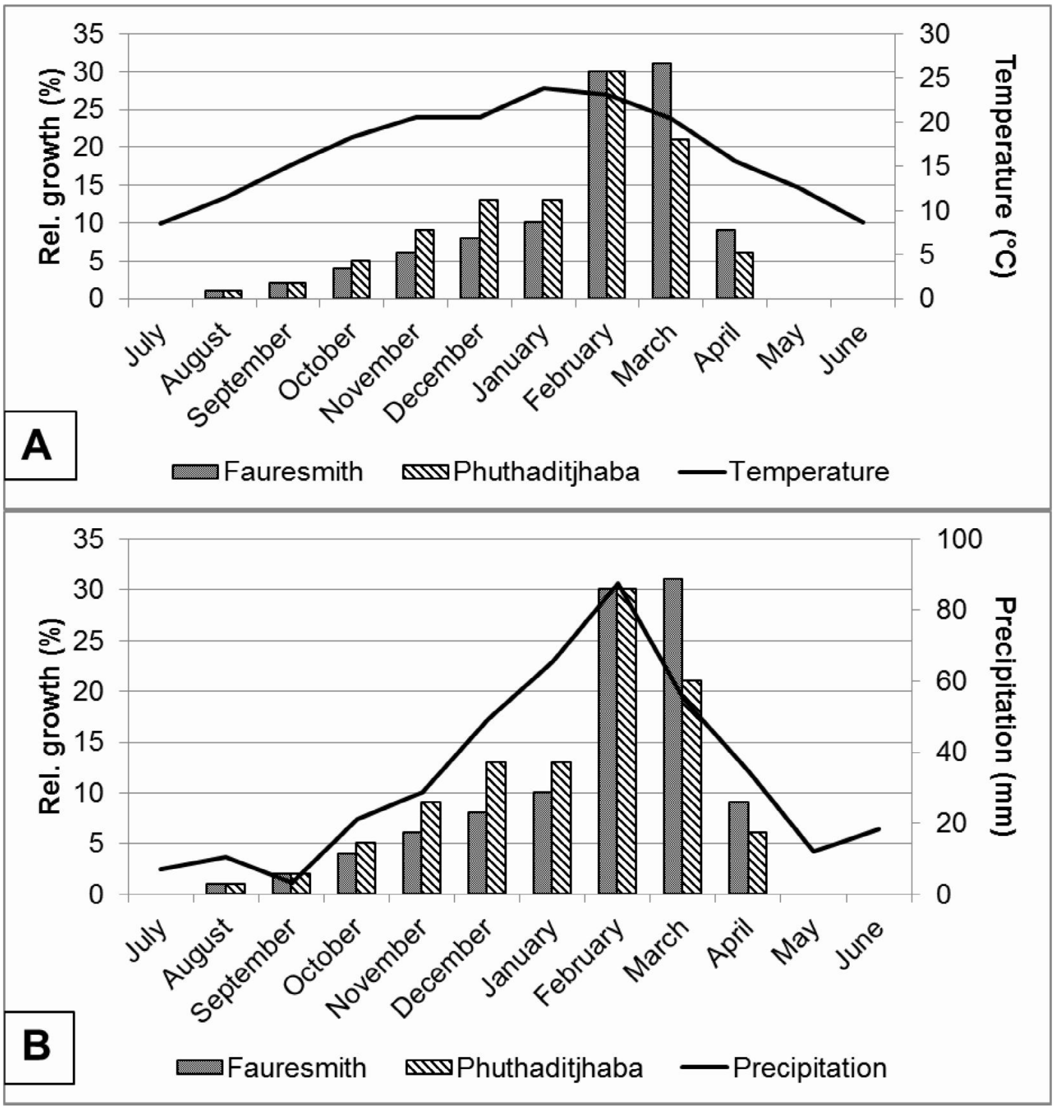

Fig. 5.1. Correlation of temperature **(A)** and precipitation **(B)** with primary productivity of vegetation in the Free State (relative growth data from Van der Westhuizen 2006) - see text for significance.

5.3.2. Caracal and hare interaction

Lepus spp. was one of the major prey items in caracal diet (see chapter 3). The highest densities were observed between December 2011 and January 2012 (Fig. 5.2), while the lowest were observed between July and August 2011. From July 2011 to the peak in mid-summer, these densities gradually increased, before gradually decreasing again until March/April 2012. After this second low, there was a sharp increase again in *Lepus* spp. densities. Monthly densities of *Lepus* spp. correlated strongly (r=0.8; p=0.002) with temperature (Fig. 5.3 A). The other climatic factors, rainfall (r=0.6; p=0.098) (Fig. 5.3 B), and humidity (r=-0.2; p=0.58) (Fig. 5.3 C) showed non-significant correlations with *Lepus* spp. monthly densities.

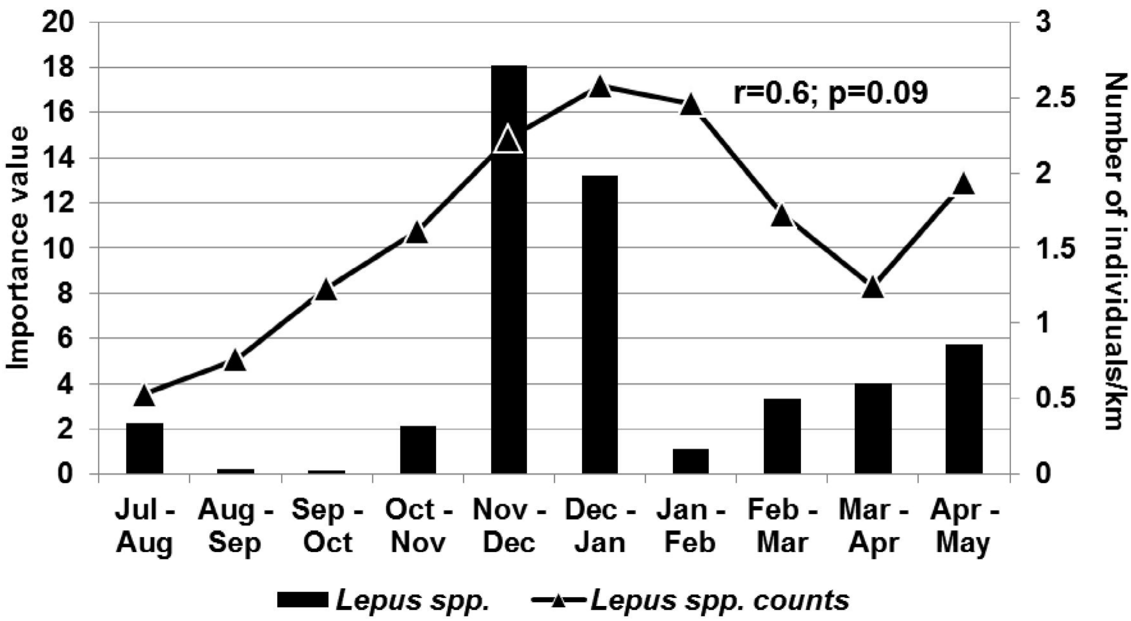

Fig. 5.2. Hare *Lepus* spp. two-monthly importance values (in caracal scats) correlated with hare two monthly densities.

The Importance Values (IV.) reflected these peaks and throughs in *Lepus* spp. densities. A definite peak was observed between November 2011 and January 2012. During the rest of the year IV. values were much lower. After the summer peak, a steady increase was observed between January and May 2012. There was a moderate correlation (0.6) between the monthly densities of *Lepus* spp. prey and the monthly importance value of *Lepus* spp. prey in caracal diet (Fig. 5.2); however, the p-value of 0.09 indicates that this relationship was not significant.

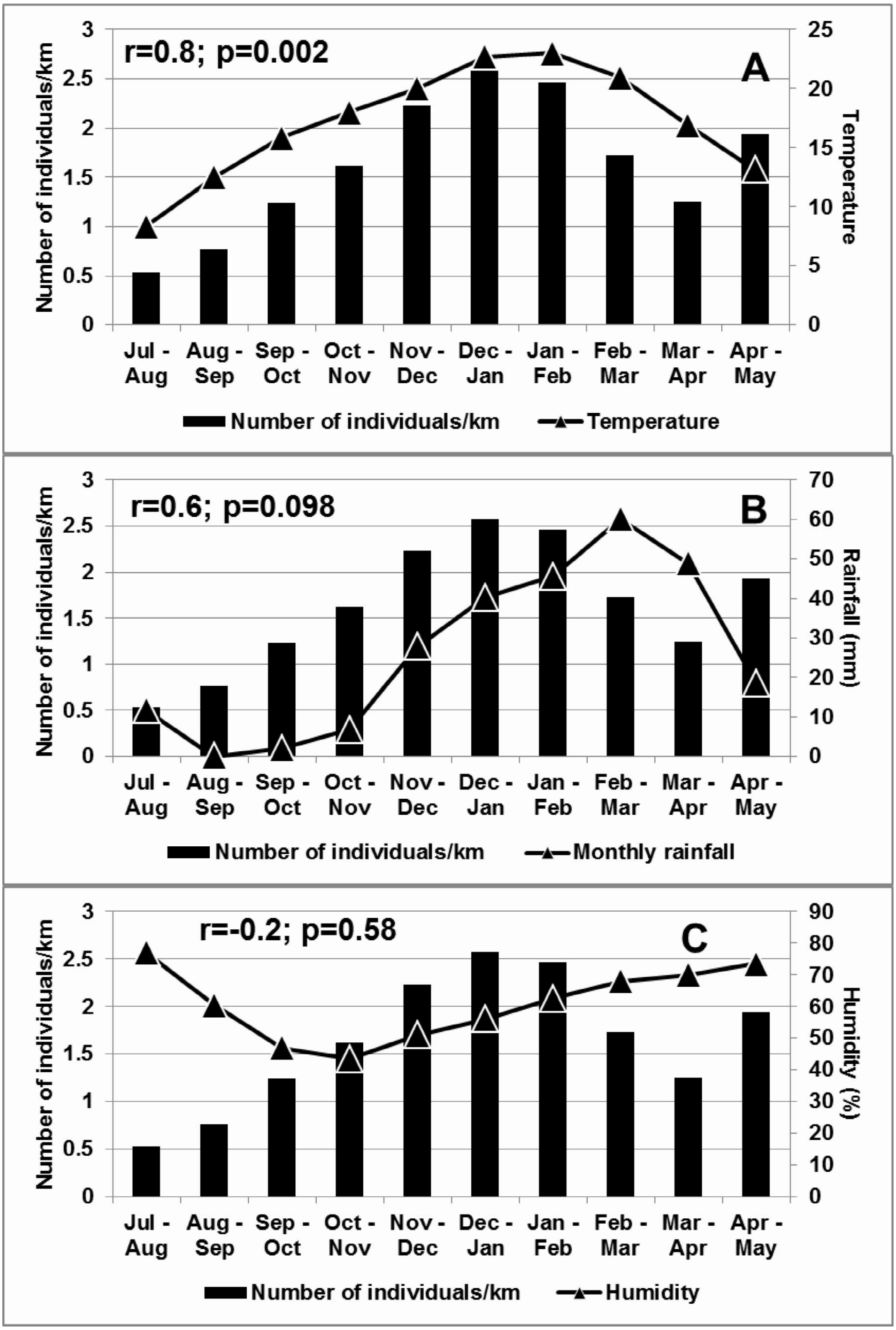

Fig. 5.3. Hare *Lepus* spp. two-monthly densities correlated with, **A**. temperature, **B**. rainfall, and **C.** humidity [Data source: South African Weather Service].

5.3.3. Caracal and springhare interaction

Pedetes capensis numbers in counts followed a one peak cyclic pattern resembling of a single birth season (Fig. 5.4). This was also confirmed by scat analysis with springhare having a mean relative IV. of 12.6% (springhare was a major prey item of caracal in the study area- see chapter 3). Highest numbers were recorded in the period Dec-Jan 2011 (2.8/km) and lowest numbers in the period Feb-Mar 2012 (0.7/km). Densities were relatively constant at a low level (<1.5/km) in the periods Jul-Sep 2011 and Feb-May 2012. Monthly densities of *Pedetes capensis* showed non-significant correlations with temperature (r=0.5; p=0.18) (Fig. 5.5 A), rainfall (r=-0.2; p=0.57) (Fig. 5.5 B) and humidity (r=-0.7; p=0.03) (Fig. 5.5 C).

In scats the highest IV. was observed between October and December. The lowest IV.'s was observed between July and August 2011 and between March and April 2012. No *Pedetes capensis* was found in scats between February and March 2012. The spearman rank correlation showed a strong significant correlation (r=0.8; p=0.004) between *Pedetes capensis* monthly densities and the monthly importance value of *Pedetes capensis* in caracal diet (Fig. 5.4).

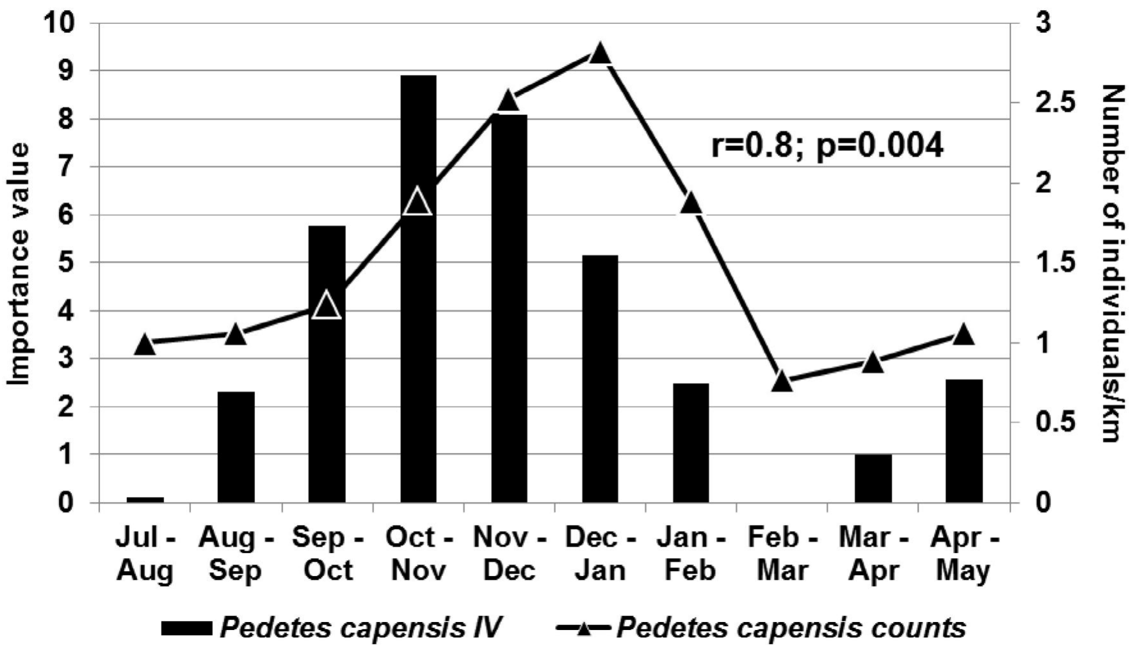

Fig. 5.4. Springhare *Pedetes capensis* two-monthly importance values (in caracal scats) correlated with springhare two-monthly densities.

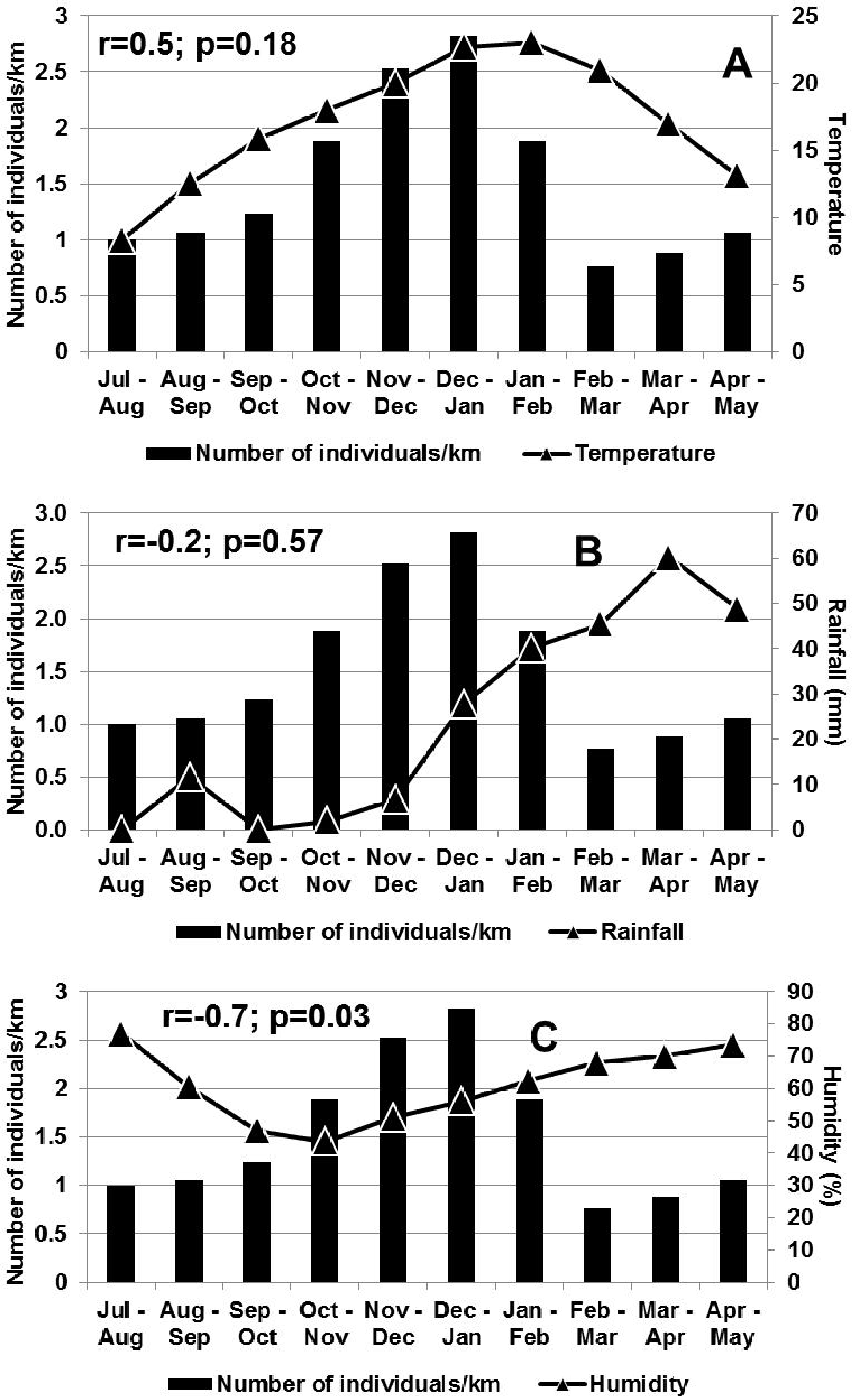

Fig. 5.5. Springhare *Pedetes capensis* two-monthly densities correlated with, **A.** temperature, **B.** rainfall, and, **C.** humidity [Data source: South African Weather Service].

5.3.4. Other prey observations

The young of *Antidorcas marsupialis* were observed in the period between September and November 2011 (peak), but also in February 2012. Steenbok, mountain reedbuck, blesbok & black wildebeest all had young in Dec 2011.

While adult Smith's red rock rabbit animals were spotted throughout the study period, only two observations of young were made, both during February 2012. Latrine sites were concentrated in the Besemkaree Koppies Shrubland vegetation and rocky areas of the study area (Fig. 5.6).

One of the rock hyrax colonies (location: 30◦ 18′ 38.30″ S, 25◦ 55′ 21.20″ E) had estimated populations sizes of 29 $\pm$ 2 (Lincoln index used) and 23 (Robson–Whitlock index used) while the other (location: 30◦ 18′ 52.21″ S, 25◦ 56′ 0.85″ E) had an estimated population size of 30 (Robson–Whitlock index used).

The young of Orange River francolin (n=2) were only observed in October 2011; the Orange River francolin were commonly observed throughout the study period in groups ranging between three and six, with the larger groups becoming more obvious in the period between October and December. No helmeted guineafowl young were recorded, but adults were commonly observed throughout the study period. Northern black-korhaan *Afrotis afraoides* were frequently spotted during the drive counts, but densities could not be determined as a result of poor visibility, especially on the sections of the count where grass was high.

Other *ad hoc* observations in the field included observations of nightjar (unknown species) in November, increased observations of millipedes between October and December, and increased observations of ground beetles (Carabidae) in December.

5.3.5. Carcasses

Sheep, mountain reedbuck, springbok, aardwolf, springhare and hare carcasses were found throughout the duration of the study period (May 2011 to May 2012). A total of eight mountain reedbuck carcasses were found (Jul 2011=1, Sep 2011=2, Oct 2011=1, Nov 2011=2, Dec 2011=1, May 2012=1). Two aardwolf carcasses were found, in December 2012 and March 2012, and both showed signs of caracal feeding behaviour). One scrub hare carcass and one springhare carcass was found in June 2011 and September 2011, respectively.

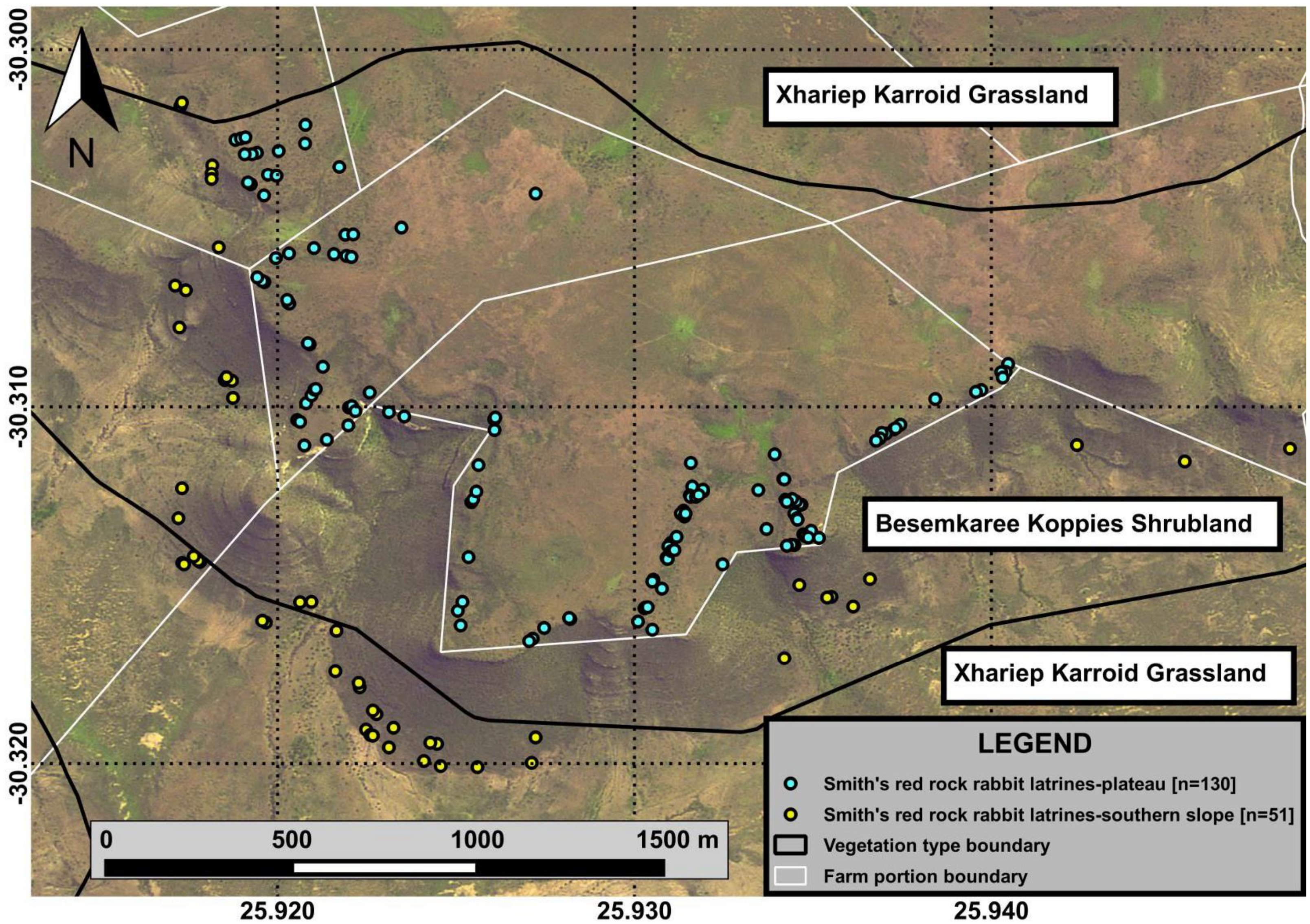

Fig. 5.6. Smith's red rock rabbit latrines in the study area, southern Free State (vegetation types from Mucina & Rutherford 2006).

5.4. Discussion

5.4.1. Primary productivity and prey availability

This study indicated how the availability of specific prey species and groups fluctuate throughout the year in the study area. This could be coupled to breeding season, which in turn could be coupled to climate and its effect on primary productivity. The overall breeding season in the study area seemed to be influenced mostly by temperature and stretched through both wet and dry periods (see Walter Lieth climate diagram: Chapter 2). The data suggests that the specific rangeland ecosystem is productive with potential prey species reproducing at different times of the year.

The precise breeding season of Cape hare *Lepus capensis* and scrub hare *Lepus saxatilis* could not be determined in this study. Wessels (1978) lists the birth peak of *L. capensis* as July to December in the Free State, while Lynch (1983) recorded *L. saxatilis* pregnant females between September and November. Very little is known about the reproduction of Smith's red rock rabbit *Pronolagus rupestris*, but there is indication that this species breeds between September and February (see Skinner & Chimimba 2005). In the current study young *P. rupestris* were spotted only in February. Springhare *Pedetes capensis* density estimations in this study showed a peak in numbers between December 2011 and January 2012.

In this study mountain reedbuck *Redunca fulvorufula* were frequently spotted among thick vegetation, on the hilly landscape of the study area (see Chapter 2). Taylor *et al.* (2005) argued that mountain reedbuck has habitat preference (marginal habitat, such as steep rocky hillsides) that causes them to compete very little with other ungulate species, including sheep, for vegetation. With this in mind it would be advantageous for farmers to have this species roaming on their farms in agricultural areas, especially if caracal is found to actively select for mountain reedbuck as a food source. This species is reported to have a birth peak between December and February in the Free State (Lynch 1983); this may also be the case in the study area, as a very young mountain reedbuck (± 2 weeks old) was found in December 2011.

In the Free State the birth peaks of springbok *Antidorcas marsupialis* are normally correlated with the onset of summer rains (Lynch 1983). This was also the case during this study with births occurring shortly after rainfall in mid-spring. Numerous springbok lambs were spotted next to the road in November 2011 while doing the drive count. These would certainly have been easy prey for caracal (and black-backed jackal). Steenbok *Raphicerus campestris* young are born throughout the year in the Free State, but may show a peak during the rainy season (Lynch 1983).

In the study area sheep have lambs in two periods, September-October and March-April. This is also the period when farmers report the most losses from predation.

Helmeted guineafowl, a potential prey of caracal, has a peak in between season between October and March according to Hockey *et al.* (2005). Hockey *et al.* (2005) lists the breeding season of orange river francolin as August to September. The northern black-korhaan *Afrotis afraoides*, also observed in the present study and a potential prey of caracal, has a peak in breeding between September and March (Hockey *et al.* 2005).

5.4.2. Prey usage

The bulk of the caracal's diet consisted of mammalian prey. The following Mammalia orders were identified in scat analysis: Carnivora, Hyracoidea, Lagomorpha, Rodentia and Ruminantia. Hares, rock hyrax, springhare and sheep were all major prey items of caracal (see Chapter 3) and were utilised by caracal throughout the year, even during the cold winter months. Caracal also predated on numerous "minor" prey, such as birds, antelope (mountain reedbuck, springbok and steenbok), Muridae (*Micaelamys namaquensis*, *Otomys* spp. and *Gerbilliscus leucogaster*), Carnivora (yellow mongoose and aardwolf), Invertebrata (Coleoptera, Orthoptera, Isoptera, Lepidoptera and Diplopoda) and Plantae (grass).

In this study, temperature did not correlate with monthly densities of springhare, but it should be noted that these densities did show a peak in December 2011/January 2012. Densities were also much lower in the winter and autumn months, suggesting that temperature had at least some effect on springhare densities. Literature (Skinner & Chimimba 2005) also supports the opinion that springhare ventures farther from burrows during warm periods than during colder periods. Humidity is not predicted to have had any major effect on springhare activity, though high humidity may increase the succulence of vegetation that springhare feed on and limit water loss through evaporation (Brown & Peinke 2007), especially during the winter months in this study when rainfall was low, but humidity high.

Although hares contributed more to the volume of scats than springhares (29% vs. 21%), the inclusion of hares in scats was less correlated with the monthly densities of this prey. However, caracal did feed markedly more on hares during the warmest summer months (November and December) when this prey occurred in very high densities (e.g. between 13 and 18 individual animals/km). These densities were correlated with temperature which is in agreement with contemporary literature (Skinner & Chimimba 2005) that *Lepus* spp. is sensitive to weather conditions (temperature and rainfall). Hare densities did show a moderate correlation with rainfall, but this correlation was not significant ($p=0.095$).

The small stock component was most evident during the lambing seasons of sheep, confirming the notion that farmers lose a lot of sheep during this time. The figure of 20 sheep per year being killed by a single adult caracal (see Chapter 3) could potentially be a number that relates to the two breeding seasons of *Ovis aries*. Farmers in the study area have reported caracal in the area killing 20 lambs in a period of two weeks (P. van den Berg pers. comm.).

Springbok were consumed by caracal between August and September 2011 and again in February 2012. This may be explained as a result of Springbok lambs arriving in spring and late summer.

Although mice only contributed a monthly mean of 0.05% (relative importance value) to caracal scats, this group reached a peak of 12% in May-June (late-autumn, early-winter). This relates to the general peak in murid densities. The annual density fluctuation pattern for this group has been described by Avenant & Cavallini (2007; study area *c*. 30 km from the current study area) and Avenant (2011; for the larger southern and central Free State area) as: the mouse breeding season lasts from *c*. mid-spring to late-autumn, with peak densities in late-autumn; the cold, dry winters then result in a sudden, massive drop in numbers (of ≥50%), annually observed from early to mid-winter; densities then stay low until the start of the reproductive season in c. mid-spring.

Mountain reedbuck was eaten throughout the study period as this prey was seemingly abundant on the hilly landscape of the study area. Peaks were observed in June and November 2011.

Another prey item that was frequently spotted during drive counts was aardwolf. This prey was eaten by caracal in June 2011, February 2012 and March 2012. Both Aardwolf and yellow mongoose (found in scats in Jul 2011 and May 2012) were probably eaten on opportunistic basis as these were commonly available food sources.

The value of caracal in the ecosystem has been proposed as a regulator (Palmer & Fairall 1988) and predator (Wiid & Butler 2014) of rock hyrax. Palmer & Fairall (1988) report that caracal consume approximately 15 or 16 hyrax per year. Using the same method, this study indicated that caracal consumed an estimated 54.6 hyrax per year in the specific study area (see Chapter 3). Rock hyrax was the second most important prey of caracal in this study (Rel.%IV.=22.8) (see Chapter 3).

Although scat analysis could not identify specific bird species in the current study, the bird remains found between August and December 2011 did resemble medium-sized ground living bird remains. This falls in the time when species, such as Orange river francolin (Aug-Sep), Northern Black-Korhaan (Sep-Mar) and Helmeted guinifowl (Oct-Mar) reproduce.

Grass and invertebrates were assumed to be eaten accidentally or on an opportunistic basis.

5.4.3. Scavenging

Of the eight mountain reedbuck carcasses found in the study area, at least two showed signs of caracal feeding behaviour (e.g. position of carcass and hind quarters clearly being fed on by caracal). One of these mountain reedbuck carcasses was caught on a fence, while the other five could have died from natural causes or could have been killed by predators. These carcasses were too old to accurately determine the cause of death. Mountain reedbuck carcasses were mostly adult ewes (one of these was a young animal). Only one adult ram was killed by caracal during the study period. Caracal also killed at least one of the two Aardwolf carcasses found in the study area. Sheep carcasses could not be examined due to logistic reasons; however, the owner of one of the farms reported that caracal killed about three young sheep during the study period. Most of these recorded caracal kills (mountain reedbuck, aardwolf and sheep) in the study area were later scavenged upon by black-backed jackal (*ad hoc* field observations). There is some evidence in literature that caracal scavenge (Avenant & Nel 1998), but no such field observations on scavenging behaviour was recorded during the current study. Even when scats were examined for the presence of invertebrates associated with the decomposition of carrion (Rowe-Rowe 1983; Hiscocks & Perrin 1987; Van der Merwe *et al.* 2009), was no indication found. These invertebrates were only included in the diets of Cape grey mongoose and yellow mongoose. Diet categories, such as e.g. sheep, mountain reedbuck and springbok found in Cape grey mongoose and yellow mongoose scats, were regarded as scavenged, since these prey categories are too large to be hunted by either of these carnivores (see Rowe-Rowe 1983 and Loveridge & Macdonald 2003). Cape grey mongoose scats were used in this regard, because it has a particularly small home range (0.21 km^2 – 0.63 km^2) (Cavallini & Nel 1990). It was presumed not to have scavenged a great distance from any carcass in the field. Cape grey mongoose scats containing scavenged remains would therefore give an indirect indication of the relative position of carcasses in the field. The current study suggests that these smaller carnivores probably benefited from at least some of the prey killed by the meso-predators.

5.4.4. The effect of habitat heterogeneity on social and ranging behaviour of caracal

Caracal home ranges can vary depending on the sex of the animal and prey densities (Avenant & Nel 1998). Taking into account the habitat preferences and habits of Muridae prey (Skinner & Chimimba 2005) that caracal preyed on, it can be reasoned that caracal moved through a variety of habitat types in search for food. *Micaelamys namaquensis*, for example is a nocturnal species confined to rocky habitats, *Gerbilliscus leucogaster* is a nocturnal species preferring habitat with sandy substrate, while *Otomys auratus* is a predominantly crepuscular species preferring damp habitat, possibly in the vicinity of the numerous wetlands in the study area. Based on the habitat preferences of springhare, rock hyrax and Lagomorpha species

(Skinner & Chimimba 2005) that caracal preyed on, it was also evident that caracal moved through both, flat habitat, characterised by open grassland with sandy substrate and sloping habitat with hard substrate, characterised by dense vegetation and rocky outcrops. Despite high densities of *Elephantulus myurus* in rocky habitat, scat analysis did not show any trace of this prey, presumably because *Elephantulus myurus* is predominantly diurnal (Skinner & Chimimba 2005). *Rhabdomys pumilio*, also a diurnal species, was not represented in any scats. However, the fact that that caracal diet included diurnal prey such as *Procavia capensis*, suggests that caracal in the study area do hunt during daytime, specifically on the sloping terrain and rocky areas (Melville *et al.* 2004). Caracal in the study area are, thus, mostly, but not exclusively nocturnal. Exact home ranges was not determined in this study, however, based on the habitat heterogeneity of the study area, caracal probably did not have to move great distances in order to encounter a variety of habitat types and prey groups contained within these habitats. Literature (Avenant & Nel 1998) suggests that caracal would have smaller home ranges in habitats characterised by high productivity compared to habitats characterised by low productivity. The specific study area would qualify as a productive rangeland ecosystem of diverse habitat types, allowing caracal to have smaller home range sizes; however, it remains uncertain whether those individual animals, responsible for killing small stock, increased their home ranges due to human presence and extermination. Farmers in the area has the opinion that damage-causing caracal would capture lambs in one area then move to neighbouring farms, before returning at a later stage to the same farm. This agrees with the findings of Avenant & Nel (1998) that male caracal follow a specific route to cover their home range, and move back to the same point (after *c.* 10 days). This specific aspect of caracal ranging behaviour will be tested in the future with the collaring of caracal in the specific study area (N. Avenant pers. comm.). Female caracal and young in the study area would have benefited from this high productivity ecosystem, especially during the overall breeding season of prey, given that caracal birth peaks occur between October and February (Bernard & Stuart 1987; Stuart & Wilson 1988). The current study also shows that caracal in the study area took full advantage of small stock, especially during small stock birth peaks (March-April and September-October).

6. Conclusions, management implications and recommendations

6.1. Specific finds from this study

The following specific key findings were observed in this study:

1. Caracal fed predominantly on mammalian prey: relative importance value (Rel.IV.)=99.4%.
2. The major prey items were Lagomorpha (hare *Lepus* spp. and Smith's red rock rabbit *Pronolagus rupestris*; mean Rel.IV.=38.2%), rock hyrax *Procavia capensis* (19.6%), springhare *Pedetes capensis* (16.7%) and sheep *Ovis aries* (10.2%). Minor prey included endemic antelopes springbok *Antidorcas marsupialis,* mountain reedbuck *Redunca fulverufula* and steenbok *Raphicerus campestris* (mean Rel.IV.=3.8%), a number of bird species (2.9%), small carnivores (1.1%), mice (1.0%) and invertebrates (0.3%). Plant material (mean Rel.IV.=0.5%) was ingested opportunistically and in small quantities.
3. The ingestion of most prey groups, including small stock, fluctuated over months and showed different peaks and troughs. Most of these peaks could be correlated with higher prey densities within that prey group in the study area.
4. A number of correlations (mostly negative) could be found between the IV. and Rel.IV. of especially the major prey groups, clearly indicating prey switching during specific periods.
5. Opportunistic feeding behaviour was, further, evident from the observation of utilizing an increased diversity of prey during lean times, when minor prey items became more important in caracal diet.
6. Caracal fed markedly more on small stock during and immediately following the two lambing seasons, March to April and September to October, reaching Rel.IV.s of up to 35%. Both these periods were associated with low major prey densities, and high prey species diversity and numbers in scats.
7. It was estimated that a single caracal in the study area may kill approximately 20 sheep lambs annually, which is expected to have substantial financial and socio-economic implications in the long run.

8. One adult caracal was also estimated to consume >70 hares and rabbits, >50 hyraxes, >20 springhares, >230 mice, *c*. 10 small carnivores and c. 30 birds per annum; further indication that caracal has a valuable role to play in this agri-ecosystem.
9. Caracal and yellow mongoose had the narrowest niche breadths, black-backed jackal fed on the largest spectrum of prey species, and the niche breadth of Cape grey mongoose was intermediate.
10. Highest niche overlap was observed between caracal and black-backed jackal (1.0), and between Cape grey mongoose and yellow mongoose (0.9). Moderate niche overlap was observed between caracal and Cape grey mongoose and between black-backed jackal and Cape grey mongoose (both 0.6). Smallest niche overlap was found between caracal and yellow mongoose (0.3), and black-backed jackal and yellow mongoose (<0.1).
11. All four carnivore species displayed seasonal fluctuations in food niche breadths. Food niche overlaps fluctuated accordingly.
12. Both damage-causing predators utilised small stock throughout the year, but more notably during the lambing seasons (March-April and September-October); during most of the year they fed on a larger proportion of natural prey.
13. The diet component of small stock, and the resulting financial losses, is less obvious in an accumulating expression (e.g. over a year), but is pronounced during specific periods (e.g. during the lambing seasons).
14. Caracal and syntopic carnivore consumption of natural prey is influenced by their availability and abundance.
15. Although caracal may be seen as a generalist feeder, they clearly displayed a more specialised feeding pattern than black-backed jackal. Caracal fed on a smaller variety of prey than black-backed jackal, and their food niche breadth were more constant throughout the 13-month study period.
16. Meso-predators caracal and black-backed jackal are on the same trophic level (meso-predators), but competition is expectantly reduced when they utilise the same prey resource in different relations and at different times of the year
17. Trophic status explained niche overlap and breadth differences when the diets of caracal, black-backed jackal, Cape grey mongoose and yellow mongoose

were compared. The latter two carnivores utilised more smaller prey items, such as invertebrates and mice, than both caracal and black-backed jackal.

18. Minor prey items are not necessarily less important in the diet of caracal. During times of energy stress (as indicated by a decrease in prey density, an increase in the diversity of prey utilised by all four carnivores, and a resultant increase in food niche overlaps) minor prey items may even play a vital role in the diet of carnivores. An occasional larger prey, such as mountain reedbuck or aardwolf, would also supply a large volume of meat in one single hunt (which may benefit especially lactating female caracal, or females with young when they have already started their carnivorous diet).

6.2. General conclusions

Based on the results of this study, I conclude as follows:

1. Caracal do predate on small stock in the study area, and are persecuted by the farmers as a result.
2. There is not yet a sustainable solution, and the extent of both these actions is expected to have serious economic and ecological impacts in the long run. The problem is worsened by the severe lack of information on caracal (and black-backed jackal) ecology and management, especially in farming areas. This study is one of less than a handful that has described and compared the diets of caracal and black-backed jackal in the same farming area, at the same time.
3. Different measures of quantifying carnivore diets have been used in literature. The most common are percentage occurrence (%Occ.) and percentage volume/volumetric contribution (%Vol.). In order to describe the diet of the carnivores in a more comprehensive manner, this study used both methods in addition to calculating an importance value (IV.). These were also expressed in terms of relative occurrence (Rel.%Occ.), relative volumetric contribution (Rel.%Vol.) and relative importance value (Rel.IV., expressed as a percentage). The results from the study suggest that different aspects of a carnivore's diet are revealed and emphasised when more than one diet description method is applied.
4. Caracal in the study area are generalists and opportunistic feeders that feed on the most abundant prey, but also specialise and utilise specific prey types

during specific times of the year. This trend is most clearly observed when diet is described on a monthly basis. Some prey types are utilised throughout the year, whilst others are only eaten, or peak, at specific times. This is a reflection of the seasonal availability of prey items in the study area, coupled to their breeding seasons.

5. Although not specialised scavengers, caracal is known to scavenge opportunistically. Scavenging behaviour of caracal was not recorded and could not be quantified in this study, but the potential of scavenging behaviour to have taken place cannot be excluded. The few *ad hoc* field observations suggest that black-backed jackal do scavenge on sheep and springbok; but not caracal. This may be supported by the fact that both sheep and springbok volumetric contribution (%Vol.) to caracal scats absolutely agree with the presence (%Occ.) data. For black-backed jackal the %Vol. data are lower than the %Occ. data, meaning that at least some of the sheep/springbok might have been scavenged; for caracal it means that the chance of scavenging, instead of eating what they have killed, may be less.

6.3. Management implications

Some key findings may have implications for future management planning in the study area:

1. Both caracal and black-backed jackal do predate on small stock, but for most of the year also feed on a larger proportion of natural prey.
2. Late-autumn, winter and spring are times of high energy needs for these damage-causing carnivores, but also times of low natural prey availability.
3. The current study found a relationship between the small stock lambing season and the time of the year when small stock remains peak in caracal and black-backed jackal scats.
4. Current sheep lambing seasons therefore co-occur with the time of year when the natural prey densities are low, and when caracal and black-backed jackal consume most sheep (lambs). The ecological parameters and the characteristics of the specific habitat on farms (e.g. topography, vegetation, climate, prey type and interventions, should be carefully considered in management strategies. All of the above will have an impact on caracal feeding behaviour (e.g. the list of prey species included in the caracal's diet,

the relationship in which caracal utilises different prey groups, and how accessible small stock is to caracal).

5. The current study has also opened up numerous questions with regards to caracal diet.
   a. How does the diet of specific, individual, caracal compare to the larger population of caracal in the region?
   b. Which caracal (e.g. experienced territorial male, inexperienced young territorial male, lactating female, female with young) actually kill small stock?
   c. Will caracal adapt and continue killing small stock if the lambing seasons were to be moved, and to what extent is this possible / profitable?
   d. How often does an encounter with a herd of sheep result in small stock being killed?
   e. Are caracal actively selecting small stock as prey, or are more small stock simply being killed as a result of increased encounter rates during the lambing seasons?
   f. Do caracal actually approach (hunt) small stock, or do they kill them on chance encounters?
   g. Where do the caracal individuals, indicated in (b), forage?; and will it prevent depredation if flocks (or lambs) are moved away from these areas, especially during specific times of the year?

Answers to these questions should allow both small stock farmers/game ranch managers and conservationists to make more informed decisions and plan more effective management strategies for the control of damage causing caracal and black-backed jackal.

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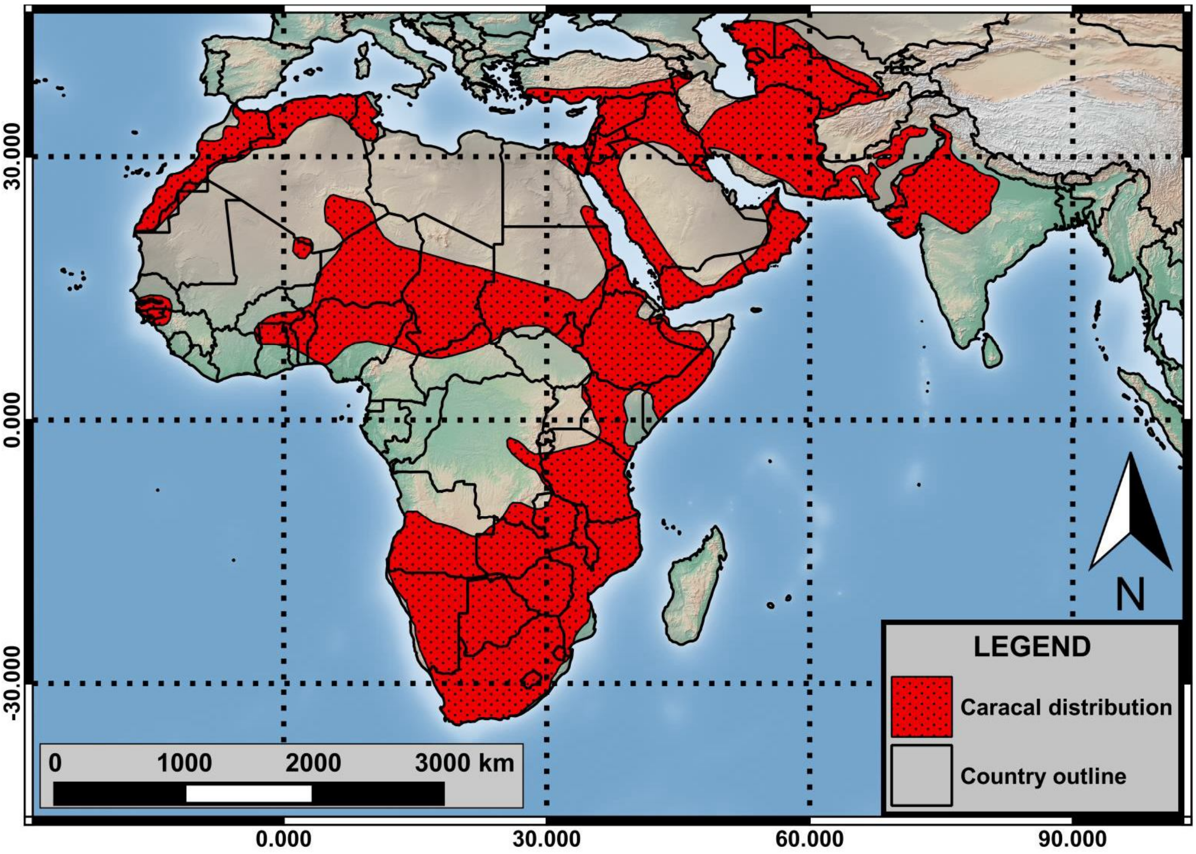
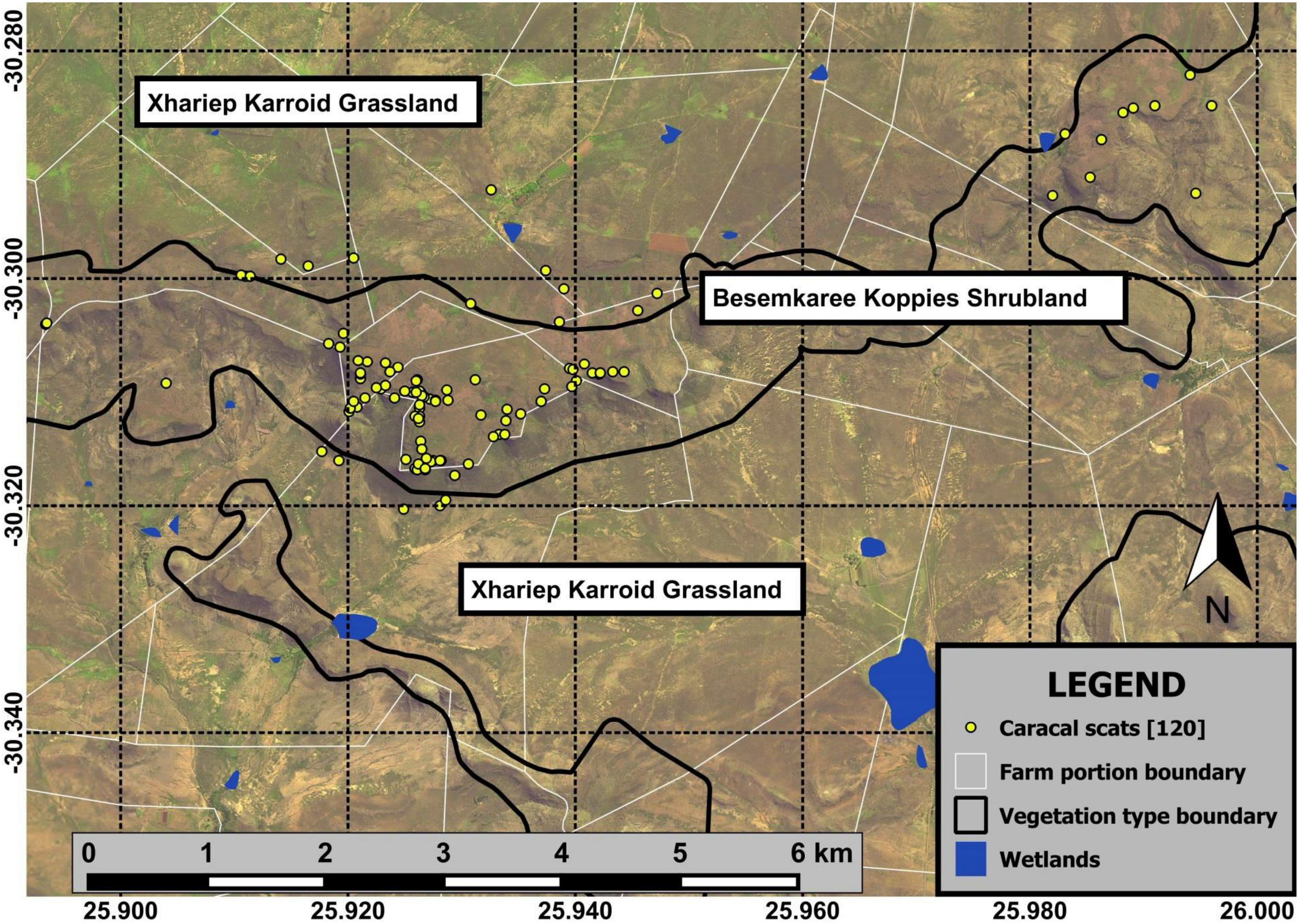
APPENDICES

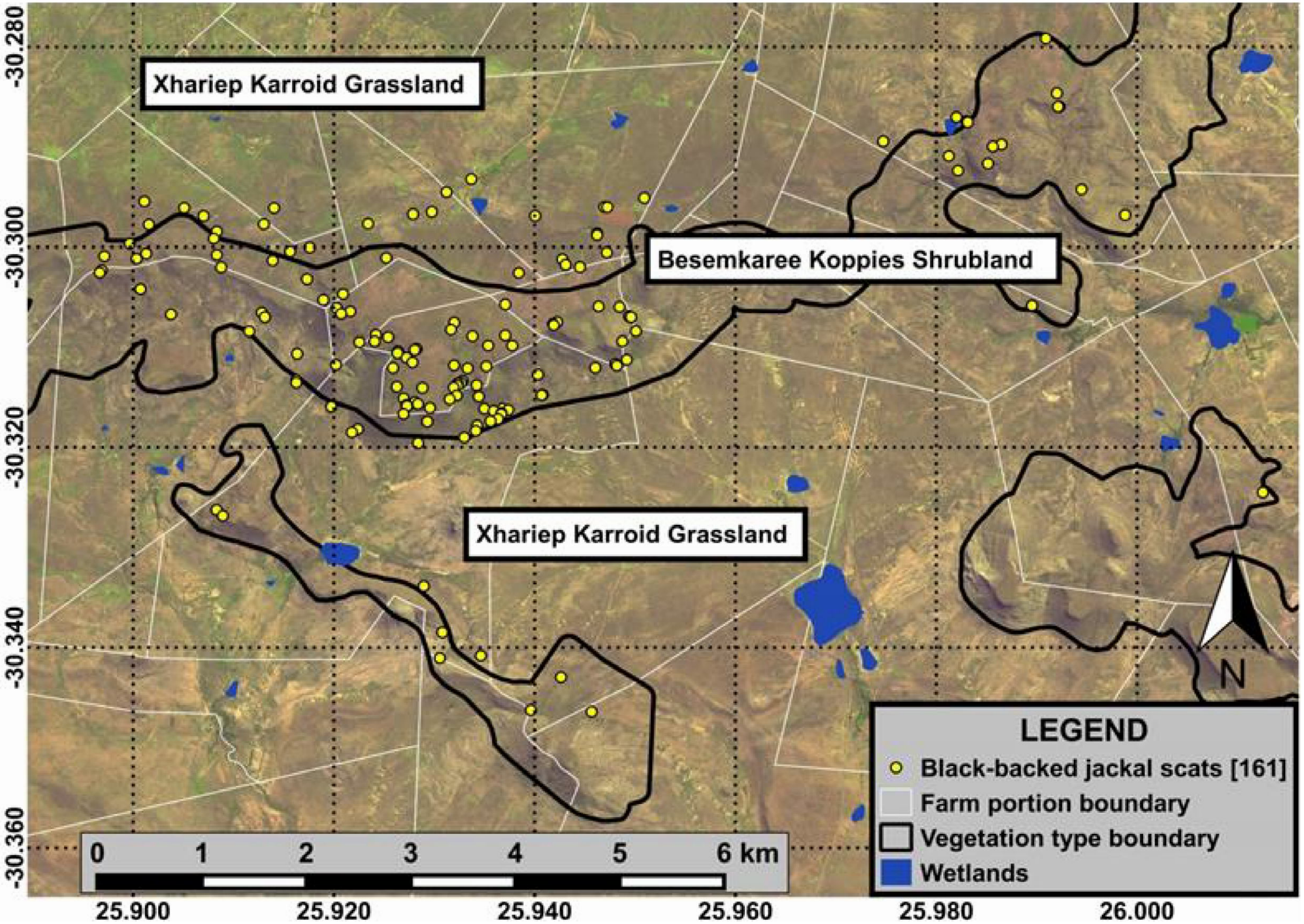
Appendix 1. Caracal distribution (Data source: IUCN 2013).
Base map source: http://www.naturalearthdata.com/downloads/50m-raster-data/



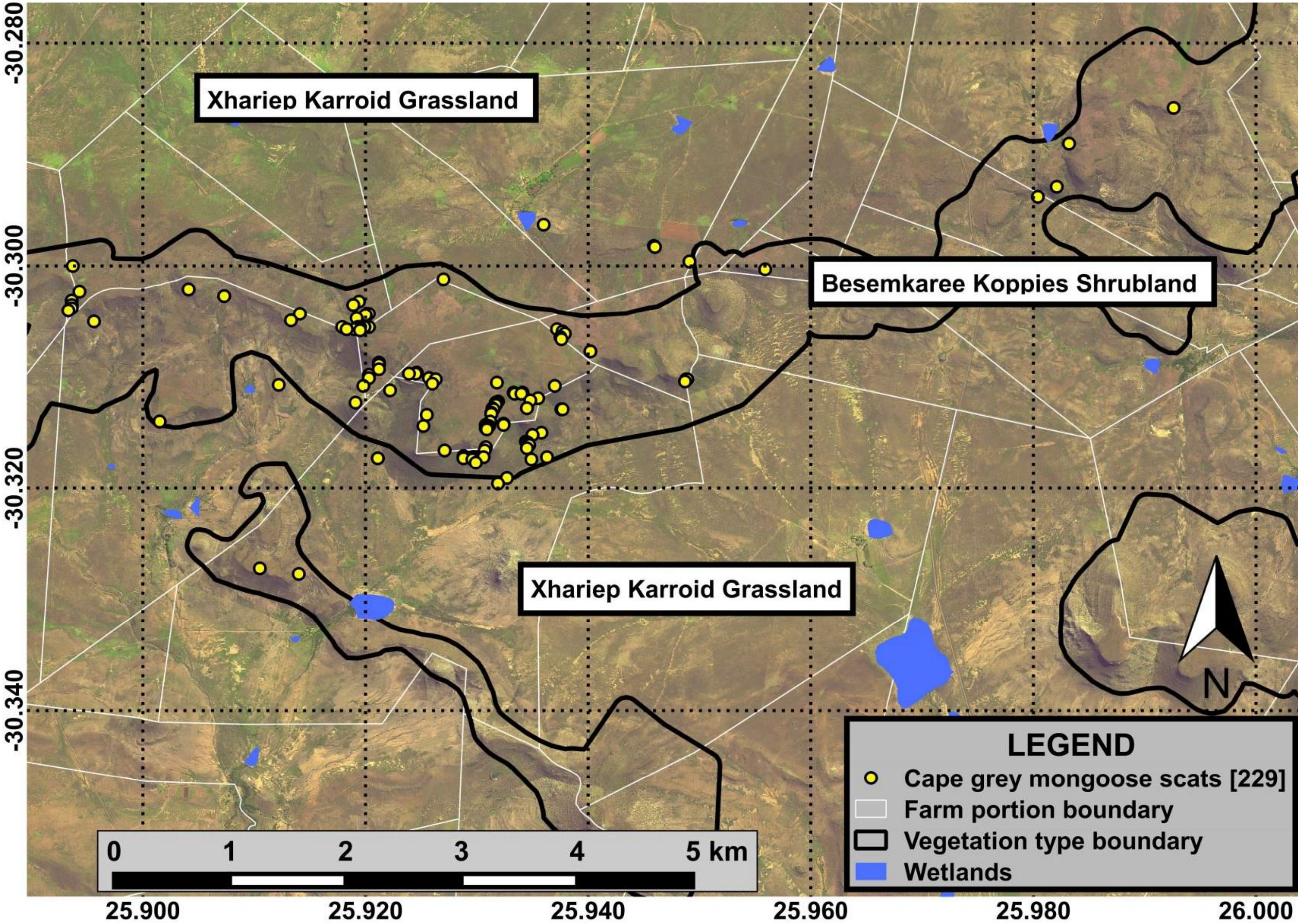
Appendix 2. Caracal scats sampled in the study area, southern Free State (vegetation types from Mucina & Rutherford 2006).



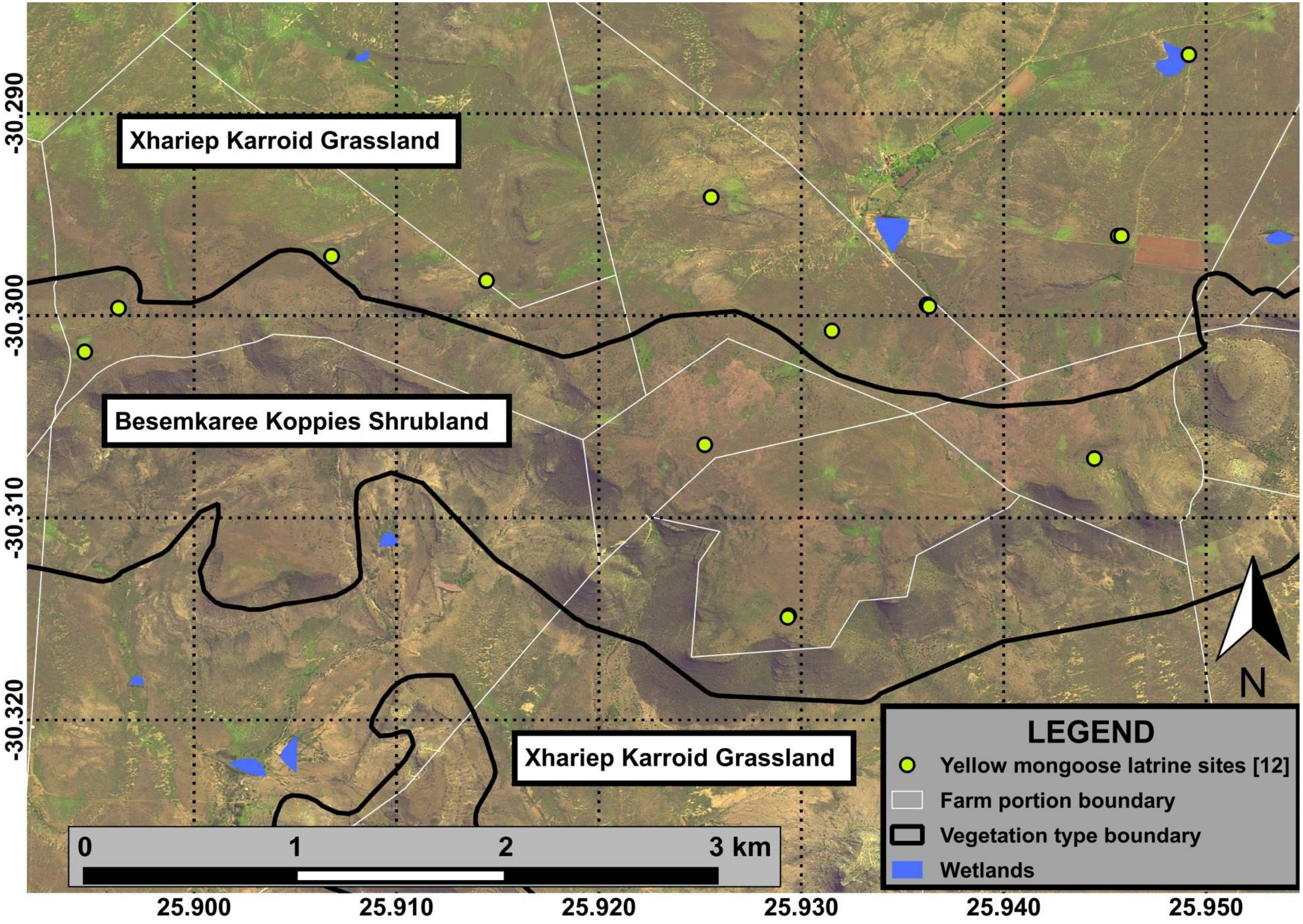
Appendix 3. Black-backed jackal scats sampled in the study area, southern Free State (vegetation types from Mucina & Rutherford 2006).



Appendix 4. Cape grey mongoose scats sampled in the study area, southern Free State (vegetation types from Mucina & Rutherford 2006).



Appendix 5. Yellow mongoose latrine sites in the study area, southern Free State (vegetation types from Mucina & Rutherford 2006).



Appendix 6. List of mammal species in the study area, southern Free State (summarised from Skinner & Chimimba 2005, Watson 2006, Stuart & Stuart 2007 and Kingdon & Hoffmann 2013).

TAXON	COMMON NAME	Diurnal (D), Nocturnal (N), Crepuscular (Cr.)	Terrestrial (T), arborial (A) or aquatic (Aq)
Order AFROSORICIDA			
Chlorotalpa sclateri (Broom, 1907)	Sclater's golden mole	N (D)	T
Order MACROSCELIDEA			
Elephantulus myurus Thomas & Schwann, 1906	Eastern rock elephant-shrew	D (N)	T
Order TUBULIDENTATA			
Orycteropus afer (Pallas, 1766)	Aardvark	N	T
Order HYRACOIDEA			
Procavia capensis (Pallas, 1766)	Rock hyrax	D	T & A
Order LAGOMORPHA			
Lepus capensis Linnaeus, 1758	Cape hare	N	T
Lepus saxatilis F. Cuvier, 1823	Scrub hare	N	T
Pronolagus rupestris (A. Smith, 1834)	Smith's red rock rabbit	N	T
Order RODENTIA			
Cryptomys hottentotus (Lesson, 1826)	African mole-rat	N	T
Hystrix africaeaustralis Peters, 1852	Cape porcupine	N	T
Pedetes capensis (Forster, 1778)	Springhare	N	T
Xerus inauris (Zimmermann, 1780)	South African ground squirrel	D	T
Graphiurus murinus (Desmarest, 1822)	Woodland dormouse	N	A
Rhabdomys pumilio (Sparrmann, 1784)	Four-striped grass mouse	Cr.	T
Mus minutoides A. Smith, 1834	Pygmy mouse	N	T
Mastomys coucha (A. Smith, 1836)	Southern multimammate mouse	N	T
Micaelamys namaquensis (A. Smith, 1834)	Namaqua rock mouse	N	T (A)
Otomys karoensis , previously O. saundersiae Roberts, 1929	Saunders' vlei rat	-	-
Otomys auratus, previously O. irroratus (Brants, 1827)	Vlei rat	Cr. (D & N)	T (Aq)
Mystromys albicaudatus (A. Smith, 1834)	White-tailed mouse	N	T
Gerbillurus paeba (A. Smith, 1836)	Hairy-footed gerbil	N	T
Gerbilliscus leucogaster (Peters, 1852)	Bushveld gerbil	N	T
Gerbilliscus brantsii (A. Smith, 1836)	Highveld gerbil	N	T
Saccostomus campestris Peters, 1846	Pouched mouse	N	T
Dendromus melanotis A. Smith, 1834	Grey climbing mouse	N	T (A)
Malacothrix typica (A. Smith, 1834)	Gerbil mouse	N	T
Order PRIMATES			
Papio hamadryas (Linnaeus, 1758)	Chacma baboon	D	T & A
Cercopithecus pygerythrus (F. Cuvier, 1821)	Vervet monkey	D	T & A
Order EULIPOTYPHLA			
Myosorex varius (Smuts, 1832)	Forest shrew	N summer; D winter	T
Suncus varilla	Lesser dwarf shrew	N (D)	T
Crocidura cyanea (Duvernoy, 1838)	Reddish-grey musk shrew	N & D	T
Atelerix frontalis A. Smith, 1831	Southern African hedgehog	N	T
Order CHIROPTERA			
Tadarida aegyptiaca (E. Geoffroy, 1818)	Egyptian free-tailed bat	N	NA
Neoromicia capensis (A. Smith, 1829)	Cape serotine bat	N	NA
Rhinolophus clivosus Cretzschmar, 1828	Geoffroy's horseshoe bat	N	NA

Appendix 6. continued…

TAXON	COMMON NAME	Diurnal (D), Nocturnal (N), Crepuscular (Cr.)	Terrestrial (T), arborial (A) or aquatic (Aq)
Order CARNIVORA			
Proteles cristatus (Sparrman, 1783)	Aardwolf	N	T
Parahyaena brunnea (Thunberg, 1820)	Brown hyaena	N	T
Caracal caracal (Schreber, 1776)	Caracal	N	T
Felis silvestris Forster, 1780	African wild cat	N	T (A)
Felis nigripes Burchell, 1824	Black-footed cat	N	T
Leptailurus serval (Schreber, 1776)	Serval	N	T
Genetta genetta Linnaeus, 1758	Small-spotted genet	N	T (A)
Suricata suricatta (Schreber, 1776)	Meerkat (also Suricate)	D	T
Cynictis penicillata (G. Cuvier, 1829)	Yellow mongoose	D	T
Galerella pulverulenta (Wagner, 1839)	Cape grey mongoose	D	T (A)
Atilax paludinosus (G. Cuvier, 1829)	Marsh mongoose	N	T & Aq
Otocyon megalotis (Desmarest, 1822)	Bat-eared fox	D & N	T
Vulpes chama (A. Smith, 1833)	Cape fox	N	T
Canis mesomelas Schreber, 1775	Black-backed jackal	D & N	T
Poecilogale albinucha (Gray, 1864)	African striped weasel	N	T
Ictonyx striatus (Perry, 1810)	Striped polecat	N	T
Order SUIFORMES			
Phacochoerus africanus (Gmelin, 1788)	Common warthog	D	T
Order RUMINANTIA			
Tragelaphus strepsiceros (Pallas, 1766)	Greater kudu	D	T
Connochaetes gnou (Zimmerman, 1780)	Black wildebeest	D	T
Connochaetes taurinus (Burchell, 1823)	Blue wildebeest	D	T
Damaliscus pygargus (Pallas, 1767)	Bontebok/blesbok	D	T
Oryx gazella (Linnaeus, 1758)	Gemsbok	D	T
Sylvicapra grimmia (Linnaeus, 1758)	Common duiker	D	T
Redunca fulvorufula (Afzelius, 1815)	Mountain reedbuck	D & N	T
Antidorcas marsupialis (Zimmermann, 1780)	Springbok	D	T
Raphicerus campestris (Thunberg, 1811)	Steenbok	D & N	T
Aepyceros melampus (Lichtenstein, 1812)	Impala	D & N	T
Oreotragus oreotragus (Zimmermann, 1783)	Klipspringer	D	T
Ovis aries (Linnaeus, 1758)	Domestic sheep	D	T

Appendix 7. List of Amphibians in the study area, southern Free State (summarised from Du Preez 1996 and Bates 1992)

Scientific name	English common name	Afrikaans common name
Amieta angolensis Bocage, 1866	Common river frog	Gewone rivierpadda
Amieta fuscigula Duméril & Bibron, 1841	Cape river frog	Kaapse rivierpadda
Amietophrynus gutturalis Power, 1927	Guttural toad	Gorrelskurwepadda
Amietophrynus rangeri Hewitt, 1935	Raucous toad	Lawaaipadda
Cacosternum boettgeri (Boulenger, 1882)	Common Caco	Gewone blikslanertjie
Kassina senegalensis Duméril & Bibron, 1841	Bubbling kassina	Borrelvleipadda
Poyntonophrynus vertebralis Smith, 1848	Southern pigmy toad	Dwergskurwepadda
Pyxicephalus adspersus Tschudi, 1838	Giant bullfrog	Groot brulpadda
Tomoptera cryptotis Boulenger, 1907	Tremolo sand frog	Trillersandpadda
Tomoptera tandyi Channing & Bogart, 1996	Tandy's sand frog	Tandy se sandpadda
Vandijkophrynus gariepensis gariepensis Smith, 1848	Karoo toad	Karoo-skurwepadda
Xenopus laevis Daudin, 1802	Common platanna	Gewone platanna

Appendix 8. List of reptile species in the study area, southern Free State (summarised from Bates 1992).

ORDER	SUB-ORDER	Family and common name	Species	Diurnal (D), Nocturnal (N) or crepuscular (Cr)	Terrestrial (T), rock-living (R), arborial (Ar), aquatic (Aq) or fossorial (F)
SQUAMATA	SERPENTES	**Family Colubridae**			
		Boomslang	*Dispholidus typus viridis*	D	A
		Brown house snake	*Boaedon fuliginosus*	N	T
		Cape wolf snake	*Lycophidion capense capense*	N	T
		Fork-marked sand snake	*Psammophis trinasalis*	D	T
		Red-lipped snake	*Crotaphopeltis hotamboeia*	N	T
		Spotted Grass Snake	*Psammophylax rhombeatus rhombeatus*	D	T
		Common slug eater	*Duberria lutrix lutrix*	D & Cr.	T
		Common/Rhombie egg eater	*Dasypeltis scabra*	D, N & Cr	T & Ar
		Cross-marked grass snake	*Psammophis crucifer*	D	T
		Sundevall's Shovel-snout	*Prosymna sundevallii*	-	F
		Karoo sand snake	*Psammophis notostictus*	D	T
		Mole snake	*Pseudaspis cana*	D	T & F
		Family Typhlopidae			
		Delalande's Beaked Blind Snake	*Rhinotyphlops lalandei*	-	F
		Family Atractaspididae			
		Cape centipede eater	*Aparallactus capensis**	-	F
		Family Leptotyphlopidae			
		Peter's thread snake	*Leptotyphlops scutifrons*	-	F
		Family Elapidae			
		Cape cobra	*Naja nivea*	D & Cr	T (Ar)
		Spotted harlequin snake	*Homoroselaps lacteus*	N	T & F
		Family Viperidae			
		Puffadder	*Bitis arietans arietans*	D, N & Cr	T
	SAURIA	**Family Scincidae**			
		Cape skink	*Trachylepis capensis*	D	T
		Speckled skink	*Trachylepis punctatissima*	D	T
		Thin-tailed legless skink	*Acontias gracilicauda*	-	F
		Striped skink	*Mabuya striata punctatissima**	D	R & Ar
		Variegated skink	*Mabuya variegata punctulata*	D	T & R
		Family Agamidae			
		Southern rock agama	*Agama atra*	D	T
		Family Lacertidae			
		Striped sandveld lizard	*Nucras taeniolata holubi*	Cr	T
		Spotted sand lizard	*Pedioplanis lineoocellata pulchella*	D	T
		Southern Karusa Lizard	*Karusasaurus polyzonus*	D	T
		Family Gerrhosauridae			
		Yellow throated plated lizard	*Gerrhosaurus flavigularis*	D	T
		Family Gekkonidae			
		Bibron's thick-toed gecko	*Chondrodactylus bibronii*	N, Cr.	R
		Cape gecko	*Pachydactylus capensis*	N	T
		Family Varanidae			
		Rock monitor	*Varanus albigularis albigularis*	D	T (Ar)
		Water monitor	*Varanus niloticus niloticus*	-	Aq
TESTUDINES	CRYPTODYRA	Greater Dwarf Tortoise	*Homopus femoralis*	D	T
		Leopard totoise	*Stigmochely's pardalis*	D	T
	PLEURODYRA	Marsh/Helmeted terrapin	*Pelomedusa subrufa*	D	Aq

Appendix 9. List of Arthropoda identified in the study area (using pitfall traps), southern Free State.

Class	Order	Family
Insecta	Coleoptera	Carabidae (Cicindelinae)
		Tenebrionidae
		Meloidae
		Scarabaeidae
	Blattodea	-
	Hymenoptera	Formicidae
		Mulillidae
	Hemiptera	Pentatomidae
		Reduviidae
	Orthoptera	Anostostomatidae
		Acrididae
	Lepidoptera	Psychidae
		Noctuidae
	Isoptera	Hodotermitidae
		Trinervitermes
	Diptera	Calliphoridae
Arachnida	Araneae	-
	Scorpiones	-
	Solpugida	Solifugae
	Ixodida	-
Diplopoda	-	-

Note: Some Arthropoda species (-) could only be identified to class and order level; not to family level.

Appendix 10. List of 127 bird species in the study area, southern Free State generated from SABAP2 data (Nine pentads: 3010_2550, 3010_2555, 3010_2600, 3015_2550, 3015_2555, 3015_2600, 3020_2550, 3020_2555, 3020_2600) [http://sabap2.adu.org.za/].

Scientific Name	Common Name
Acrocephalus baeticatus	Reed-Warbler, African
Acrocephalus gracilirostris	Swamp-Warbler, Lesser
Afrotis afraoides	Korhaan, Northern Black
Alopochen aegyptiacus	Goose, Egyptian
Anas erythrorhyncha	Teal, Red-billed
Anas smithii	Shoveler, Cape
Anas undulata	Duck, Yellow-billed
Anthropoides paradiseus	Crane, Blue
Anthus cinnamomeus	Pipit, African
Anthus crenatus	Pipit, African Rock
Anthus leucophrys	Pipit, Plain-backed
Anthus similis	Pipit, Long-billed
Apus caffer	Swift, White-rumped
Ardea cinerea	Heron, Grey
Batis pririt	Batis, Pririt
Bostrychia hagedash	Ibis, Hadeda
Bubulcus ibis	Egret, Cattle
Buteo rufofuscus	Buzzard, Jackal
Calandrella cinerea	Lark, Red-capped
Cercomela familiaris	Chat, Familiar
Cercomela sinuata	Chat, Sickle-winged
Cercotrichas coryphoeus	Scrub-Robin, Karoo
Certhilauda semitorquata	Lark, Eastern Long-billed
Charadrius pecuarius	Plover, Kittlitz's
Charadrius tricollaris	Plover, Three-banded
Chersomanes albofasciata	Lark, Spike-heeled
Chlidonias hybrida	Tern, Whiskered
Chrysococcyx caprius	Cuckoo, Diderick
Ciconia nigra	Stork, Black
Cisticola aridulus	Cisticola, Desert
Cisticola fulvicapilla	Neddicky, Neddicky
Cisticola juncidis	Cisticola, Zitting
Cisticola subruficapilla	Cisticola, Grey-backed
Cisticola textrix	Cisticola, Cloud
Cisticola tinniens	Cisticola, Levaillant's
Colius colius	Mousebird, White-backed
Colius striatus	Mousebird, Speckled
Columba guinea	Pigeon, Speckled
Coracias garrulus	Roller, European
Corvus albus	Crow, Pied
Cossypha caffra	Robin-Chat, Cape
Creatophora cinerea	Starling, Wattled

Appendix 10 continued…

Scientific Name	Common Name
Crithagra albogularis	Canary, White-throated
Crithagra atrogularis	Canary, Black-throated
Crithagra flaviventris	Canary, Yellow
Dendrocygna viduata	Duck, White-faced
Elanus caeruleus	Kite, Black-shouldered
Emberiza capensis	Bunting, Cape
Emberiza impetuani	Bunting, Lark-like
Emberiza tahapisi	Bunting, Cinnamon-breasted
Eremomela icteropygialis	Eremomela, Yellow-bellied
Estrilda astrild	Waxbill, Common
Euplectes orix	Bishop, Southern Red
Euplectes progne	Widowbird, Long-tailed
Eupodotis caerulescens	Korhaan, Blue
Falco amurensis	Falcon, Amur
Falco naumanni	Kestrel, Lesser
Falco rupicolus	Kestrel, Rock
Fulica cristata	Coot, Red-knobbed
Galerida magnirostris	Lark, Large-billed
Himantopus himantopus	Stilt, Black-winged
Hirundo albigularis	Swallow, White-throated
Hirundo cucullata	Swallow, Greater Striped
Hirundo fuligula	Martin, Rock
Hirundo rustica	Swallow, Barn
Hirundo semirufa	Swallow, Red-breasted
Hirundo spilodera	Cliff-Swallow, South African
Jynx ruficollis	Wryneck, Red-throated
Lamprotornis nitens	Starling, Cape Glossy
Lanius collaris	Fiscal, Common
Macronyx capensis	Longclaw, Cape
Malcorus pectoralis	Warbler, Rufous-eared
Melierax canorus	Goshawk, Southern Pale Chanting
Merops apiaster	Bee-eater, European
Mirafra fasciolata	Lark, Eastern Clapper
Motacilla capensis	Wagtail, Cape
Muscicapa striata	Flycatcher, Spotted
Myrmecocichla formicivora	Chat, Ant-eating
Nectarinia famosa	Sunbird, Malachite
Neotis ludwigii	Bustard, Ludwig's
Numida meleagris	Guineafowl, Helmeted
Oena capensis	Dove, Namaqua
Oenanthe monticola	Wheatear, Mountain
Oenanthe pileata	Wheatear, Capped
Onychognathus nabouroup	Starling, Pale-winged

Appendix 10
continued…

Scientific Name	Common Name
Ortygospiza atricollis	Quailfinch, African
Parisoma layardi	Tit-Babbler, Layard's
Parisoma subcaeruleum	Tit-Babbler, Chestnut-vented
Parus afer	Tit, Grey
Passer diffusus	Sparrow, Southern Grey-headed
Passer domesticus	Sparrow, House
Passer melanurus	Sparrow, Cape
Plectropterus gambensis	Goose, Spur-winged
Ploceus velatus	Masked-Weaver, Southern
Prinia flavicans	Prinia, Black-chested
Prinia maculosa	Prinia, Karoo
Pternistis swainsonii	Spurfowl, Swainson's
Pycnonotus nigricans	Bulbul, African Red-eyed
Quelea quelea	Quelea, Red-billed
Recurvirostra avosetta	Avocet, Pied
Rhinopomastus cyanomelas	Scimitarbill, Common
Riparia paludicola	Martin, Brown-throated
Saxicola torquatus	Stonechat, African
Scleroptila levaillantoides	Francolin, Orange River
Scopus umbretta	Hamerkop, Hamerkop
Serinus alario	Canary, Black-headed
Sigelus silens	Flycatcher, Fiscal
Spreo bicolor	Starling, Pied
Stenostira scita	Flycatcher, Fairy
Streptopelia capicola	Turtle-Dove, Cape
Streptopelia semitorquata	Dove, Red-eyed
Streptopelia senegalensis	Dove, Laughing
Sylvietta rufescens	Crombec, Long-billed
Tachybaptus ruficollis	Grebe, Little
Tadorna cana	Shelduck, South African
Telophorus zeylonus	Bokmakierie, Bokmakierie
Threskiornis aethiopicus	Ibis, African Sacred
Trachyphonus vaillantii	Barbet, Crested
Tricholaema leucomelas	Barbet, Acacia Pied
Tringa nebularia	Greenshank, Common
Turdus smithi	Thrush, Karoo
Upupa africana	Hoopoe, African
Urocolius indicus	Mousebird, Red-faced
Vanellus armatus	Lapwing, Blacksmith
Vanellus coronatus	Lapwing, Crowned
Vidua macroura	Whydah, Pin-tailed
Zosterops pallidus	White-eye, Orange River

Appendix 11. Relative mean monthly values of rodent species (relative to all prey ingested) in caracal **(A)**, black-backed jackal **(B)**, Cape grey mongoose **(C)** and yellow mongoose **(D)** diet in the study area, southern Free State.

Species	Statistic	A	B	C	D
Micaelamys namaquensis	Rel. % occ.	1.6978	13.3668	2.2446	1.3583
	Rel. % vol.	1.0307	15.1656	3.7384	0.7063
	Rel. IV.	0.0175	2.0271	0.0839	0.0096
Otomys spp.	Rel. % occ.	1.7395	8.5072	4.8019	3.5717
	Rel. % vol.	1.2459	9.5902	9.3776	1.9534
	Rel. IV.	0.0217	0.8159	0.4503	0.0698
Rhabdomys pumilio	Rel. % occ.		1.9265	4.5437	2.6078
	Rel. % vol.		2.0456	6.5323	1.1859
	Rel. IV.		0.0394	0.2968	0.0309
Mus minutoides	Rel. % occ.			0.5703	1.6396
	Rel. % vol.			0.5607	0.6650
	Rel. IV.			0.0032	0.0109
Mastmys coucha	Rel. % occ.		0.9470	0.1157	0.8377
	Rel. % vol.		1.1393	0.0613	0.8452
	Rel. IV.		0.0108	0.0001	0.0071
Gerbilliscus leucogaster	Rel. % occ.	0.4902	0.5952		
	Rel. % vol.	0.2993	0.7091		
	Rel. IV.	0.0015	0.0042		
Saccostomus campestris	Rel. % occ.		0.3788	0.2688	
	Rel. % vol.		0.5762	0.0945	
	Rel. IV.		0.0022	0.0003	
Dendromus melanotis	Rel. % occ.				0.1812
	Rel. % vol.				0.0953
	Rel. IV.				0.0002
Unidentified muridae	Rel. % occ.		0.3968	0.0926	0.1282
	Rel. % vol.		0.2222	0.0913	0.0597
	Rel. IV.		0.0009	0.0001	0.0001
Pedetes capensis	Rel. % occ.	14.3724	2.4529	0.0926	
	Rel. % vol.	15.3050	3.4732	0.2684	
	Rel. IV.	2.1997	0.0852	0.0002	
Xerus inauris	Rel. % occ.				0.1812
	Rel. % vol.				0.1430
	Rel. IV.				0.0003

Appendix 12. Relative mean monthly values of Ruminantia species (relative to all prey ingested) in caracal **(A)**, black-backed jackal **(B)**, Cape grey mongoose **(C)** and yellow mongoose **(D)** diet in the study area, southern Free State.

Species	Statistic	A	B	C	D
Ovis aries	Rel. % occ.	12.8639	7.2931	0.6482	0.1445
	Rel. % vol.	13.6377	8.5963	0.6237	0.1513
	Rel. IV.	1.7543	0.6269	0.0040	0.0002
Redunca fulvorufula	Rel. % occ.	5.6675	7.2555	0.0779	0.1812
	Rel. % vol.	5.8094	9.6547	0.1251	0.6674
	Rel. IV.	0.3292	0.7005	0.0001	0.0012
Antidorcas marsupialis	Rel. % occ.	2.7044	10.1522	0.2688	
	Rel. % vol.	2.8942	13.3309	0.5669	
	Rel. IV.	0.0783	1.3534	0.0015	
Raphicerus campestris	Rel. % occ.	0.3968	0.3968		0.1894
	Rel. % vol.	0.4684	0.6092		0.0796
	Rel. IV.	0.0019	0.0024		0.0002

Appendix 13. Relative mean monthly values of medium sized mammalian prey species (relative to all prey ingested) in caracal **(A)**, black-backed jackal **(B)**, Cape grey mongoose **(C)** and yellow mongoose **(D)** diet in the study area, southern Free State.

Species	Statistic	A	B	C	D
Lepus spp.	Rel. % occ.	18.3292	9.3569	4.5215	2.3676
	Rel. % vol.	19.3902	9.9665	5.0866	1.4899
	Rel. IV.	3.5541	0.9326	0.2300	0.0353
Pronolagus rupestris	Rel. % occ.	8.1603	5.7236	1.3576	0.7027
	Rel. % vol.	8.7920	7.7031	1.8054	0.2273
	Rel. IV.	0.7175	0.4409	0.0245	0.0016
Procavia capensis	Rel. % occ.	15.7758	1.6757		
	Rel. % vol.	17.4205	2.3812		
	Rel. IV.	2.7482	0.0399		
Pedetes capensis	Rel. % occ.	14.3724	2.4529	0.0926	
	Rel. % vol.	15.3050	3.4732	0.2684	
	Rel. IV.	2.1997	0.0852	0.0002	

Appendix 14. Relative mean monthly values of Arthropoda species (relative to all prey ingested) in caracal **(A)**, black-backed jackal **(B)**, Cape grey mongoose **(C)** and yellow mongoose **(D)** diet in the study area, southern Free State.

Arthropoda group	Statistic	A	B	C	D
Isoptera	Rel. % occ.	0.49020	1.09613	19.78245	20.39551
	Rel. % vol.	0.06500	0.09484	32.93707	47.91374
	Rel. IV.	0.00032	0.00104	6.51576	9.77225
Coleoptera	Rel. % occ.	1.73954	3.57650	11.86399	19.92420
	Rel. % vol.	0.56950	0.27479	8.81760	27.33684
	Rel. IV.	0.00991	0.00983	1.04612	5.44665
Orthoptera	Rel. % occ.	1.37722	3.78456	19.97749	16.22551
	Rel. % vol.	0.14210	0.14962	7.48686	4.79407
	Rel. IV.	0.00196	0.00566	1.49569	0.77786
Diptera	Rel. % occ.			1.13043	0.20367
	Rel. % vol.			1.02821	0.01893
	Rel. IV.			0.01162	0.00004
Hymenoptera (Ants)	Rel. % occ.		0.67959	0.91841	1.34843
	Rel. % vol.		0.02622	0.51765	0.13702
	Rel. IV.		0.00018	0.00475	0.00185
Lepidoptera	Rel. % occ.	0.39683	0.18939	2.58540	7.32762
	Rel. % vol.	0.00468	0.01778	1.82986	3.75783
	Rel. IV.	0.00002	0.00003	0.04731	0.27536
Mantodea	Rel. % occ.			0.57890	0.81079
	Rel. % vol.			0.02169	0.05900
	Rel. IV.			0.00013	0.00048
Blattodea	Rel. % occ.				0.15435
	Rel. % vol.				0.00859
	Rel. IV.				0.00001
Diplopoda	Rel. % occ.	0.98039	0.77561	6.00095	4.48349
	Rel. % vol.	0.57801	0.37278	2.45259	2.47744
	Rel. IV.	0.00567	0.00289	0.14718	0.11108
Scorpiones	Rel. % occ.		3.66869	6.43786	8.22945
	Rel. % vol.		0.31112	3.39769	2.54255
	Rel. IV.		0.01141	0.21874	0.20924
Araneae	Rel. % occ.		1.48810	1.89022	0.83934
	Rel. % vol.		0.18095	0.51144	0.11600
	Rel. IV.		0.00269	0.00967	0.00097
Acari	Rel. % occ.			0.09259	
	Rel. % vol.			0.00268	
	Rel. IV.			0.00000	

Appendix 15. Relative mean monthly values of vertebrate prey species (relative to all prey ingested) in caracal **(A)**, black-backed jackal **(B)**, Cape grey mongoose **(C)** and yellow mongoose **(D)** diet in the study area, southern Free State.

Taxonomic Group	Statistic	A	B	C	D
Mammalia	Rel % occ.	94.29	92.67	76.98	69.07
	Rel. % vol.	95.26	96.53	86.04	80.24
	Rel. IV.	89.82	89.46	66.24	55.42
Reptilia	Rel % occ.			8.94	1.39
	Rel. % vol.			3.96	1.33
	Rel. IV.			0.35	0.02
Aves	Rel % occ.	5.71	7.33	14.08	29.54
	Rel. % vol.	4.74	3.47	10.00	18.43
	Rel. IV.	0.27	0.25	1.41	5.44