A review of the genus *Caligus* (Copepoda: Caligidae) from South Africa

By

Nicolaas Johannes Grobler

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Department of Zoology and Entomology

University of the Free State

Promotor **Prof JG Van As**

Co-promotor **Prof PAS Olivier**

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N.J. Grobler, J.G. Van As & P.A.S. Olivier, 2003. Additional morphological information on two species of *Caligus* (Copepoda: Caligidae) parasitic on South African marine and estuarine fish. *African Zoology*, **38** (1): 139-143.

N.J. Grobler, K.W. Christison, P.A.S. Olivier & J.G. Van As, 2003. Observations on the development of *Udonella caligorum* Johnston, 1835 (Monogenea: Polyonchoinea) on a parasitic copepod species of *Caligus* (Copepoda: Caligidae), collected from Lake St Lucia, South Africa. *African Zoology*, **38** (2): 393-396.

- **Paper in press**

N.J. Grobler, J.G. Van As & P.A.S. Olivier, 2004. New morphological information on the parasitic copepods *Caligus epinepheli* Yamaguti, 1936 and *Caligus rotundigenitalis* Yu, 1933 (Copepoda: Caligidae) from South Africa. *Crustaceana.* In Press.

APPENDIX II

- **Published conference proceedings**

N.J. Grobler, J.G. Van As & D.P. Cyrus, 2003. *Caligus* parasites collected from marine and estuarine fish in KwaZulu-Natal, South Africa. *Journal of the South African Veterinary Association*, **74** (3): 89.

N.J. Grobler, N.J. Smit, C.C. Reed & L. Basson, 2003. Skin and gill parasites of the Kob, *Argyrosomus japonicus* (Temminck & Schlegel, 1843) collected at the De Hoop Nature Reserve, South Africa. *Journal of the South African Veterinary Association*, **74** (3): 98.

N.J. Grobler & D.P. Cyrus, 2003. Tissue burrowing copepods of *Hilsa kelee*. *Journal of the South African Veterinary Association*, **74** (3): 98.

Introduction

The genus *Caligus* Müller, 1785 is the most abundant copepod genus parasitic on fishes. These parasites have been recorded from all oceans of the world living on the outer surfaces, within buccal cavities, or on the gills of their hosts. At least some members of these caligid copepods cause a good deal of damage to their fish hosts by their feeding activities. Fishes harbouring *Caligus* belong to very diverse groups, from the primitive elasmobranchs to highly advanced teleosts. Some hosts are commercially important, so the ravages of these small crustacean parasites have economic repercussions, especially in North America and Europe (Grobler 2000).

Most of the work done along the South African coastline is largely due to the work of Bassett-Smith (1898), Barnard (1948, 1955a, 1955b, 1957), Kensley (1970), Kensley and Grindley (1973), Oldewage (1987), and Oldewage and Van As (1989). The genus *Caligus* comprises approximately 315 nominal species (Margolis *et al*. 1975), of which only 28 species have been recorded off the coast of South Africa. Most of the information on this genus from the continent is limited to very old and often incomplete taxonomic descriptions. Grobler *et al.* (2004) reported 28 species of *Caligus* from South Africa, and the validity of each species will be discussed, based on the studies from material in the South African Museum, as well as material collected by myself.

A thorough revision of the whole genus is necessary, but this tremendously huge task seems almost impossible. The revision of the South African species is a start, and hopefully fellow parasitic copepodologists will follow this trend. Full descriptions and figures are given for species new to science as well as descriptions of species recorded for the first time from South Africa, and of species that were previously inadequately described. Permission was granted to dissect some specimens, and those not dissected were drawn *in situ*. This study forms a well-outlined reference for future studies on *Caligus* species from South Africa.

Of the species recorded from South Africa, *Caligus bonito* Wilson, 1905, *C. coryphaenae* Steenstrup & Lütken, 1861, and *C. elongatus* Nordmann, 1832 are cosmopolitan in distribution. These caligids are also non-host specific, thus being found on a variety of fish hosts. South Africa hosts a number of endemic species of *Caligus*. The term endemic is used, as these species are either found on endemic fish hosts, or have never been recorded outside the South African coastal waters. The endemic species of *Caligus* include *C. engraulidis* Barnard, 1948, *C. hottentotus* Barnard, 1957, *C. mortis* Kensley, 1970, *C. penrithi* Kensley & Grindley, 1973, and *C. tetrodontis* Barnard, 1948. *Caligus engraulidis* has been collected for the first time since its original description by Barnard (1948), and seems to be a parasite of certain mullet species.

A detailed synopsis (Table 1.1) of all *Caligus* species collected from the South African coast is given which summarises the hosts and localities of the known species, as well as the species collected for the first time from South African waters. A host/parasite synopsis (Table 1.2) is also included, outlining the *Caligus* species found on a specific fish host. It is worth noting that three fish hosts, *Katsuwonus pelamis* (Linnaeus, 1758), *Rhabdosargus holubi* (Steindachner, 1881), and *Scomberomorus commerson* (Lacepède, 1800), were all found to host at least four different species of *Caligus* parasites. *Seriola lalandi* Valenciennes, 1833 is host to three different species of *Caligus*, including a lesser known species of *Caligus*, *C. lalandei* Barnard, 1948, a parasite not collected since its original description. These two synopses form the basis reference to future collections of *Caligus* species. A separate table (Table 1.3) is included with the catalogue numbers of voucher specimens in the South African Museum, as well as new material (*Caligus* sp. A and *Caligus* sp. B) collected during the present study.

Many of the *Caligus* species in the collection of the South African Museum have disappeared. This was due to the fact that specimens on loan was either never returned or got lost. The same applies to the specimens in the collection of the Rand Afrikaans University, Johannesburg. These species in question cannot be redescribed in the present study, but will be included in the synopsis. However, this material will not be included in the key to the South African *Caligus* species, due to questionable records. Two records, that of *Caligus affinis* Heller, 1866, and *C. labracis* Scott, 1902, will be excluded from the South African collection records. These two species were misidentified. Specimens of the misidentified *C. affinis* were subsequently collected from the same host, *Pomatomus saltatrix* (Linnaeus, 1766), in the present study, and a detailed discussion is included in Chapter 3 on this species (*Caligus* sp. B). Another species, *Caligus africanus* Oldewage & Van As, 1989, is not a valid species and is synonimised with *Caligus tetrodontis*.

Two species of *Caligus*, *C. epinepheli* Yamaguti, 1936, and *C. rotundigenitalis* Yu, 1933, will be included in the key to the South African species, but full taxonomic descriptions will be omitted as these two species were studied with the aid of scanning electron microscopy. No additional specimens were available for full species descriptions. A detailed description of various morphological characters in question for both these species are provided, where the taxonomic confusion of *C. epinepheli* is also sorted out. Additional morphological information is also given for four species of *Caligus*, *C. acanthopagri* Lin, Ho & Chen, 1994, *C. confusus* Pillai, 1961, *C. engraulidis*, and *C. mortis*. The males of *Caligus engraulidis* and *C. mortis* are described for the first time, and two new species are described. As a result of the misidentification of species and the description of two new species, the total number of species reported from South Africa remains 28 (Table 1.1).

Table 1.1. A synopsis of parasite/host - and locality records of *Caligus* Müller, 1785 species from South African Coastal waters.

***Caligus acanthopagri* Lin, Ho & Chen, 1994**		
Host species	**Locality**	**Reference**
Acanthopagrus berda	Lake St Lucia	Grobler *et al.* (2003)
	Mhlatuze Estuary	Present study
Rhabdosargus holubi	Lake St Lucia	Grobler *et al.* (2003)
	Mhlatuze Estuary	Present study
***Caligus aesopus* Wilson, 1940**		
Seriola lalandi	False Bay	Kensley & Grindley (1973)
***Caligus arii* Basset-Smith, 1898**		
Arius acutirostris	South Africa	Bassett-Smith (1898)
Arius caelatus	South Africa	Bassett-Smith (1898)
***Caligus assymmetricus* Pillai, 1965**		
Scomberomorus commerson	Sodwana Bay	Oldewage & Van As (1989)
Katsuwonus pelamis	Sodwana Bay	Oldewage & Van As (1989)
***Caligus biseriodentatus* Shen, 1957**		
Scomberomorus commerson	Port Elizabeth	Oldewage & Van As (1989)
Sarda sarda	Port Elizabeth	Oldewage & Van As (1989)
***Caligus bonito* Wilson, 1905**		
Sarda sarda	False Bay	Barnard (1955b)
Sarda orientalis	Port Elizabeth	Cressey & Cressey (1980)
Sarda sarda	Port Elizabeth	Cressey & Cressey (1980)
Katsuwonus pelamis	Sodwana Bay	Oldewage & Van As (1989)
***Caligus brevicaudatus* Scott, 1901**		
No host record	No locality record	Barnard (1955b)
***Caligus confusus* Pillai, 1961**		
Alepes djedaba	Durban	Kensley & Grindley (1973)
Caranx sexfasciatus	Lake St Lucia	Grobler *et al.* (2003)
Rhabdosargus holubi	Lake St Lucia	Grobler *et al.* (2003)
***Caligus coryphaenae* Steenstrup & Lütken, 1861**		
Squalus acanthias	Algoa Bay	Barnard (1955a)
Thunnus obesus	Cape Point	Kensley & Grindley (1973)
Katsuwonus pelamis	Cape Point	Kensley & Grindley (1973)
Katsuwonus pelamis	Sodwana Bay	Oldewage & Van As (1989)
Pomatomus saltatrix	Cape Agulhas	Oldewage (1992)

Table 1.1. (cont.) A synopsis of parasite/host – and locality records of *Caligus* Müller, 1785 species from South African Coastal waters.

	Port Elizabeth	Oldewage (1992)
Ranzania laevis	Milnerton	No reference
***Caligus curtus* Müller, 1785**		
Chelidonichthys capensis	South Africa	Oldewage & Avenant-Oldewage (1993)
Chelidonichthys queketti	South Africa	Oldewage & Avenant-Oldewage (1993)
***Caligus diaphanus* Nordmann, 1832**		
Trachinotus botla	Sodwana Bay	Oldewage & Van As (1989)
***Caligus elongatus* Nordmann, 1832**		
Merluccius capensis	Table Bay	Barnard (1955b)
Trachurus trachurus	Table Bay	Barnard (1955b)
***Caligus engraulidis* Barnard, 1948**		
Stolephorus holodon	Zwartkops River, Algoa Bay	Barnard (1948)
Liza tricuspidens	Lake St Lucia	Present study
Mugil cephalus	Lake St Lucia	Present study
***Caligus epinepheli* Yamaguti, 1936**		
Diplodus sargus capensis	De Hoop Nature Reserve	Grobler *et al*. (2004)
Rhabdosargus holubi	Lake St Lucia	Grobler *et al*. (2004)
***Caligus hottentotus* Barnard, 1957**		
Pachymetopon blochii	Table Bay	Barnard (1957)
***Caligus infestans* Heller, 1865**		
Scomberomorus commerson	Sodwana Bay	Oldewage & Van As (1988)
Scomberomorus commerson	Sodwana Bay	Oldewage & Van As (1989)
Galeichthys feliceps	Port Alfred	Oldewage (1992)
***Caligus lalandei* Barnard, 1948**		
Seriola lalandi	Kalk Bay	Barnard (1948)
***Caligus lunatus* Wilson, 1928**		
Seriola lalandi	False Bay	Barnard (1955b)
***Caligus mauritanicus* Brian, 1924**		
Pomatomus saltatrix	False Bay	Barnard (1955b)
Caranx rhonchus	False Bay	Barnard (1955b)
Chiloglanis cameronensis	False Bay	Barnard (1955b)
Dentex gibbosus	False Bay	Barnard (1955b)
Dentex sp.	False Bay	Barnard (1955b)
Plectorhinchus mediterraneus	False Bay	Barnard (1955b)
Pagrus pagrus	False Bay	Barnard (1955b)

Table 1.1. (cont.) A synopsis of parasite/host – and locality records of *Caligus* Müller, 1785 species from South African Coastal waters.

***Caligus mortis* Kensley, 1970**		
Clinus superciliosus	Saldanha Bay	Kensley & Grindley (1973)
	De Hoop Nature Reserve	Grobler *et al.* (2002)
	Jeffreys Bay	Grobler *et al.* (2002)
Chorisochismus dentex	De Hoop Nature Reserve	Grobler *et al.* (2002)
	Jeffreys Bay	Grobler *et al.* (2002)
Clinus cottoides	De Hoop Nature Reserve	Grobler *et al.* (2002)
	Jeffreys Bay	Grobler *et al.* (2002)
Liza richardsonii	De Hoop Nature Reserve	Grobler *et al.* (2002)
Sarpa salpa	De Hoop Nature Reserve	Grobler *et al.* (2002)
***Caligus pelamydis* Krøyer, 1836**		
No host record	Simons Bay	Brady (1910)
No host record	Simons Bay	Barnard (1955a)
Chelidonichthys capensis	False Bay	Barnard (1955a)
	Table Bay	Barnard (1955a)
Thyrsites atun	False Bay	Barnard (1955a)
	Table Bay	Barnard (1955a)
Sarda sarda	Port Elizabeth	Cressey & Cressey (1980)
***Caligus penrithi* Kensley & Grindley, 1973**		
Cheilodactylus pixi	Algoa Bay	Kensley & Grindley (1973)
Cheilodactylus fasciatus	Algoa Bay	Kensley & Grindley (1973)
***Caligus productus* Dana, 1852**		
Katsuwonus pelamis	Sodwana Bay	Oldewage & Van As (1989)
Scomberomorus commerson	Sodwana Bay	Oldewage & Van As (1989)
Thunnus albacares	Sodwana Bay	Oldewage & Van As (1989)
***Caligus rotundigenitalis* Yu, 1933**		
Rhabdosargus holubi	Lake St Lucia	Grobler *et al.* (2004)
***Caligus saucius* Dojiri, 1989**		
Cirripectes castaneus	KwaZulu Reef	Dojiri (1989)
***Caligus tetrodontis* Barnard, 1948**		
Torquigener hypselogeneion	Port Elizabeth	Barnard (1948)
Arothron hispidus	Cebe, Transkei	Oldewage (1987)
Amblyrhynchotes honckenii	Knysna	Oldewage & Van As (1989)
Arothron hispidus	Cebe, Transkei	Oldewage (1990)
Chelidonichthys capensis	Mossel Bay	Oldewage (1992)
Amblyrhynchotes honckenii	De Hoop Nature Reserve	Present study
Amblyrhynchotes honckenii	Jeffreys Bay	Present study

Table 1.1. (cont.) A synopsis of parasite/host – and locality records of *Caligus* Müller, 1785 species from South African Coastal waters.

***Caligus zei* Norman & Scott, 1906**		
Thyrsites atun	False Bay	Barnard (1955b)
***Caligus* sp. A**		
Argyrosomus japonicus	De Hoop Nature Reserve	Present study
	Jeffreys Bay	Present study
***Caligus* sp. B**		
Pomatomus saltatrix	Durban	Kensley & Grindley (1973)
Pomatomus saltatrix	De Hoop Nature Reserve	Present study
Pomatomus saltatrix	Mhlatuze Estuary	Present study

Table 1.2. A synopsis of host/parasite - and locality records of *Caligus* species from South African Coastal waters.

***Acanthopagrus berda* (Forsskål, 1775)**		
Parasite species	**Locality**	**Reference**
Caligus acanthopagri	Lake St Lucia	Grobler *et al.* (2003)
	Mhlatuze Estuary	Present study
***Alepes djedaba* (Forsskål, 1775)**		
Caligus confusus	Durban	Kensley & Grindley (1973)
***Amblyrhynchotes honckenii* (Bloch, 1785)**		
Caligus tetrodontis	Knysna	Oldewage & Van As (1989)
	De Hoop Nature Reserve	Present study
	Jeffreys Bay	Present study
***Argyrosomus japonicus* (Temminck & Schlegel, 1843)**		
Caligus sp. A	De Hoop Nature Reserve	Present study
	Jeffreys Bay	Present study
***Arius acutirostris* Day, 1877**		
Caligus arii	South Africa	Bassett-Smith (1898)
***Arius caelatus* Valenciennes, 1840**		
Caligus arii	South Africa	Bassett-Smith (1898)
***Arothron hispidus* (Linnaeus, 1758)**		
Caligus tetrodontis	Cebe, Transkei	Oldewage (1987)
***Caranx rhonchus* Geoffroy Saint-Hilaire, 1817**		
Caligus mauritanicus	False Bay	Barnard (1955b)
***Caranx sexfasciatus* Quoy & Gaimard, 1825**		
Caligus confusus	Lake St Lucia	Grobler *et al.* (2003)

Table 1.2. (cont.) A synopsis of host/parasite – and locality records of *Caligus* Müller, 1785 species from South African Coastal waters.

***Cheilodactylus fasciatus* Lacepède, 1803**		
Caligus penrithi	Algoa Bay	Kensley & Grindley (1973)
***Cheilodactylus pixi* Smith, 1980**		
Caligus penrithi	Algoa Bay	Kensley & Grindley (1973)
***Chelidonichthys capensis* (Cuvier, 1829)**		
Caligus pelamydis	False Bay	Barnard (1955a)
	Table Bay	Barnard (1955a)
Caligus curtus	South Africa	Oldewage & Avenant-Oldewage (1993)
***Chelidonichthys queketti* (Regan, 1904)**		
Caligus curtus	South Africa	Oldewage & Avenant-Oldewage (1993)
***Chiloglanis cameronensis* Boulenger, 1904**		
Caligus mauritanicus	False Bay	Barnard (1955b)
***Chorisochismus dentex* (Pallas, 1769)**		
Caligus mortis	De Hoop Nature Reserve	Grobler *et al.* (2002)
	Jeffreys Bay	Grobler *et al.* (2002)
***Cirripectes castaneus* (Valenciennes, 1836)**		
Caligus saucius	KwaZulu Reef	Dojiri (1989)
***Clinus cottoides* Valenciennes, 1836**		
Caligus mortis	De Hoop Nature Reserve	Grobler *et al.* (2002)
	Jeffreys Bay	Grobler *et al.* (2002)
***Clinus superciliosus* (Linnaeus, 1758)**		
Caligus mortis	Saldanha Bay	Kensley & Grindley (1973)
	De Hoop Nature Reserve	Grobler *et al.* (2002)
	Jeffreys Bay	Grobler *et al.* (2002)
***Dentex gibbosus* (Rafinesque, 1810)**		
Caligus mauritanicus	False Bay	Barnard (1955b)
***Dentex* sp.**		
Caligus mauritanicus	False Bay	Barnard (1955b)
***Diplodus sargus capensis* (Smith, 1844)**		
Caligus epinepheli	De Hoop Nature Reserve	Grobler *et al.* (2004)
***Galeichthys feliceps* Valenciennes, 1840**		
Caligus infestans	Port Alfred	Oldewage (1992)
***Katsuwonus pelamis* (Linnaeus, 1758)**		
Caligus assymmetricus	Sodwana Bay	Oldewage & Van As (1989)
Caligus bonito	Sodwana Bay	Oldewage & Van As (1989)
Caligus coryphaenae	Cape Point	Kensley & Grindley (1973)

Table 1.2. (cont.) A synopsis of host/parasite – and locality records of *Caligus* Müller, 1785 species from South African Coastal waters.

	Sodwana Bay	Oldewage & Van As (1989)
Caligus productus	Sodwana Bay	Oldewage & Van As (1989)
***Liza richardsonii* (Smith, 1846)**		
Caligus mortis	De Hoop Nature Reserve	Grobler *et al.* (2002)
***Liza tricuspidens* (Smith, 1935)**		
Caligus engraulidis	Lake St Lucia	Present study
***Merluccius capensis* Castelnau, 1861**		
Caligus elongatus	Table Bay	Barnard (1955b)
***Mugil cephalus* Linnaeus, 1758**		
Caligus engraulidis	Lake St Lucia	Present study
***Pachymetopon blochii* (Valenciennes, 1830)**		
Caligus hottentotus	Table Bay	Barnard (1957)
***Pagrus pagrus* (Linnaeus, 1758)**		
Caligus mauritanicus	False Bay	Barnard (1955b)
***Plectorhinchus mediterraneus* (Guichenot, 1850)**		
Caligus mauritanicus	False Bay	Barnard (1955b)
***Pomatomus saltatrix* (Linnaeus, 1766)**		
Caligus coryphaenae	Cape Agulhas	Oldewage (1992)
	Port Elizabeth	Oldewage (1992)
Caligus mauritanicus	False Bay	Barnard (1955b)
Caligus sp. B	Durban	Kensley & Grindley (1973)
Caligus sp. B	De Hoop Nature Reserve	Present study
Caligus sp. B	Mhlatuze Estuary	Present study
***Ranzania laevis* (Pennant, 1776)**		
Caligus coryphaenae	Milnerton	No reference
***Rhabdosargus holubi* (Steindachner, 1881)**		
Caligus acanthopagri	Lake St Lucia	Grobler *et al.* (2003)
	Mhlatuze Estuary	Present study
Caligus confusus	Lake St Lucia	Grobler *et al.* (2003)
Caligus epinepheli	Lake St Lucia	Grobler *et al.* (2004)
Caligus rotundigenitalis	Lake St Lucia	Grobler *et al.* (2004)
***Sarda orientalis* (Temminck & Schlegel, 1844)**		
Caligus bonito	Port Elizabeth	Cressey & Cressey (1980)
***Sarda sarda* (Bloch, 1793)**		
Caligus biseriodentatus	Port Elizabeth	Oldewage & Van As (1989)
Caligus bonito	False Bay	Barnard (1955b)

Table 1.2. (cont.) A synopsis of host/parasite – and locality records of *Caligus* Müller, 1785 species from South African Coastal waters.

	Port Elizabeth	Cressey & Cressey (1980)
Caligus pelamydis	Port Elizabeth	Cressey & Cressey (1980)
***Sarpa salpa* (Linnaeus, 1758)**		
Caligus mortis	De Hoop Nature Reserve	Grobler *et al.* (2002)
***Scomberomorus commerson* (Lacepède, 1800)**		
Caligus assymmetricus	Sodwana Bay	Oldewage & Van As (1989)
Caligus biseriodentatus	Port Elizabeth	Oldewage & Van As (1989)
Caligus infestans	Sodwana Bay	Oldewage & Van As (1988)
	Sodwana Bay	Oldewage & Van As (1989)
Caligus productus	Sodwana Bay	Oldewage & Van As (1989)
***Seriola lalandi* Valenciennes, 1833**		
Caligus aesopus	False Bay	Kensley & Grindley (1973)
Caligus lalandei	Kalk Bay	Barnard (1948)
Caligus lunatus	False Bay	Barnard (1955b)
***Squalus acanthias* Linnaeus, 1758**		
Caligus coryphaenae	Algoa Bay	Barnard (1955a)
***Stolephorus holodon* (Boulenger, 1900)**		
Caligus engraulidis	Zwartkops River, Algoa Bay	Barnard (1948)
***Thunnus albacares* (Bonnaterre, 1788)**		
Caligus productus	Sodwana Bay	Oldewage & Van As (1989)
***Thunnus obesus* (Lowe, 1839)**		
Caligus coryphaenae	Cape Point	Kensley & Grindley (1973)
***Thyrsites atun* (Euphrasen, 1791)**		
Caligus pelamydis	False Bay	Barnard (1955a)
	Table Bay	Barnard (1955a)
Caligus zei	False Bay	Barnard (1955b)
***Torquigener hypselogeneion* (Bleeker, 1852)**		
Caligus tetrodontis	Port Elizabeth	Barnard (1948)
***Trachinotus botla* (Shaw, 1803)**		
Caligus diaphanus	Sodwana Bay	Oldewage & Van As (1989)
***Trachurus trachurus* (Linnaeus, 1758)**		
Caligus elongatus	Table Bay	Barnard (1955b)

Table 1.3. Catalogue numbers of *Caligus* Müller, 1785 species from the South African Museum (voucher specimens collected in the present study are highlighted).

Caligus acanthopagri Lin, Ho & Chen	5 ovig ♀♀, 5 ♂♂	SAM A45161
Caligus aesopus Wilson	3 ovig ♀♀, 19 ♀♀, 2 ♂♂	SAM A12994
	2 ♀♀	SAM A45005
Caligus confusus Pillai	2 ovig ♀♀, 2 ♂♂	SAM A45162
	1 ovig ♀, 1 ♀	SAM A12995
Caligus coryphaenae Steenstrup & Lütken	1 ovig ♀, 3 ♂♂	SAM A11753
	6 ovig ♀♀	SAM A11808
Caligus engraulidis Barnard	2 ovig ♀♀, 2 ♂♂	SAM A45163
	1 ovig ♀	SAM A8520
Caligus epinepheli Yamaguti	No specimens deposited	
Caligus hottentotus Barnard	1 ovig ♀, 2 ♀♀	SAM A11780
Caligus lalandei Barnard	1 ovig ♀, 3 ♀♀, 1 ♂	SAM A8517
Caligus mortis Kensley	1 ovig ♀	SAM A12708
	1 ♀	SAM A12990
	1 ovig ♀	SAM A12991
	1 ♀	SAM A12992
	1 ovig ♀	SAM A12993
	2 ovig ♀♀	SAM A11814
	1 ovig ♀, 1 ♂	SAM A44115
Caligus pelamydis Krøyer	5 ovig ♀♀, 3 ♀♀	SAM A45006
Caligus penrithi Kensley & Grindley	8 ovig ♀♀, 4 ♀♀	SAM A45007
Caligus rotundigenitalis Yu	No specimens deposited	
Caligus tetrodontis Barnard	2 ovig ♀♀, 2 ♂♂	SAM A45165
	2 ovig ♀♀, 2 ♀♀, 4 ♂♂	SAM A3778
Caligus sp. A	2 ovig ♀♀, 1 ♂	SAM A45166
Caligus sp. B	1 ovig ♀, 1♀, 2 ♂	SAM A45164
	2 ovig ♀♀, 1 ♂	SAM A12996

The objective of the present study is to review all the known species of *Caligus* from South Africa. As mentioned, this will include all the available material in the South African Museum, as well as the material collected in the present study, which is a continuation of my masters dissertation, completed in 2000. Due to the fact that this thesis is a review of the genus *Caligus*, it requires inclusion of some of the work already presented in my masters dissertation, Grobler (2000). Text that were used in my maters dissertation will be referred to in chapters 1 and 2. Scanning electron micrographs used in my masters dissertation include those for *Caligus*

acanthopagri, *C. confusus*, *C. engraulidis*, and *C. mortis*. The editors of the journals where my scientific publications were accepted and published were contacted and permission was granted to use any part of the published papers for use in my thesis. It has become a norm to include as much detail as possible in the species descriptions, making future identifications of *Caligus* species more taxonomically viable. This trend was followed and explored with the use of scanning electron microscopy, where the taxonomic confusion of *Caligus epinepheli* was dealt with. During the present study, which started with the commencement of my postgraduate studies, four scientific publications were accepted and published in international journals, and I have presented numerous poster and oral presentations at both national and international conferences (see Appendixes I, II).

Against this background information in Chapter 1, the outline of the thesis is discussed briefly. A detailed description of the collection localities, collection of fish hosts, materials and methods, and taxonomic terms used for *Caligus* taxonomy is discussed in Chapter 2. The review of the known species of *Caligus* from South Africa, which include full species descriptions, as well as additional morphological information provided by scanning electron microscopy, is discussed in Chapter 3. An in-depth discussion on the South African species of *Caligus*, including a proposed grouping of species within the genus using morphological information of the exopodal segment of the fourth leg, as well as future studies on species of *Caligus* is discussed in Chapter 4. Chapter 4 also includes a key to the South African caligid genera and a key to the South Africa species of *Caligus*, based on the review of the genus in Chapter 3. Chapter 5 outlines all the species with no reference material, as well as the species which were misidentified. The literature cited for the purpose of this study is provided in Chapter 6, followed by the acknowledgements and abstracts. Appendix I contains four papers published during the course of this study. Appendix II contains two conference proceedings published during the course of this study.

Study Areas

South African Coastline

Two major currents influence the South African coastline and intertidal life, i.e. the warm Agulhas Current along the east coast and the cold Benguela along the west coast. The Indian Ocean has a huge gyre of water circulating anticlockwise, driven by winds. This equatorial water mass splits when it reaches Madagascar, part moving around the island and down the coast of Mozambique, where it is known as the Mozambique Current, while a second stream passes around the eastern side of Madagascar. The two currents unite again as they flow along the coast of KwaZulu-Natal, forming an input into the Agulhas Current. This is the mightiest current bathing the South African coast, and brings warm water from the tropics to the east coast, with the result a warm subtropical east coast province. As the Agulhas moves southwards, its central core follows the edge of the continental shelf, where the relatively shallow coastal waters abruptly become deeper. The edge of the continental shelf swings away from the shore from Transkei southwards, deflecting the Agulhas Current away from the coast. As a result, the warm temperate south coast province, from about Port St Johns to Cape Point, has cooler coastal waters and a different set of animals and plants from that of the Natal and Mozambique coasts. Towards the south the Agulhas swings eastwards as the Return Agulhas Current, and unites with three smaller circuits known as the semi-basin, regional and Return Agulhas circulations (Branch & Branch 1995, Grobler 2000).

Under the influence of the currents described above, the southern African coastline is divided into four distinct marine regions as defined by Branch and Branch (1995):

West Coast: cold temperate waters, north of Walvis Bay to Cape Town;

South Coast: warm temperate waters, Cape Town to East London;

East Coast: subtropical waters, East London to north of Maputo and

East Coast: tropical waters, north of Maputo past Beira.

This study was, however, only conducted on the south coast and subtropical east coast.

East Coast

As the meeting place of river and ocean, an estuary is a unique complex, driven by two major forces: freshwater inflow from the river`s upstream reaches, and the ebb and flow of the ocean`s tides, which together create a dynamic ecosystem (Grobler 2000). Estuaries are thus extremely variable, with each rise and fall of the tide bringing changes to a variety of physical conditions within the estuary. Because estuaries depend on the interaction of sea and river, they are also extraordinary vulnerable and easily damaged by man`s activities (Branch & Branch 1995). These

sanctuaries provide a sheltered food-rich haven for many fish species. Most fish, which occur in estuaries, breed in the sea, presumably because estuaries are too harsh for the eggs and young larvae. However, large numbers of their juveniles then return to the estuaries and develop there until mature enough to breed.

The Coastal Research Unit of Zululand (CRUZ), situated within the Zoology Department of the University of Zululand, monitor the conditions of both Lake St Lucia and Mhlatuze Estuary. As part of the research program of CRUZ, fish collected during their surveys in Lake St Lucia and Mhlatuze Estuary were studied for parasitic copepods.

Lake St Lucia (between 27°50'S and 28°25'S, and 32°21'E and 32°34'E)

Lake St Lucia on the east coast of South Africa (Figs. 2.1a, c, 2.2a) is the largest estuarine area in southeast Africa and occupies about 80% of the estuarine area of KwaZulu-Natal. It is approximately 325 km² in area, depending on lake level (Begg 1978), and has a mean depth of only one meter. Lake St Lucia is subject to extreme long-term salinity fluctuations due to its shallow nature and irregular inflow of freshwater, making it a unique estuarine system. The fresh water supply to the lake is derived from the rivers Mkuze, Hluhluwe, Nyalazi, Mzinene and Mpate, from rainfall, and from ground-water seepage along the eastern shores (Bruton & Cooper 1980).

Lake St Lucia supports a substantial subsistence fishing community and represents an important local source of income. The villagers harvest its resources with simple fishing baskets that are thrust to the bottom to trap the fish below. The practice has sustained these people for more than half a millennium. Gill nets are slowly replacing the ancient fishing methods, and thus more fish of different size are caught. Estuaries are always under threat because of various reasons. Siltation is the major threat, but urban sprawl in the catchment areas, dams, afforestation, alien invasive plants, agricultural run-off have all an adverse impact. UNESCO declared the Lake St Lucia system a world heritage site in 1999, and conservation of this ecosystem must be upgraded before it is further degraded by human impact (Grobler 2000).

Mhlatuze Estuary (between 28°46'S and 28°51'S, and 31°59'E and 32°07'E)

Mhlatuze Estuary (Figs. 2.1a, b, 2.2c) is situated about 100 km south of Lake St Lucia and covers approximately 12 km² (Begg 1978). This estuary is situated in Richards Bay, a large industrial harbour city, and faces the impact of human settlement and the rundown of industrial waste. The main freshwater supply to the estuary is from the Mhlatuze River. With the building of the Richards Bay Harbour, careful planning went into the attempt to separate the ecologically

important shallows from the deeper lagoon where the harbour was built. An earth embankment or berm was constructed to divide the estuary in half, and a new mouth was cut so that the river and upper reaches of the estuary still maintained direct contact with the sea. This planning allowed the conservation of the sanctuary area, and also served to prevent river silt from washing down into the harbour.

South Coast

De Hoop Nature Reserve (34°28'S, 20°30'E)

The south coast of South Africa is famous for the rocky shores along the coastline. This unique ecological habitat is home to many invertebrates and vertebrates, especially intertidal fish species. De Hoop Nature Reserve (Figs. 2.1a, 2.3d, e) has a rocky shore coastline and is famous for the many different invertebrate species found along this shoreline. As these areas have rocky shores, many intertidal pools are formed during the low tide. Many different fish species are trapped in these intertidal pools until the ebb tide release them to the open waters again. Many juvenile fish species are trapped in these pools, but adult fish species are also periodically entrapped (Grobler 2000).

Jeffreys Bay (34°2.2'S, 24°56.5'E)

Jeffreys Bay (Fig. 2.1a) has a coastline consisting of sandy beaches as well as rocky shores (Grobler 2000). The main difference between De Hoop Nature Reserve and Jeffreys Bay is that De Hoop Nature Reserve is a strictly controlled marine reserve, where no organisms may be removed without collection permits issued by Cape Nature Conservation. Tidal pools found at Jeffreys Bay is much smaller in size compared to De Hoop Nature Reserve, and harbor a smaller diversity of fish species.

Fish hosts

Collection of fish hosts

The most effective methods of fish collection in the two estuaries is the use of gill nets, seine, cast nets, and the occasional use of fishing rods (Figs. 2.2b, d-h, 2.3a, b). As a result of the use of gill nets, infestation statistics are omitted, as caligid copepods tend to leave their stressed hosts. The use of gill nets was very effective, but as mentioned, caligid copepods tend to leave their stressed hosts, especially when entangled fish die. Gill nets were removed after three hours, and fish hosts studied for any caligid copepods. Seine, medium and small sized mesh, were used in shallow water near embankments. A wide variety of juvenile fish species, as well as true estuarine

fish hosts were collected. The occasional use of cast nets were used near embankments, where seine could not be used. Intertidal fish species were effectively collected with hand nets, cast nets, hand lines and the use of fishing rods during low tides (Figs. 2.3f, g).

Caligus parasites

Examination of caligid copepods

Caligid copepods were carefully removed from the hosts (Figs. 2.3c, h) with the aid of a No. 270 soft hair brush. Collected specimens were preserved in 70% ethanol and supplied with a collection number. Two different collection numbers were used for the east coast and the south coast. The collection number for the east coast is as follows: field trip number / number of fish caught. Specimen collection numbers from Lake St Lucia are collective data numbers of the University of the North, as they collected most of the specimens from Lake St Lucia. For example 17 / 05 refers to the 17th fieldtrip and the fifth fish that was caught. The collection number for the south coast is as follows: Year / Month / Day – collection number (Grobler 2000). Data from De Hoop Nature Reserve and Jeffreys Bay were collected by myself and forms part of the parasite collection of the Aquatic Parasitology Research Group, Department of Zoology and Entomology, University of the Free State, Bloemfontein. All specimens collected from Mhlatuze Estuary belongs to the collection of CRUZ, but voucher specimens will be deposited in the collection of the Aquatic Parasitology Research Group. Voucher specimens of all collected species have also been deposited in the collection of the South African Museum.

South African Museum material

All the material catalogued SAM A is from the collection of the South African Museum in Cape Town, kindly provided on loan by Liz Hoenson from the Crustacea Section of the South African Museum. All the voucher specimens of the present study have received SAM A catalogue numbers and are included in Table 1.3 in Chapter 1. Vials found with wrong SAM A catalogue numbers and those with no catalogue numbers at all, are discussed in Chapter 5.

Study methods

Light microscopy

A technique described by Humes and Gooding (1964), the wooden slide technique, was used for the species descriptions. Caligid specimens were placed in 85% lactic acid for at least 24 hours. Lactic acid is a clearing agent for the preparation of temporary mounts of whole or dissected copepods. Ethanol preserved specimens became clear within a few minutes to some hours, depending upon their size and the duration of preservation. When first placed in the undiluted acid, the copepods may become somewhat contracted, but soon regain, and thereafter, retain their normal size and shape.

Lactic acid renders the cuticle more supple than it is in most preservatives and thus more favorable for dissection, since setae, etc., are less easily broken off and lost. The refractive index of lactic acid is particularly suitable for study of fine detail. Dissection of appendages was made with the aid of minute needles. The dissected parts and appendages were examined under a Leitz compound microscope with a series of magnification up to x 1,000. All drawings were made with the aid of a drawing tube.

Morphological measurements

The total lengths of all the *Caligus* species were obtained from microscope projection drawings. In both the females and males the total length was measured from the frontal border of the frontal plate to the posterior border of the caudal rami, excluding the setae on the caudal rami. The mean body measurements given in the description are the average, followed by the range in parentheses. All these measurements follow the norm of length by width (long x wide). Measurements are given in either millimeters or micrometers. All scanning electron microscopy measurements are given in micrometers.

Preparation of specimens for scanning electron microscopy

Specimens for scanning electron microscopy were first hydrated from 70% ethanol to distilled water. The caligids were washed for one day in fresh water in order to get rid of salt crystals. After washing, the specimens were cleaned using a soft hair brush to remove excess debris. Specimens were then placed in 0.1M phosphate buffer (pH 7.3) (Table 2.1) to remove any excess mucous, without damaging the tegument. Clean specimens were dehydrated to absolute ethanol, critical-point dried, sputter coated with gold and studied in a Jeol WinSEM JSM 6400 at 10kV (Grobler 2000).

Table 2.1. Recipe for Phosphate Buffer.

PHOSPHATE BUFFER	
Solution A	
$Na_2HPO_4.12H_2O$	35.814 g/l
or Na_2HPO_4	14.19 g/l
Solution B	
KH_2PO_4	13.610 g/l

Add 80 parts of solution A to 20 parts of solution B. Keep refrigerated (Grobler 2000).

Classification and general morphology of *Caligus* Müller, 1785

The classification of the genus *Caligus* is outlined below, followed by the general morphology of all the somatic regions and appendages associated with this genus. A diagram illustrating the morphological features of an adult *Caligus* is shown in Figure 2.4 and these features are discussed below. The classification of the genus *Caligus* was compiled from various resources. The taxonomy used in this thesis is based on the taxonomy used by Kabata (1979) and Huys and Boxshall (1991).

Classification

Empire	Eukaryota
Kingdom	Animalia
Phylum	Arthropoda
Subphylum	Mandibulata
Infraphylum	Crustacea Pennant, 1777
Class	Maxillopoda Dahl, 1956
Subclass	Copepoda Milne Edwards, 1840
Infraclass	Neocopepoda Boxshall, 1991
Superorder	Podoplea Giesbrecht, 1882
Order	Siphonostomatoida Thorell, 1859
Family	Caligidae Burmeister, 1835
Subfamily	Caliginae Dana, 1852
Genus	*Caligus* Müller, 1785

General morphology

All caligid parasites are of similar shape. The most characteristic feature of representatives of the family Caligidae is the structure of the cephalothorax. These tagma function like sucker-like attachment organs, with anterior and lateral margins sealed by frontal plates and marginal membranes respectively. The posterior rim of the sucker is created by the third pair of legs, the sympods of which form, together with the interpodal bars, a broad lamina, effectively cutting off the concave interior of the sucker from the outside (Kabata 1992). The convex dorsal shield is applied to the fish in the manner of an inverted saucer. The caligid body consists of four tagmata, in addition to the cephalothorax, also the fourth leg-bearing segment, genital complex and abdomen. The structure of *Caligus* can thus be used as a typical example of the family Caligidae.

Cephalothorax

The cephalothorax incorporates the thoracic segments up to and including the third leg-bearing segment (Kabata 1992). It is a roundish or oval structure, covered by a slightly convex dorsal shield, its rims overhanging most of the thoracic appendages, and applied to the surface of the fish in the manner of an inverted saucer. The third pair of leg forms an uninterrupted wall sealing off the posterior end of the cavity formed by the cephalothorax and is a hallmark of representatives of the Caligidae.

Lunules

Located ventrally on the frontal plates at the frontal margin of the cephalothorax, these two semicircular structures function as sensory organs. Many authors have mistakenly identified the lunules as suckers, but the lunules are used in conjunction with the antennules as sensory organs. The lunules develop from the anterior margin from part of the marginal membrane. The cups of the lunules are of different depths, in some species they are very shallow, with incomplete margins (Kabata 1979). The lunules are characteristic of all *Caligus* parasites.

Antennule

The antennule is the first cephalic appendage and of copepods living parasitically on fishes it is more insignificant in size. It has become flat and its base fits neatly under the frontal plate. The sensory function of the antennule was demonstrated by Scott (1901), who found these appendages very richly innervated, each seta receiving a separate branch of the antennular nerve. This author saw the tips of the antennule in *Caligus* repeatedly raised and lowered while the copepod was in motion, and it appeared to palpate the substrate (Kabata 1979).

Antenna

The antenna is the second cephalic appendage and caligid copepods use their piercing antennae to anchor them on the host, in addition to the suction of the inverted saucer-shaped shield. The piercing antennae pull the copepod firmly down onto the host, and thus create a very low-profile shape. To produce suction, the saucer-like cephalothorax must be pressed down, and the downward pressure on the bases of the antenna translates itself into displacement of the elbow-like joint of the appendage and locks in the claws that are inserted into the tissues of the fish. To loosen this grip the suction must be released and the joint unflexed. The copepod is then ready to move (Kabata 1979). Water resistance is minimized by this downward pressure and allows the caligid copepods to cling to their hosts` surfaces without the danger of being swept away by a current of water. The antenna of male specimens usually differ from female specimens, making it one of the important dimorphic characters.

Mouthparts

Copepods parasitic on fishes can be divided into two groups by the type of their mouths, the poecilostomes, and the siphonostomes. The poecilostome mouth is, in effect, a transverse slit and the anterior side of the slit is overhung by the labrum. The mouth of the Cyclopoida is similar to that of the Poecilostomatoida. *Caligus* species have cone-shaped, sucking mouthparts and is formed by partial fusion of the labrum and labium, and is characterised as a siphonostome mouth. This siphonostome mouth is a tube or syphon, built around and above the oesophageal opening and separating it from the buccal rim by a distance equal to the length of the lips (Kabata 1979). The lateral margins of the lips remain separate from each other for a short distance at the base, creating a small triangular opening through which the mandibles enter the buccal cone. The tip of the labium carries a structure known as the strigil, and is armed with about 100 fine sharp teeth. A rhythmic fluctuation in the pressure pushing the tip of the labium into the skin would cause the two halves of the strigil to move away from each other, pivoting on a common base, each divergent move being followed by a convergent one. As can be supposed from their structure, the teeth of the strigil would execute sawing movements, particularly effective during their inward stroke. The resulting accumulation of debris can be picked up from the surface by the movement of the mandibles, the mandibular teeth acting as conveyors moving the fish tissue into the buccal cavity (Kabata 1979).

Mandible

The adults of the caligiform siphonostomes are fairly uniform in the structure of the mandible, which forms the third cephalic appendage. A series of either uniform or varied teeth is usually borne on the blade-like tip. In representatives of the Caligidae the mandible consists of four parts which may or may not correspond to segments (Kabata 1979). In other families mandibular segmentation is often obscure or absent. It was found in the present study that all the species of *Caligus* studied have a mandible consisting of 12 teeth on the blade-like tip, thus omitting this character in the species descriptions.

Maxillule

Forming the fourth cephalic appendage, Lewis (1969) concluded that in "Caligoidea" the true maxillule is the structure which consists at least of a spine and a setiform node or papilla lateral to the mouth cone. Judging from the size and structure of the maxillule in the parasitic Crustacea, the maxillule is no longer directly involved in feeding, and certainly not in the manipulation of food (Kabata 1979). It is not opposable with the other member of the pair and has limited opportunity of contact with the particles of food being ingested. Its setous armature may have a sensory function and therefore be construed as a kind of "taster", searching for food debris, but it is just speculation from Kabata (1979).

Maxilla

The maxilla is the fifth and last cephalic appendage. Kabata (1979) referred to the maxilla as brachiform, in recognition of the superficial resemblance it bears to that of a human arm. The proximal, more robust part of the appendage is described as lacertus, or upper arm. The lacertus articulates with the brachium, or lower arm. The distal end of the brachium is connected with a third flexible and armed rod, the calamus. A similar, shorter rod, the canna, arises from the brachium on the outer side of the calamus. The brachiform maxilla is most frequently used to manipulate the frontal filament during the developmental stages of most siphonostomes (Kabata 1979). In adult Caligidae, the maxilla also assists in movements over the surface of the fish.

Maxilliped

A striking feature in male *Caligus* species is the broad and robust maxilliped. In the siphonostome copepods the maxilliped is a subchelate appendage (Kabata 1979). The corpus, or main body, is a robust structure and unsegmented. The corpus has near its mid-length the myxa, a low swelling that is often armed with a patch of denticles and/or a short spiniform seta or spine.

The corpus articulates with the subchela. The subchela consists of the shaft and claw. The maxilliped functions as a prehensile limb and is probably also associated with feeding. The male uses the maxilliped to grasp the female during mating and might use it also to manipulate and transfer the spermatophores. The female maxilliped is never used in any activity associated with reproduction.

Swimming legs

Fusion of the third leg-bearing segment with the cephalothorax, as in *Caligus*, brings with it extensive modification of the series of swimming legs. The endopod of the first leg is retained as a mere vestige. The second leg shows no changes, but the third leg has been profoundly modified. Expansion of the sympods of this pair, accompanied by a great increase in the width of the interpodal bar results in the development of a broad apron, which extends right across the posterior margin of the dorsal shield. Both rami are reduced and the space between them filled by an oval cuticular flap, the velum. Made watertight along the anterior and lateral margins by a hyaline strip of marginal membrane, the shield is now an inverted saucer-like structure perfectly suited to act as a sucker. The first two pairs work together as locomotory appendages, propelling the copepod along the surface of the fish or through the water (Kabata & Hewitt 1971). The fourth leg remains outside the cephalothoracic shield and is functionally divorced from the preceding legs. It loses its endopod and its exopod is greatly modified. The fifth pair of legs is located on the ventral side of the posterolateral corner of the genital complex and is vestigial. The sixth leg is present normally only in the males and is also vestigial, comprising only three or four setae.

Cuticular spines

Cuticular spines are the most common structures present in parasitic copepods that are attributable to the influence of parasitism. Two well-known cuticular spines in *Caligus* parasites are the postantennary process and the sternal furca.

Postantennary process

In the caligids the postantennary process is a simple, somewhat hooked sclerite with an inflated base, and is always associated with some sensory setules (Kabata 1979). The full functional use of this process is not fully understood. The sensory setules associated with this process vary from species, it was found that in some species the number of setules is constant, while in other species the number may vary. The shape of the process is an important distinguishing character, which may vary from female and male specimens.

Sternal furca

Situated on the ventral surface in the interval between the maxillipeds and the first pair of legs, the sternal furca is a more or less rectangular box of cuticle with an open dorsal wall. By the appropriate action of two pairs of antagonistic muscles attached to the dorsal outgrowths the box can be tilted and the two posterior processes placed at different angles in relation to the surface of the body. The function of the sternal furca is most probably like that of a brake, when the copepod is in danger of slipping backwards over the host, or to assist in raising the arch of the cephalic shield to reduce pressure underneath and augment the force of its suction (Kabata 1979). The sternal furca is an important morphological feature to distinguish between different species of *Caligus*. The sternal furca is usually the same in the female and male, but variations are found in some species where the sternal furca may vary from female and male specimens.

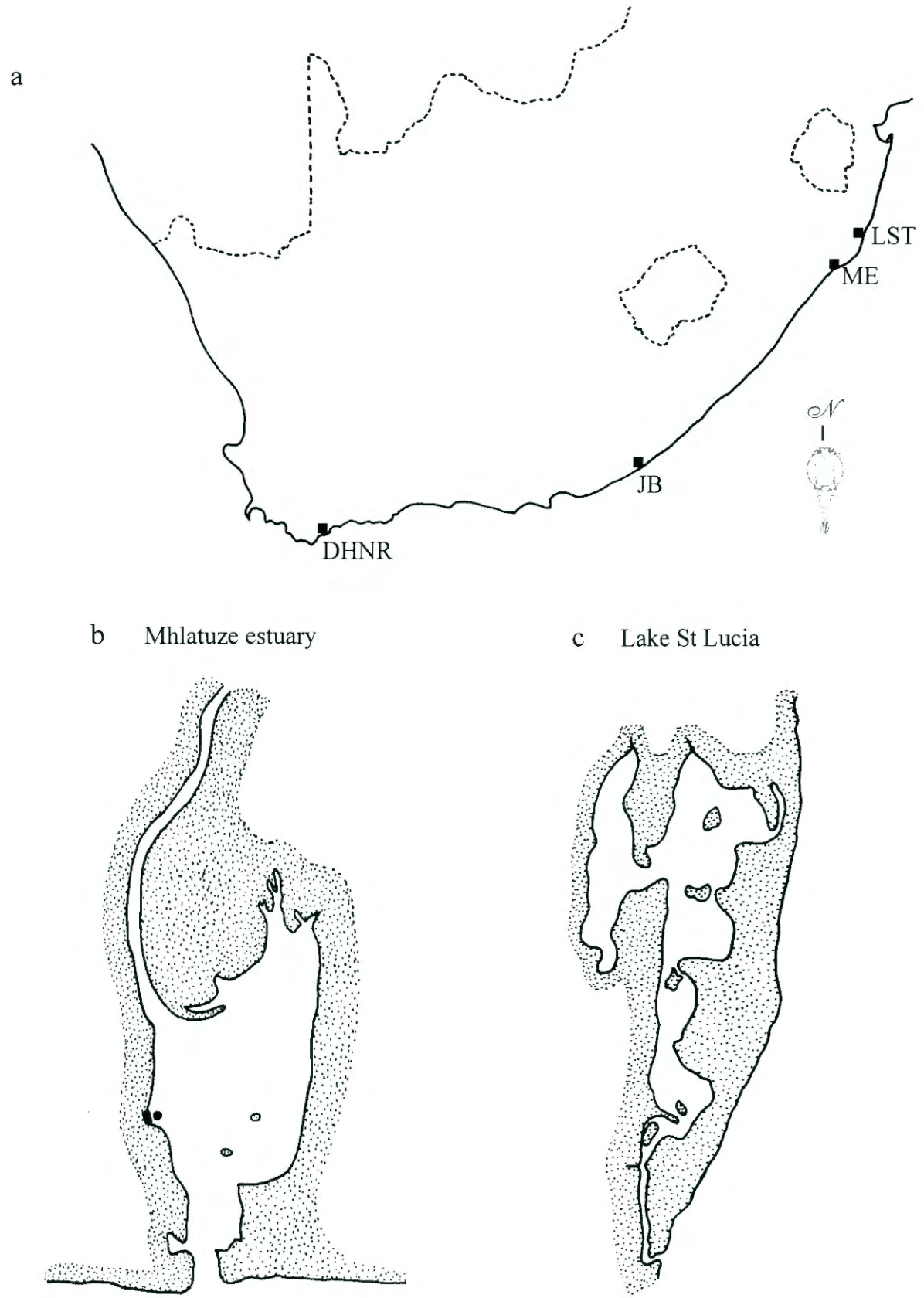


Fig. 2.1. **a.** Diagram illustrating the four collection localities along the South African coastline. **b.** Mhlatuze Estuary. **c.** Lake St Lucia. DHNR-De Hoop Nature Reserve, JB-Jeffreys Bay, LST-Lake St Lucia, ME-Mhlatuze Estuary.

Figs. 2.2a-b. Lake St Lucia. **a.** View of Lake St Lucia. **b.** Gill netting. **Figs. 2.2c-h.** Mhlatuze Estuary. **c.** View of Mhlatuze Estuary. **d.** Small seine. **e.** Medium seine. **f.** Fish collected in medium seine. **g.** Cast net. **h.** Fish collected in cast net.

Figs. 2.3a-c. Mhlatuze Estuary. **a.** Fish removed from gill nets. **b.** Gill netting from boat. **c.** Field laboratory, examining fish hosts for parasitic copepods. **Figs. 2.3d-h.** De Hoop Nature Reserve. **d.** Rocky shoreline. **e.** Intertidal pools. **f.** Cast net used to collect fish in intertidal pools. **g.** Fish collected by fishing rod. **h.** Field laboratory, examining fish hosts for parasitic copepods.

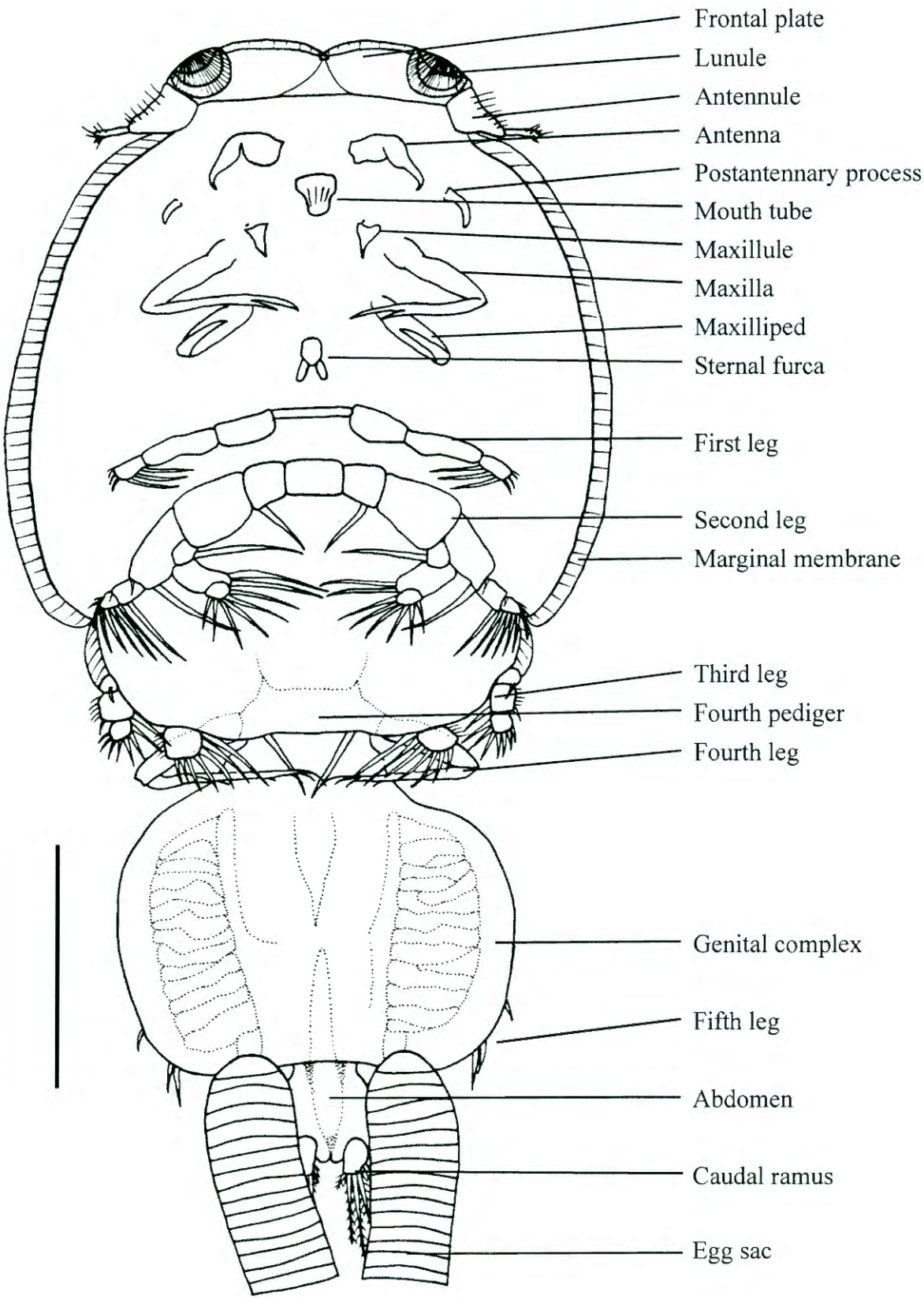


Fig. 2.4. Diagram illustrating the morphological features of an adult female *Caligus acanthopagri* Lin, Ho & Chen, 1994 . Scale bar: 1 mm.

Revision of the South African species of *Caligus*

As discussed in Chapter 1, reference material is only available for 15 species of *Caligus*. Full species descriptions are given for 13 species. Five species, *Caligus engraulidis*, *C. hottentotus*, *C. lalandei*, *C. penrithi*, and *C. tetrodontis*, are redescribed for the first time since their original descriptions. One new species, named *Caligus* sp. A, is described. No species name is given for this new species, until it has been accepted and published in a refereed journal. Another unidentified species, *Caligus* sp. B, is described. The confusion between closely related species must first be sorted out before this species (*Caligus* sp. B) is accepted as a new species. The species descriptions are done alphabetically, while *Caligus epinepheli* and *C. rotundigenitalis* is included after the species description of the two unknown species. These two species are discussed based on scanning electron microscopy studies.

Morphological features are best described and illustrated using the wooden-slide and lactid acid technique described by Humes and Gooding (1964). The use of scanning electron microscopy is, however, a valuable tool supplementing the study of some morphological features to gain additional information and clarify misunderstood features. Six species, including the two species mentioned above, (*Caligus acanthopagri*, *C. confusus*, *C. engraulidis*, *C. epinepheli*, *C. mortis*, and *C. rotundigenitalis*) were studied with the aid of scanning electron microscopy, and the results are discussed below.

***Caligus acanthopagri* Lin, Ho & Chen, 1994**

Figs. 3.1.a-u, 3.2a-d

Caligus acanthopagri: Lin, Ho & Chen, 1994: 253-264, fig. 1A-I, 2A-H, 3A-I, 4A-F; Grobler, Van As & Olivier, 2003: 139-143, figs. 13-16.

Material examined.

South African Museum: Voucher specimens from present study, including five ovigerous females and five males, have been deposited in the collection of the SA Museum, SAM A45161.

Present study: Voucher specimens have been deposited in the collection of the Aquatic Parasitology Research Group, Department of Zoology and Entomology, University of the Free State, Bloemfontein. All specimens were collected from the skin of the hosts and are listed in Table 3.1.

Table 3.1. Total number of *Caligus acanthopagri* Lin, Ho & Chen, 1994 specimens collected from fish hosts in Lake St Lucia and Mhlatuze Estuary, including collection numbers.

Host species	# ♀♀, ♂♂ *Caligus*	Locality	Collection number
Acanthopagrus berda	5 ovig ♀♀, 1 ♀	Lake St Lucia	97/1/21-1
Acanthopagrus berda	10 ovig ♀♀, 2 ♂♂	Lake St Lucia	97/1/21-2
Acanthopagrus berda	14 ovig ♀♀, 4 ♀♀, 7 ♂♂	Lake St Lucia	97/1/21-3
Acanthopagrus berda	19 ovig ♀♀, 7 ♀♀, 5 ♂♂	Lake St Lucia	97/1/21-4
Acanthopagrus berda	124 ovig ♀♀, 30 ♀♀, 69 ♂♂	Lake St Lucia	97/1/21-5
Acanthopagrus berda	1 ovig ♀, 2 ♂♂	Lake St Lucia	97/1/21-6
Acanthopagrus berda	1 ♀, 1 ♂	Lake St Lucia	97/1/21-8
Acanthopagrus berda	23 ovig ♀♀, 7 ♀♀, 19 ♂♂	Lake St Lucia	97/1/21-11
Acanthopagrus berda	123 ovig ♀♀, 5 ♀♀, 37 ♂♂	Lake St Lucia	14/64-66
Acanthopagrus berda	6 ovig ♀♀, 6 ♂♂	Lake St Lucia	15/029
Acanthopagrus berda	20 ovig ♀♀, 2 ♀♀, 2 ♂♂	Lake St Lucia	16/078
Rhabdosargus holubi	11 ovig ♀♀, 5 ♀♀, 3 ♂♂	Lake St Lucia	97/1/21-10A
Acanthopagrus berda	15 ovig ♀♀, 1 ♂	Mhlatuze Estuary	20/06/01-01
Acanthopagrus berda	5 ovig ♀♀, 1 ♂	Mhlatuze Estuary	20/06/01-02
Acanthopagrus berda	19 ovig ♀♀, 1 ♂	Mhlatuze Estuary	20/06/01-04
Rhabdosargus holubi	1 ♂	Mhlatuze Estuary	19/06/01-02

Description.

Female. Body (Fig. 3.1a) 3.11 (2.83-4.17) mm long. Cephalothoracic shield longer than wide, 1.98 (1.81-2.42) x 1.73 (1.62-2.13) mm, excluding lateral hyaline membranes. Fourth pediger wider than long, 0.22 (0.17-0.30) x 0.47 (0.40-0.55) mm. Genital complex slightly wider than long, 0.91 (0.70-1.13) x 0.96 (0.83-1.21) mm. Abdomen one-segmented, slightly longer than wide, 0.34 (0.28-0.38) x 0.32 (0.27-0.39) mm. Caudal ramus (Fig. 3.1n) wider than long, 83.6 (70.7-99.6) x 101.4 (80.4-116.9) µm. Posterior margin of each ramus armed with two outer, one small, medial and three large terminal plumose setae.

Antennule. Two-segmented (Fig. 3.1b). Proximal segment trapezoid, much broader than distal segment, with 30 plumose setae on anterodistal margin. Distal segment rod-shaped, much longer than wide, armed with one subterminal seta on posterior margin and 11 setae and two aesthetascs on distal margin.

Antenna. Three-segmented (Fig. 3.1c). Proximal segment smallest with posteromedial process. Second segment largest, robust. Distal segment a strongly curved hook, bearing one basal seta and one seta in middle region.

Postantennary process. Hook-like (Fig. 3.1d), with two basal papillae each bearing three long setules and one similar papilla located nearby on sternum.

Maxillule. Dentiform (Fig. 3.1e), slightly curved, with papilla bearing three setae.

Maxilla. Two-segmented, brachiform (Fig. 3.1f). Proximal segment (lacertus) unarmed. Distal segment (brachium) slender with medium sized flabellum with both margins serrated and two unequal elements (a short canna and a longer calamus) terminally, canna and calamus with both margins serrated.

Maxilliped. Three-segmented (Fig. 3.1g). Proximal segment (corpus) stout, unarmed. Second (shaft) and distal (claw) segments fused to form subchela, claw strong with basal seta.

Sternal furca. Base longer than wide (Fig. 3.1h), with parallel and bluntly pointed tines, tines just more than half the length of base.

Leg 1. Protopod (Fig. 3.1i) with one medium sized, plumose seta on posterior margin and another smaller plumose seta on anterodistal margin. Endopod vestigial, bearing minute element distally. Exopod two-segmented. First segment with row of setules on posterior margin and small, spiniform seta on anterodistal corner. Second segment with four terminal elements (elements two and three each with accessory process, elements one, two and three naked, fourth element four times as long as element one, naked) and three equal plumose setae on posterior margin.

Leg 2. Coxa small (Fig. 3.1j), with spinule bearing papilla on ventral surface and large plumose inner seta on posterior margin. Protopod with anterodistal small, naked seta, patch of fringed anterodistal membrane, posterior margin covered by a striated membrane, with one centrally situated seta. Exopod three-segmented. First segment with one anterodistal, curved spine, both margins of spine with striated membrane, posterior margin with one plumose seta. Second segment with one anterodistal spine, both margins of spine with striated membrane, posterior margin with one long plumose seta. Third segment with three spines on anterodistal margin (first spine smallest, naked, second spine hyaline element, third spine with striated membrane along outer margin and plumose inner margin) and five long, plumose setae. Endopod three-segmented. First segment with one long, plumose seta. Second segment with two long, plumose setae. Third segment with six plumose terminal setae. Second and third segments with prominent patches of spinules on the ventral surface.

Leg 3. Anterior margin of protopod more sclerotised than the rest of the segment, bearing a striated membrane and two medial naked setules (Fig. 3.1k). Exopod three-segmented. First

segment with large terminal claw. Second segment with one anterodistal spine and one posterodistal plumose seta. Third segment with three spines of different lengths and four plumose setae. Second and third segment with rows of setules on lateral margins. Endopod two-segmented. First segment expanded laterally into velum on outer margin and bearing one long, plumose seta on posterior margin. Second segment with six long, plumose setae, rows of setules on lateral margins.

Leg 4. Protopod (Fig. 3.1l) with small, plumose anterodistal seta. Exopod two-segmented. First segment bearing terminal spine with both margins serrated. Second segment with one subterminal and three terminal spines, all with both margins serrated. All exopod spines with basal pecten.

Armature on rami of legs 1-4:

	Exopod	Endopod
Leg 1	1-0; III, 1, 3	(vestigial)
Leg 2	I-1; I-1; I, II, 5	0-1; 0-2; 6
Leg 3	I-0; I-1; III, 4	0-1; 6
Leg 4	I-0; I, III	(missing)

Leg 5. Represented by two papillae (Fig. 3.1m) on posterolateral corner of genital complex, one tipped with small plumose seta, other with two similar plumose setae.

Male. Body (Fig. 3.1o) 4.67 (4.13-5.48) mm long. Cephalothoracic shield longer than wide, 3.08 (2.63-3.59) x 2.57 (2.21-2.76) mm, excluding lateral hyaline membranes. Fourth pediger wider than long, 0.37 (0.31-0.42) x 0.63 (0.47-0.72) mm. Genital complex slightly wider than long, 0.73 (0.66-0.84) x 0.75 (0.65-0.87) mm. Abdomen two-segmented. First segment wider than long, 0.25 (0.21-0.31) x 0.35 (0.31-0.40) mm, with laterally protruded distal margin. Second segment wider than long, 0.26 (0.23-0.31) x 0.35 (0.30-0.41) mm. Caudal ramus (Fig. 3.1u) wider than long, 127.7 (112.8-141.7) x 138.2 (129.1-154.6) µm. Armature of caudal ramus as in female.

Antenna. Three-segmented (Fig. 3.1p). Proximal segment unarmed. Second segment large, robust, with corrugated medial and ventral surfaces. Distal segment smallest, armed terminally with a seta and a hyaline plate.

Postantennary process. Hook-like (Fig. 3.1q), with two basal papillae each bearing three long setules and one similar papilla located nearby on sternum.

Maxillule. Dentiform (Fig. 3.1r), almost straight, with papilla bearing three setae.

Maxilliped. Three-segmented. Corpus bearing four unequal ridges on medial margin (Fig. 3.1s). Claw with strong basal seta.

Leg 5. Represented by two papillae (Fig, 3.1t) on posterolateral margin of genital complex, one tipped with medium sized plumose seta, other with two similar plumose setae.

Leg 6. Represented by one papilla (Fig. 3.1t) on posterolateral margin of genital complex, tipped with two medium sized plumose setae.

Remarks. Caligus acanthopagri bears closest resemblance to *C. latigenitalis* that was first recorded by Shiino (1954) from the body surface of *Acanthopagrus schlegelii* (Bleeker, 1854) in Japan. The only discernible morphological difference between these two closely allied species is the fine structure on the distal end of the exopod of leg 4. In *C. acanthopagri* the distal end of the exopod of leg 4 is equipped with two corner processes with two hyaline membranes, but in *C. latigenitalis* there are two short, but heavy, digital processes.

Caligus acanthopagri displays an unusual feature for copepods in that the males are on average distinctly larger than the female. The most characteristic features of *C. acanthopagri* are the possession of a short one-segmented abdomen, an accessory process on the middle two of the terminal four elements on the exopod of leg 1, and a slender, two-segmented exopod bearing an armature of I-0; I, III on leg 4. Lin *et al.* (1994) separated *C. acanthopagri* from five species, based on the three features mentioned above. *Caligus acanthopagri* can be easily distinguished from *C. dieuzeidei* Brian, 1933 in the structures of the postantennary process, maxillule and caudal ramus; from *C. glandifer* Shiino, 1954 in the size of the genital double somite (as large as the carapace in *C. glandifer*); from *C. latigenitalis* in the fine structure on the distal end of the exopod of leg 4; from *C. russellii* Kurian, 1952 in the structures of the maxilliped and sternal furca; and from *C. willungae* Kabata, 1965 in the structures of the carapace and caudal ramus. Grobler *et al*. (2003) reported *Caligus acanthopagri* for the first time from the South African coastline.

SEM study. The outer spine on the first segment of leg 4 bears a basal pecten (Fig. 3.2a). The bases of the three terminal spines of leg 4 exopod have also basal pecten (Fig. 3.2b). A posterior extension of the proximal segment of the antennule on the dorsal side in the male of *C. acanthopagri* is shown in Figure 3.2c. Lin *et al.* (1994) did not mention anything about this extension, but from the drawing in their species description it is evident that their specimen did have the extension of the antennule. This feature has not been observed in any other *Caligus* species studied. The sternal furca (Fig. 3.2d) has parallel and bluntly pointed tines. The tines are just more than half the length of the base.

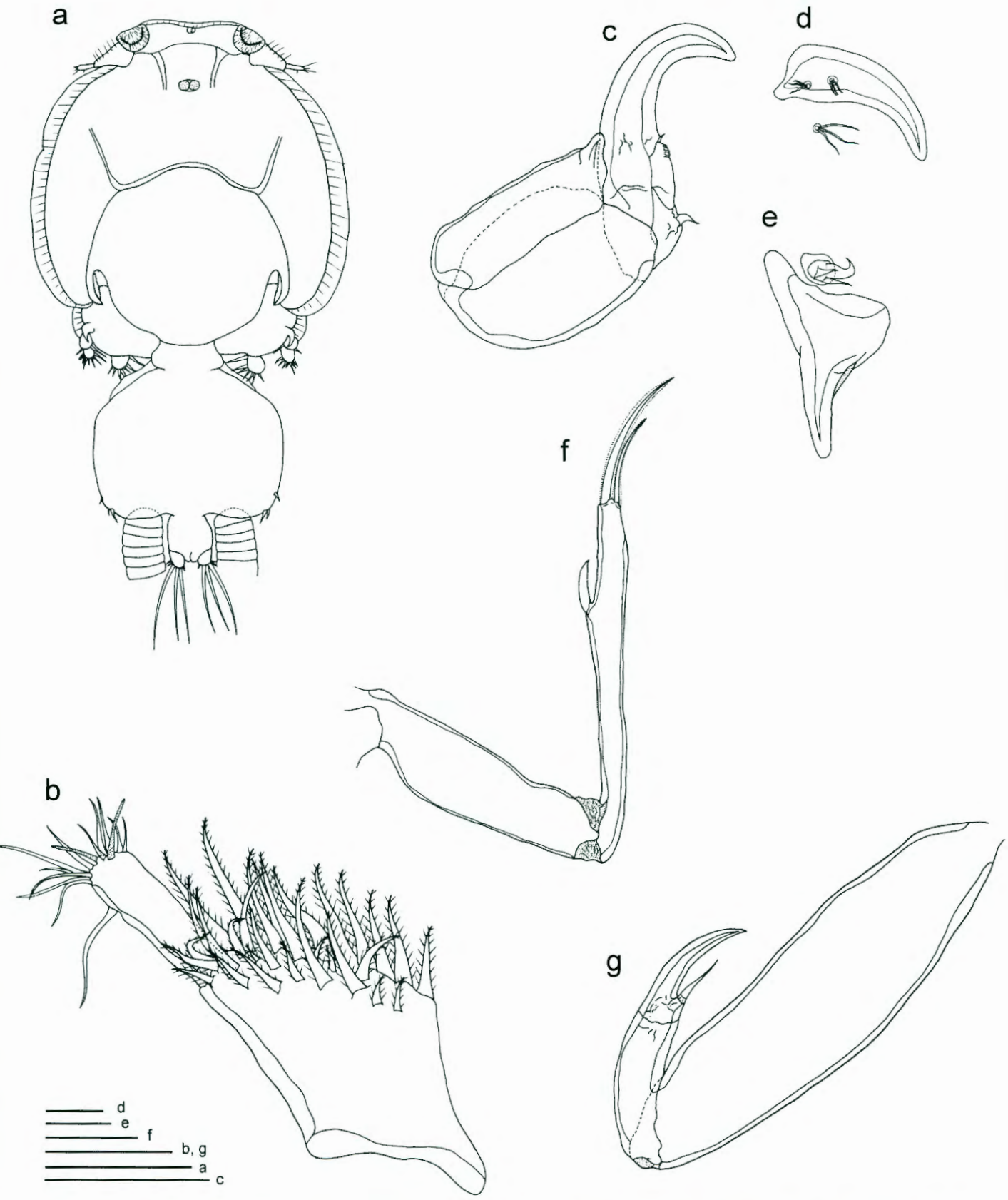


Fig. 3.1. *Caligus acanthopagri* Lin, Ho & Chen, 1994, female. **a.** habitus, dorsal. **b.** antennule, ventral. **c.** antenna, ventral. **d.** postantennary process, ventral. **e.** maxillule, ventral. **f.** maxilla. **g.** maxilliped. Scale bars: 1 mm in a; 100 μm in b, c, f, g; 50 μm in d, e.

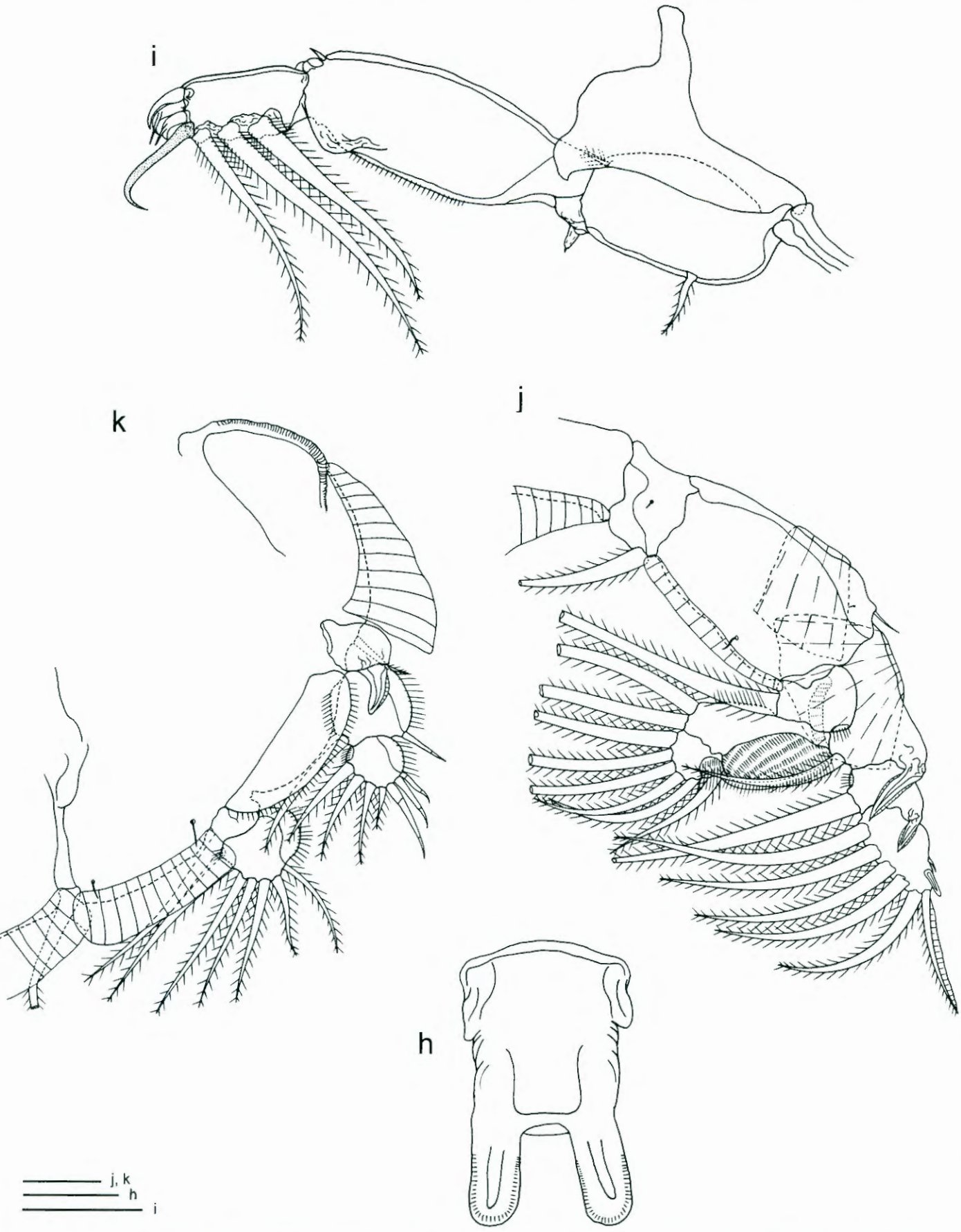


Fig. 3.1. (cont.) *Caligus acanthopagri* Lin, Ho & Chen, 1994, female. **h.** sternal furca. **i.** leg 1, ventral. **j.** leg 2, ventral. **k.** leg 3, ventral. Scale bars: 100 µm in i-k; 50 µm in h.

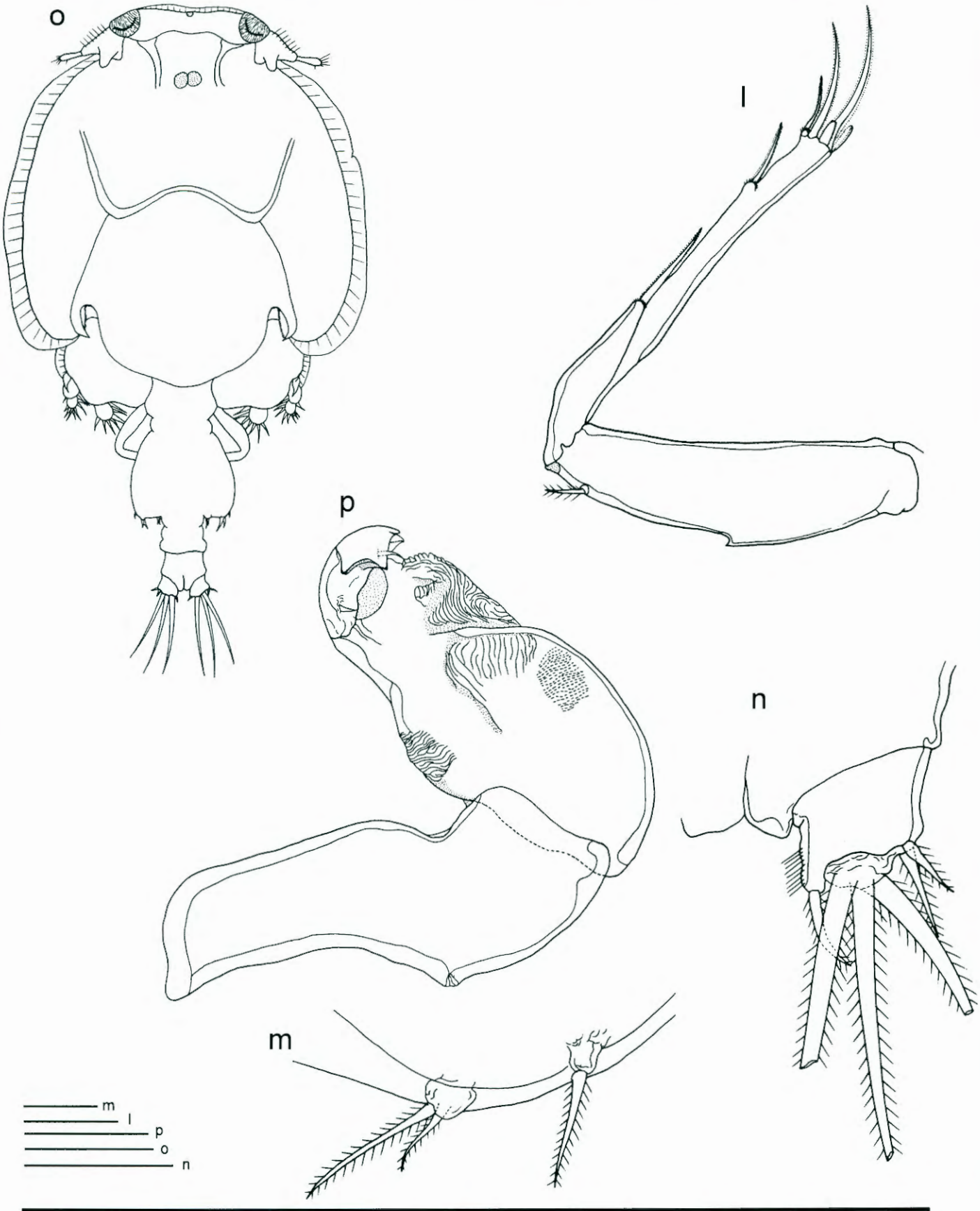


Fig. 3.1. (cont.) *Caligus acanthopagri* Lin, Ho & Chen, 1994, female. **l.** leg 4, ventral. **m.** posterolateral side of genital complex, showing leg 5, ventral. **n.** caudal ramus, ventral. *Caligus acanthopagri*, male. **o.** habitus, dorsal. **p.** antenna, ventral. Scale bars: 1 mm in o; 100 µm in l, n, p; 50 µm in m.

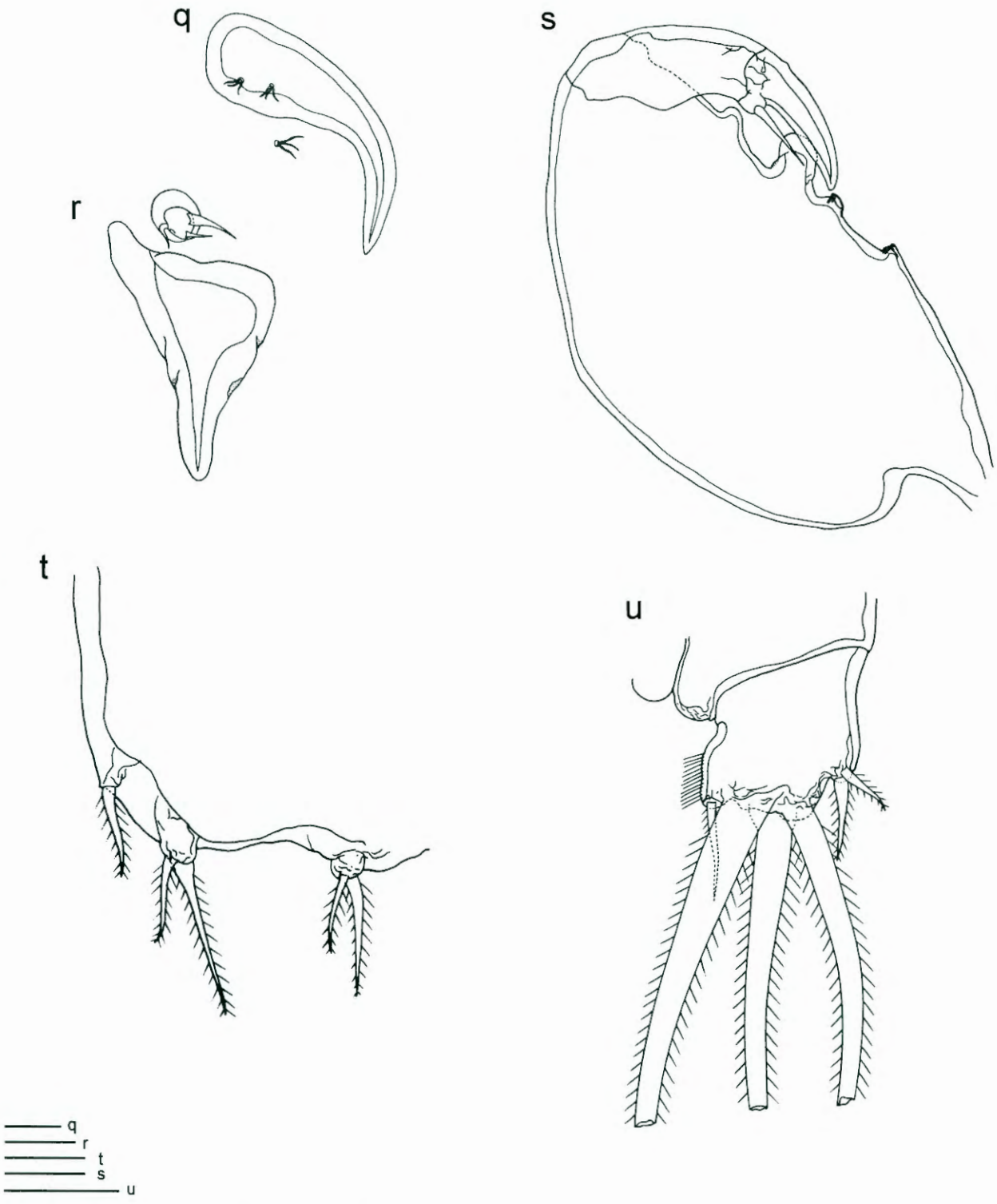
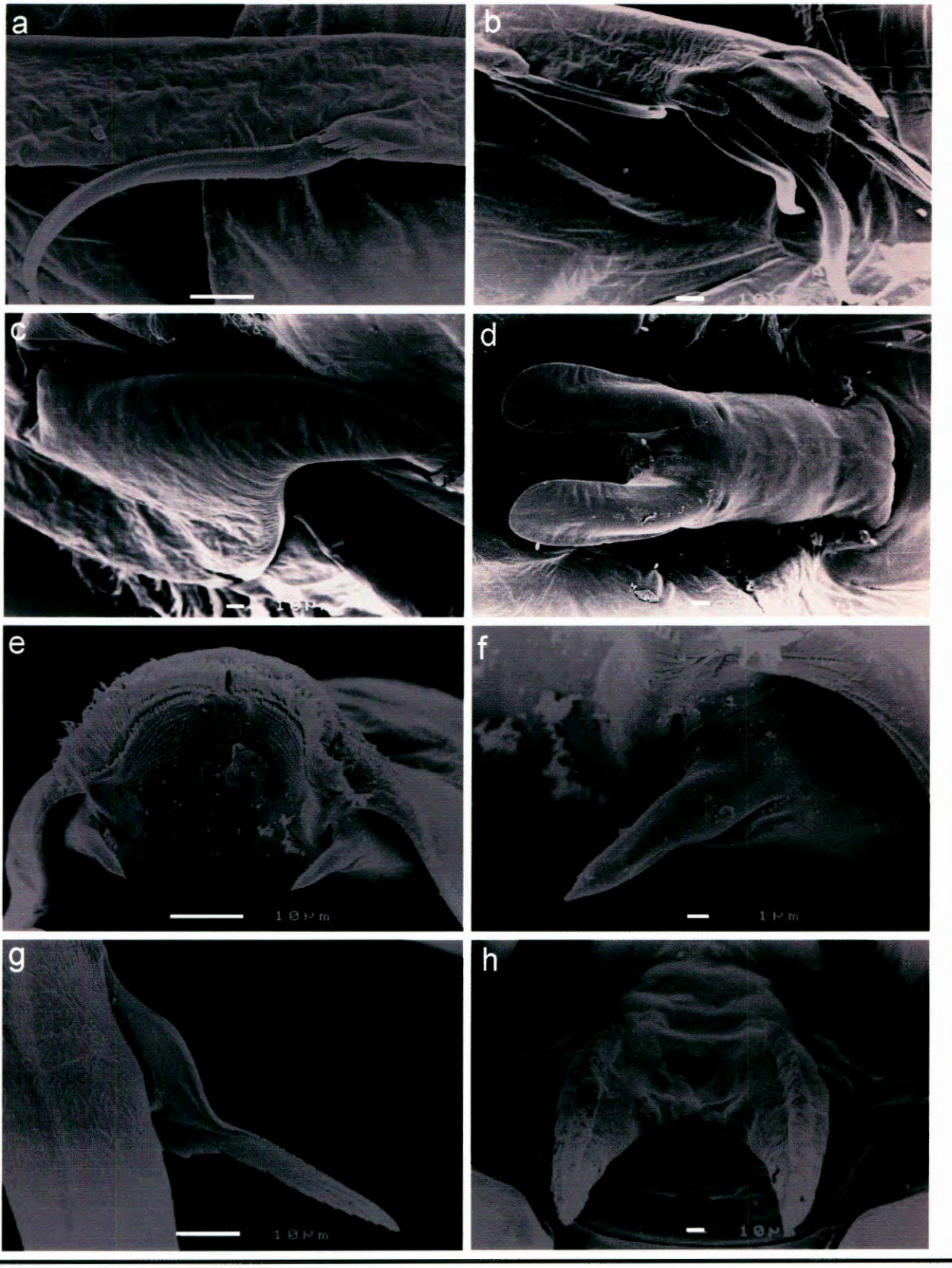


Fig. 3.1. (cont.) *Caligus acanthopagri* Lin, Ho & Chen, 1994, male. **q.** postantennary process. **r.** maxillule. **s.** maxilliped. **t.** posterolateral side of genital complex, showing leg 5 and leg 6, ventral. **u.** caudal ramus, ventral. Scale bars: 100 μm in s, u; 50 μm in q, r, t.



Figs. 3.2a-d. Scanning electron micrographs of *Caligus acanthopagri* Lin, Ho & Chen, 1994, male. **a.** outer spine on the first segment of leg 4. **b.** three terminal spines on leg 4 exopod with basal pecten. **c.** posterior extension of the proximal segment of the antennule. **d.** sternal furca. **Figs. 3.2e-h.** *Caligus confusus* Pillai, 1961, female. **e.** pair of buccal stylets on roof of labrum. **f.** buccal stylet. **g.** serrated flabellum on brachium of maxilla. **h.** sternal furca. Scale bars: 100 µm in c; 10 µm in a, b, d, e, g, h; 1 µm in f.

Caligus aesopus Wilson, 1920

Figs. 3.3a-u

Caligus aesopus: Wilson, 1920: 72-74, plate 3, figs. 8-10, plate 4, figs. 11-13; Hewitt, 1963: 61, 71-78, 114, plate 4, figs. 1-8, plate 5, figs. 1-6; Yamaguti, 1963: 49, plate 53, figs. 3a-e; Kensley & Grindley, 1973: 74, 75, figs. 3d-f.

Material examined.

South African Museum: SAM A45005: Two females collected from the body surface of *Seriola lalandi* Valenciennes, 1833, False Bay. SAM A12994: Three ovigerous females, 19 females and two males from body surface of *S. lalandi*, False Bay.

Present study: No specimens of this species were collected in the present study.

Description.

Female. Body (Fig. 3.3a) 4.26 (3.60-4.80) mm long. Cephalothoracic shield slightly wider than long, 1.99 (1.67-2.20) x 2.03 (1.67-2.21) mm, excluding lateral hyaline membranes. Fourth pediger wider than long, 0.41 (0.27-0.47) x 0.59 (0.53-0.67) mm. Genital complex longer than wide, 1.30 (0.70-1.63) x 0.91 (0.67-1.17) mm. Abdomen one-segmented, slightly longer than wide, 0.49 (0.33-0.60) x 0.46 (0.33-0.61) mm. Caudal ramus (Fig. 3.3n) as long as wide, 92.9 (83.3-100) x 92.9 (83.3-100) µm. Posterior margin of each ramus armed with two outer, one small medial and three large terminal plumose setae.

Antennule. Two-segmented (Fig. 3.3b). Setae missing on proximal and distal segments. Proximal segment trapezoid, much broader than distal segment, with 20 plumose setae. Distal segment rod-shaped, much longer than wide, armed with one subterminal seta on posterior margin and seven setae and one aesthetasc on distal margin.

Antenna. Three-segmented (Fig. 3.3c). Proximal segment with spatula-like process on posteromedial corner. Second segment subrectangular and unarmed. Distal segment a curved claw bearing one small seta in middle region.

Postantennary process. Basal part of process with two setules-bearing papillae and two tooth-like outgrowths opposite to each other (Fig. 3.3d). Another similar papilla located nearby on sternum. Claw flattened and fringed with membrane.

Maxillule. Dentiform (Fig. 3.3e) with conical process on outer margin. Basal papilla with three short setae.

Maxilla. Two-segmented (Fig. 3.3f). Proximal segment (lacertus) unarmed. Distal segment (brachium) carrying small flabellum with both margins serrated and two unequal elements (a short canna and a longer calamus) terminally, canna and calamus with both margins serrated.

Maxilliped. Three-segmented (Fig. 3.3g). Proximal segment (corpus) largest but unarmed. Second (shaft) and distal (claw) segments fused to form subchela, claw sharply pointed, with basal seta. Second segment bearing a conical process distally.

Sternal furca. Base subrectangular (Fig. 3.3h). Tines shorter than base, with blunt tips. Distal part of inner borders parallel, diverging inwards, small serrations subterminally.

Leg 1. Protopod (Fig. 3.3i) with one long, plumose seta on posterior margin and another small, plumose seta on anterodistal margin. Endopod vestigial, tipped with minute element distally. Exopod two-segmented. First segment with row of setules on posterior margin and small, spiniform seta on anterodistal corner. Second segment with four terminal elements (elements two and three each with accessory process, elements one, two and three with both margins serrated, fourth element naked) and three plumose setae on posterior margin.

Leg 2. Coxa small (Fig. 3.3j), with spinule bearing papilla on ventral surface and large plumose inner seta on posterior margin. Protopod with anterodistal small, naked seta, patch of fringed anterodistal membrane, posterior margin covered by a striated membrane, with one centrally situated seta. Exopod three-segmented. First segment with one anterodistal, curved spine, both margins of spine serrated, posterior margin with one long, plumose seta. Second segment with one anterodistal spine, both margins of spine serrated, posterior margin with one long, plumose seta. Third segment with three spines on anterodistal margin (first spine smallest, outer margin of spine with striated membrane, second spine with serrated inner margin, third spine with striated membrane along outer margin and plumose inner margin) and five long, plumose setae. Endopod three-segmented. First segment with one long, plumose seta. Second segment with two plumose setae and a crest of prominent setules on outer and inner margin. Third segment with six plumose terminal setae and a crest of setules on outer corner.

Leg 3. Anterior margin of protopod more sclerotised than the rest of the segment, bearing a striated membrane (Fig. 3.3k). Row of denticles above exopod. Circlet of strong teeth (ten in total) above endopod and apically bifid projecting rib inner to teeth. Exopod three-segmented. First segment with large, strongly curved, terminal claw. Second segment with one anterodistal spine and one posterodistal plumose seta. Third segment with three spines of different lengths and four plumose setae of equal length. Second and third segment with rows of setules on lateral margins. Endopod two-segmented. First segment expanded laterally into velum on outer margin and bearing one long, plumose seta on posterior margin. Second segment with six long, plumose setae.

Leg 4. (Fig. 3.3l) Protopod with small, plumose anterodistal seta. Exopod three-segmented. First and second segments bearing terminal spines with both margins finely serrated. Third segment bearing three terminal spines, all with both margins finely serrated. All exopod spines with basal pecten.

Armature on rami of legs 1-4:

	Exopod	Endopod
Leg 1	1-0; IV, 3	(vestigial)
Leg 2	I-1; I-1; II, I, 5	0-1; 0-2; 6
Leg 3	I-0; I-1; III, 4	0-1; 6
Leg 4	I-0; I-0; III	(missing)

Leg 5. Represented by two papillae (Fig. 3.3m) on posterolateral corner of genital complex, one tipped with small plumose seta, other with two similar plumose setae.

Male. Body (Fig. 3.3o) 3.86 (3.85-3.88) mm long. Cephalothoracic shield slightly wider than long, 2.16 (2.15-2.17) x 2.23 (2.21-2.25) mm, excluding lateral hyaline membranes. Fourth pediger wider than long, 0.31 (0.30-0.31) x 0.67 (0.66-0.67) mm. Genital complex longer than wide, 0.83 (0.81-0.84) x 0.71 (0.70-0.72) mm. Abdomen one-segmented, slightly wider than long, 0.53 (0.52-0.54) x 0.55 (0.55-0.56) mm. Caudal ramus (Fig. 3.3u) wider than long, 108.3 (107.6-109) x 125 (124.8-125.2) μm. Armature of caudal ramus as in female.

Antenna. Three-segmented (Fig. 3.3p). Proximal segment unarmed. Second segment with spatula-like process on posteromedial corner. Distal segment a curved claw bearing one seta in middle region. No corrugated patches.

Maxillule. Dentiform process bifid (Fig. 3.3q). Basal papilla with two short and one longer setae.

Maxilliped. Three-segmented (Fig. 3.3r). Corpus large and unarmed. Claw sharply pointed, with strong basal seta.

Leg 5. Represented by two papillae (Fig. 3.3s) on posterolateral corner of genital complex, one tipped with small plumose seta, other with similar plumose seta and one dentiform process-bearing seta.

Leg 6. Represented by two papillae (Fig. 3.3t) on posterolateral corner of genital complex, both tipped with small plumose setae.

Remarks. In comparing the *Caligus* species from South Africa, it was found that the female of *C. aesopus* is closest to *C. confusus*; 1) in having a relatively small abdomen in comparison with the genital complex; 2) an antennule with a long distal segment, 3) bearing an accessory process on the dentiform process of the maxillule, and 4) both species being in group 1 based on the armature of the exopod of the fourth leg. However, *Caligus aesopus* is distinguishable from *C. confusus* in having the genital complex smaller than the cephalothoracic shield, and having 10 strong teeth on the protopod of the third leg, whereas *C. confusus* has 15 strong teeth. *Caligus aesopus* was only collected from the Yellowtail, *Seriola lalandi*, and has not been recorded since the collection by Kensley and Grindley (1973).

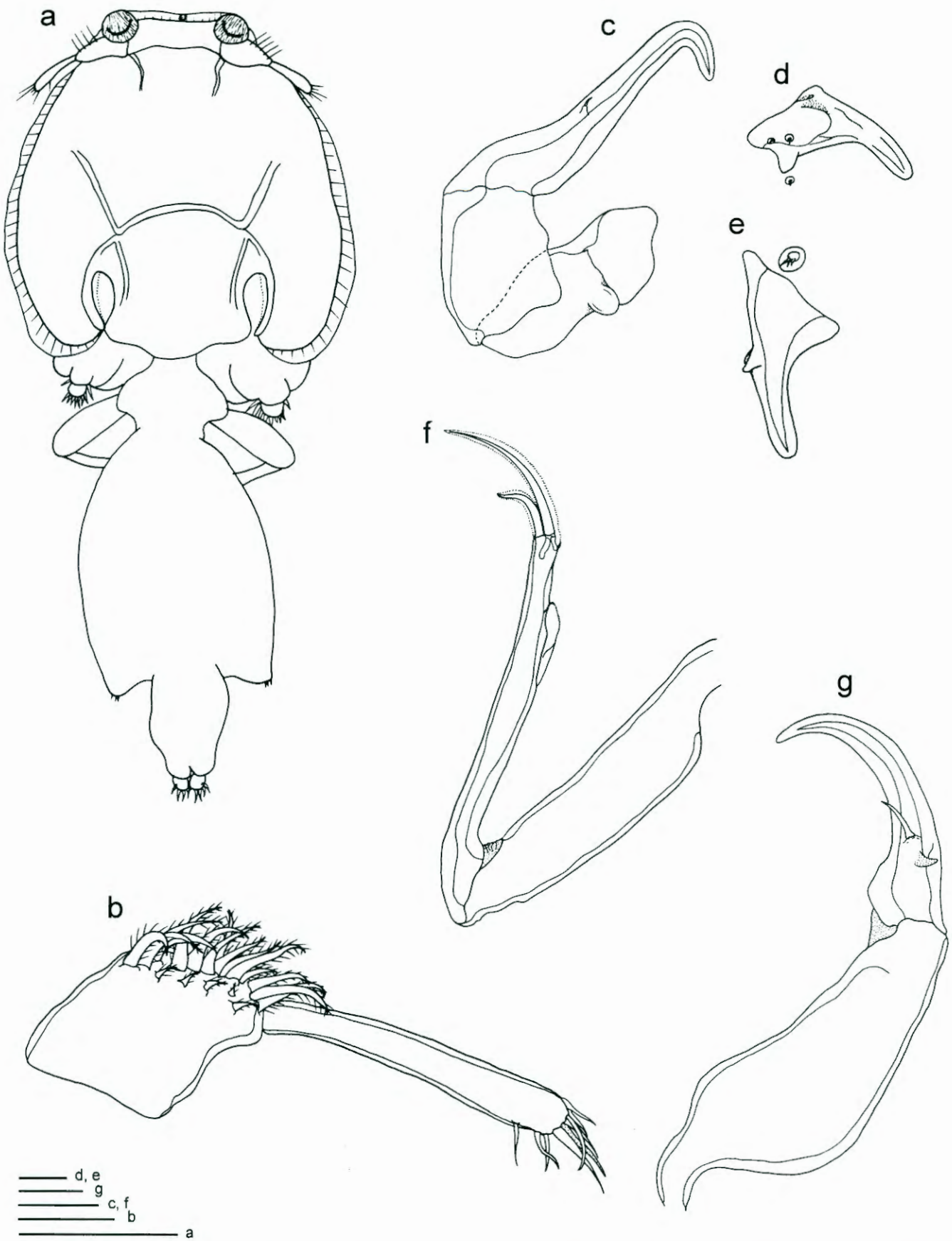


Fig. 3.3. *Caligus aesopus* Wilson, 1920, female. **a.** habitus, dorsal. **b.** antennule, ventral. **c.** antenna, ventral. **d.** postantennary process, ventral. **e.** maxillule, ventral. **f.** maxilla. **g.** maxilliped. Scale bars: 1 mm in a; 100 μm in b, c, f, g; 50 μm in d, e.

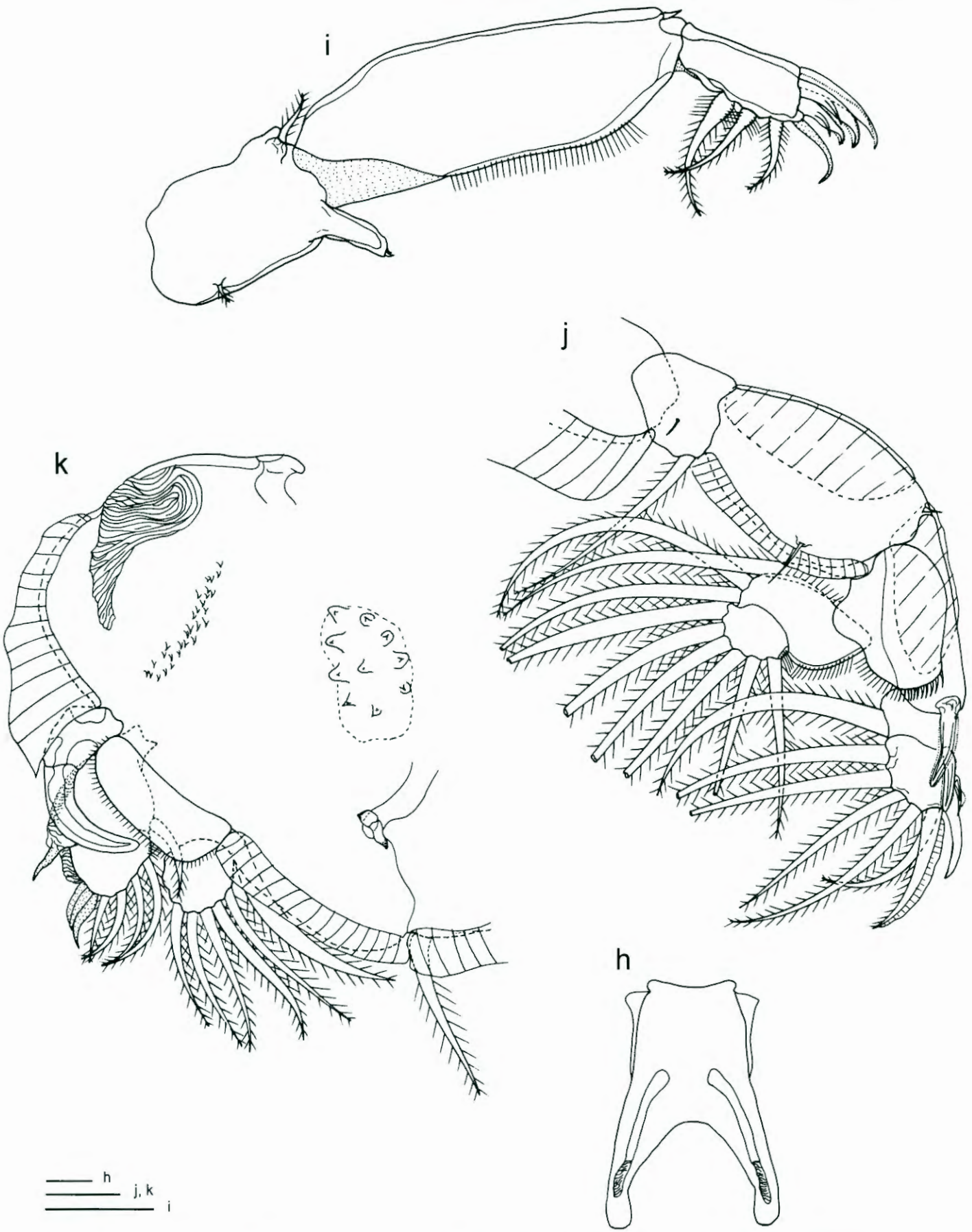


Fig. 3.3. (cont.) *Caligus aesopus* Wilson, 1920, female. **h.** sternal furca. **i.** leg 1, ventral. **j.** leg 2, ventral. **k.** leg 3, ventral. Scale bars: 100 μm in i-k; 50 μm in h.

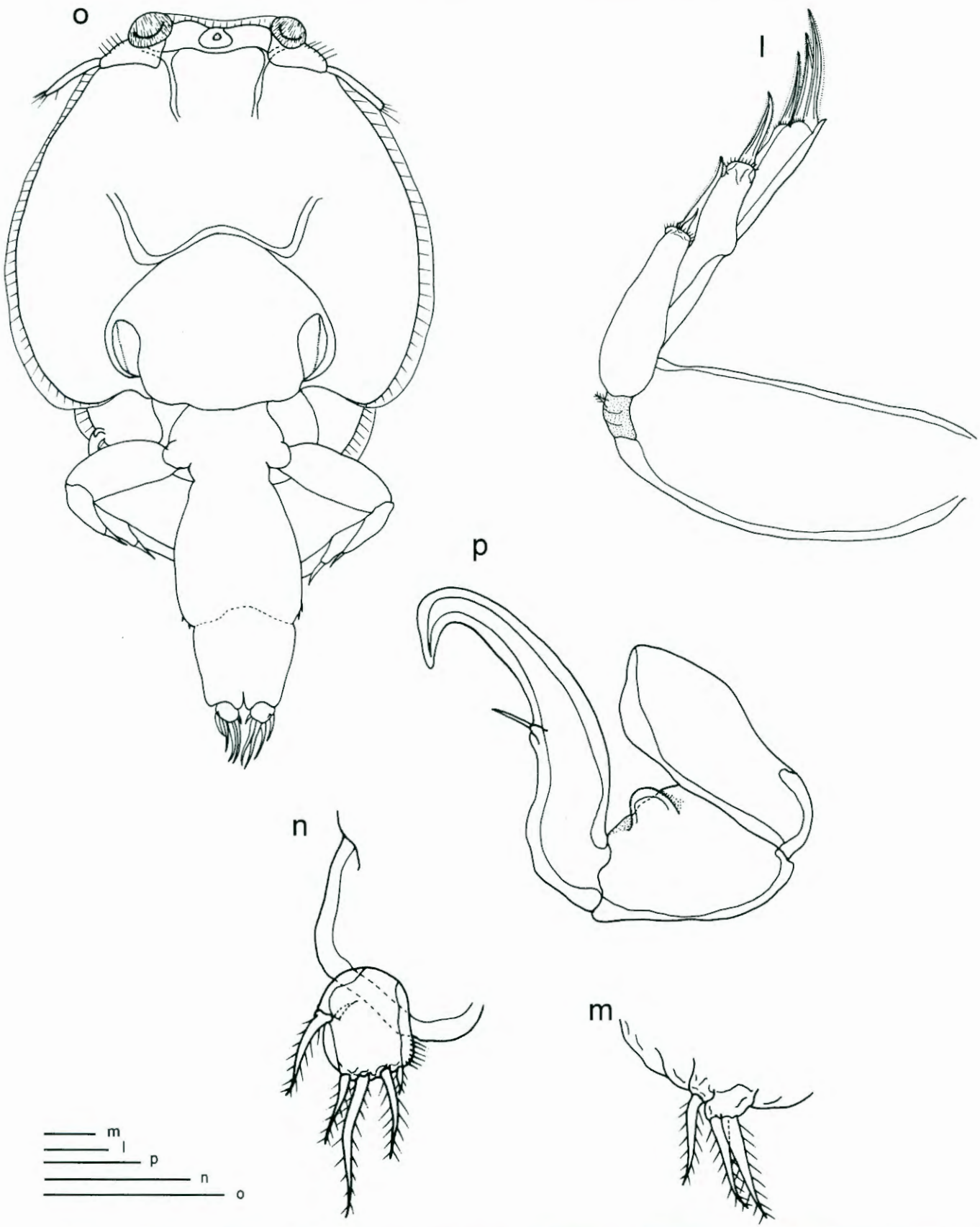


Fig. 3.3. (cont.) *Caligus aesopus* Wilson, 1920, female. **l.** leg 4, ventral. **m.** posterolateral side of genital complex, showing leg 5, ventral. **n.** caudal ramus, ventral. *Caligus aesopus*, male. **o.** habitus, dorsal. **p.** antenna, ventral. Scale bars: 1 mm in o; 100 µm in l, p; 50 µm in m, n.

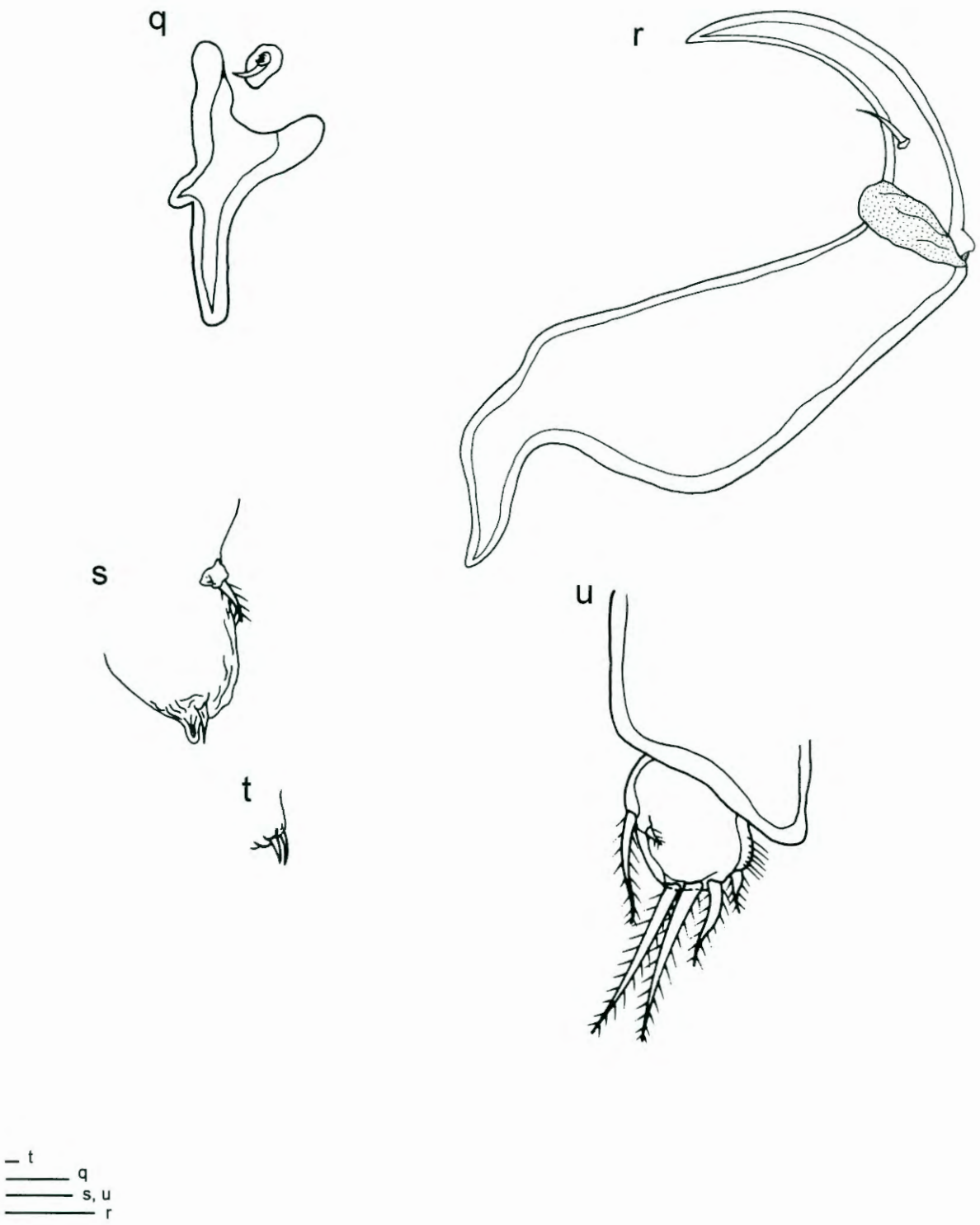


Fig. 3.3. (cont.) *Caligus aesopus* Wilson, 1920, male. **q.** maxillule. **r.** maxilliped. **s.** posterolateral side of genital complex, showing leg 5, ventral. **t.** leg 6, ventral. **u.** caudal ramus, ventral. Scale bars: 100 μm in r; 50 μm in q, s, u; 10 μm in t.

Caligus confusus Pillai, 1961

Figs. 3.2e-h, 3.4a-t, 3.5a-h

Caligus confusus: Pillai, 1961: 104, figs. 10A-P; Pillai, 1963: 83; Kirtisinghe, 1964: 68-69, 127, figs. 70-71; Pillai, 1967: 1580, 1671, fig. 44; Kabata, 1968: 9, 10, fig. 3f; Lewis, 1968: 53-59, figs. 22a-i, 23a-g; Ho & Lin, 2001: 177-201, fig. 1A-G, fig. 2 A-E, fig. 3A-E; Grobler, Van As & Olivier, 2003: 139-143, figs. 1-8, figs. 9-12.

Material examined.

South African Museum: SAM A12995: Two females collected from the operculum of *Alepes djedaba* Forsskål, 1775, Durban. Voucher specimens from present study, two ovigerous females and two males, have been deposited in the collection of the SA Museum, SAM A45162.

Present study: Voucher specimens have been deposited in the collection of the Aquatic Parasitology Research Group, Department of Zoology and Entomology, University of the Free State, Bloemfontein. All specimens were collected from the gills and operculum of the hosts and are listed in Table 3.2.

Table 3.2. Total number of *Caligus confusus* Pillai, 1961 specimens collected from fish hosts in Lake St Lucia, including collection numbers.

Host species	# ♀♀, ♂♂ *Caligus*	Locality	Collection number
Caranx sexfasciatus	2 ♀♀, 1 ♂	Lake St Lucia	6/046
Caranx sexfasciatus	1 ♀, 1 ♂	Lake St Lucia	8/046
Caranx sexfasciatus	6 ovig ♀♀, 3 ♂♂	Lake St Lucia	10/12
Caranx sexfasciatus	2 ovig ♀♀, 2 ♂♂	Lake St Lucia	10/13
Rhabdosargus holubi	2 ovig ♀♀, 1 ♂	Lake St Lucia	8/044

Description.

Female. Body (Fig. 3.4a) 5.11 (4.64-5.28) mm long. Cephalothoracic shield slightly longer than wide, 2.01 (1.79-2.23) x 1.97 (1.76-2.21) mm, excluding lateral hyaline membranes. Fourth pediger wider than long, 0.32 (0.27-0.37) x 0.56 (0.51-0.62) mm. Genital complex with neck-like narrow part in anterior and protruded posterolateral portion, 2.42 (2.04-2.67) x 1.18 (0.91-1.28) mm. Abdomen one-segmented, longer than wide, 0.49 (0.38-0.57) x 0.41 (0.34-0.48) mm. Caudal ramus (Fig. 3.4n) small, slightly longer than wide, 51.7 (49.2-52.9) x 47.1 (45.1-48.7) µm.

Posterior margin of each ramus armed with two small outer, one small medial and three large terminal plumose setae.

Antennule. Two-segmented (Fig. 3.4b). Proximal segment shorter than distal segment and armed with 27 plumose setae on anterior surface. Distal segment rod-shaped, much longer than wide, armed with one subterminal seta on posterior margin and 12 setae and two aesthetascs on distal margin.

Antenna. Three-segmented (Fig. 3.4c). Proximal segment small with hyaline membrane on posterior surface. Second segment with medial corrugated patch. Distal segment a curved claw bearing one small basal seta.

Postantennary process. Basal part of process with two setules-bearing papillae and a tooth-like outgrowth on medial surface (Fig. 3.4d). Another similar papilla located nearby on sternum. Process heavily sclerotized and fringed with membrane.

Maxillule. Dentiform (Fig. 3.4e), bearing two tooth-like basal outgrowths. Process proper with hyaline membrane. Basal papilla with three short setae.

Maxilla. Two-segmented (Fig. 3.4f). Proximal segment (lacertus) unarmed. Distal segment (brachium) carrying large flabellum (Fig. 3.2g) with both margins serrated and two unequal elements (a short canna and a longer calamus) terminally, canna and calamus with both margins serrated.

Maxilliped. Three-segmented (Fig. 3.4g). Proximal segment (corpus) large, with heavily sclerotized transverse ridge across middle region. Second (shaft) and distal (claw) segments fused to form subchela, claw sharply pointed with basal seta.

Sternal furca. Base rectangular (Fig. 3.2h, 3.4h) with cuneiform outgrowth at anterodistal corners. Tines divergent and pointed.

Leg 1. Protopod (Fig. 3.4i) with one long, plumose seta on posterior margin and another small, plumose seta on anterodistal margin. Endopod vestigial, tipped distally with 2 small elements. Exopod two-segmented. First segment with row of setules on posterior margin and small, spiniform seta on anterodistal corner. Second segment with four terminal elements (elements two and three each with accessory process (Fig. 3.5a), elements one, two and three with both margins serrated, element four naked) and three different sized plumose setae on posterior margin.

Leg 2. Coxa small (Fig. 3.4j), with three spinule-bearing papillae on anterior surface and large, plumose inner seta on posterior margin. Protopod with anterodistal small, naked seta, patch of fringed anterodistal membrane, posterior margin covered by a striated membrane, with one centrally situated seta. Exopod three-segmented. First segment with one anterodistal, curved spine, both margins of spine serrated, posterior margin with one plumose seta. Second segment

with one anterodistal, curved spine, both margins of spine serrated, posterior margin with one plumose seta. Third segment with three spines on anterodistal margin (first spine smallest with both margins serrated, second spine with striated membrane on both margins, third spine with striated membrane along outer margin and plumose inner margin) and five long, plumose setae. Endopod three-segmented. First segment protruded laterally and armed with row of teeth, and one long, plumose seta. Second segment with two plumose setae and a crest of prominent setules on outer and inner margin. Third segment with six plumose terminal setae and crest of setules on outer corner.

Leg 3. Anterior margin of protopod more sclerotised than the rest of the segment, bearing a striated membrane (Fig. 3.4k). Circlet of strong teeth (15 in total) above endopod and apically bifid projecting rib inner to teeth (Fig. 3.5b). Exopod three-segmented. First segment with large terminal claw, strongly curved. Second segment with one anterodistal spine and one posterodistal plumose seta. Third segment with three spines of different lengths and four plumose setae. Second and third segments with rows of setules on lateral margins. Endopod two-segmented. First segment expanded laterally into velum on outer margin and bearing one long, plumose seta on posterior margin. Second segment with six long, plumose setae, and row of setules on lateral margin.

Leg 4. Protopod (Fig. 3.4l) with small plumose anterodistal seta. Exopod three-segmented (Fig. 3.5c). First and second segments bearing terminal spines with both margins finely serrated. Third segment bearing three terminal spines with both margins finely serrated. All exopod spines with basal pecten.

Armature on rami of legs 1-4:

	Exopod	Endopod
Leg 1	1-0; III, 1, 3	(vestigial)
Leg 2	I-1; I-1; II, I, 5	0-1; 0-2; 6
Leg 3	I-0; I-1; III, 4	0-1; 6
Leg 4	I-0; I-0; III	(missing)

Leg 5. Represented by two papillae (Fig. 3.4m) on posterolateral margin of genital complex, one tipped with small plumose setae, other with two similar plumose setae and another isolated, plumose seta anterior to leg 5.

Male. Body (Fig. 3.4o) 2.64 (2.33-2.81) mm long. Cephalothoracic shield slightly longer than wide, 1.57 (1.36-1.69) x 1.53 (1.41-1.61) mm, excluding lateral hyaline membranes. Fourth pediger wider than long, 0.22 (0.20-0.25) x 0.40 (0.35-0.43) mm. Genital complex (Fig. 3.5d) slightly longer than wide, 0.55 (0.47-0.61) x 0.51 (0.44-0.58) mm. Abdomen one-segmented, wider than long, 0.26 (0.22-0.29) x 0.40 (0.34-0.45) mm. Caudal ramus (Fig. 3.4t) different from female in being wider than long, 71.6 (68.6-74.1) x 83.4 (77.9-85.8) µm, but with similar armature, only difference is the length of the one outer plumose seta which is much longer than the smaller one.

Antenna. Three-segmented (Fig. 3.4p). Proximal segment with large corrugated patch on medial surface. Second segment with corrugated medial and ventral surfaces. Distal segment a large claw bearing basal seta.

Maxillule. Dentiform process (Fig. 3.4q) with two corrugated patches in basal region.

Maxilliped. Three-segmented (Fig. 3.4r). Corpus large and robust, not bearing sclerotized ridge as in female. Second segment (shaft) unarmed. Claw long, sharply pointed, with strong basal seta.

Leg 5. Represented by two papillae (Figs. 3.4s, 3.5e) on posterolateral margin of genital complex, one tipped with small plumose setae, other with two similar plumose setae and another isolated, plumose seta anterior to leg 5.

Leg 6. Represented by two papillae (Figs. 3.4s, 3.5f) on posterolateral corner of genital complex, one tipped with small plumose seta, other with two similar plumose setae.

Remarks. Caligus confusus was described by Pillai in 1961 from *Scomber sansun* Forsskål, 1775. Kensley and Grindley (1973) collected three female *C. confusus* specimens from the gill chambers of *Alepes djedaba* from Durban, with a total length of 4.0 mm. These South African specimens were much larger than those specimens described by Pillai (1961) from Indian waters, where the female was only 2.9 mm in length and the male 1.8 mm in length. The females in the present study are even larger than those collected by Kensley and Grindley (1973).

In comparing the *Caligus* species from South Africa, it was found that *C. confusus* is closest to *C. aesopus*, in 1) having a relatively small abdomen in comparison with the genital complex; 2) an antennule with a long distal segment, bearing an accessory process on the dentiform process of the maxillule; 3) both species being in group 1 based on the fourth leg (refer to page 143). However, *Caligus confusus* is distinguishable from *C. aesopus* in having the genital complex larger than the cephalothoracic shield, and having 15 strong teeth on the protopod of the third leg, whereas *C. aesopus* has 10 strong teeth. *Caligus confusus* has been found on many different carangid hosts, but has not been recorded from the host *Caranx sexfasciatus*. These caligids were collected from

the gill chambers of both *Caranx sexfasciatus* and *Rhabdosargus holubi* in the Lake St Lucia system (Grobler *et al*. 2003).

SEM study. The roof of the labrum carries a pair of buccal stylets (Figs. 3.2e, f). These stylets are found in only three of the siphonostome families, namely Pennelidae, Lernaeopodidae and the Caligidae. Kabata (1979) only mentioned the buccal stylets and no direct function of these structures were given. It is suggested that it may be used to pierce the skin of the host when the mouth tube is attached to the hosts` skin for feeding or act as a hold fast for the mouth when the strigil is used to rasp off skin debris with its sawing movements. On the mid-length of the brachium of the maxilla a flap of striated membrane is situated. This flap is known as the flabellum and is finely serrated on both margins (Fig. 3.2g). The sternal furca has a squarish base (Fig. 3.2h). Its tines are about the length of the base, with outer borders parallel and inner borders diverging. The second segment of leg 1 exopod has four dissimilar terminal elements. Elements two and three (Fig. 3.5a) are armed with a spiniform accessory process, equaling to half the length of the elements. The strong teeth and bifid projecting rib (Fig. 3.5b) on the protopod of leg 3 that are used for accessory adhesion is characteristic of this species. These structures are also found on *Caligus aesopus* and *C. constrictus* Heller, 1968, but the teeth patch is much longer than in *C. confusus*. The exopod of leg 4 is three-segmented (Fig. 3.5c). The first segment bears two outer setules and one spine, with the second segment bearing one spine. The third segment bears three terminal spines of different lengths.

The male is remarkably smaller than the female. The genital complex (Fig. 3.5d) carries the rudimentary leg 5 (Fig. 3.5e) and leg 6 (Fig. 3.5f) on the posterolateral margin. Leg 5 (Fig. 3.5e) consists of four setae, one isolated plumose seta and two papillae, one with one plumose seta, and other with two plumose setae on posterolateral margin of genital complex. Leg 6 (Fig. 3.5f) consists of three setae, two papillae on posterolateral corner of genital complex, one papilla bearing one plumose seta, and other with two plumose setae. Patterns on the dorsal shield of the male of *C. confusus* were also observed (Figs. 3.5g, h). No such patterns were observed in any other *Caligus* species studied to date. Small setae (Fig. 3.5h) were also observed. These patterns and setae were observed only in the male, and the function of these secondary features are not fully understood.

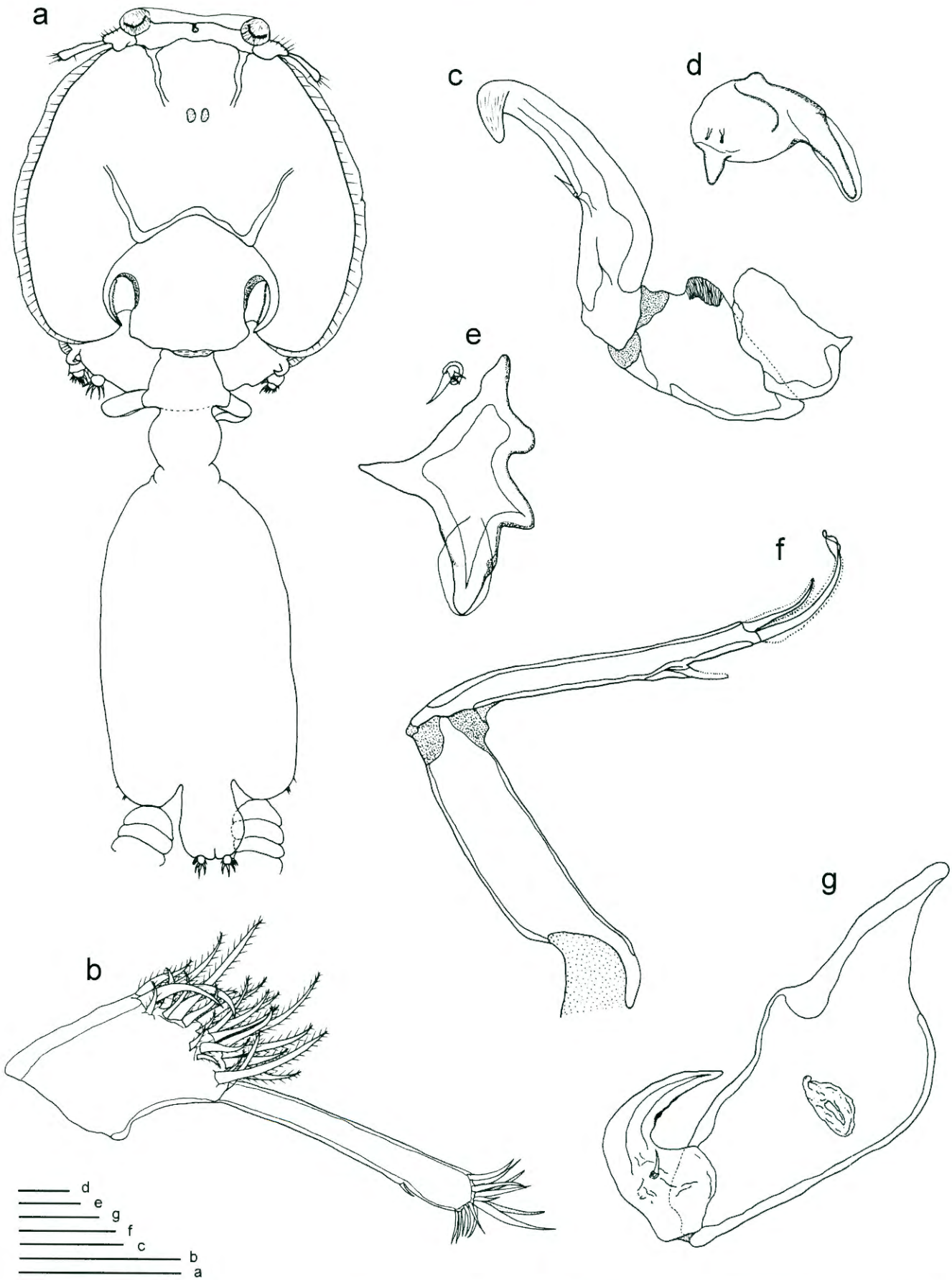


Fig. 3.4. *Caligus confusus* Pillai, 1961, female. **a.** habitus, dorsal. **b.** antennule, ventral. **c.** antenna, ventral. **d.** postantennary process, ventral. **e.** maxillule, ventral. **f.** maxilla. **g.** maxilliped. Scale bars: 1 mm in a; 100 µm in b, c, f, g; 50 µm in d, e.

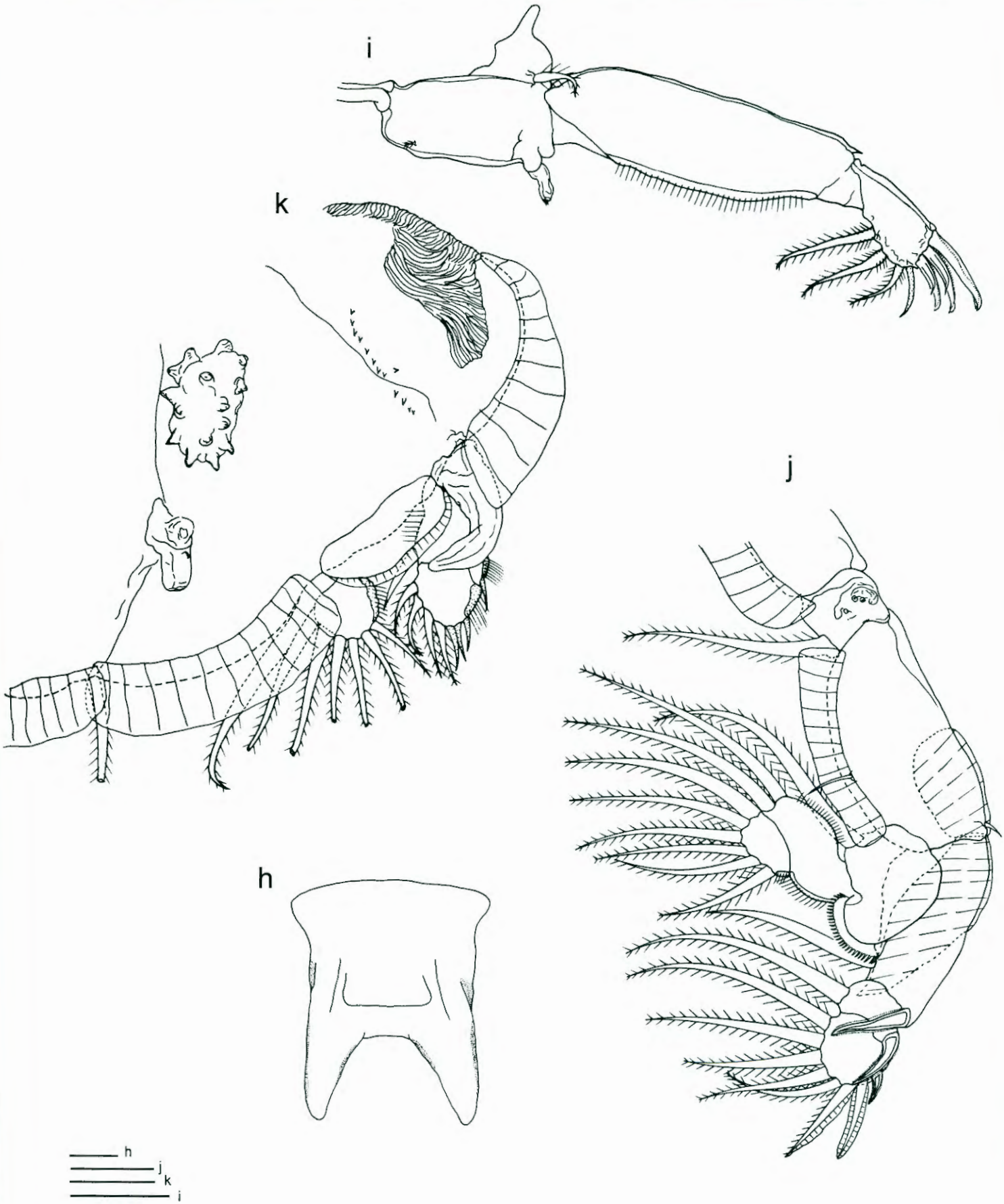


Fig. 3.4. (cont.) *Caligus confusus* Pillai, 1961, female. **h.** sternal furca. **i.** leg 1, ventral. **j.** leg 2, ventral. **k.** leg 3, ventral. Scale bars: 100 µm in i-k; 50 µm in h.

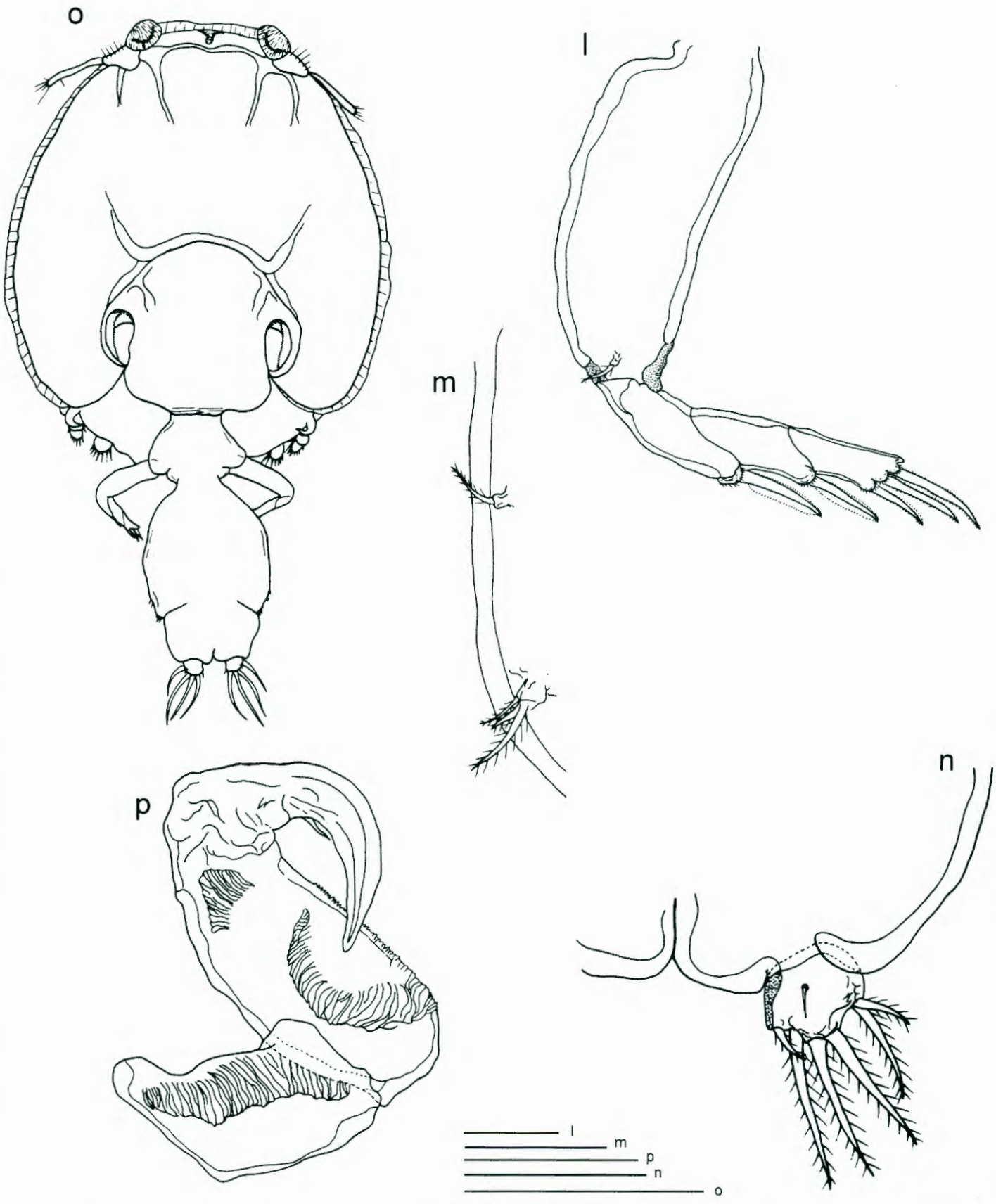


Fig. 3.4. (cont.) *Caligus confusus* Pillai, 1961, female. **l.** leg 4, ventral. **m.** posterolateral side of genital complex, showing leg 5, ventral. **n.** caudal ramus, ventral. *Caligus confusus*, male. **o.** habitus, dorsal. **p.** antenna, ventral. Scale bars: 1 mm in o; 100 μm in l-n, p.

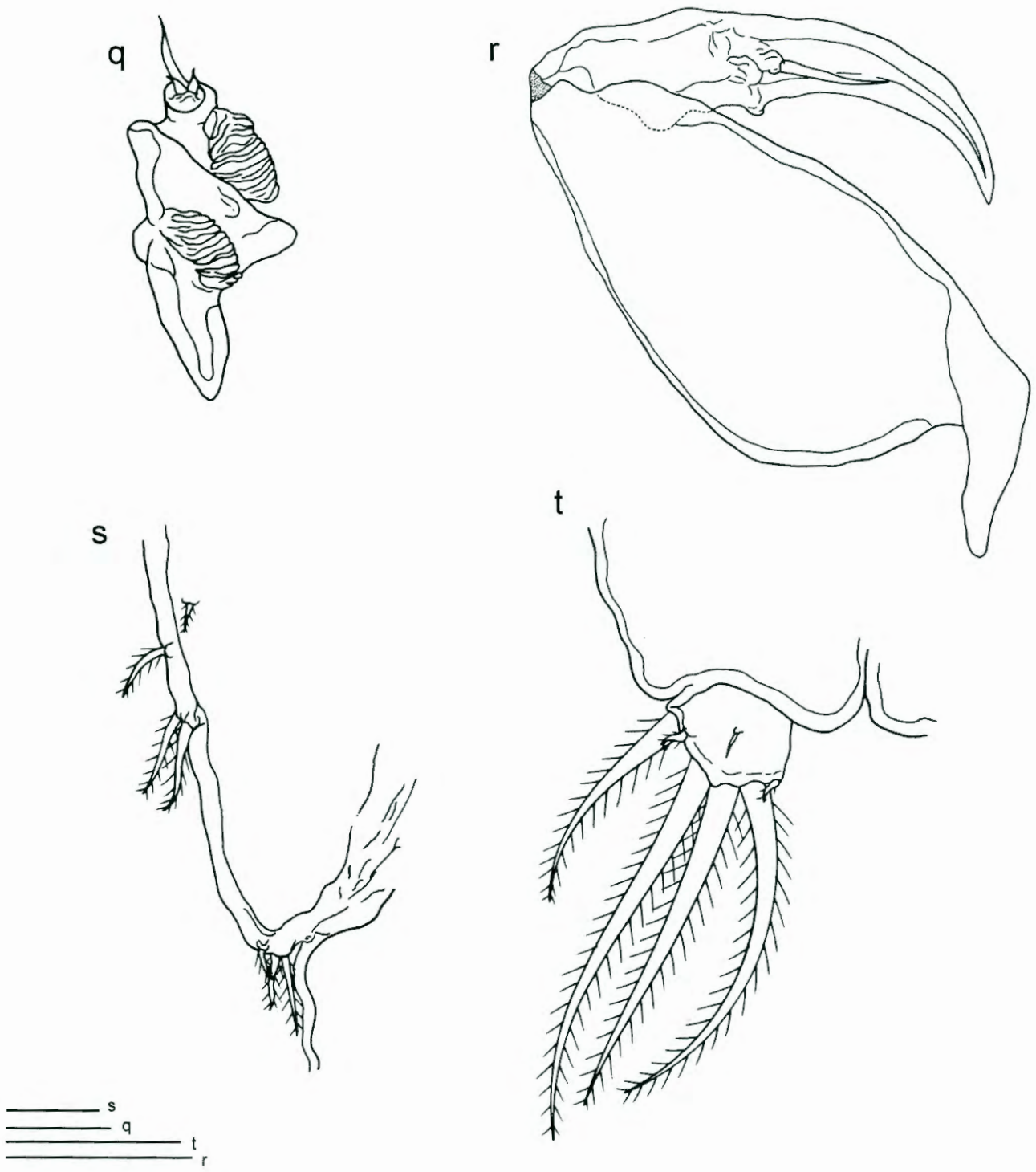
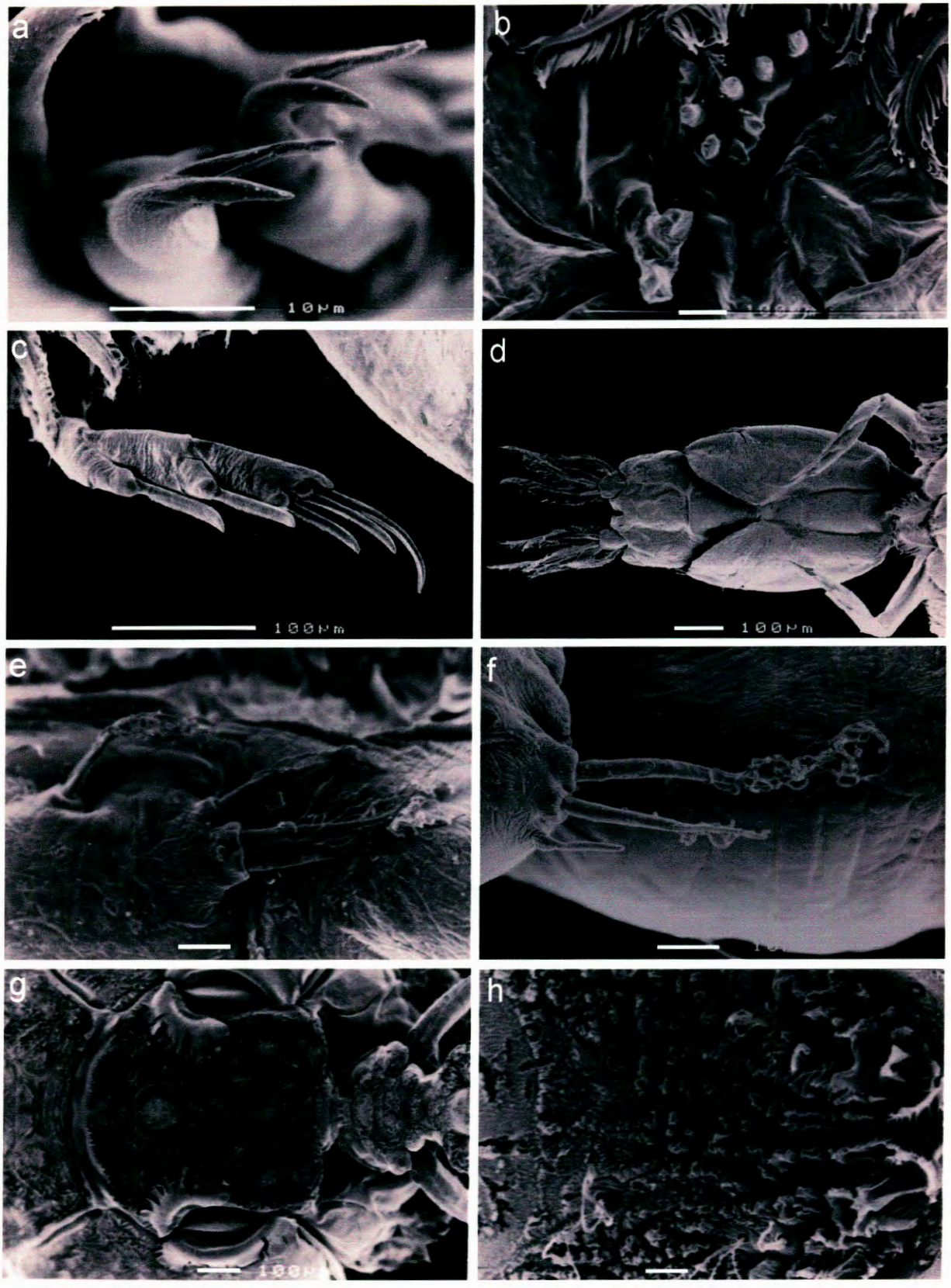


Fig. 3.4. (cont.) *Caligus confusus* Pillai, 1961, male. **q.** maxillule. **r.** maxilliped. **s.** posterolateral side of genital complex, showing leg 5 and leg 6, ventral. **t.** caudal ramus, ventral. Scale bars: 100 µm in r, t; 50 µm in q, s.



Figs. 3.5a-c. Scanning electron micrographs of *Caligus confusus* Pillai, 1961, female. **a.** elements 2 and 3 with spiniform secondary process of leg 1 exopod. **b.** teeth and bifid projecting rib on protopod of leg 3. **c.** leg 4 exopod. **Figs. 3.5d-h.** *Caligus confusus*, male. **d.** genital complex, abdomen and caudal rami, ventral view. **e.** leg 5. **f.** leg 6. **g.** patterns on dorsal side. **h.** patterns with small sensory setae. Scale bars: 100 µm in b, c, d, g; 10 µm in a, e, f, h.

Caligus coryphaenae Steenstrup & Lütken, 1861

Figs. 3.6a-t

Caligus coryphaenae: Steenstrup & Lütken, 1861: 352, 354, 360-362, 429, plate IV (fig. 7); Brian, 1935: 152, 202-204, 206, fig. XIX (1, 2, 9), XX (3-8); Yamaguti, 1936: 5-6, 19, plate IV (figs. 40-54); Heegaard, 1949: 240-244, figs. 6-10; Barnard, 1955a: 244-246, figs. 8a-d; Shiino, 1959a: 1-8, 22-25, figs. 1A-J, 2A-I; Shiino, 1959b: 267, 294-297, figs. 12A-K; Kurian, 1961: 66-67, 68-70, figs. 16-24; Ho, 1963: 82-84, 96, figs. 4, 5; Pillai, 1963: 513-522, figs. 1A-J; Shiino, 1963: 336-337, fig. 1; Yamaguti, 1963: 49, 51, 59, plate 59 (figs. 3a-c); Kirtisinghe, 1964: 50-52, fig. 10-21; Lewis, 1967: 1, 91, 101-109, 130, 190, 191, 192, figs. 37a-i, 38a-f, 39a-f; Pillai, 1967: 1574, 1672, fig. 28; Silas & Ummerkutty, 1967: 877, 884-886, 897, 903, 945-946, 947, 957, 965, 992, fig. 3 (1-14); Kensley & Grindley, 1973: 75, 76, figs. 4a-f; Cressey, 1991: 7, 30, figs. 77-81.

Material examined.

South African Museum: SAM A11753: One ovigerous female and three males from *Katsuwonus pelamis* (Linnaeus, 1758), Cape Point. SAM A11808: Six ovigerous females from *Thunnus obesus* (Lowe, 1839), Cape Point. SAM A40294: One male from *Ranzania laevis* (Pennant, 1776), Milnerton.

Present study: No specimens of this species were collected in the present study.

Description.

Female. Body (Fig. 3.6a) 7.81 (7.61-8.13) mm long. Cephalothoracic shield longer than wide, 3.38 (3.13-3.86) x 2.79 (2.57-3.06) mm, excluding lateral hyaline membranes. Fourth pediger wider than long, 0.45 (0.41-0.50) x 1.04 (0.96-1.14) mm. Genital complex longer than wide, 1.92 (1.83-2.03) x 1.74 (1.53-1.96) mm. Abdomen five-segmented. First segment 0.49 x 0.81 mm. Second segment 0.31 x 0.70 mm. Third segment 0.53 x 0.77 mm. Fourth segment 0.32 x 0.67 mm. Fifth segment 0.41 x 0.70 mm. Caudal ramus (Fig. 3.6m) longer than wide, 233.4 (232.4-234.1) x 201.6 (200.1-206.2) µm. Posterior margin of each ramus armed with two outer and three large terminal plumose setae.

Antennule. Two-segmented (Fig. 3.6b). Setae missing on proximal and distal segments. Aesthetascs missing on distal segment. Proximal segment trapezoid, much broader than distal segment, with 10 plumose setae on anterior margin, including one very long plumose seta. Distal segment rod-shaped, much longer than wide, armed with one subterminal seta on posterior margin and four medium sized and one very long setae on distal margin.

Antenna. Three-segmented (Fig. 3.6c). Proximal segment unarmed. Second segment subrectangular and unarmed. Distal segment a curved claw bearing one short basal seta and another similar seta in middle region.

Postantennary process. Minute process (Fig. 3.6d) with three setules-bearing papillae located nearby on sternum.

Maxillule. Dentiform (fig. 3.6e) with basal papilla bearing three short setae.

Maxilla. Two-segmented (Fig. 3.6f). Proximal segment (lacertus) unarmed. Distal segment (brachium) carrying medium-sized flabellum with both margins serrated and two unequal elements (a short canna and a longer calamus) terminally, canna and calamus with both margins serrated.

Maxilliped. Three-segmented (Fig. 3.6g). Proximal segment (corpus) largest with small process near base of shaft. Second (shaft) and distal (claw) segments fused to form subchela. Shaft bearing small basal seta. Claw pointed, with minute anterodistal seta.

Sternal furca. Base short and narrow (Fig. 3.6k). Tines stout and winged. Accessory sclerotised processes on either side of furca.

Leg 1. Protopod (Fig. 3.6h) with one medium sized plumose seta on posterior margin and another smaller, plumose seta on anterodistal margin. Endopod vestigial, naked. Exopod two-segmented. First segment with row of setules on posterior margin and medium sized, spiniform seta on anterodistal corner. Second segment with four terminal elements (elements two and three each with accessory process and outer margins serrated, element one with both margins finely serrated, element four smallest, naked) and three plumose setae on posterior margin.

Leg 2. Coxa small (Fig. 3.6i), with spinule bearing papilla on ventral surface and large plumose inner seta on posterior margin. Protopod with anterodistal medium sized, naked seta, patch of fringed anterodistal membrane, posterior margin covered by a striated membrane, with one centrally situated seta. Exopod three-segmented. First segment with one anterodistal curved spine, both margins of spine with striated membrane, posterior margin with one medium sized plumose seta. Second segment with one anterodistal spine, both margins of spine with striated membrane, posterior margin with one long plumose seta. Third segment with three spines on anterodistal margin (first spine smallest, naked, second spine with both margins serrated, third spine with striated membrane along outer margin and plumose inner margin), five long, plumose setae, one minute spine on ventral surface next to fifth plumose seta, and crest of hairs on inner margin. Endopod three-segmented. First segment with one long, plumose seta and prominent crest of setules on outer margin. Second segment with two plumose setae and prominent crest of setules on outer and inner margin. Third segment with six plumose terminal setae and prominent crest of setules on outer margin.

Leg 3. Anterior margin of protopod more sclerotised than the rest of the segment and bearing a striated membrane (Fig. 3.6j). Row of denticles above exopod. Exopod three-segmented. First segment with large terminal claw with both margins bearing striated membrane. Second segment with one anterodistal spine and one posterodistal plumose seta. Third segment with three spines of different lengths and four plumose setae of different lengths. Second and third segment with rows of setules on lateral margins. Endopod two-segmented. First segment expanded laterally into velum on outer margin and bearing one long, plumose seta on posterior margin. Second segment with six plumose setae of different length, and row of setules on lateral margin.

Leg 4. Protopod (Fig. 3.6l) with very long plumose anterodistal seta. Exopod three-segmented. First and second segments bearing terminal spines with both margins finely serrated. Third segment bearing three terminal spines with both margins finely serrated. All exopod spines with basal pecten.

Armature on rami of legs 1-4:

	Exopod	Endopod
Leg 1	1-0; III, 1, 3	(vestigial)
Leg 2	I-1; I-1; II, I, 5, I	0-1; 0-2; 6
Leg 3	I-0; I-1; III, 4	0-1; 6
Leg 4	I-0; I-0; III	(missing)

Leg 5. No visible setae representing leg 5.

Male. Body (Fig. 3.6n) 5.31 (4.97-5.51) mm long. Cephalothoracic shield longer than wide, 3.32 (3.17-3.43) x 2.80 (2.61-2.93) mm, excluding lateral hyaline membranes. Fourth pediger wider than long, 0.37 (0.33-0.39) x 1.07 (1.05-1.09) mm. Genital complex wider than long, 0.89 (0.81-0.93) x 1.19 (1.17-1.25) mm. Abdomen two-segmented. First segment 0.33 (0.32-0.35) x 0.76 (0.71-0.80) mm. Second segment 0.53 (0.50-0.57) x 0.68 (0.63-0.72) mm. Caudal ramus (Fig. 3.6t) slightly longer than wide, 233.3 (233.1-233.5) x 221.1 (210-226.6) µm. Posterior margin of each ramus armed with two outer, three large terminal plumose setae, and another plumose seta situated ventrally between outer and middle terminal plumose setae.

Antenna. Three-segmented (Fig. 3.6o). Proximal segment bearing large process posteroventrally. Second segment large with corrugated patch on posteroventral corner. Distal segment a curved claw bearing one medial seta and an accessory basal claw.

Postantennary process. Process (Fig. 3.6p) more developed as in female, but without any definition. No setules-bearing papillae as in female.

Maxillule. Dentiform process (Fig. 3.6q). Basal papilla with three small setae.

Maxilliped. Three-segmented (Fig. 3.6r). Corpus large and unarmed, bearing a sclerotised ridge on medial margin. Claw pointed, with strong basal seta and small seta in middle of subchela.

Leg 5. Represented by three papillae (Fig. 3.6s) on posterolateral margin of genital complex, one tipped with medium sized plumose seta, other with one small and one long plumose seta, third papilla with one very long plumose seta.

Leg 6. Represented by two papillae (Fig. 3.6s) on posterolateral margin of genital complex, one tipped with one small plumose seta, other with one small and one long plumose setae.

Remarks. This is a very widely distributed species and has been recorded several times from the South African coast. It parasitises fish species from the family Scombridae and have been recorded from mackerels, tunas and bonitos. *Caligus coryphaenae* has some unique features, which include; 1) the very long plumose setae found on the antennule, as well as exceptionally long plumose setae of legs 5 and 6 in the male; 2) elements two and three of leg 1 exopod carry an accessory process and these elements are heavily serrated on the outer margins, with the element four of leg 1 exopod small and naked; 3) the abdomen is five-segmented in the female, the only known species with this unique feature; 4) in both the female and the male the postantennory process is greatly reduced, having basically no function at all; 5) in both the female and the male the sternal furca has accessory sclerotised processes near the base; 6) the male having a plumose seta ventrally on the caudal ramus between the outer and middle terminal plumose setae.

Only one female was used for measuring the five-segmented abdomen, as this was the only specimen where the segments could be differentiated from each other. One problem encountered in the species description was the missing setae on the antennules of the specimens studied. Some specimens are in a rather poor state, a contributing factor in the missing setae of the antennules.

Cressey (1991) suggested that this species do not belong in the genus *Caligus*, a view shared by myself. For one, this is the only species known with a minute postantennary process, and giving the unique feature of the sternal furca, which has accessory sclerotised processes at either side, and the one minute spine on the ventral surface next to the fifth plumose seta of the third exopodal segment of the second leg, this species have features to be assigned to a genus of its own. Such action can only be considered appropriate after an overall re-evaluation of the whole *Caligus* genus.

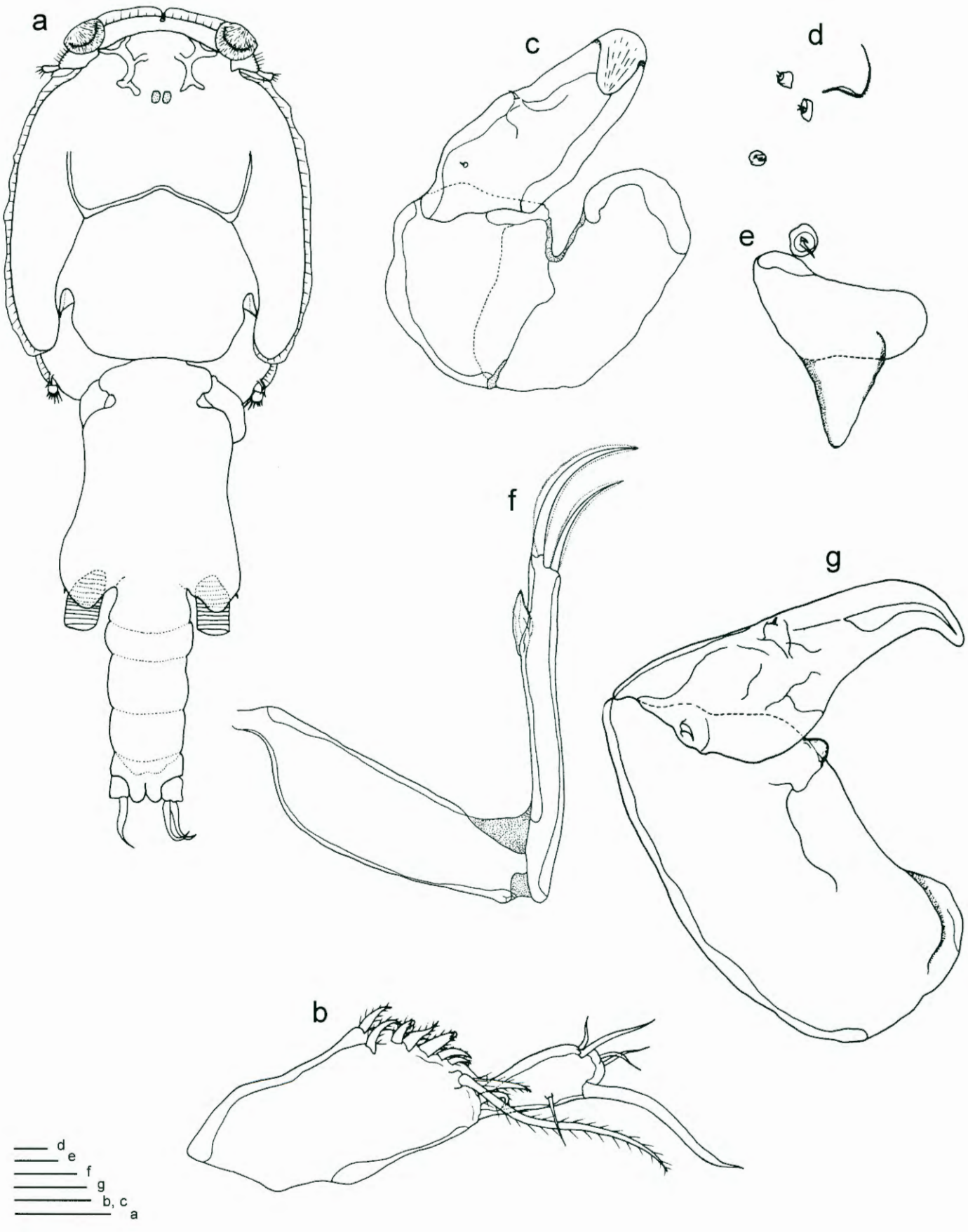


Fig. 3.6. *Caligus coryphaenae* Steenstrup & Lütken, 1861, female. **a.** habitus, dorsal. **b.** antennule, ventral. **c.** antenna, ventral. **d.** postantennary process, ventral. **e.** maxillule, ventral. **f.** maxilla. **g.** maxilliped. Scale bars: 1 mm in a; 100 μm in b, c, f, g; 50 μm in e; 30 μm in d.

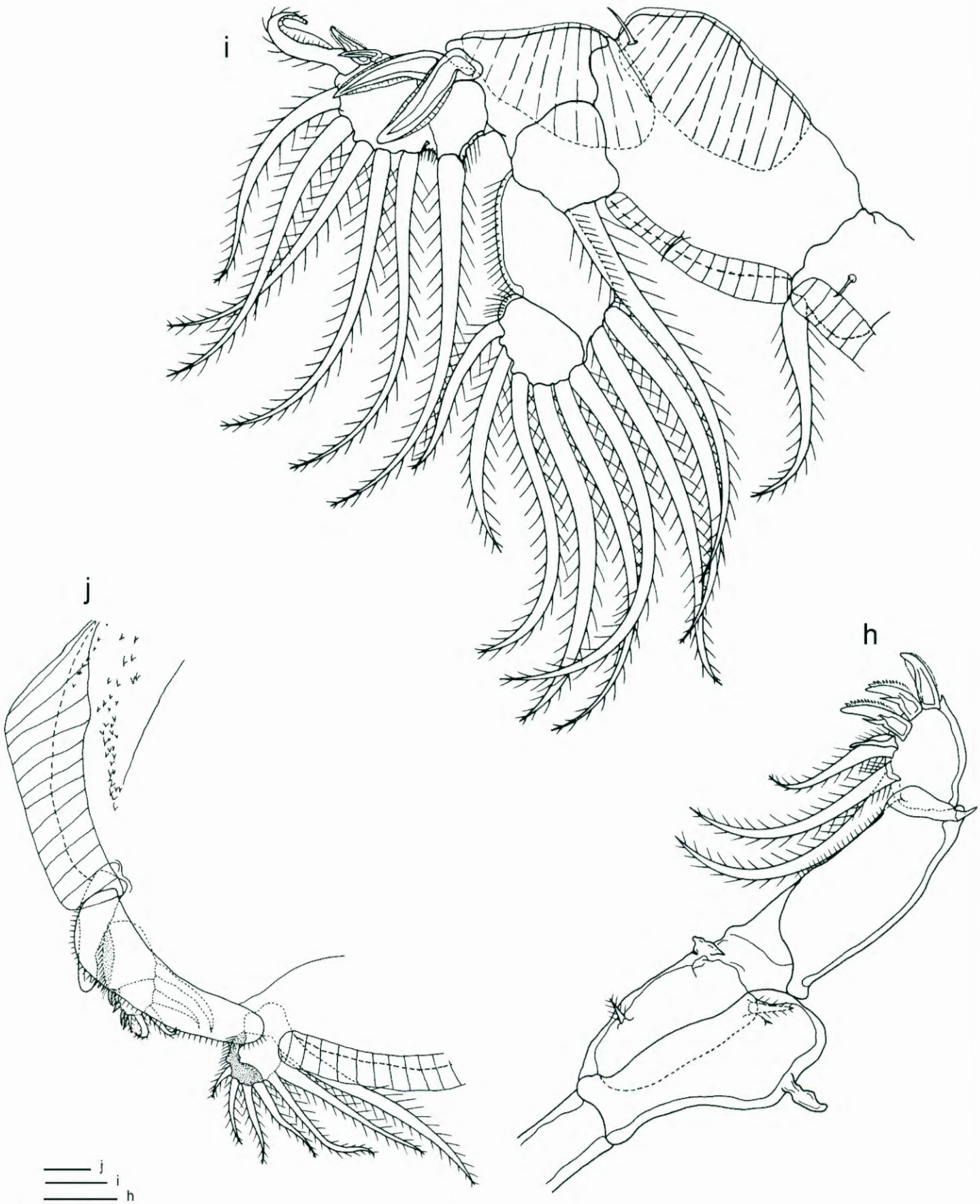


Fig. 3.6. (cont.) *Caligus coryphaenae* Steenstrup & Lütken, 1861, female. **h.** leg 1, ventral. **i.** leg 2, ventral. **j.** leg 3, ventral. Scale bars: 100 μm in h-j.

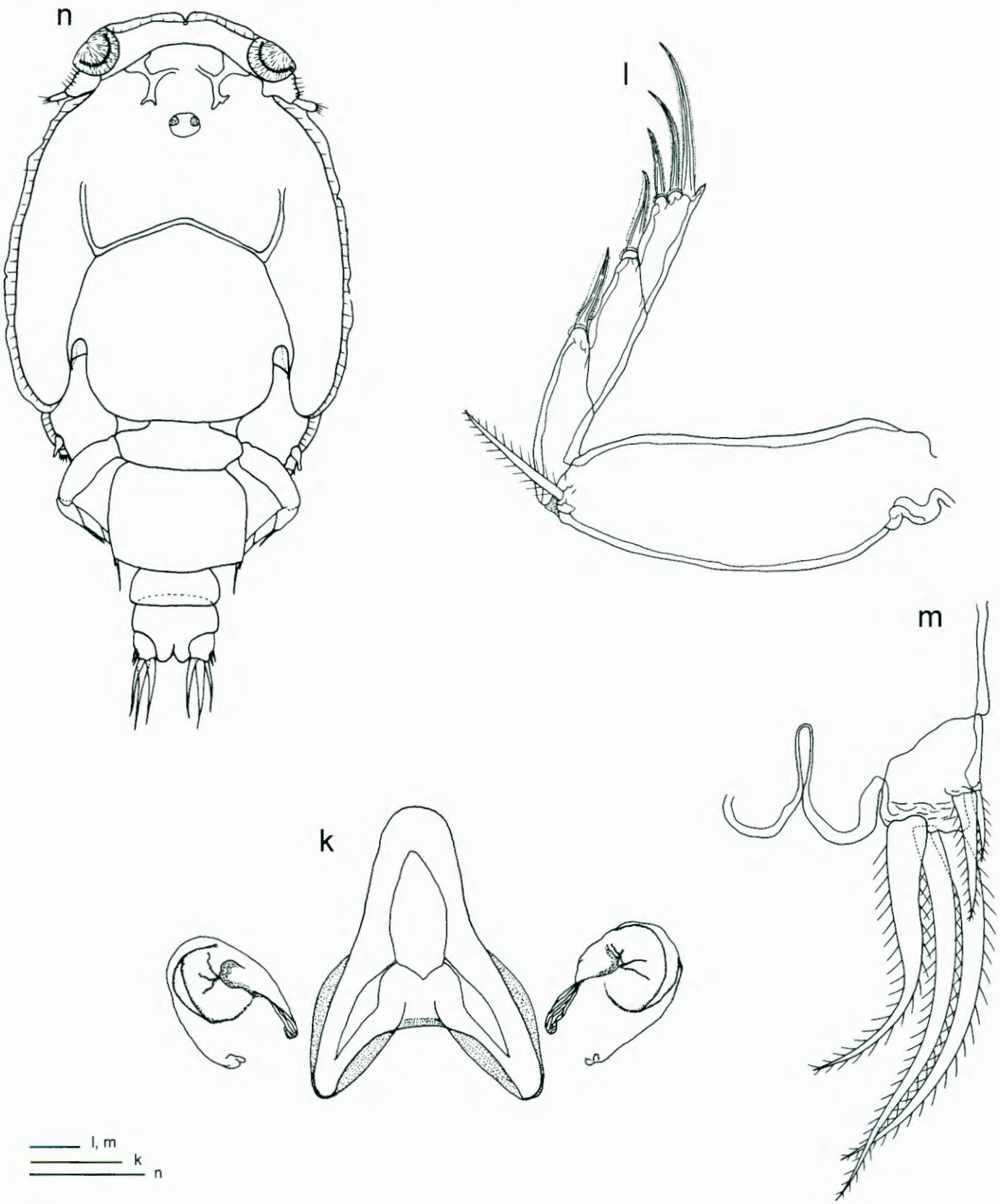


Fig. 3.6. (cont.) *Caligus coryphaenae* Steenstrup & Lütken, 1861, female. **k.** sternal furca. **l.** leg 4, ventral. **m.** caudal ramus, ventral. *Caligus coryphaenae*, male. **n.** habitus, dorsal. Scale bars: 1 mm in n; 100 µm in k-m.

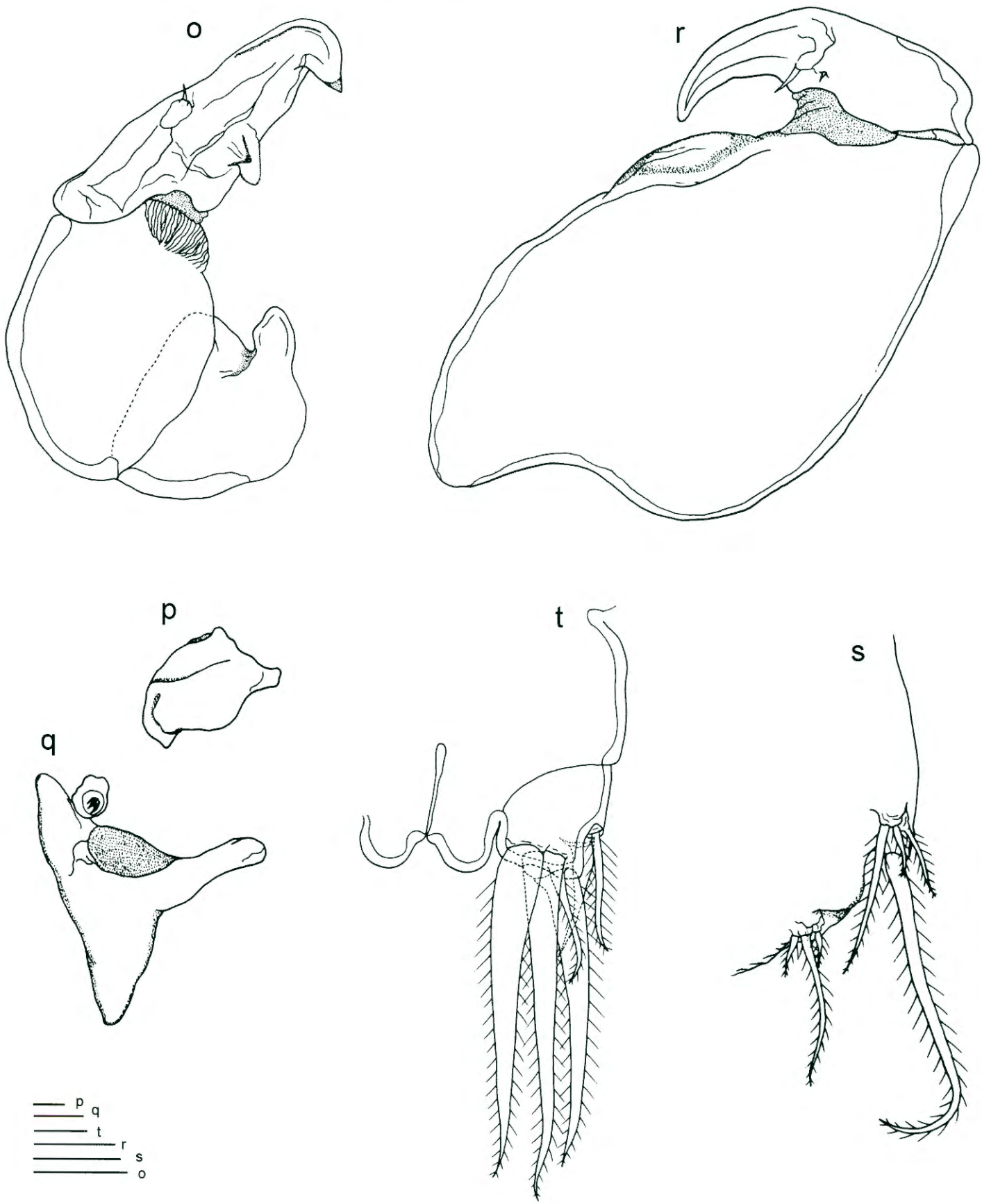


Fig. 3.6. (cont.) *Caligus coryphaenae* Steenstrup & Lütken, 1861, male. **o.** antenna. **p.** postantennary process. **q.** maxillule. **r.** maxilliped. **s.** posterolateral side of genital complex, showing leg 5 and leg 6, ventral. **t.** caudal ramus, ventral. Scale bars: 100 μm in s, u; 50 μm in q, r, t.

Caligus engraulidis Barnard, 1948

Figs. 3.7a-u, 3.8a-h

Caligus engraulidis: Barnard, 1948: 244-245, fig. 3; Barnard, 1955a: 245, 249, fig. 10c, d; Barnard, 1955b: 100; Barnard, 1957: 11; Yamaguti, 1963: 52, plate 3, fig. 1a-c.

Material examined.

South African Museum: SAM A8520: One ovigerous female collected from the body surface of *Stolephorus holodon* (Boulenger, 1900), Zwartkops River, Algoa Bay. Voucher specimens from present study, two ovigerous females and two males, have been deposited in the collection of the SA Museum, SAM A45163.

Present study: Voucher specimens have been deposited in the collection of the Aquatic Parasitology Research Group, Department of Zoology and Entomology, University of the Free State, Bloemfontein. All specimens were collected from the skin of the hosts and are listed in Table 3.3.

Table 3.3. Total number of *Caligus engraulidis* Barnard, 1948 specimens collected from fish hosts in Lake St Lucia, including collection numbers.

Host species	# ♀♀, ♂♂ *Caligus*	Locality	Collection number
Liza tricuspidens	1 ovig ♀, 1 ♂	Lake St Lucia	9/045
Mugil cephalus	5 ovig ♀♀, 4 ♂♂	Lake St Lucia	15/001
Mugil cephalus	1 ovig ♀, 1 ♀, 2 ♂♂	Lake St Lucia	17/4
Mugil cephalus	2 ovig ♀♀, 1 ♂	Lake St Lucia	17/5
Mugil cephalus	1 ♀, 3 ♂♂	Lake St Lucia	17/6
Mugil cephalus	1 ovig ♀, 1 ♂	Lake St Lucia	17/8
Mugil cephalus	1 ♂	Lake St Lucia	17/9

Description.

Female. Body (Fig. 3.7a) 5.23 (4.76-5.67) mm long. Cephalothoracic shield longer than wide, 2.99 (2.73-3.14) x 2.67 (2.51-2.81) mm, excluding lateral hyaline membranes. Fourth pediger wider than long, 0.32 (0.27-0.37) x 0.74 (0.66-0.79) mm. Genital complex wider than long, 1.26 (1.17-1.33) x 1.43 (1.36-1.51) mm. Abdomen one-segmented, slightly longer than wide, 0.49 (0.42-0.56) x 0.44 (0.39-0.48) mm. Caudal ramus (Fig. 3.7n) more than twice as long as wide,

360.3 (354.6-364.1) x 166.7 (162.3-170.4) µm. Posterior margin of each ramus armed with two outer (one small, one medium sized), one medium sized medial and three large terminal plumose setae.

Antennule. Two-segmented (Fig. 3.7b). Proximal segment trapezoid, much broader than distal segment, with 27 usual plumose setae on anterior surface. Distal segment rod-shaped, much longer than wide, armed with one subterminal seta on posterior margin and 10 setae and two aesthetascs on distal margin.

Antenna. Three-segmented (Fig. 3.7c). Proximal segment with sclerotised process on ventral margin. Second segment subrectangular, bearing a corrugated patch posterolaterally. Distal segment a curved claw bearing one medium sized seta in the middle region.

Postantennary process. Claw-like (Fig. 3.7d) with two basal papillae, one bearing two setules, other four setules. Another similar papilla on sternum bearing two setules.

Maxillule. Dentiform (Fig. 3.7e) with papilla bearing three small setae.

Maxilla. Two-segmented (Fig. 3.7f). Proximal segment (lacertus) unarmed. Distal segment (brachium) carrying small flabellum with both margins serrated and two unequal elements (a short canna and a longer calamus) terminally, canna and calamus with both margins serrated.

Maxilliped. Three-segmented (Fig. 3.7g). Proximal segment (corpus) largest, bearing ridge on medial margin. Second (shaft) and distal (claw) segments fused to form subchela, claw pointed, with strong basal seta.

Sternal furca. Base broad anteriorly, decreasing in size posteriorly (Figs. 3.7h, 3.8a). Tines wing-like, with blunt tip and fringed with hyaline membrane on outer and inner margins.

Leg 1. Protopod (Fig. 3.7i) with one medium sized plumose seta on posterior margin and another medium sized plumose seta on anterodistal margin. Endopod vestigial, tipped with two small elements distally. Exopod two-segmented. First segment with row of setules on posterior margin and small, spiniform seta on anterodistal corner. Second segment with four identical terminal elements (Fig. 3.8b), equal in length, with minute ridges and both margins finely serrated (Fig. 3.8c), and three plumose setae on posterior margin.

Leg 2. Coxa small (Fig. 3.7j), with spinule-bearing papillae on anterior surface and large, plumose inner seta on posterior margin. Protopod with anterodistal small, naked seta, patch of fringed anterodistal membrane, posterior margin covered by a striated membrane, with one centrally situated seta. Exopod three-segmented. First segment with one anterodistal curved spine, both margins with striated membrane, posterior margin with one long, plumose seta. Second segment with one anterodistal, small curved spine, naked, posterior margin with one long, plumose seta. Third segment with three spines on anterodistal margin (first spine smallest, naked, second spine

with striated membrane on outer margin and inner margin serrated, third spine with outer margin serrated and plumose inner margin) and five long, plumose setae. Endopod three-segmented. First segment protruded laterally and armed with row of setules, and one long, plumose seta. Second segment with two plumose setae and prominent crest of setules on outer and inner margin. Third segment with six plumose terminal setae and crest of setules on outer corner.

Leg 3. Anterior margin of protopod more sclerotised than the rest of the segment, bearing a striated membrane (Fig. 3.7k). Row of denticles above exopod. Exopod three-segmented. First segment with large terminal claw with striated membrane on both margins. Second segment with one anterodistal spine and one posterodistal plumose seta. Third segment with three spines of different lengths and four plumose setae of different lengths. Second and third segment with rows of setules on lateral margins. Endopod two-segmented. First segment expanded laterally into velum on outer margin and bearing one long, plumose seta on posterior margin. Second segment with six plumose setae and row of setules on lateral margin.

Leg 4. Protopod (Figs. 3.7l, 3.8d) with medium sized plumose anterodistal seta. Long and slender exopod, indistinctly two-segmented. First segment bearing medium sized spine with both margins finely serrated. Second segment armed with two spines of different size, first spine three times shorter than terminal spine with both margins finely serrated, terminal spine with both margins heavily serrated (Fig. 3.8e). All exopod spines with basal pecten.

Armature on rami of legs 1-4:

	Exopod	Endopod
Leg 1	1-0; IV, 3	(vestigial)
Leg 2	I-1; I-1; II, I, 5	0-1; 0-2; 6
Leg 3	I-0; I-1; III, 4	0-1; 6
Leg 4	I-0; II	(missing)

Leg 5. Represented by two papillae (Fig. 3.7m) on posterolateral corner of genital complex, one tipped with small plumose seta, other with two similar plumose setae.

Male. Body (Fig. 3.7o) 5.29 (4.91-5.89) mm long. Cephalothoracic shield longer than wide, 3.05 (2.76-3.29) x 2.74 (2.49-2.88) mm, excluding lateral hyaline membranes. Fourth pediger wider than long, 0.36 (0.30-0.41) x 0.75 (0.69-0.82) mm. Genital complex (Fig. 3.7u) wider than long, 0.93 (0.79-1.06) x 1.18 (1.03-1.32) mm. Abdomen one-segmented (Fig. 3.7u), longer than wide, 0.68 (0.59-0.75) x 0.59 (0.51-0.68) mm. Caudal ramus (Fig. 3.7u) more than twice as long as

wide, 481.2 (466.3-491.7) x 184.4 (178.2-188.4) µm. Posterior margin of each ramus armed with two outer (one small, one medium), one medium medial, and three large terminal plumose setae. Both the genital complex and abdomen (Fig. 3.7u) bear numerous small outgrowths and denticles on the ventral side.

Antenna. Three-segmented (Fig. 3.7p). Proximal unarmed. Second segment with medial, ventral, and posterolateral corrugated patches. Distal segment a trifid claw (Fig. 3.8h), covered by overlapping cuticular flap, and bearing one strong basal seta.

Postantennary process. Claw-like (Fig. 3.7q) with two basal papillae, each bearing three setules. Another similar papilla on sternum bearing four setules.

Maxillule. Much reduced process (Fig. 3.7r) with tooth-like outgrowth on distal margin.

Maxilliped. Three-segmented (Fig. 3.7s). Proximal segment (corpus) largest, bearing two outgrowths on medial margin, one forming a bifid ridge, the other a tooth-like outgrowth. Second (shaft) and distal (claw) segments fused to form subchela, claw pointed, with strong basal seta, and anterodistal minute element.

Leg 5. Represented by two papillae (Fig. 3.7t) on posterolateral margin of genital complex, one tipped with medium sized plumose seta, other with two similar plumose setae.

Leg 6. Represented by one papilla (Fig. 3.7t) on posterolateral margin of genital complex, bearing only one small naked seta.

Remarks. The only known specimen of *Caligus engraulidis* was the one ovigerous female collected and described by Barnard (1948) from the Natal anchovy *Stolephorus holodon* (Boulenger, 1900). This specimen is in a rather poor state; the cephalothorax is separated from the genital complex and abdomen; the fourth pediger is missing, but the fourth legs are still intact. Subsequently specimens of *Caligus engraulidis* were collected on various occasions from two mullet species in Lake St Lucia. These specimens fit the description of *C. engraulidis*, which have the following unique features; 1) the possession of long and slender caudal rami, 2) a slender, indistinctly two-segmented exopod bearing an armature of 0-I, II on leg 4, with the large terminal spine heavily serrated on both margins. Only one other species is known to have a serrated terminal spine on leg 4, being *Caligus pageti* Russell, 1925. *Caligus engraulidis* is easily distinguished from *C. pageti* by having a very short spine on the first segment of the exopod of leg 4, in comparison to a very long spine of *C. pageti*. The serrations are not so well sclerotised in *C. pageti* as in *C. engraulidis.* Both these species are found on mullets, and this serrated terminal spine could relate them, but further studies on this feature are needed. The male antenna is a trifid claw in *Caligus engraulidis*, and a bifid claw in *C. pageti*. As Barnard (1948) collected only one

specimen from *Stolephorus holodon*, and all the specimens in the present study were collected from mullet species, *Caligus engraulidis* is then placed as a parasite of mullet species, and the specimen found on the anchovy could have been a misplaced infestation. Material collected in the present study represents new hosts and distribution records for the South African coastline.

The following error is rectified from the original description by Barnard (1948): The genital complex does bear rudimentary fifth legs, which were omitted by Barnard (1948).

SEM study. The tines of the sternal furca (Fig. 3.8a) are flattened on the outer and inner margins, creating thus a very thin layer of membrane, which may be damaged easily as was found in most of the specimens studied. Leg 1 (Fig. 3.8b) is characteristic of this species, with the four terminal elements on the second exopodal segment being exactly the same. All four elements bear fine ridges and very fine serrated margins (Fig. 3.8c), which could not be seen using the Humes and Gooding (1964) technique. None of the species studied have this characteristic. Leg 4 (Fig. 3.8d) is two-segmented, and bears a very small terminal spine on the first segment of the exopod. The long and heavily serrated terminal spine (Fig. 3.8e) is another characteristic of this species. Small sensory setae were found on both the dorsal side of the lunules (Fig. 3.8f) and the marginal membrane of the dorsal shield (Fig. 3.8g). As the lunules are sensory adaptations assisting the antennules, sensory setae are thus not uncommon. The function of these sensory setae may be for finding suitable hosts. The trifid claw of the male antenna (Fig. 3.8h) is covered by an overlapping cuticular flap, and bears a strong basal seta. This is a unique feature as only a few species bear a trifid claw in the male antenna.

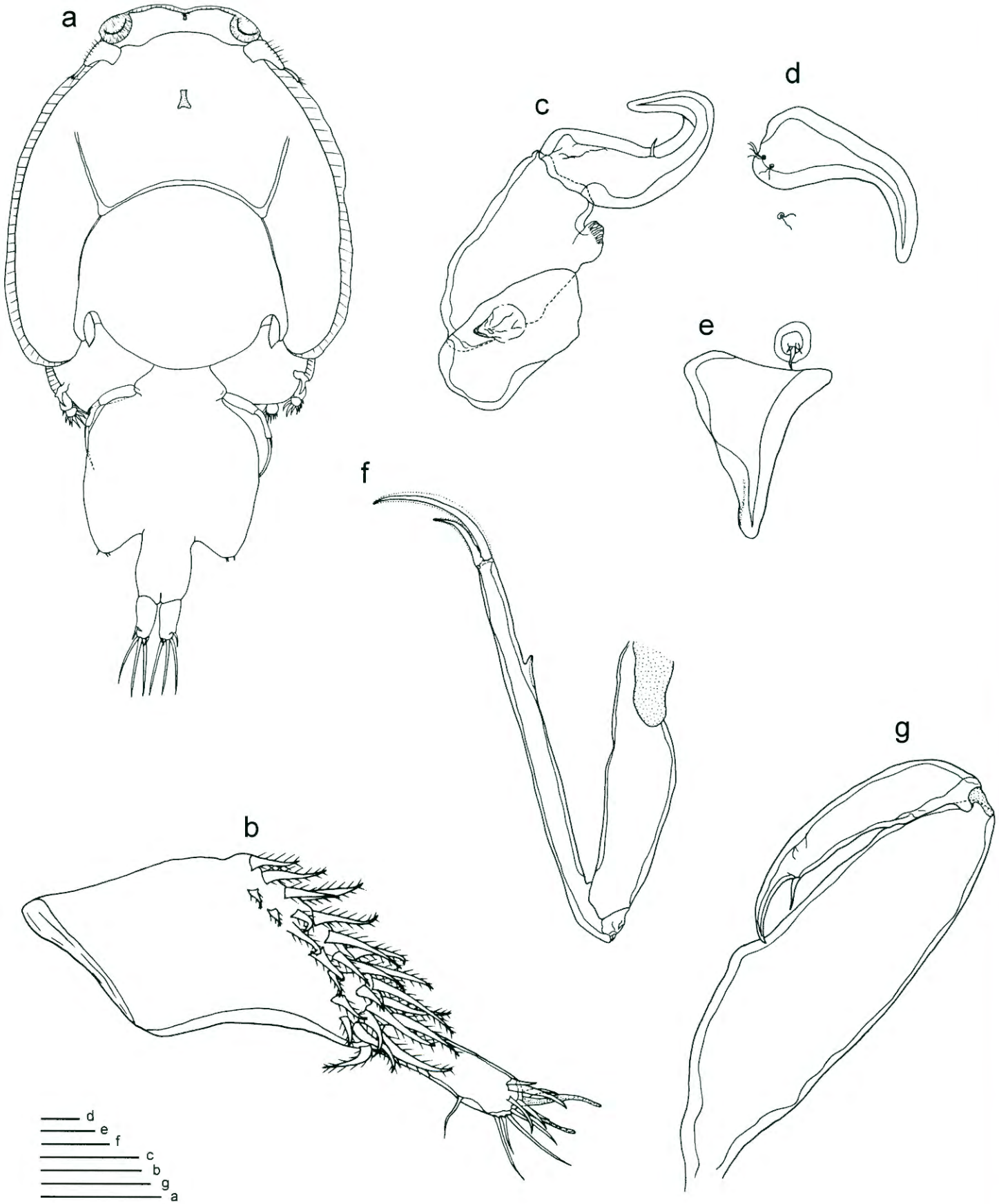


Fig. 3.7. *Caligus engraulidis* Barnard, 1948, female. **a.** habitus, dorsal. **b.** antennule, ventral. **c.** antenna, ventral. **d.** postantennary process, ventral. **e.** maxillule, ventral. **f.** maxilla. **g.** maxilliped. Scale bars: 1 mm in a; 100 μm in b, c, f, g; 50 μm in d, e.

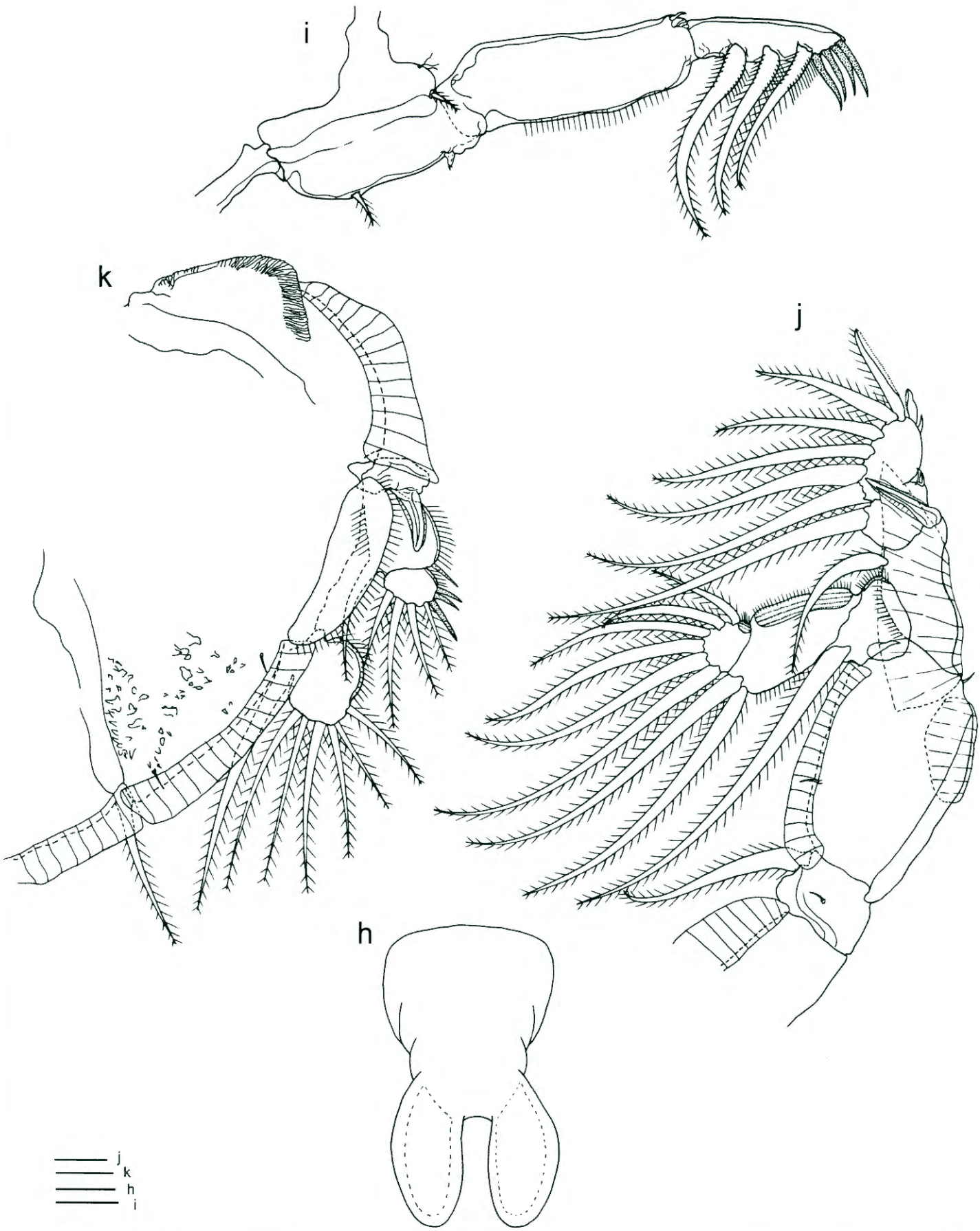


Fig. 3.7. (cont.) *Caligus engraulidis* Barnard, 1948, female. **h.** sternal furca. **i.** leg 1, ventral. **j.** leg 2, ventral. **k.** leg 3, ventral. Scale bars: 100 μm in i-k; 50 μm in h.

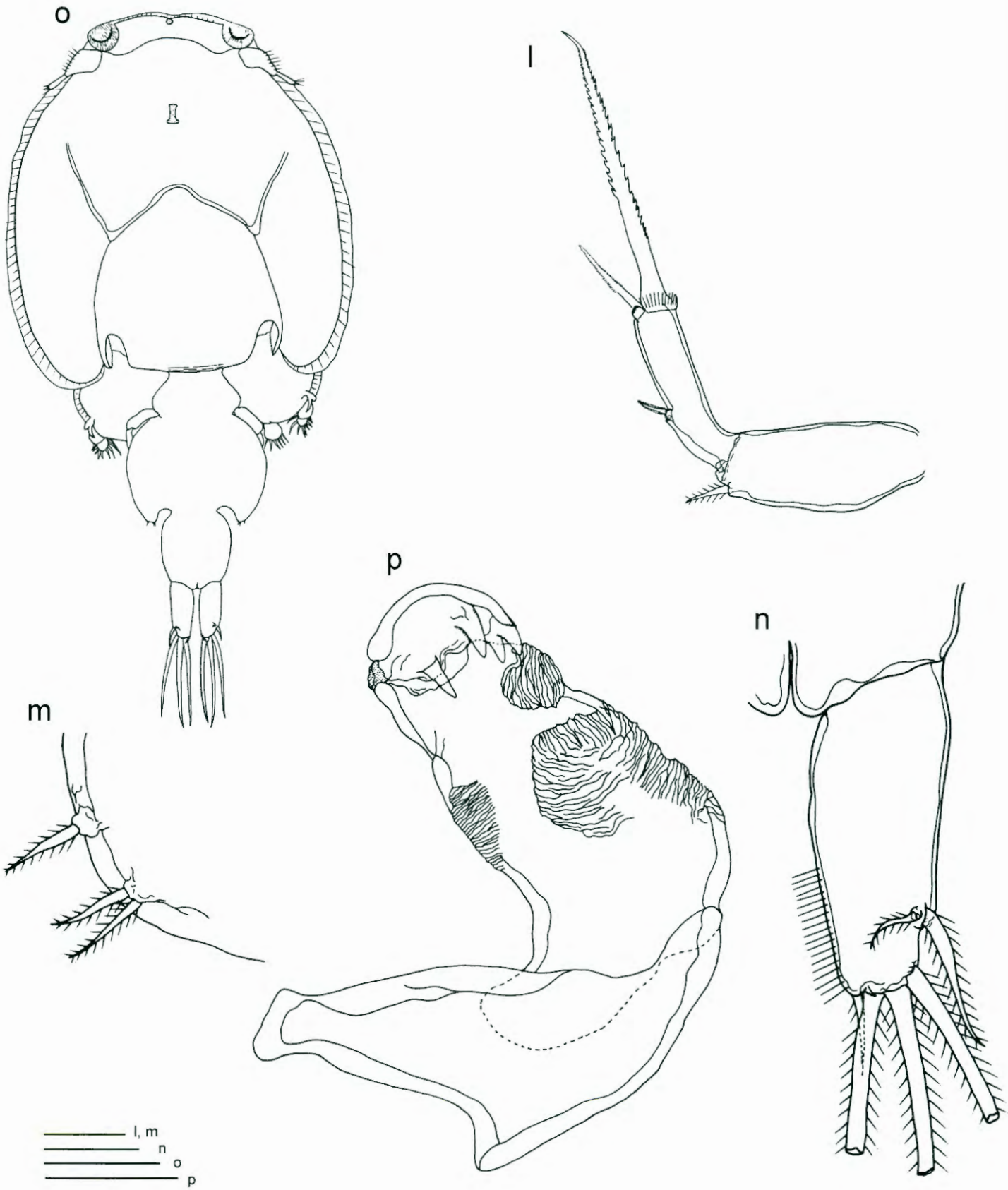


Fig. 3.7. (cont.) *Caligus engraulidis* Barnard, 1948, female. **l.** leg 4, ventral. **m.** posterolateral side of genital complex, showing leg 5, ventral. **n.** caudal ramus, ventral. *Caligus engraulidis*, male. **o.** habitus, dorsal. **p.** antenna, ventral. Scale bars: 1 mm in o; 100 µm in l, n, p; 50 µm in m.

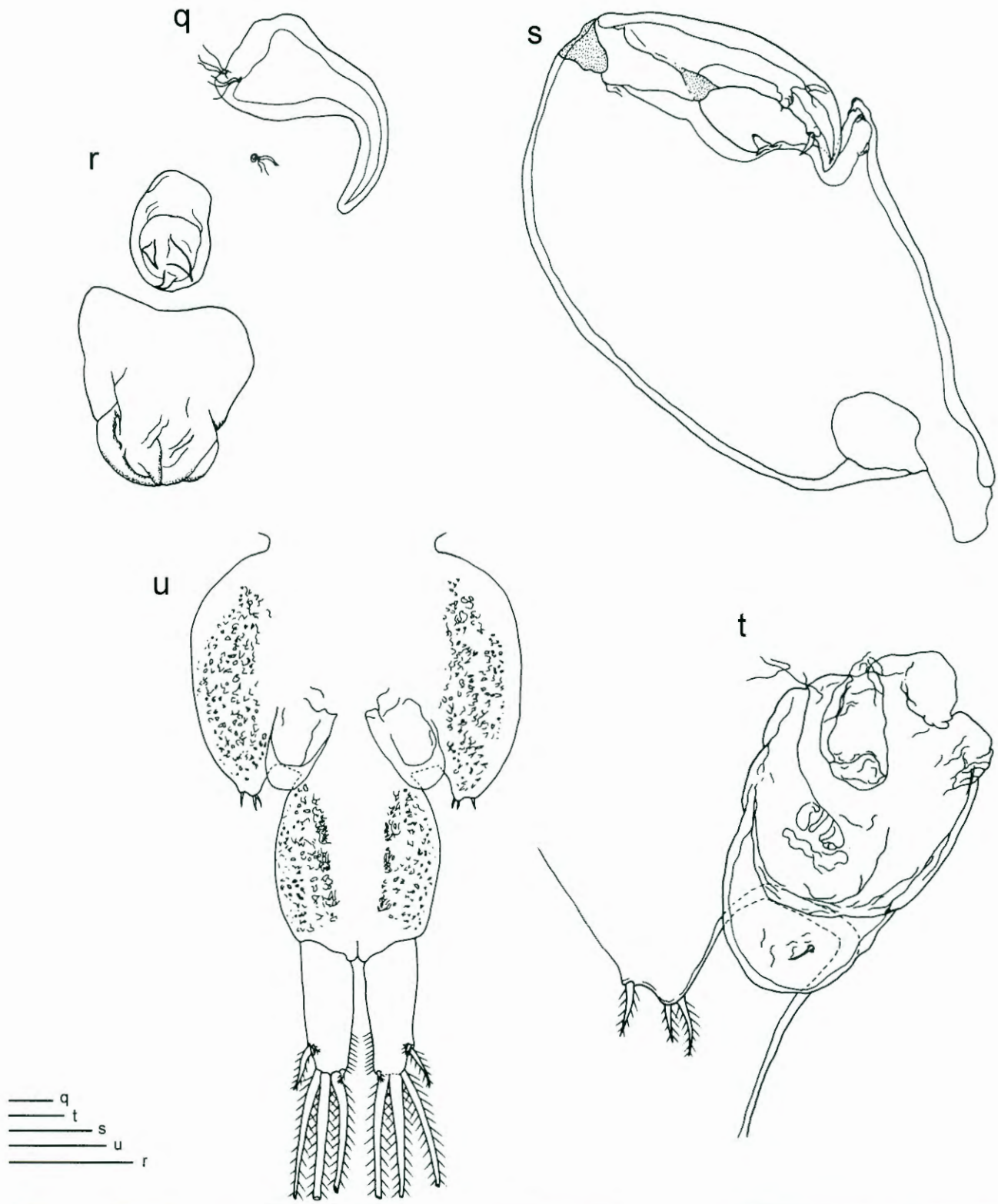
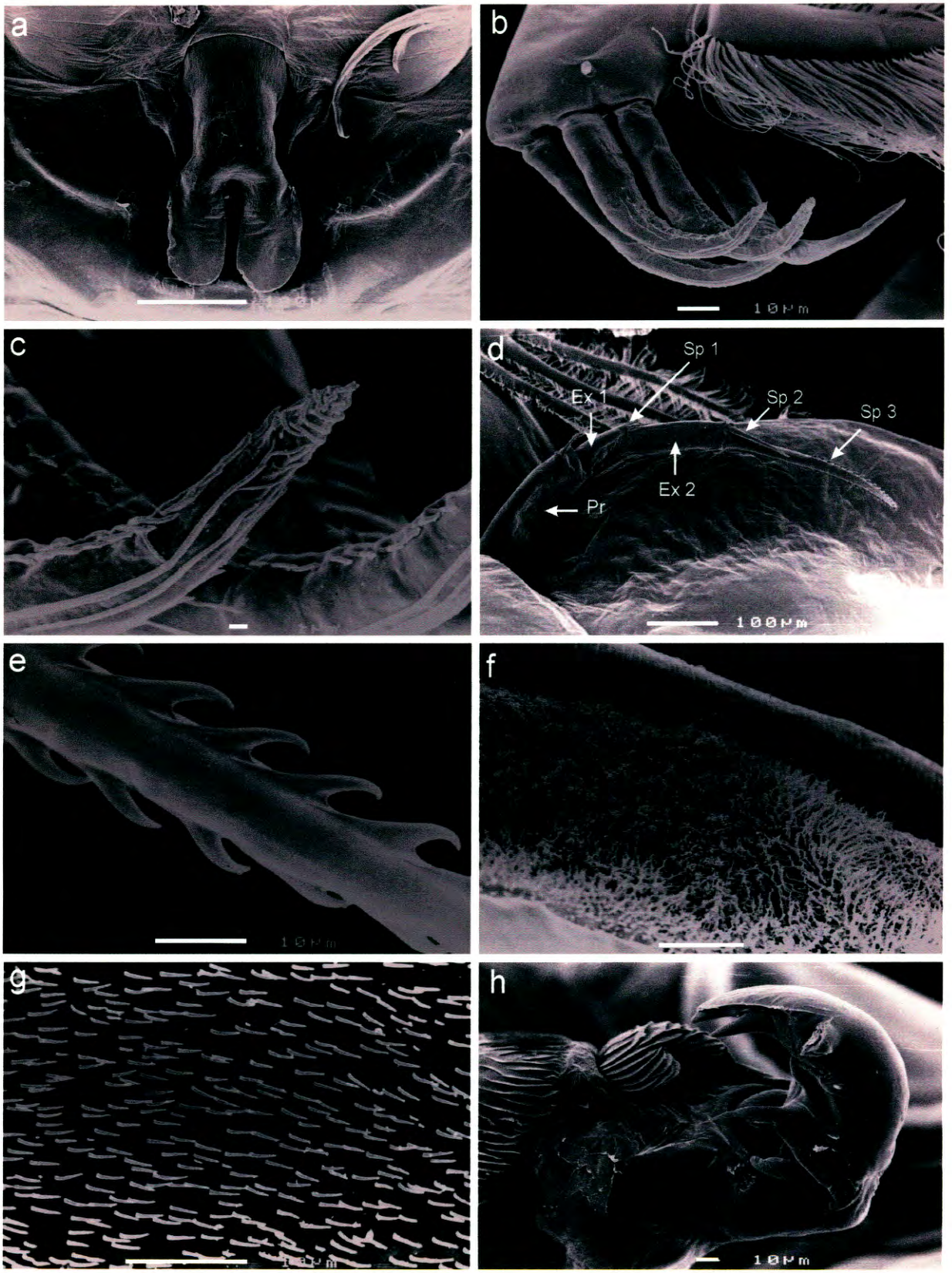


Fig. 3.7. (cont.) *Caligus engraulidis* Barnard, 1948, male. **q.** postantennary process. **r.** maxillule. **s.** maxilliped. **t.** posterolateral side of genital complex, showing leg 5 and leg 6, ventral. **u.** genital complex, abdomen, caudal ramus, ventral. Scale bars: 300 μm in u; 100 μm in s; 50 μm in q, r, t.



Figs. 3.8a-g. Scanning electron micrographs of *Caligus engraulidis* Barnard, 1948, female. **a.** sternal furca. **b.** terminal elements on leg 1 2nd exopod. **c.** ridges and serrations on terminal elements. **d.** leg 4. **e.** Serrated terminal spine, leg 4. **f.** setae on dorsal side of lunules. **g.** setae on marginal membrane of cephalothoracic shield. **Fig. 3.8h.** *Caligus engraulidis,* male. **h.** trifid claw. Scale bars: 100 µm in a, b, d; 10 µm in **e**, f, g, h; 1µ m in c. Pr-Protopod, Ex 1& 2-1st & 2nd exopodal segments, Sp 1, 2 & 3-Spines 1, 2 & 3.

Caligus hottentotus Barnard, 1957

Figs. 3.9a-n

Caligus hottentotus: Barnard, 1957: 11, fig. 7.

Material examined.

South African Museum: SAM A11780: One ovigerous female and two females from the body surface of *Pachymetopon blochii* Valenciennes, 1830, Table Bay. Two females with no catalogue number (see chapter 5, mixed-up specimens).

Present study: No specimens of this species were collected in the present study.

Description.

Female. Body (Fig. 3.9a) 4.39 (4.18-4.67) mm long. Cephalothoracic shield longer than wide, 2.74 (2.52-2.98) x 2.54 (2.35-2.78) mm, excluding lateral hyaline membranes. Fourth pediger wider than long, 0.38 (0.36-0.42) x 0.64 (0.61-0.68) mm. Genital complex wider than long, 1.03 (0.93-1.18) x 1.21 (1.05-1.41) mm. Abdomen one-segmented, slightly wider than long, 0.35 (0.30-0.39) x 0.42 (0.40-0.46) mm. Caudal ramus (Fig. 3.9n) almost three times longer than wide, 348.7 (299.8-381.2) x 128.9 (121.4-139.2) µm. Posterior margin of each ramus armed with two small outer, one small, medial and three terminal plumose setae, small setule on ventral surface. Terminal setae on caudal ramus damaged or missing in all specimens studied.

Antennule. Two-segmented (Fig. 3.9b). Proximal segment trapezoid, much broader than distal segment, with 27 usual plumose setae on anterodistal surface. Distal segment rod-shaped, much longer than wide, armed with one subterminal seta on posterior margin and nine setae and two aesthetascs on distal margin.

Antenna. Three-segmented (Fig. 3.9c). Proximal segment with conical posteromedial process. Second segment subrectangular and unarmed. Distal segment a curved claw bearing one short seta in middle region, and an accessory claw-like process, bearing a basal claw as well.

Postantennary process. Curved claw (Fig. 3.9d) with two basal papillae bearing one setule each, and another similar papilla located nearby on sternum.

Maxillule. Dentiform (Fig. 3.9e) with basal papilla bearing three short setae.

Maxilla. Two-segmented (Fig. 3.9f). Proximal segment (lacertus) unarmed. Distal segment (brachium) carrying small flabellum with both margins serrated and two unequal elements (a short canna and a longer calamus) terminally, canna and calamus with both margins serrated.

Maxilliped. Three-segmented (Fig. 3.9g). Proximal segment (corpus) largest with protrusion in basal region. Second (shaft) and distal (claw) segments fused to form subchela. Shaft bearing small seta in middle region. Claw pointed, with strong basal seta.

Sternal furca. Base box-like (Fig. 3.9h), bearing fine striations on posteroventral surface. Tines stout and stocky.

Leg 1. Protopod (Fig. 3.9i) with one small plumose seta on posterior margin and another small plumose seta on anterodistal margin. Endopod vestigial, indistinctly two-segmented, naked. Exopod two-segmented. First segment with row of setules on posterior margin and small, spiniform seta on anterodistal corner. Second segment with four terminal elements (elements one, two and three equal in length, naked, element four longest, naked) and three plumose setae on posterior margin.

Leg 2. Coxa small (Fig. 3.9j), with spinule bearing papilla on ventral surface and large plumose inner seta on posterior margin. Protopod with anterodistal medium sized, naked seta, patch of fringed anterodistal membrane, posterior margin covered by a striated membrane, with one centrally situated seta. Exopod three-segmented. First segment with one anterodistal curved spine, both margins of spine with striated membrane, posterior margin with one medium sized plumose seta. Second segment with one anterodistal spine, outer margin of spine with striated membrane, posterior margin with one long plumose seta. Third segment with three spines on anterodistal margin (first spine smallest, both margins serrated, second spine with both margins serrated, third spine with striated membrane along outer margin and plumose inner margin) and five long, plumose setae. Endopod three-segmented. First segment with one long, plumose seta. Second segment with two plumose setae and prominent crest of setules on outer and inner margin. Third segment with six plumose terminal setae and crest of setules on outer corner.

Leg 3. Anterior margin of protopod more sclerotised than the rest of the segment, bearing a striated membrane (Fig. 3.9k). Exopod three-segmented. First segment with large terminal claw, slightly curved, both margins with striated membrane. Second segment with one anterodistal spine and one posterodistal plumose seta. Third segment with three spines of different lengths and four plumose setae of different lengths. Second and third segment with rows of setules on lateral margins. Endopod two-segmented. First segment expanded laterally into velum on outer margin and bearing one long, plumose seta on posterior margin. Second segment with six plumose setae of different lengths and row of setules on lateral margin.

Leg 4. Protopod (Fig. 3.9l) with small plumose anterodistal seta. Exopod two-segmented. First segment bearing terminal spine with both margins finely serrated. Second segment bearing three terminal spines, all with both margins finely serrated. All exopod spines with basal pecten.

Armature on rami of legs 1-4:

	Exopod	Endopod
Leg 1	1-0; III, 1, 3	(vestigial)
Leg 2	I-1; I-1; II, I, 5	0-1; 0-2; 6
Leg 3	I-0; I-1; III, 4	0-1; 6
Leg 4	I-0; III	(missing)

Leg 5. Represented by two papillae (Fig. 3.9m) on posterolateral corner of genital complex, one tipped with small plumose seta, other with two similar plumose setae.

Remarks. Barnard (1957) described *Caligus hottentotus* from the hottentot fish *Pachymetopon blochii* (Valenciennes, 1830). Only three females remain in the collection of the South African Museum, with the male being missing. This species has not been collected since the original description, and an effort should be made to collect the host species. Characteristic features of this species are; 1) relatively long caudal ramus, 2) the antenna bearing an additional claw-like process, which also has a basal claw, something not known from any other species studied, 3) the four terminal elements on leg 1 second exopodal segment, and 4) the armature and details of the spines on leg 4 exopod.

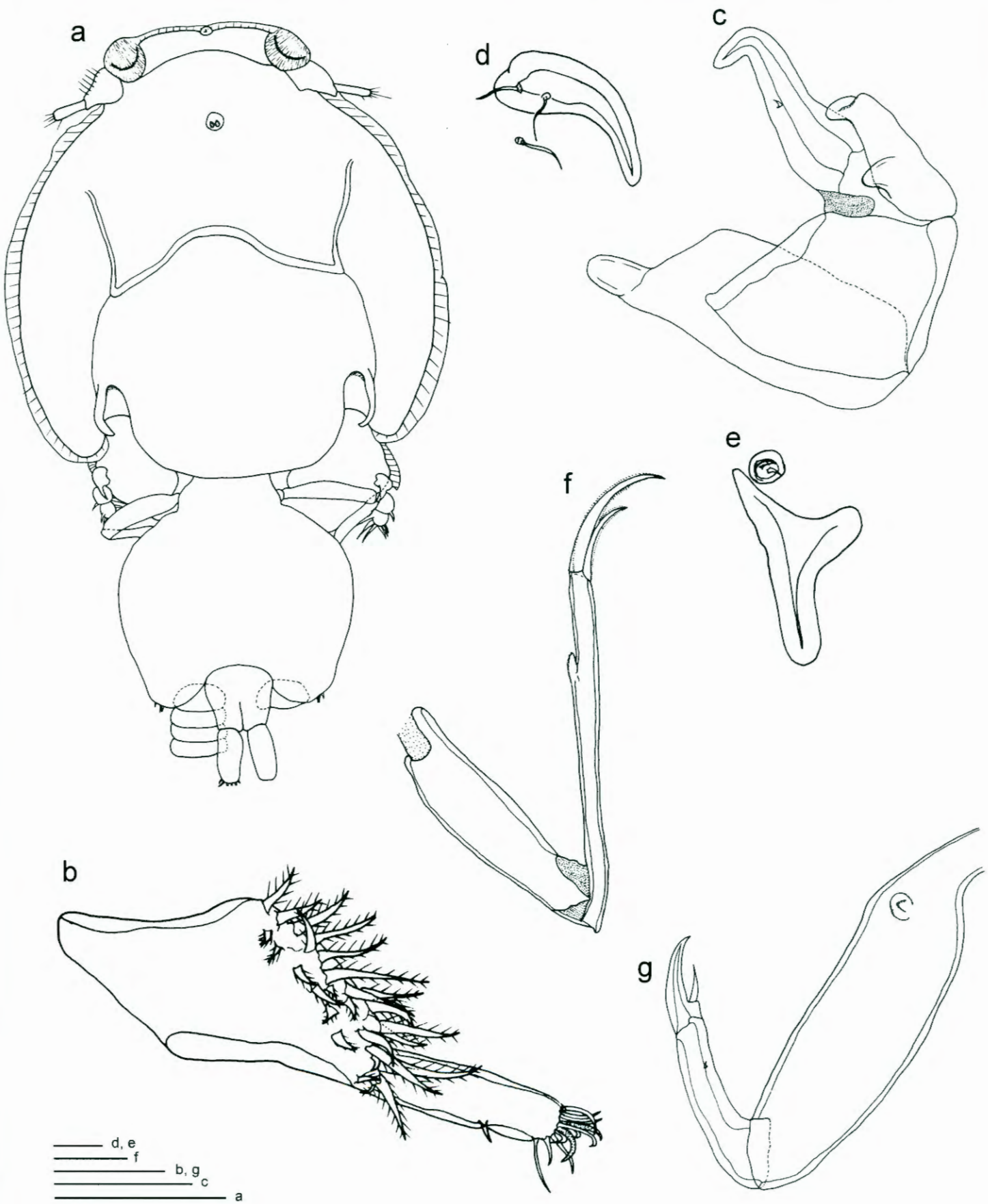


Fig. 3.9. *Caligus hottentotus* Barnard, 1957, female. **a.** habitus, dorsal. **b.** antennule, ventral. **c.** antenna, ventral. **d.** postantennary process, ventral. **e.** maxillule, ventral. **f.** maxilla. **g.** maxilliped. Scale bars: 1 mm in a; 100 µm in b, c, f, g; 50 µm in d, e.

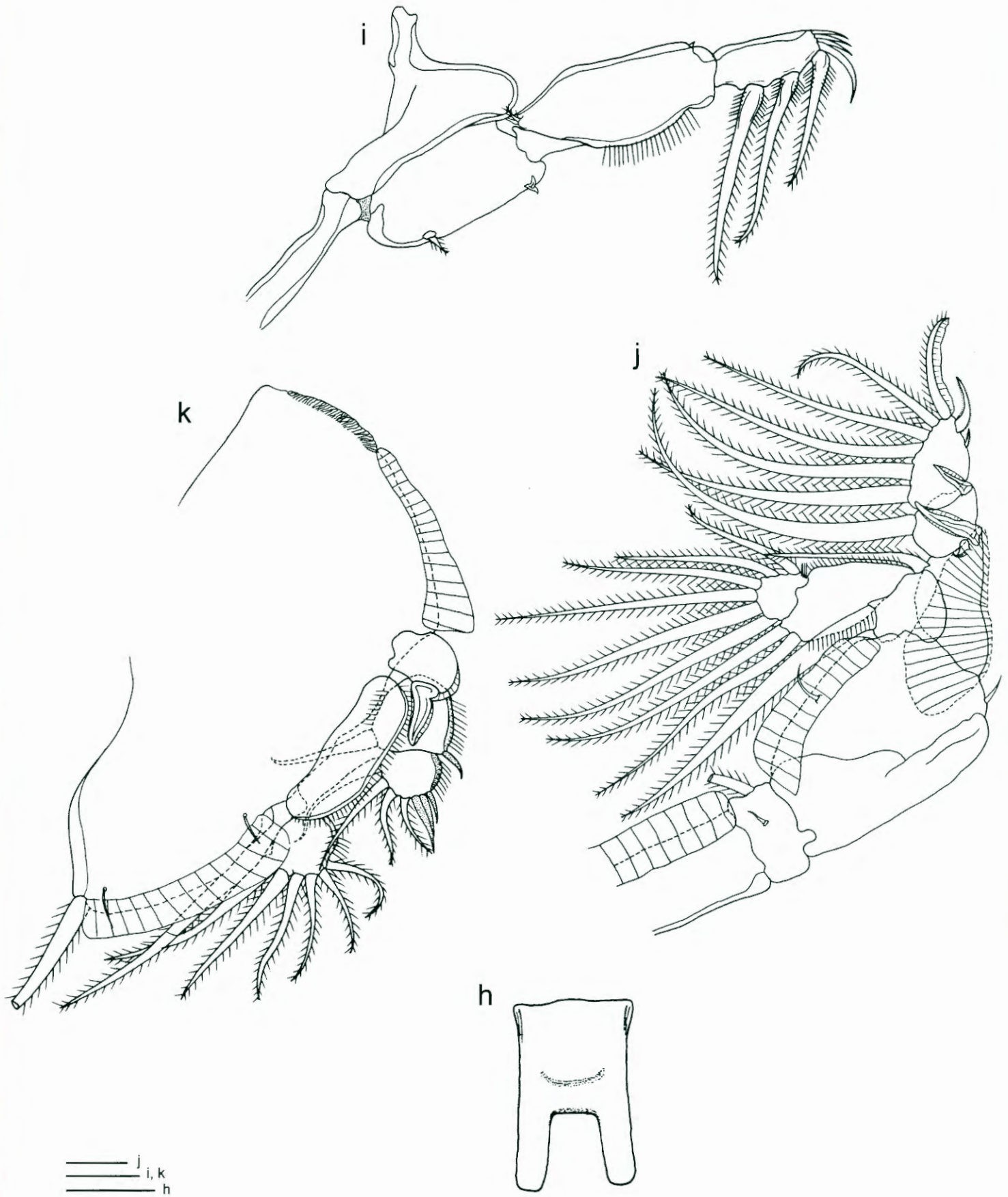


Fig. 3.9. (cont.) *Caligus hottentotus* Barnard, 1957, female. **h.** sternal furca. **i.** leg 1, ventral. **j.** leg 2, ventral. **k.** leg 3, ventral. Scale bars: 100 µm in i-k; 50 µm in h.

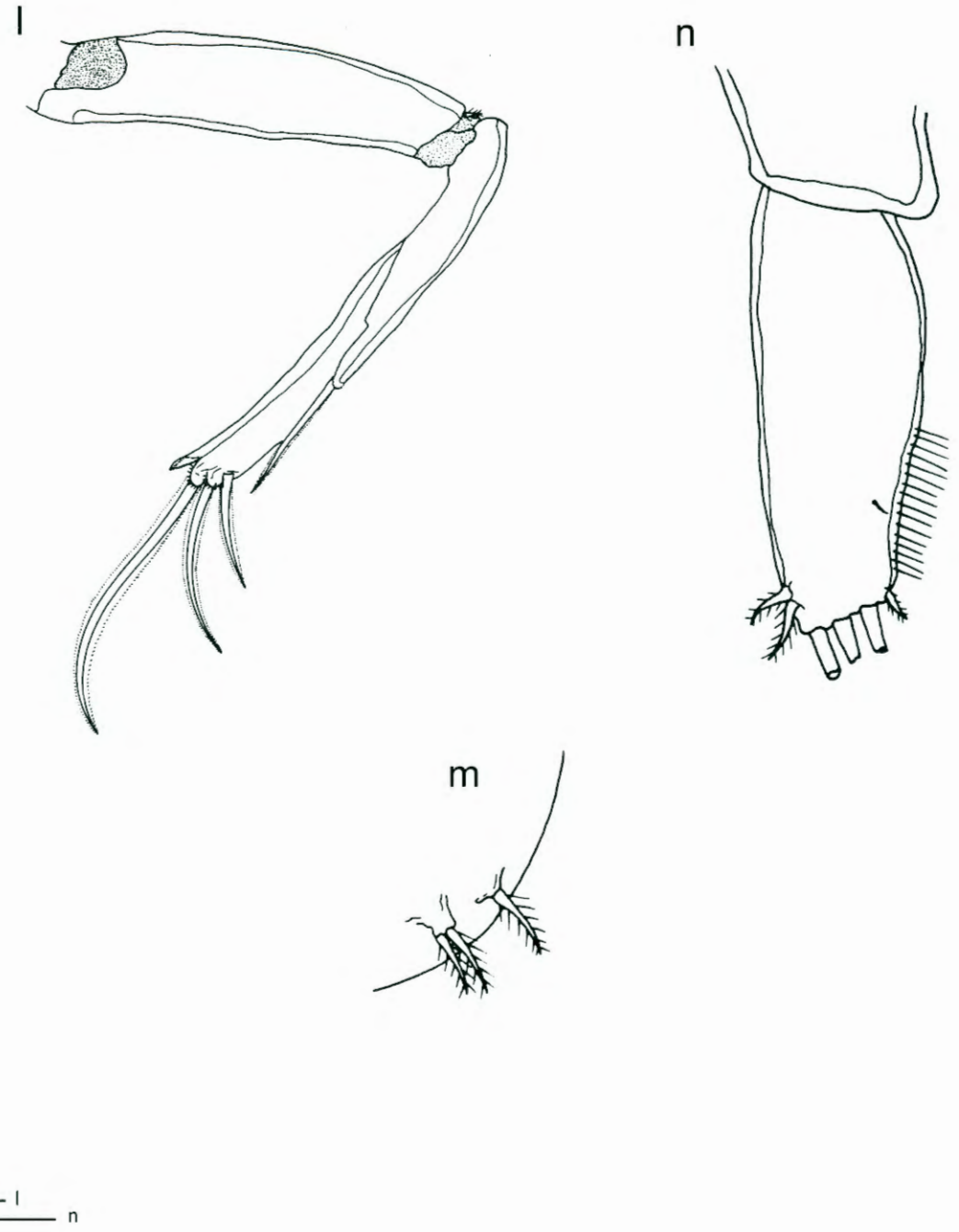


Fig. 3.9. (cont.) *Caligus hottentotus* Barnard, 1957, female. **l.** leg 4, ventral. **m.** posterolateral side of genital complex, showing leg 5, ventral. **n.** caudal ramus, ventral. Scale bars: 100 μm in l, n; 30 μm in m.

Caligus lalandei Barnard, 1948

Figs. 3.10a-q

Caligus lalandei: Barnard, 1948: 243-244, fig. 2, Barnard, 1955a: 244, 246-247, fig. 9a-c; Barnard, 1955b: 99; Yamaguti, 1963: 55, plate 65, fig. 3a-c.

Material examined.

South African Museum: SAM A8517: One ovigerous female, three females and one male from the body surface of *Seriola lalandi* Valenciennes, 1833, Kalk Bay.

Present study: No specimens of this species were collected in the present study.

Description.

Female. Body (Fig. 3.10a) 9.18 (8.33-10.07) mm long. Cephalothoracic shield longer than wide, 3.88 (3.60-4.23) x 3.46 (3.23-3.77) mm, excluding lateral hyaline membranes. Fourth pediger wider than long, 0.47 (0.43-0.50) x 1.13 (1.07-1.17) mm. Genital complex longer than wide, 2.48 (2.03-2.87) x 1.90 (1.73-2.10) mm. Abdomen one-segmented, longer than wide, 1.75 (1.67-1.87) x 0.72 (0.64-0.82) mm. Caudal ramus (Fig. 3.10m) almost four times longer than wide 1.22 (1.07-1.36) x 0.32 (0.30-0.33) mm. Posterior margin of each ramus armed with two outer, one medial, and three large terminal naked setae.

Antennule. Two-segmented (Fig. 3.10b), setae missing on proximal and distal segments. Aesthetascs missing on distal segment. Proximal segment shorter than distal segment and armed with 21 plumose setae on anterodistal surface. Distal segment rod-shaped, much longer than wide, armed with one subterminal seta on posterior margin and six setae on distal margin.

Antenna. Three-segmented (Fig. 3.10c). Proximal segment with large posteromedial process. Second segment unarmed. Distal segment a curved claw bearing one medium sized seta in middle region.

Postantennary process. Process a curved claw (Fig. 3.10d). Basal part of process with two papillae bearing one setule each. Another similar papilla located nearby on sternum.

Maxillule. Process a curved claw (Fig. 3.10e). Basal papilla with two short and one long setae.

Maxilla. Two-segmented (Fig. 3.10f). Proximal segment (lacertus) unarmed. Distal segment (brachium) carrying large flabellum with both margins serrated and two unequal elements (a short canna and a longer calamus) terminally, canna and calamus with both margins serrated, serrations on inner margin of canna dentiform.

Maxilliped. Three-segmented (Fig. 3.10g). Proximal segment (corpus) large, with ridge on medial margin. Second (shaft) and distal (claw) segments fused to form subchela, claw sharply pointed, bearing medium sized basal seta and another seta in middle region.

Sternal furca. Base short (Fig. 3.10h). Tines widening distally, with oval-like sinus between broad tines.

Leg 1. Protopod (Fig. 3.10i) with one medium sized plumose seta on posterior margin and another small plumose seta on anterodistal margin. Endopod vestigial, naked. Exopod two-segmented. First segment with row of setules on posterior margin and small, spiniform element on anterodistal corner. Second segment with four terminal elements (elements two and three with accessory process, all four elements naked) and three plumose setae on posterior margin.

Leg 2. Coxa small (Fig. 3.10j), with spinule-bearing papillae on anterior surface and large, plumose inner seta on posterior margin. Protopod with anterodistal small, naked seta, patch of fringed anterodistal membrane, posterior margin covered by a striated membrane, with one centrally situated seta. Exopod three-segmented. First segment with one anterodistal curved spine, both margins of spine with striated membrane, posterior margin with one long plumose seta. Second segment with one anterodistal curved spine, both margins of spine with striated membrane, posterior margin with one long plumose seta. Third segment with three spines on anterodistal margin (first spine smallest, naked, second spine with striated membrane on inner margin, naked on outer margin, third spine naked on outer margin and plumose inner margin) and five long, plumose setae. Endopod three-segmented. First segment with one long, plumose seta. Second segment with two plumose setae and prominent crest of setules on outer and inner margin. Third segment with six plumose terminal setae and crest of setules on outer corner.

Leg 3. Anterior margin of protopod with striated marginal membrane (Fig. 3.10k). Exopod three-segmented. First segment with large terminal claw, slightly curved, with both margins bearing striated membrane. Second segment with one anterodistal spine and one posterodistal plumose seta. Third segment with three spines of different lengths and four plumose setae of different lengths. Second and third segment with rows of setules on lateral margins. Endopod two-segmented. First segment expanded laterally into velum on outer margin and bearing one long, plumose seta on posterior margin. Second segment with six long, plumose setae, row of setules on lateral margin.

Leg 4. Protopod (Fig. 3.10l) with small plumose anterodistal seta. Exopod two-segmented. First segment bearing small terminal spine with both margins finely serrated. Second segment bearing three terminal spines, first two spines small, third spine three times longer than spines one and two, all three spines with both margins finely serrated. All exopod spines with basal pecten.

Armature on rami of legs 1-4:

	Exopod	Endopod
Leg 1	1-0; III, 1, 3	(vestigial)
Leg 2	I-1; I-1; II, I, 5	0-1; 0-2; 6
Leg 3	I-0; I-1; III, 4	0-1; 6
Leg 4	I-0; III	(missing)

Leg 5. No visible setae representing leg 5.

Male. Body (Fig. 3.10n) 15.8 mm long. Cephalothoracic shield longer than wide, 3.90 x 3.27 mm, excluding lateral hyaline membranes. Fourth pediger distinctly wider than long, 0.51 x 1.09 mm. Genital complex longer than wide, 1.41 x 1.03 mm. Abdomen two-segmented. First segment 1.13 x 0.69 mm. Second segment 2.18 x 0.53 mm. Caudal ramus exceptionally long, 7.01 x 0.12 mm. Posterior part of caudal ramus damaged, thus armature is omitted.

Antenna. Three-segmented (Fig. 3.10o). Proximal segment with large corrugated patch on ventral surface. Second segment with corrugated posteromedial and ventral surfaces. Distal segment a claw, covered by overlapping cuticular flap, and strong basal seta.

Maxilliped. Three-segmented (Fig. 3.10p). Corpus large and robust, bearing three outgrowths on medial margin, one forming a bifid ridge, the second a rounded outgrowth, the third a tooth-like outgrowth. Second segment (shaft) with minute element. Claw sharply pointed, with small ridge near distal outer margin, and medium sized basal seta.

Leg 5. Represented by two papillae (Fig. 3.10q) on posterolateral margin of genital complex, one tipped with small plumose seta, other with two similar plumose setae.

Leg 6. Represented by one papilla (Fig. 3.10q) on posterolateral margin of genital complex, bearing two small plumose seta.

Remarks. Caligus lalandei was described by Barnard (1948) from specimens collected from the Yellowtail, *Seriola lalandi*. Only four females and one male remain in the collection of the South African Museum. This species has not been collected since the original description, and an effort should be made to collect the host species. Characteristic features of this species are; 1) the exceptionally long caudal ramus in the female, and especially the male, 2) the shape of the sternal furca tines, forming an oval-like sinus between the tines, 3) the four terminal elements on leg 1 second exopodal segment, and 4) the armature and details of the spines on leg 4 exopod.

The caudal rami in both the female and male specimens are damaged, making descriptions of especially the male not viable. The maxillule of the male is also damaged, but appear to be the same as in the female. One important characteristic to note is the shape of the sternal furca in the male. The male specimen in the collection of the South African Museum bear exactly the same sternal furca as in the female, but according to the description of Barnard (1948) the sternal furca of the male differs significantly from that of the female. Based on the present study, the sternal furca is exactly the same as in the female, but needs reevaluation when more specimens are collected.

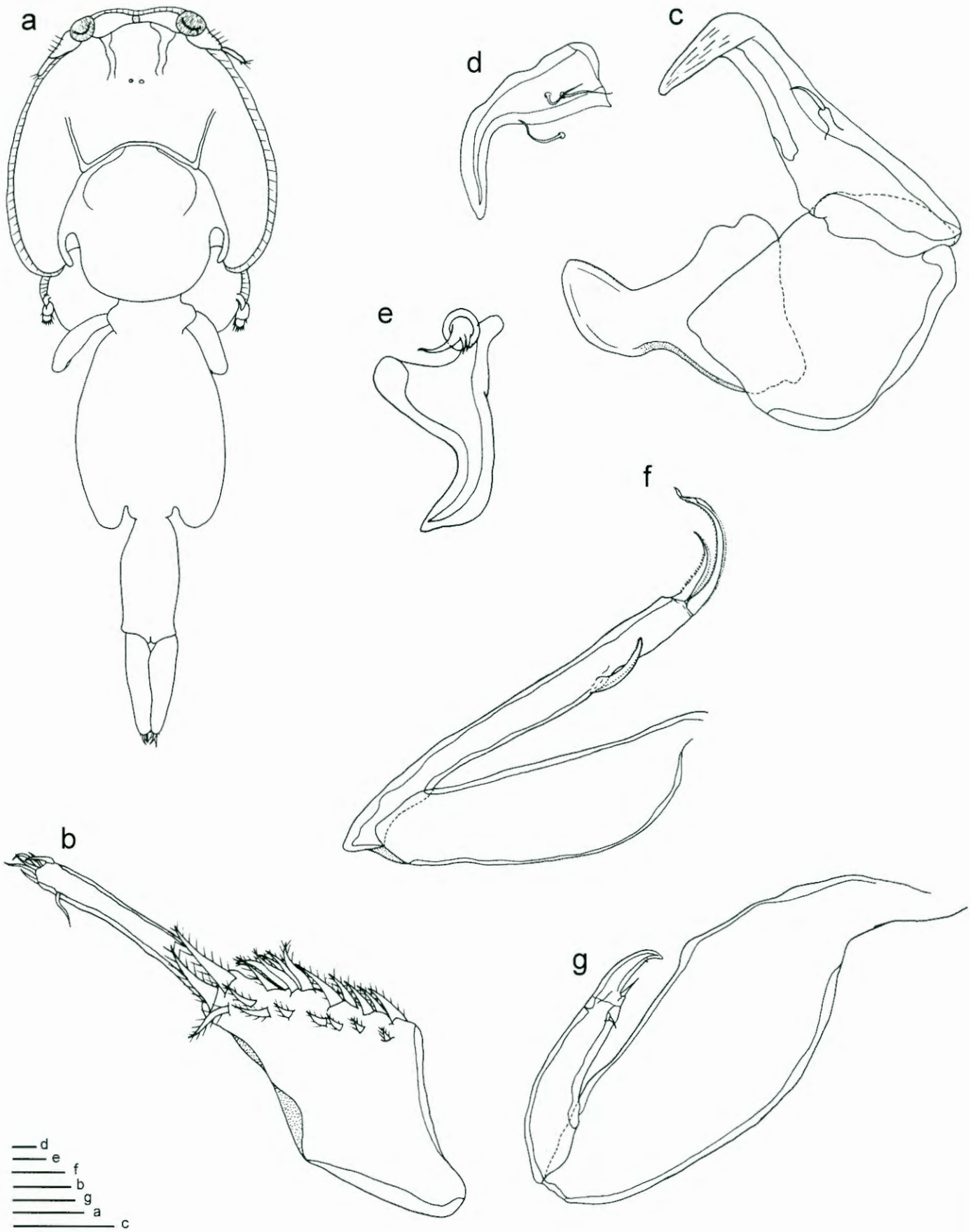


Fig. 3.10. *Caligus lalandei* Barnard, 1948, female. **a.** habitus, dorsal. **b.** antennule, ventral. **c.** antenna, ventral. **d.** postantennary process, ventral. **e.** maxillule, ventral. **f.** maxilla. **g.** maxilliped. Scale bars: 1 mm in a; 100 µm in b, c, f, g; 50 µm in d, e.

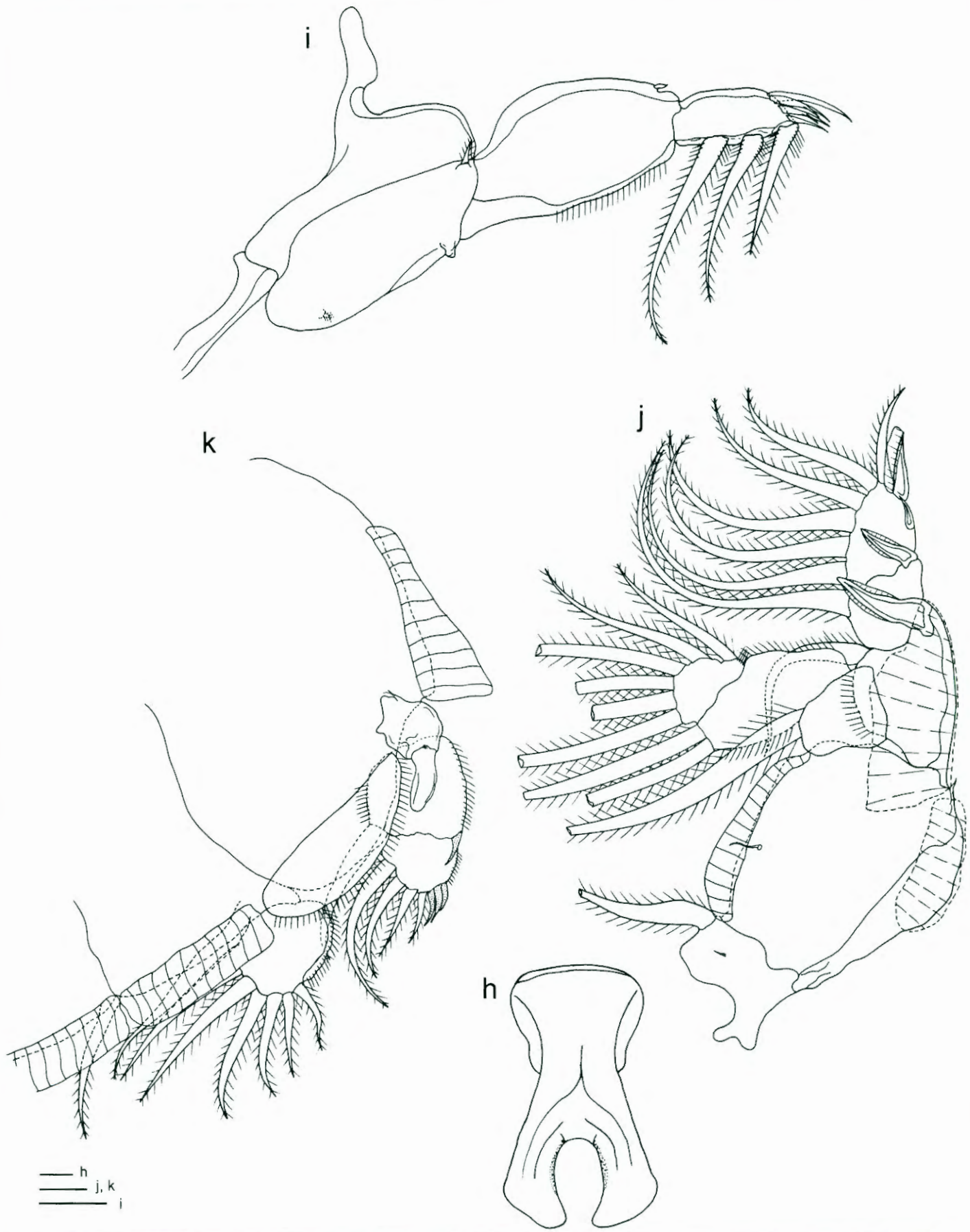


Fig. 3.10. (cont.) *Caligus lalandei* Barnard, 1948, female. **h.** sternal furca. **i.** leg 1, ventral. **j.** leg 2, ventral. **k.** leg 3, ventral. Scale bars: 100 µm in i-k; 50 µm in h.

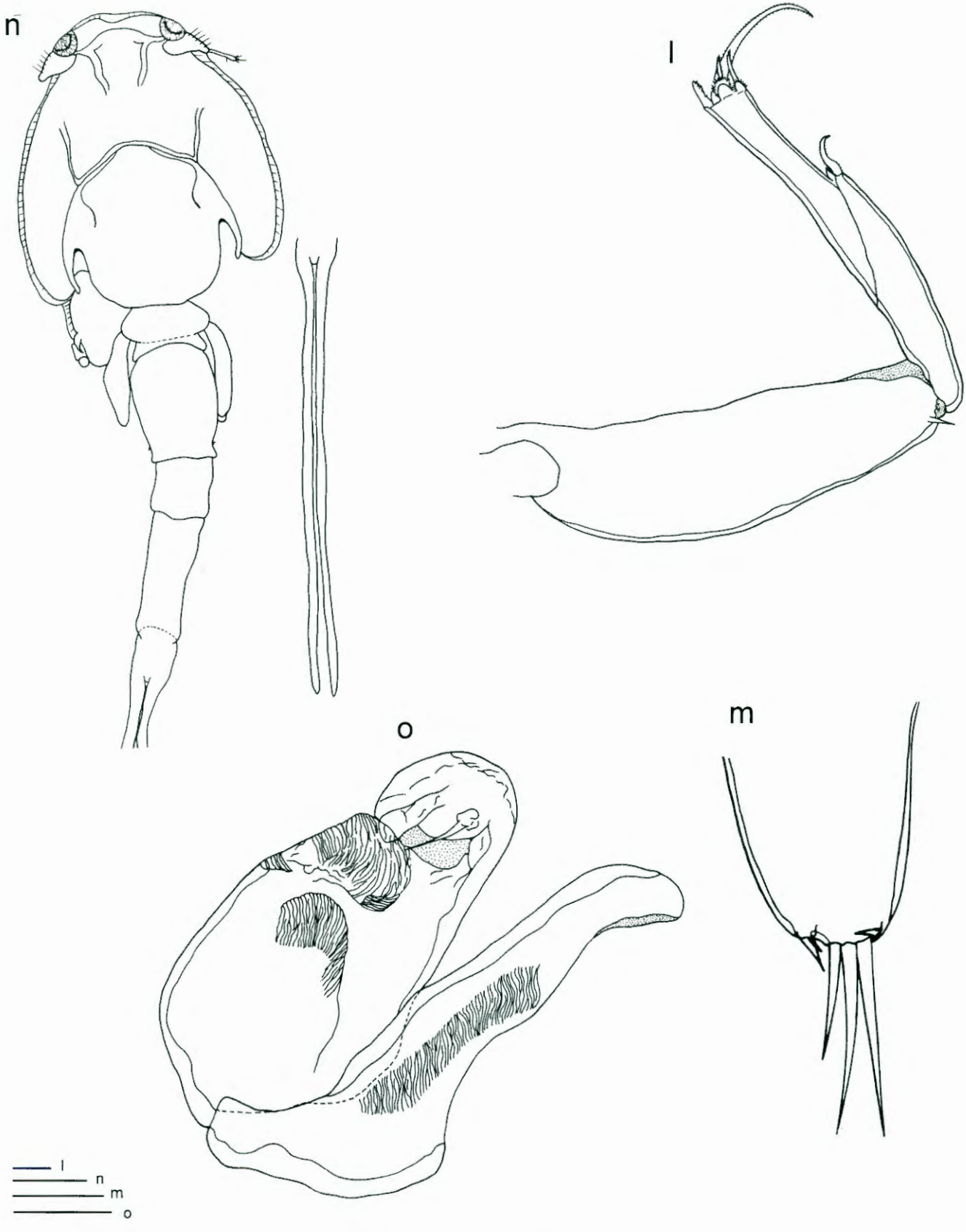


Fig. 3.10. (cont.) *Caligus lalandei* Barnard, 1948, female. **l.** leg 4, ventral. **m.** caudal ramus, ventral. *Caligus lalandei*, male. **n.** habitus, dorsal. **o.** antenna, ventral. Scale bars: 1 mm in m; 100 µm in l, n, o.

Fig. 3.10. (cont.) *Caligus lalandei* Barnard, 1948, male. **p.** maxilliped. **q.** posterolateral side of genital complex, showing leg 5 and leg 6, ventral. Scale bars: 100 μm in p, q.

Caligus mortis Kensley, 1970

Figs. 3.11a-t, 3.12a-d

Caligus mortis: Kensley, 1970: 167-172, fig. 1a-f, 2a-h; Dojiri, 1989: 363-374, figs. 1-8, 9-12, 13-17; Grobler, Van As & Olivier, 2002: 131-136, figs. 1-6, 7-12, 13-15, 16-21.

Material examined.

South African Museum: SAM A12708: One ovigerous female in intertidal rock pool, Rocky Point, Namibia. SAM A12990: One female from *Parablennius cornutus* (Linnaeus, 1758), Swakopmund, Namibia. SAM A12991: One ovigerous female from *Chorisochismus dentex* (Pallas, 1769), Möwe Point, Namibia. SAM A12992: One female from *Parablennius cornutus*, Möwe Point, Namibia. SAM A12993: One ovigerous female from *Clinus superciliosus* (Linnaeus, 1758), Möwe Point, Namibia, tip of fourth leg missing. SAM A11814: Two females from *Clinus superciliosus*, Schaapen Island, Saldanha, South Africa. Voucher specimens from present study, one ovigerous female and one male, have been deposited in the collection of the SA Museum, SAM A44115, as well as one ovigerous female and one male in the collection of the Institute of Parasitology, ASCR, Ceské Budejovice, Czech Republic, PaÚ AVCR 1987.

Present study: Voucher specimens have been deposited in the collection of the Aquatic Parasitology Research Group, Department of Zoology and Entomology, University of the Free State, Bloemfontein. Material collected in present study is listed in Table 3.4.

Table 3.4. Total number of *Caligus mortis* Kensley, 1970 specimens collected from fish hosts at De Hoop Nature Reserve and Jeffreys Bay, including collection numbers.

Host species	# ♀♀, ♂♂ *Caligus*	Locality	Collection number
Clinus superciliosus	5 ovig ♀♀, 2 ♂♂	De Hoop	97/04/07-03
Clinus superciliosus	3 ovig ♀♀, 2 ♂♂	De Hoop	97/04/07-07
Clinus superciliosus	3 ovig ♀♀, 2 ♀♀, 2 ♂♂	De Hoop	97/04/10-02
Clinus superciliosus	1 ovig ♀	Jeffreys Bay	99/01/17-02
Clinus superciliosus	3 ovig ♀♀	Jeffreys Bay	99/01/17-04
Clinus superciliosus	3 ovig ♀♀	Jeffreys Bay	99/01/18-02
Clinus superciliosus	3 ovig ♀♀	De Hoop	99/03/22-04
Clinus superciliosus	4 ovig ♀♀, 6 ♂♂	De Hoop	26/03/02-03
Clinus superciliosus	1 ♂	De Hoop	26/03/02-04

Description.

Female. Body (Fig. 3.11a) 2.54 (2.33-2.71) mm long. Cephalothoracic shield wider than long, 1.27 (1.21-1.34) x 1.37 (1.28-1.41) mm, excluding lateral hyaline membranes. Fourth pediger wider than long, 0.13 (0.12-0.14) x 0.31(0.28-0.33) mm. Genital complex wider than long, 0.84 (0.75-0.90) x 1.02 (0.94-1.11) mm, bearing triangular process terminally. Abdomen one-segmented, as long as wide, 0.23 (0.20-0.25) x 0.23 (0.21-0.24) mm. Caudal ramus (Fig. 3.11n) longer than wide, 103.6 (97.1-109.4) x 75.9 (68.9-81.2) µm. Posterior margin of each ramus armed with two small outer, one small, medial and three large terminal plumose setae.

Antennule. Two-segmented (Fig. 3.11b). Proximal segment trapezoid, much broader than distal segment, with 27 plumose setae on anterior surface. Distal segment rod-shaped, much longer than wide, armed one subterminal seta on posterior margin and 12 setae and one aesthetasc on distal margin.

Antenna. Three-segmented (Fig. 3.11c). Proximal segment with large process on posteromedial margin. Second segment unarmed. Distal segment a strongly curved hook, bearing one basal and one marginal seta.

Postantennary process. Process a curved claw (Fig. 3.11d), with two basal papillae, bearing one and two long setules respectively and one similar papilla located nearby on sternum bearing two long setules.

Maxillule. Dentiform (Fig. 3.11e). Basal papilla bearing two small and one long setae. Basal accessory process dentiform.

Maxilla. Two-segmented (Fig. 3.11f). Proximal segment (lacertus) unarmed. Distal segment (brachium) with medium sized flabellum with both margins serrated and two unequal elements (a short canna and a longer calamus) terminally, canna and calamus with both margins serrated.

Maxilliped. Three-segmented (Fig. 3.11g). Proximal segment (corpus) large and unarmed. Second (shaft) and distal (claw) segments fused to form subchela. Shaft with small, hyaline, setiform process in small pit. Claw with basal seta and minute accessory tooth near inner distal end.

Sternal furca. Base small (Fig. 3.11h). Tines not tapered, curving inward, slightly flared, and truncate at tip.

Leg 1. Protopod (Fig. 3.11i) with one medium sized plumose seta on posterior margin and another medium sized plumose seta on anterodistal margin. Endopod vestigial, medium sized, naked. Exopod two-segmented. First segment with row of setules on posterior margin and small, spiniform seta on anterodistal corner. Second segment with four terminal elements (elements two

and three with accessory process, element four longest, all four elements naked) and three plumose setae on posterior margin.

Leg 2. Coxa small (Fig. 3.11j), with spinule-bearing papillae on anterior surface and large, plumose inner seta on posterior margin. Protopod with anterodistal small, naked seta, patch of fringed anterodistal membrane, posterior margin covered by a striated membrane, with one centrally situated seta. Exopod three-segmented. First segment with one anterodistal, curved spine, both margins of spine with striated membrane, posterior margin with one plumose seta. Second segment with one anterodistal spine, both margins of spine with striated membrane, posterior margin with one long plumose seta. Third segment with three spines on anterodistal margin (first spine smallest, naked, second spine with striated membrane on both margins, third spine with striated membrane along outer margin and plumose inner margin) and five long, plumose setae. Endopod three-segmented. First segment with one long, plumose seta. Second segment with two plumose setae and prominent crest of setules on outer and inner margin. Third segment with six plumose terminal setae and crest of setules on outer corner.

Leg 3. Anterior margin of protopod more sclerotised than the rest of the segment, bearing a striated membrane and two long setules (Fig. 3.11k). Exopod three-segmented. First segment with large terminal claw, slightly curved, situated subterminally on basal swelling which bears terminal striated membrane. Second segment with one anterodistal spine and one posterodistal plumose seta. Third segment with three spines of different lengths and four plumose setae of different lengths. Second and third segment with rows of setules on lateral margins. Endopod two-segmented. First segment expanded laterally into velum on outer margin and bearing one long, plumose seta on posterior margin. Second segment with six long, plumose setae, row of setules on lateral margin.

Leg 4. Protopod (Fig. 3.11l) bearing two setules and small plumose anterodistal seta. Long and slender exopod indistinctly two-segmented. First segment with spine almost as long as terminal spine, naked and bearing pecten at base of insertion of spine. Second segment with two spines of different size, first spine relatively short, naked, not highly sclerotised, and without pecten at base of insertion of spine, terminal spine with both margins serrated and bearing pecten at base of insertion of spine.

Armature on rami of legs 1-4:

	Exopod	Endopod
Leg 1	1-0; III, 1, 3	(vestigial)
Leg 2	I-1; I-1; II, I, 5	0-1; 0-2; 6

Leg 3	I-0; I-1; III, 4	0-1; 6
Leg 4	I-0; I, I	(missing)

Leg 5. Represented by two papillae (Fig. 3.11m) on posterolateral corner of genital complex, one tipped with small plumose seta, other with two similar plumose setae.

Male: Body (Fig. 3.11o) 1.86 (1.78 – 1.93) mm long. Cephalothoracic shield slightly longer than wide, 1.17 (1.11-1.23) x 1.13 (1.08-1.19) mm, excluding lateral hyaline membranes. Fourth pediger wider than long, 95.3 (90.4-99.6) x 241.5 (232.7-248.4) µm. Genital complex slightly wider than long, 0.38 (0.35-0.40) x 0.40 (0.37-0.43) mm. Abdomen one-segmented, wider than long, 0.16 (0.15-0.17) x 0.21 (0.19-0.23) mm. Caudal ramus (Fig. 3.11t) longer than wide, 104.3 (99.7-108.9) x 84.4 (81.4-87.9) µm. Posterior margin of each ramus armed with two small outer, one small, medial and three large terminal plumose setae.

Antenna. Three-segmented (Fig. 3.11p). Proximal segment unarmed. Second segment large and robust, armed with two corrugated patches. Distal segment smallest, claw bifid, strong basal setae on each side of claw.

Maxillule: Dentiform, (Fig. 3.11q), similar to female, with small band of striations on ventral surface of process.

Maxilliped. Three-segmented (Fig. 3.11r). Proximal segment (corpus) large and unarmed. Second (shaft) and distal (claw) segments fused to form subchela. Shaft with small, hyaline, setiform process in small pit and one naked seta on inner distal corner. Claw with basal seta and minute accessory tooth near inner distal end.

Leg 5. Represented by two papillae (Fig. 3.11s) on posterolateral margin of genital complex, one tipped with medium sized plumose seta, other with two similar plumose setae.

Leg 6. Represented by one papilla (Fig. 3.11s) on posterolateral margin of genital complex, bearing two medium sized plumose setae.

Remarks. The most characteristic features of *Caligus mortis* are the shape of the sternal furca and the two-segmented exopod of leg 4 bearing an armature of I-0; I, I. The majority of *Caligus* species possess three terminal spines on the exopod of leg 4. Only eight species of the over 300 known species of this genus have been described as bearing two spines at the tip of leg 4. They are: *C. centrodonti* Baird, 1850, *C. distortus* Pillai & Natarajan, 1977, *C. engraulidis*, *C. labracis* Scott, 1902, *C. mortis*, *C. pageti*, *C. saucius* Dojiri, 1989, and *C. sensorius* Heegaard, 1962. Only five species have a two-segmented exopod of leg 4 with the formula I-0; I, I. They are: *C.*

centrodonti, *C. labracis*, *C. mortis*, *C. pageti*, and *C. sensorius* (Dojiri 1989). *Caligus mortis* can be distinguished from the other four species by the shape of the sternal furca, and the morphology and relative lengths of the exopodal spines of leg 4, particularly the setiform nature of spine 2, and spine 1 almost equal in length to the terminal spine.

The male differs from the female in being smaller as well as in the following; 1) the male antenna has two corrugated patches and well-developed adhesion pads which are absent in the female; 2) the distal segment of the male antenna has a bifid claw and two strong setae on each side of claw, whereas the distal segment of the female antenna forms a strongly curved hook, bearing one basal and one marginal seta and two minute hyaline papillae; 3) the male maxillule is similar to the female maxillule, but with a small band of striations on the middle of the process.

SEM study. The sternal furca (Fig. 3.12a) is characteristic of this species. The base is small, tines are not tapered and curve inward, are slightly flared and truncate at the tip. Leg 2 endopod is three-segmented, with the second and third segments (Fig. 3.12b) bearing prominent ventrolateral patch of spinules. The terminal setae of the caudal ramus are plumose (Fig. 3.12c), a feature found in almost all known species of *Caligus*. The claw of the antenna in the male is bifid (Fig. 3.12d), with two strong basal setae on each side of the bifid claw.

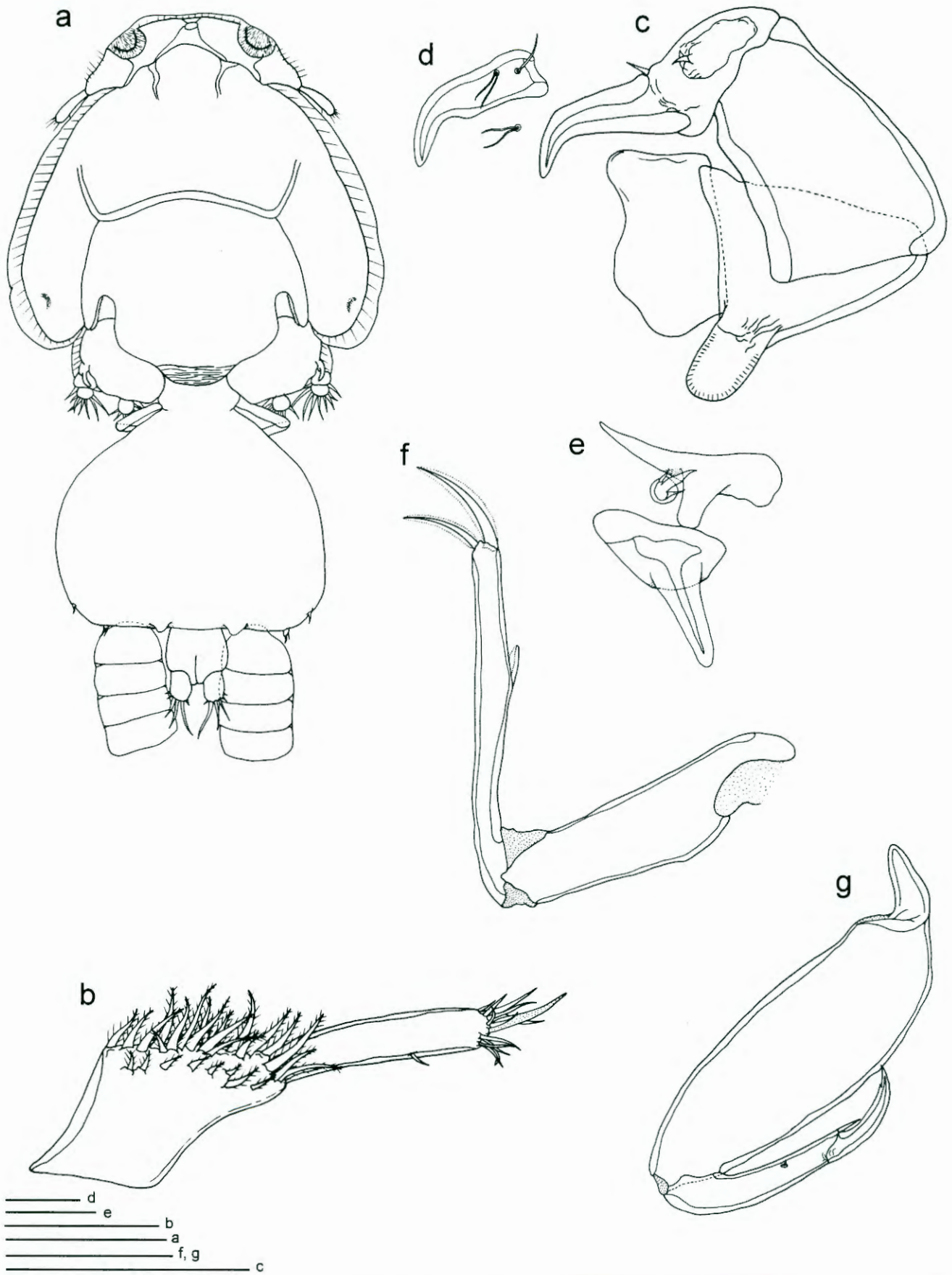


Fig. 3.11. *Caligus mortis* Kensley, 1970, female. **a.** habitus, dorsal. **b.** antennule, ventral. **c.** antenna, ventral. **d.** postantennary process, ventral. **e.** maxillule, ventral. **f.** maxilla. **g.** maxilliped. Scale bars: 500 µm in a; 100 µm in b, c, f, g; 50µm in d, e.

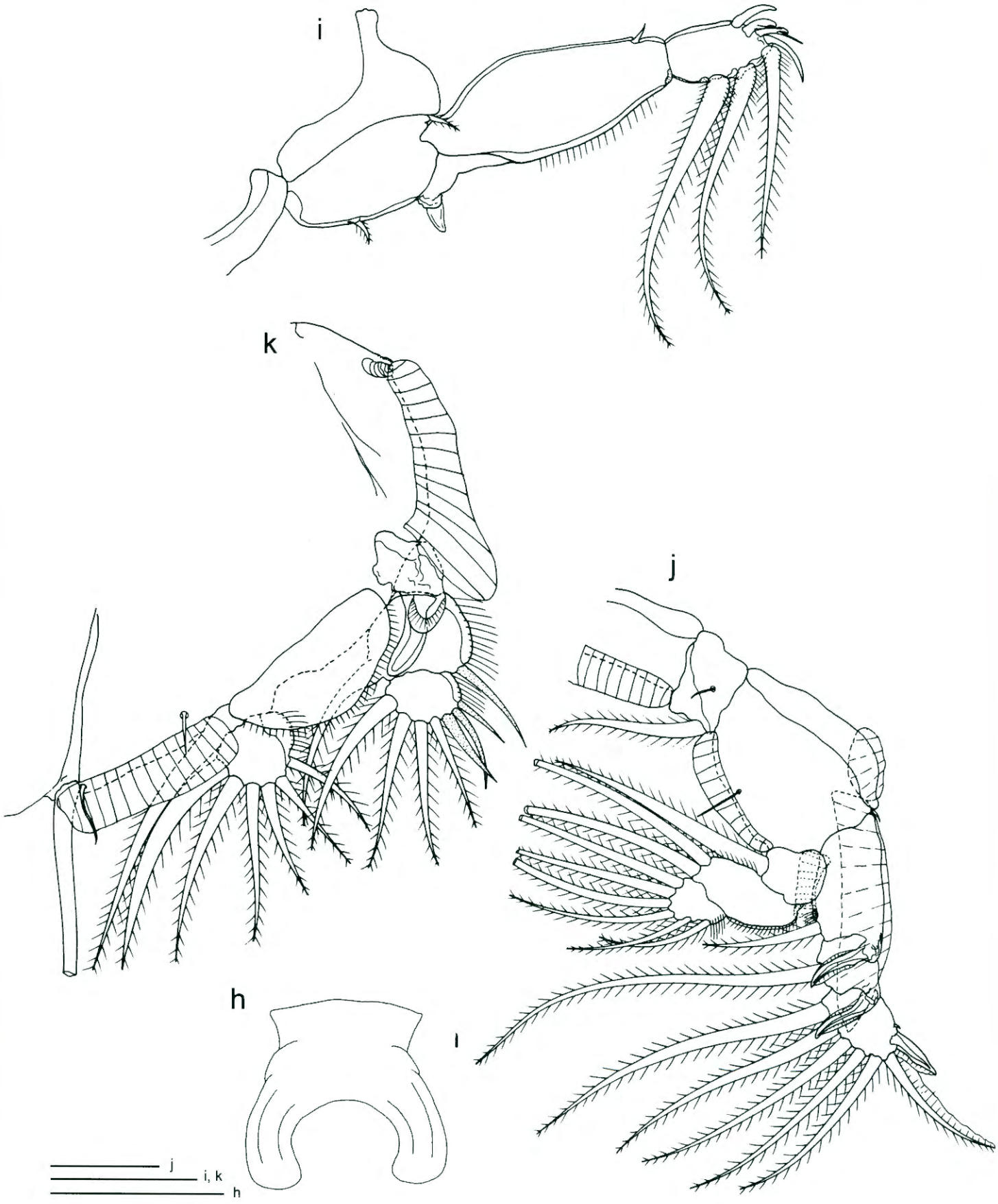


Fig. 3.11. (cont.) *Caligus mortis* Kensley, 1970, female. **h.** sternal furca. **i.** leg 1, ventral. **j.** leg 2, ventral. **k.** leg 3, ventral. Scale bars: 100 μm in i-k; 50 μm in h.

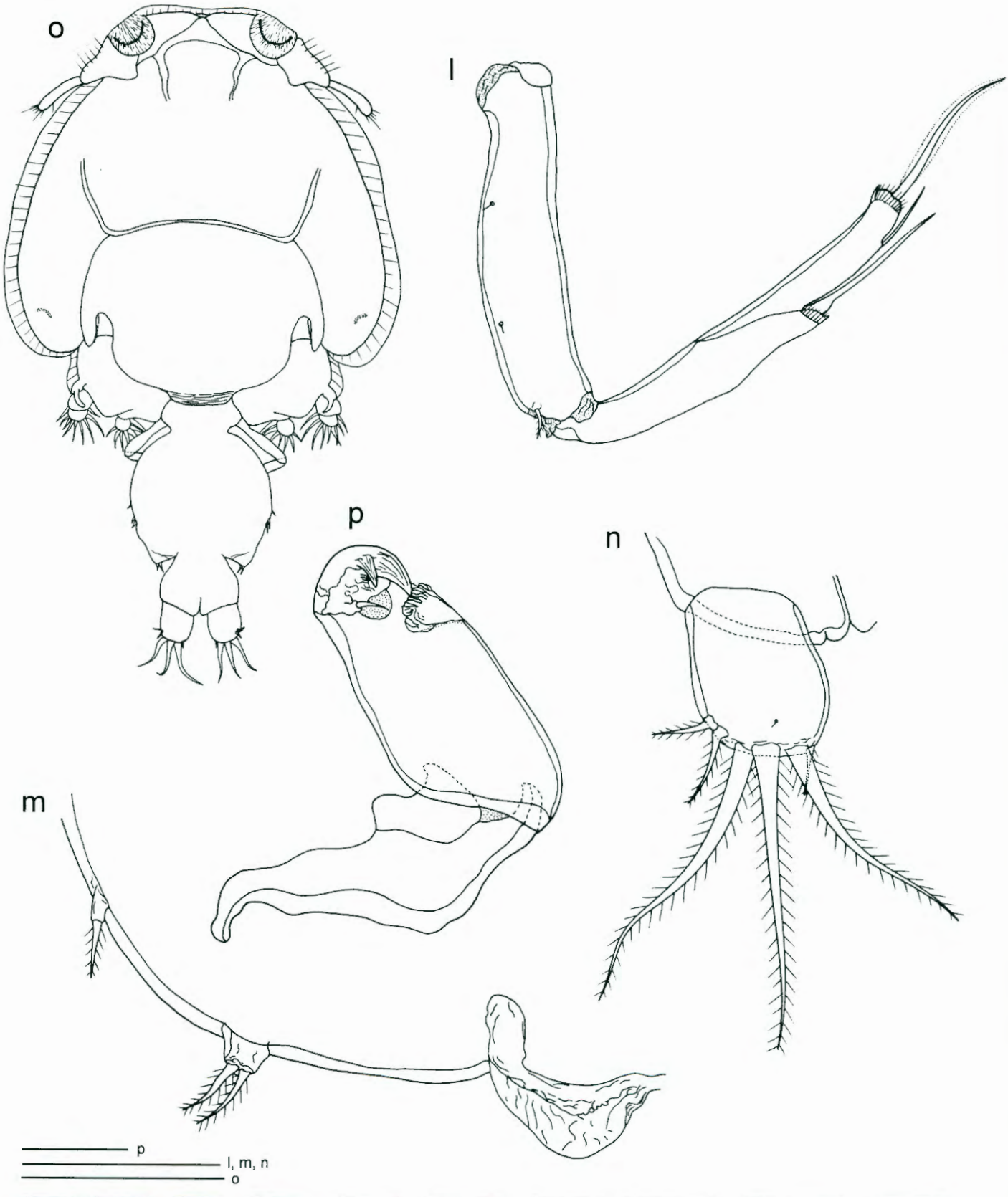


Fig. 3.11. (cont.) *Caligus mortis* Kensley, 1970, female. **l.** leg 4, ventral. **m.** posterolateral side of genital complex, showing leg 5, ventral. **n.** caudal ramus, ventral. *Caligus mortis*, male. **o.** habitus, dorsal. **p.** antenna, ventral. Scale bars: 500 μm in o; 100 μm in l-n; 50 μm in p.

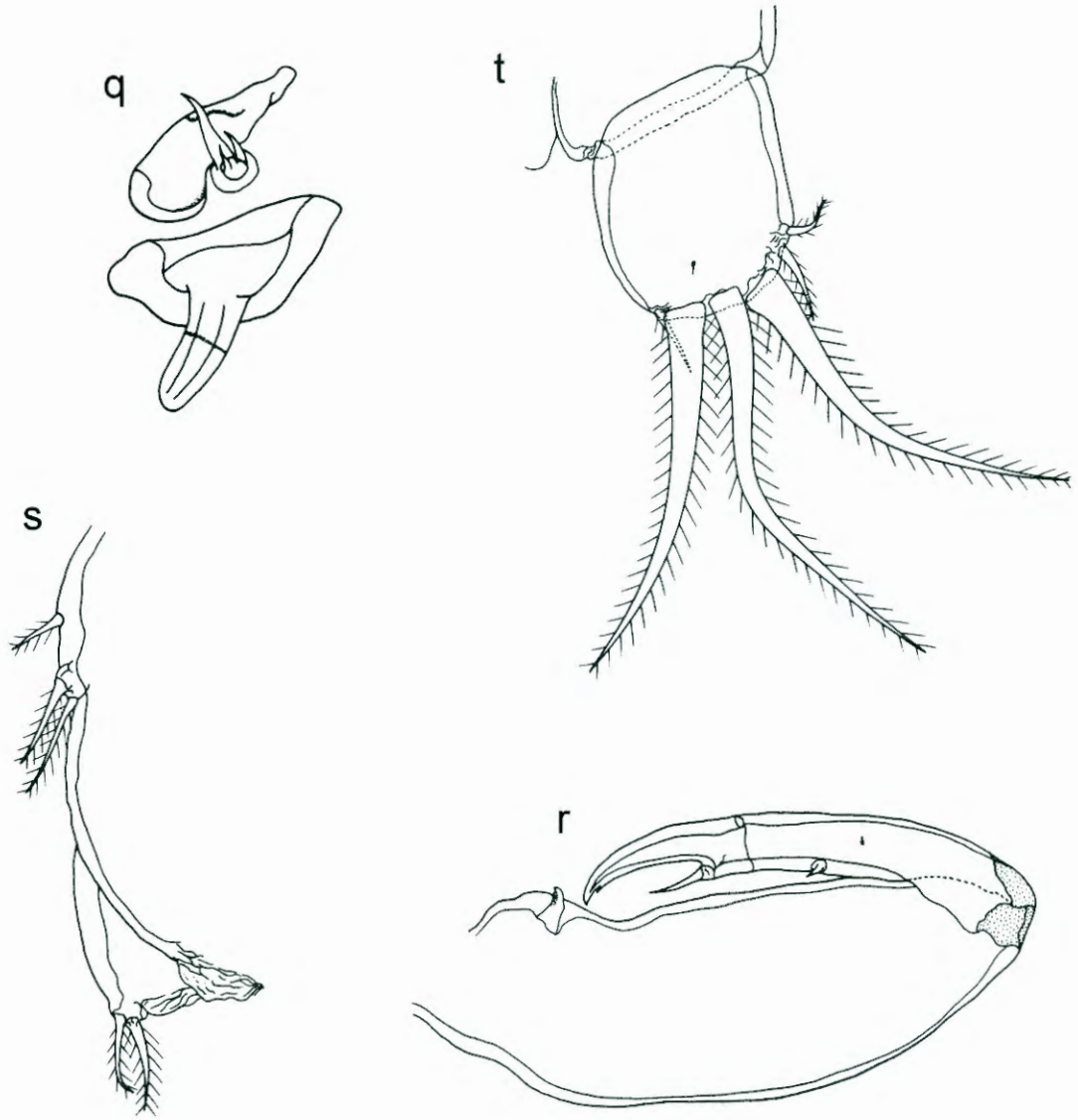
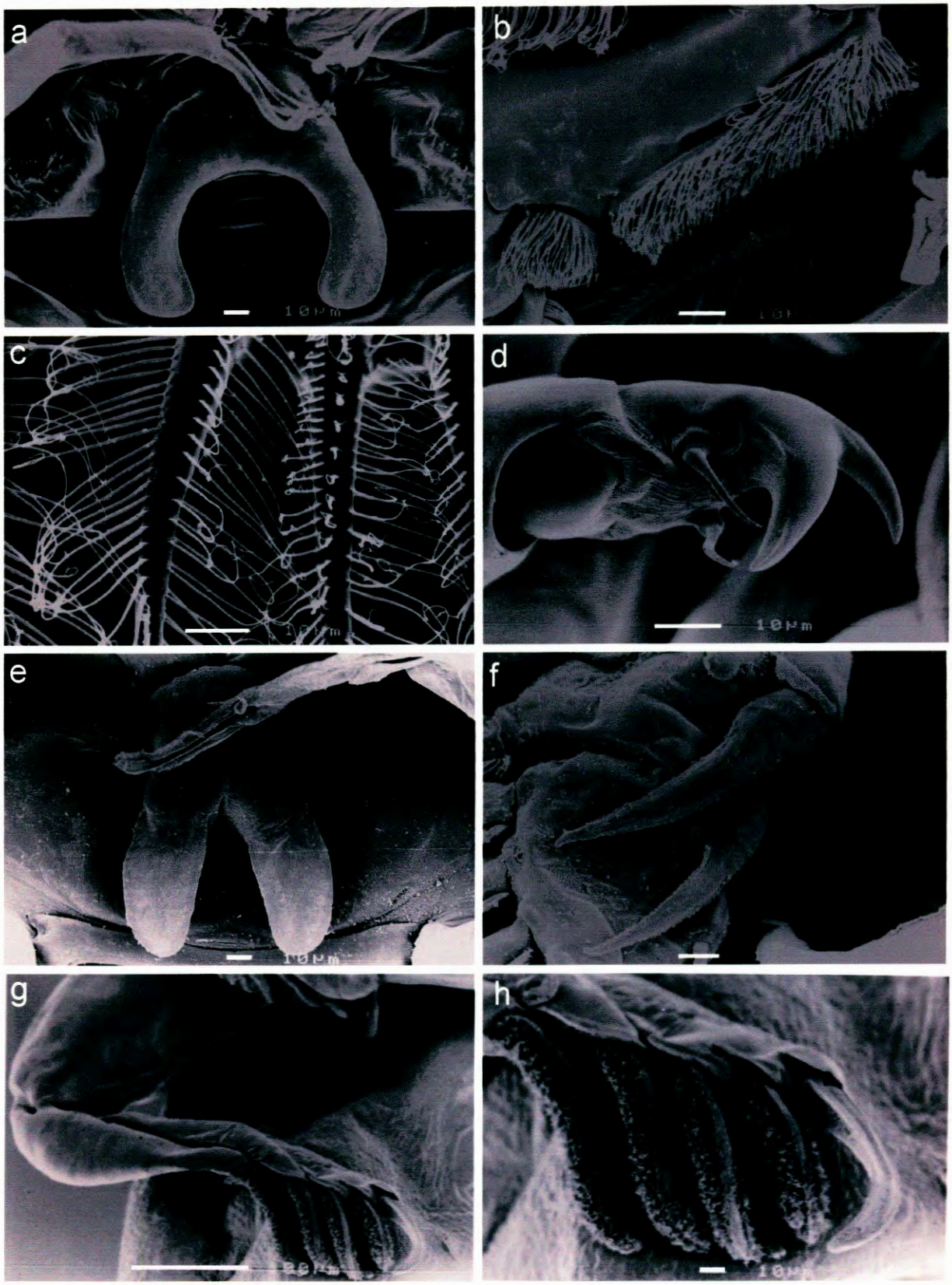


Fig. 3.11. (cont.) *Caligus mortis* Kensley, 1970, male. **q.** maxillule, ventral. **r.** maxilliped. **s.** posterolateral side of genital complex, showing leg 5 and leg 6, ventral. **t.** caudal ramus, ventral. Scale bars: 50 μm in r-t; 30 μm in q.



Figs. 3.12a-c. Scanning electron micrographs of *Caligus mortis* Kensley, 1970, female. **a.** sternal furca. **b.** 2nd, 3rd segments of leg 2 endopod with prominent ventrolateral patch of spinules. **c.** plumose setae on caudal ramus. **Fig. 3.12d.** *Caligus mortis*, male. **d.** bifid claw. **Figs. 3.12e-h.** *Caligus rotundigenitalis* Yu, 1933, female. **e.** Sternal furca. **f.** 1st, 2nd segment of leg 2 exopod with serrated spines. **g.** Leg 4. **h.** Leg 4 exopod - four of five spines covered with spinules. Scale bars: 100 µm in g; 10 µm in a-f, h.

Caligus pelamydis Krøyer, 1863

Figs. 3.13a-n

Caligus pelamydis: Krøyer, 1863: 124-126, 171, 413, plate 4, fig. 4a-g; Brady, 1910: 502, 504, 588, 589, fig. LXIX (2); Scott & Scott, 1913: 30, 57-59, plate 7, figs. 2-3, plate 9, figs. 1-5, plate LXXI, fig. 14; Wilson, 1932: 398, 406-407, fig. 254a, b; Brian, 1935: 152, 153, 183-188, 207, plate 12, figs. 1-8, plate 13, figs. 9-11; van Oorde-de Lint & Schuurmans Stekhoven, 1936: 133, 134, 192, fig. 96; Barnard, 1955a: 244, 245-246; Barnard, 1955b: 8, 99; Reshetnikova, 1955: 97, 102-103, fig. 6; Markevich, 1956: 6, 112, 125, 126, fig. 7; Nunes-Ruivo, 1956: 10-12, fig. 1a; Capart, 1959: 59, 62, 78, 83, fig. 15a, b; Noble & Noble, 1961: figs. VII-15; Hewitt, 1963: 61, 78-83, 114, fig. 6 (1-10); Yamaguti, 1963: 58, plate 78, fig. 6a-c; Noble & Noble, 1964: fig. XVI-13; Shiino, 1965: 408-414, fig. 7A-M, 8A-K; Lewis, 1967: 138-144, 192, fig. 52a-k, 53a-g; Silas & Ummerkutty, 1967: 877, 894-895, 903, 945, 946, fig. 9 (1-11).

Material examined.

South African Museum: SAM A45006: Five ovigerous females and three females from the body surface of *Seriola rivoliana* Valenciennes, 1833.

Present study: No specimens of this species were collected in the present study.

Description.

Female. Body (Fig. 3.13a) 4.53 (4.11-5.17) mm long. Cephalothoracic shield longer than wide, 1.85 (1.61-2.03) x 1.77 (1.63-1.89) mm, excluding lateral hyaline membranes. Fourth pediger wider than long, 0.27 (0.23-0.30) x 0.54 (0.51-0.59) mm. Genital complex longer than wide, 1.03 (0.79-1.13) x 0.89 (0.71-1.13) mm. Abdomen two-segmented. First segment 0.98 (0.93-1.03) x 0.43 (0.38-0.49) mm. Second segment 0.44 (0.39-0.48) x 0.38 (0.34-0.41) mm. Caudal ramus (Fig. 3.13n) longer than wide, 206.6 (196.6-233.2) x 133.4 (126.4-140.2) µm. Posterior margin of each ramus armed with two outer (one small, one long), one small, medial and three long terminal plumose setae.

Antennule. Two-segmented (Fig. 3.13b). Proximal segment trapezoid, much broader than distal segment, with 24 plumose setae on anterior surface. Distal segment rod-shaped, much longer than wide, armed with one subterminal seta on posterior margin and 11 setae and two aesthetascs on distal margin.

Antenna. Three-segmented (Fig. 3.13c). Proximal segment with conical posteromedial process. Second segment subrectangular and unarmed. Distal segment a curved claw bearing one short seta in middle region.

Postantennary process. Much reduced process (Fig. 3.13d), with two basal papillae bearing six setules each, another similar papilla located nearby on sternum.

Maxillule. Dentiform, slightly curved, sharply pointed process (Fig. 3.13e) with basal papilla bearing three short setae.

Maxilla. Two-segmented (Fig. 3.13f). Proximal segment (lacertus) unarmed. Distal segment (brachium) carrying with medium sized flabellum with both margins serrated and two unequal elements (a short canna and a longer calamus) terminally, canna and calamus with both margins serrated.

Maxilliped. Three-segmented (Fig. 3.13g). Proximal segment (corpus) largest, unarmed. Second (shaft) and distal (claw) segments fused to form subchela. Shaft bearing long seta in middle region. Claw curved.

Sternal furca. Base narrower than width across tines (Fig. 3.13h). Outer margins of tines curved, inner margins straight.

Leg 1. Protopod (Fig. 3.13i) with one large plumose seta on posterior margin and another medium sized plumose seta on anterodistal margin. Endopod vestigial, medium sized, with minute element distally. Exopod two-segmented. First segment with row of setules on posterior margin and small, spiniform seta on anterodistal corner. Second segment with four terminal elements (elements one and two with both margins serrated, element three robust, naked, element four smallest, naked) and three plumose setae on posterior margin.

Leg 2. Coxa small (Fig. 3.13j), with spinule bearing papilla on ventral surface and large plumose inner seta on posterior margin. Protopod with anterodistal small, naked seta, patch of fringed anterodistal membrane, posterior margin covered by a striated membrane, with one centrally situated seta. Exopod three-segmented. First segment with one anterodistal, curved spine, naked, posterior margin with one medium sized plumose seta. Second segment with one anterodistal, curved spine, naked, posterior margin with one long plumose seta. Third segment with three spines on anterodistal margin (first spine smallest with both margins bearing striated membrane, second spine with both margins bearing striated membrane, third spine with striated membrane along outer margin and plumose inner margin) and five long, plumose setae. Endopod three-segmented. First segment with one long, plumose seta. Second segment with two plumose setae and prominent crest of setules on outer and inner margin. Third segment with six plumose terminal setae and crest of setules on outer corner.

Leg 3. Anterior margin of protopod with striated membrane (Fig. 3.13k). Exopod three-segmented. First segment with large terminal claw, slightly curved, with both margins bearing striated membrane. Second segment with one anterodistal spine and one posterodistal plumose seta. Third segment with three spines of different lengths and four plumose setae of different lengths. Second and third segment with rows of setules on lateral margins. Endopod two-segmented. First segment expanded laterally into velum on outer margin and bearing one long, plumose seta on posterior margin. Second segment with six plumose setae of different lengths and row of setules on lateral margin.

Leg 4. Protopod (Fig. 3.13l) with small plumose anterodistal seta. Exopod three-segmented. First segment bearing terminal spine. Second segment bearing terminal spine. Third segment bearing three terminal spines. All five spines with both margins bearing prominent rows of hairs. All exopod spines with basal pecten.

Armature on rami of legs 1-4:

	Exopod	Endopod
Leg 1	1-0; III, 1, 3	(vestigial)
Leg 2	I-1; I-1; II, I, 5	0-1; 0-2; 6
Leg 3	I-0; I-1; III, 4	0-1; 6
Leg 4	I-0; I-0; III	(missing)

Leg 5. Represented by three papillae (Fig. 3.13m) on posterolateral corner of genital complex, one tipped with medium sized plumose seta, second tipped with similar, smaller, plumose seta, and third tipped with two similar, medium sized plumose setae.

Remarks. Barnard (1955a) reported *Caligus pelamydis* from the hosts *Chelidonichthys capensis* (Cuvier, 1829) and *Thyrsites atun* (Euphrasen, 1791). It has been recorded from all major oceans and from a wide variety of scombrid species. Eight females remain in the collection of the South African Museum, with the male being missing. This species has not been collected since the original description, and an effort should be made to collect the host species. Characteristic features of this species are; 1) relatively long abdomen, which is two-segmented, 2) the much reduced postantennary process, 3) the four terminal elements on leg 1 second exopodal segment, and 4) the armature and details of the spines on leg 4 exopod.

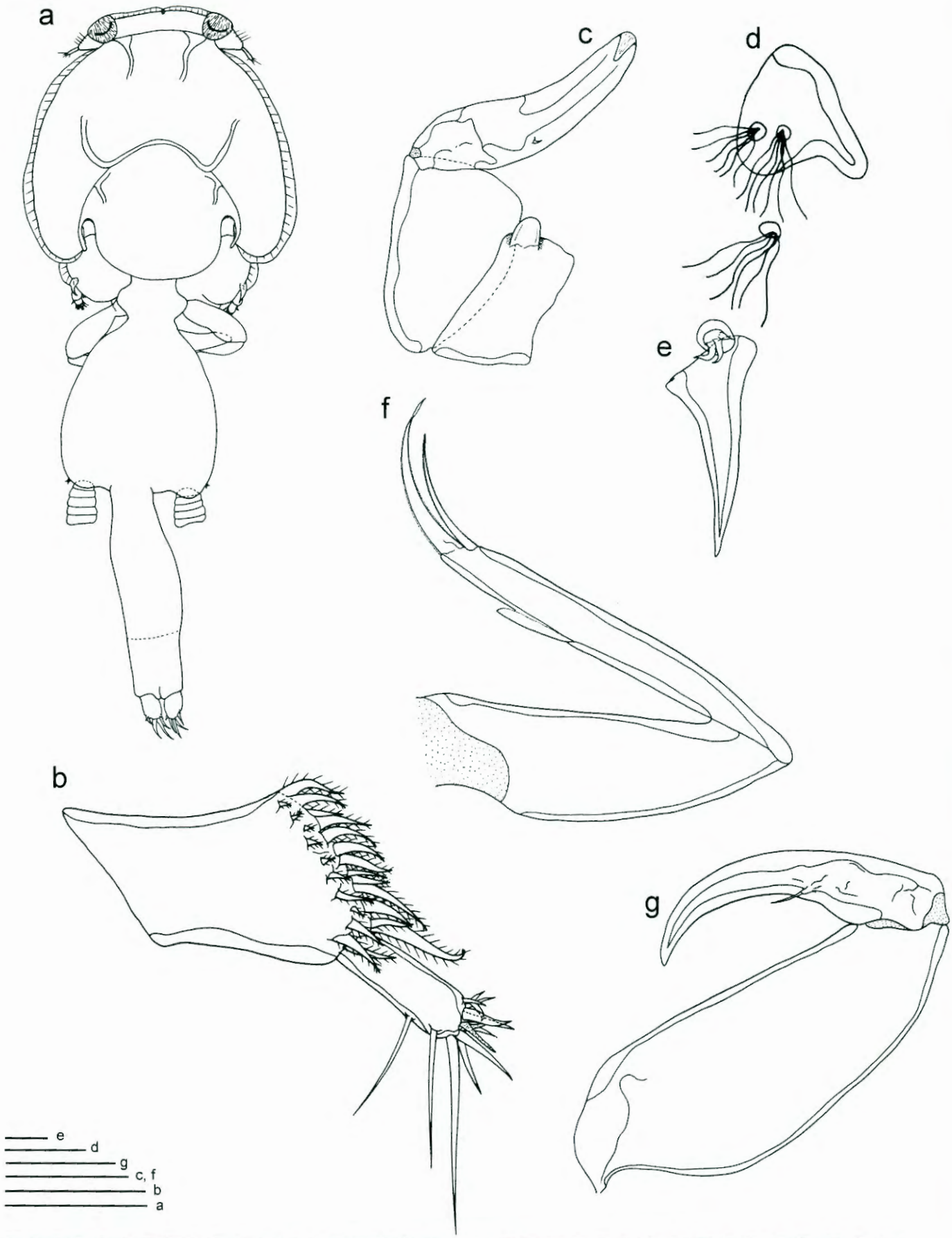


Fig. 3.13. *Caligus pelamydis* Krøyer, 1863, female. **a.** habitus, dorsal. **b.** antennule, ventral. **c.** antenna, ventral. **d.** postantennary process, ventral. **e.** Maxillule, ventral. **f.** maxilla. **g.** maxilliped. Scale bars: 1 mm in a; 100 µm in b, c, f, g; 50 µm in e; 30 µm in d.

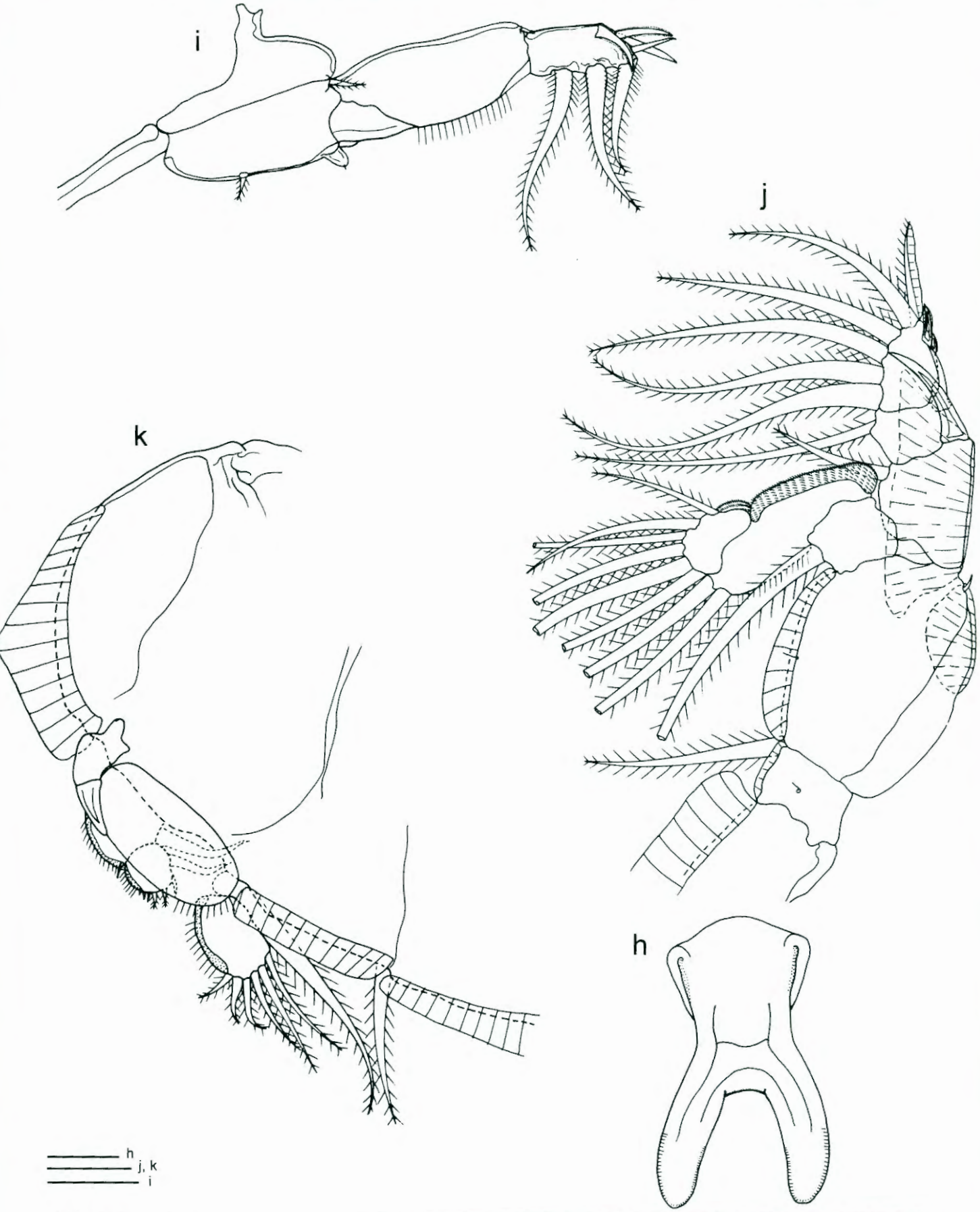


Fig. 3.13. (cont.) *Caligus pelamydis* Krøyer, 1863, female. **h.** sternal furca. **i.** leg 1, ventral. **j.** leg 2, ventral. **k.** leg 3, ventral. Scale bars: 100 µm in i-k; 50 µm in h.

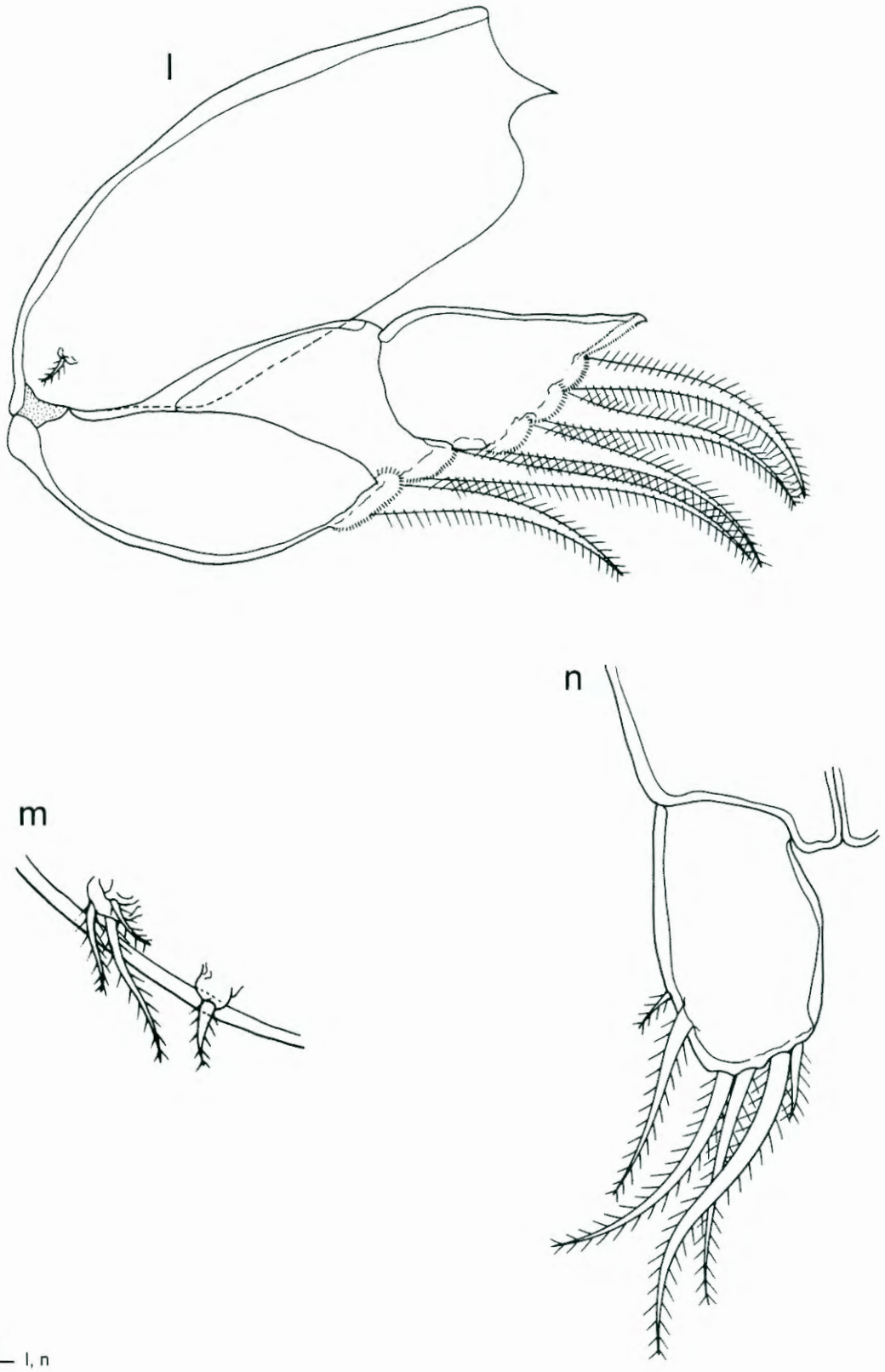


Fig. 3.13. (cont.) *Caligus pelamydis* Krøyer, 1863, female. **l.** leg 4, ventral. **m.** posterolateral side of genital complex, showing leg 5, ventral. **n.** caudal ramus, ventral. Scale bars: 100 µm in l, n; 50 µm in m.

Caligus penrithi Kensley & Grindley, 1973

Figs. 3.14a-n

Caligus penrithi: Kensley & Grindley, 1973: 77-81, fig. 5a, b, 6a-m, 7a-d.

Material examined.

South African Museum: SAM A45007: Eight ovigerous females and four females collected from the operculum of *Cheilodactylus fasciatus* Lacepède, 1803. Three females with no catalogue number (see chapter 5, mixed-up specimens). No material could be found from the type host *Cheilodactylus pixi* Smith, 1980, in the collection of the South African Museum.

Present study: No specimens of this species were collected in the present study.

Description.

Female. Body (Fig. 3.14a) 3.91 (3.70-4.07) mm long. Cephalothoracic shield wider than long, 1.81 (1.66-1.91) x 1.90 (1.67-2.13) mm, excluding lateral hyaline membranes. Fourth pediger wider than long, 0.32 (0.26-0.33) x 0.51 (0.47-0.53) mm. Genital complex wider than long, 1.01 (0.93-1.11) x 1.30 (1.12-1.47) mm. Abdomen two-segmented. First segment 0.45 (0.40-0.51) x 0.49 (0.47-0.57) mm. Second segment 0.24 (0.20-0.27) x 0.31 (0.26-0.37) mm. Caudal ramus (Fig. 3.14n) longer than wide, 157.2 (149.9-166.7) x 105.1 (99.8-110.4) µm. Posterior margin of each ramus armed with two outer (one small, one long), one small, medial and three long terminal plumose setae.

Antennule. Two-segmented (Fig. 3.14b). Proximal segment trapezoid, much broader than distal segment, with 21 plumose setae on anterodistal surface. Distal segment rod-shaped, much longer than wide, armed with one subterminal seta on posterior margin and eight setae and two aesthetasc on distal margin.

Antenna. Three-segmented (Fig. 3.14c). Proximal segment with broad posteromedial process. Second segment subrectangular and unarmed. Distal segment a curved claw bearing two small setae in middle region.

Postantennary process. Broad base (Fig. 3.14d), process a curved claw. Two basal papillae each bearing three setules, another similar papilla located nearby on sternum.

Maxillule. Dentiform, slightly curved, sharply pointed process (Fig. 3.14e) with basal papilla bearing two short and one long setae.

Maxilla. Two-segmented (Fig. 3.14f). Proximal segment (lacertus) unarmed. Distal segment (brachium with medium sized flabellum with both margins serrated and two unequal elements (a short canna and a longer calamus) terminally, canna and calamus with both margins serrated.

Maxilliped. Three-segmented (Fig. 3.14g). Proximal segment (corpus) largest, unarmed. Second (shaft) and distal (claw) segments fused to form subchela. Shaft bearing medium sized seta in middle region. Claw curved.

Sternal furca. Base narrow, broadening posteriorly (Fig. 3.14h). Outer margins of tines straight, inner margins slightly curved. Both inner margins of tines have flap of membrane subterminally.

Leg 1. Protopod (Fig. 3.14i) with one large plumose seta on posterior margin and another medium sized plumose seta on anterodistal margin. Endopod vestigial, bearing minute element distally. Exopod two-segmented. First segment with row of setules on posterior margin and small, spiniform seta on anterodistal corner. Second segment with four terminal elements (element one small, elements two, three and four equal in length, all four elements naked) and three plumose setae on posterior margin.

Leg 2. Coxa small (Fig. 3.14j), with spinule bearing papilla on ventral surface and large plumose inner seta on posterior margin. Protopod with anterodistal small, naked seta, patch of fringed anterodistal membrane, posterior margin covered by a striated membrane, with one centrally situated seta. Exopod three-segmented. First segment with one anterodistal, curved spine, both margins of spine serrated, posterior margin with one medium sized plumose seta. Second segment with one anterodistal, curved spine, both margins of spine serrated, posterior margin with one long plumose seta. Third segment with three spines on anterodistal margin (first spine smallest, naked, second spine with inner margin serrated, third spine with striated membrane along outer margin and plumose inner margin) and five long, plumose setae. Endopod three-segmented. First segment with one long, plumose seta. Second segment with two long, plumose setae and prominent crest of setules on ventral, outer and inner margin. Third segment with six plumose terminal setae and crest of setules on ventral surface.

Leg 3. Anterior margin of protopod with striated membrane (Fig. 3.14k). Exopod three-segmented. First segment with large terminal claw, slightly curved, with both margins bearing striated membrane. Second segment with one anterodistal spine and one posterodistal plumose seta. Third segment with three spines of different lengths and four plumose setae of different lengths. Second and third segment with rows of setules on lateral margins. Endopod two-segmented. First segment expanded laterally into velum on outer margin and bearing one long, plumose seta on posterior margin. Second segment with six plumose setae of different lengths and row of setules on lateral margin.

Leg 4. Protopod (Fig. 3.14l) with small plumose anterodistal seta. Exopod three-segmented. First segment bearing terminal spine. Second segment bearing terminal spine. Third segment bearing three terminal spines. All five spines with both margins finely serrated. All exopod spines with basal pecten.

Armature on rami of legs 1-4:

	Exopod	Endopod
Leg 1	1-0; III, 1, 3	(vestigial)
Leg 2	I-1; I-1; II, I, 5	0-1; 0-2; 6
Leg 3	I-0; I-1; III, 4	0-1; 6
Leg 4	I-0; I-0; III	(missing)

Leg 5. Represented by three papillae (Fig. 3.14m) on posterolateral corner of genital complex, one tipped with medium sized plumose seta, second tipped with large plumose seta, and third tipped with two similar large plumose setae.

Remarks. Kensley and Grindley (1973) described *Caligus penrithi* from the redfingers *Cheilodactylus fasciatus* Lacepède, 1803. This species has been collected once (unknown reference in South African Museum, host to be confirmed) since the original description. Characteristic features of this species are; 1) two-segmented abdomen, with the first segment being much wider anteriorly, decreasing in size posteriorly, 2) the shape of the sternal furca, with tines bearing a flap of membrane on the inner margins of the tines, subterminally, 3) the four terminal elements on leg 1 second exopodal segment, and 4) the armature and details of the spines on leg 4 exopod.

The following errors are rectified from the original description by Kensley and Grindley (1973): 1) There are four terminal elements on the second exopodal segment of the first leg, and not three as described by Kensley and Grindley (1973), the first element being a small, naked element, 2) Leg 5 consists of three papillae on the posterolateral corner of genital complex, first papilla tipped with medium sized plumose seta, second papilla tipped with large plumose seta, and third papilla tipped with two similar large plumose setae, and not three setae in total as described originally, 3) the sternal furca bears a flap of membrane on the inner margin of both tines, subterminally, and 4) the posterior margin of each ramus is armed with two outer (one small, one long), one small, medial and three long terminal plumose setae, and not five setae in total as described by Kensley and Grindley (1973).

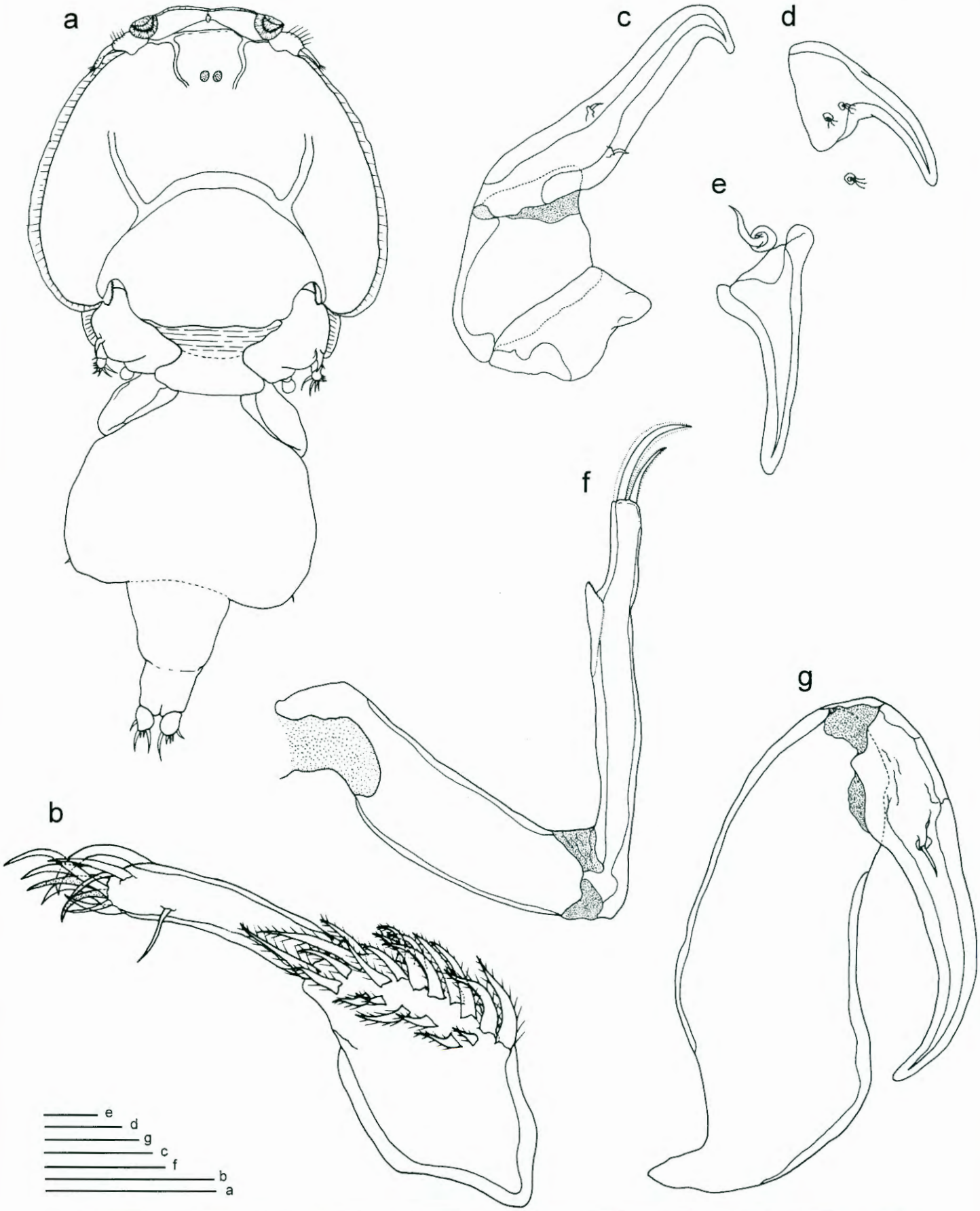


Fig. 3.14. *Caligus penrithi* Kensley & Grindley, 1973, female. **a.** habitus, dorsal. **b.** antennule, ventral. **c.** antenna, ventral. **d.** postantennary process, ventral. **e.** maxillule, ventral. **f.** maxilla. **g.** maxilliped. Scale bars: 1 mm in a; 100 μm in b, c, f, g; 50 μm in d, e.

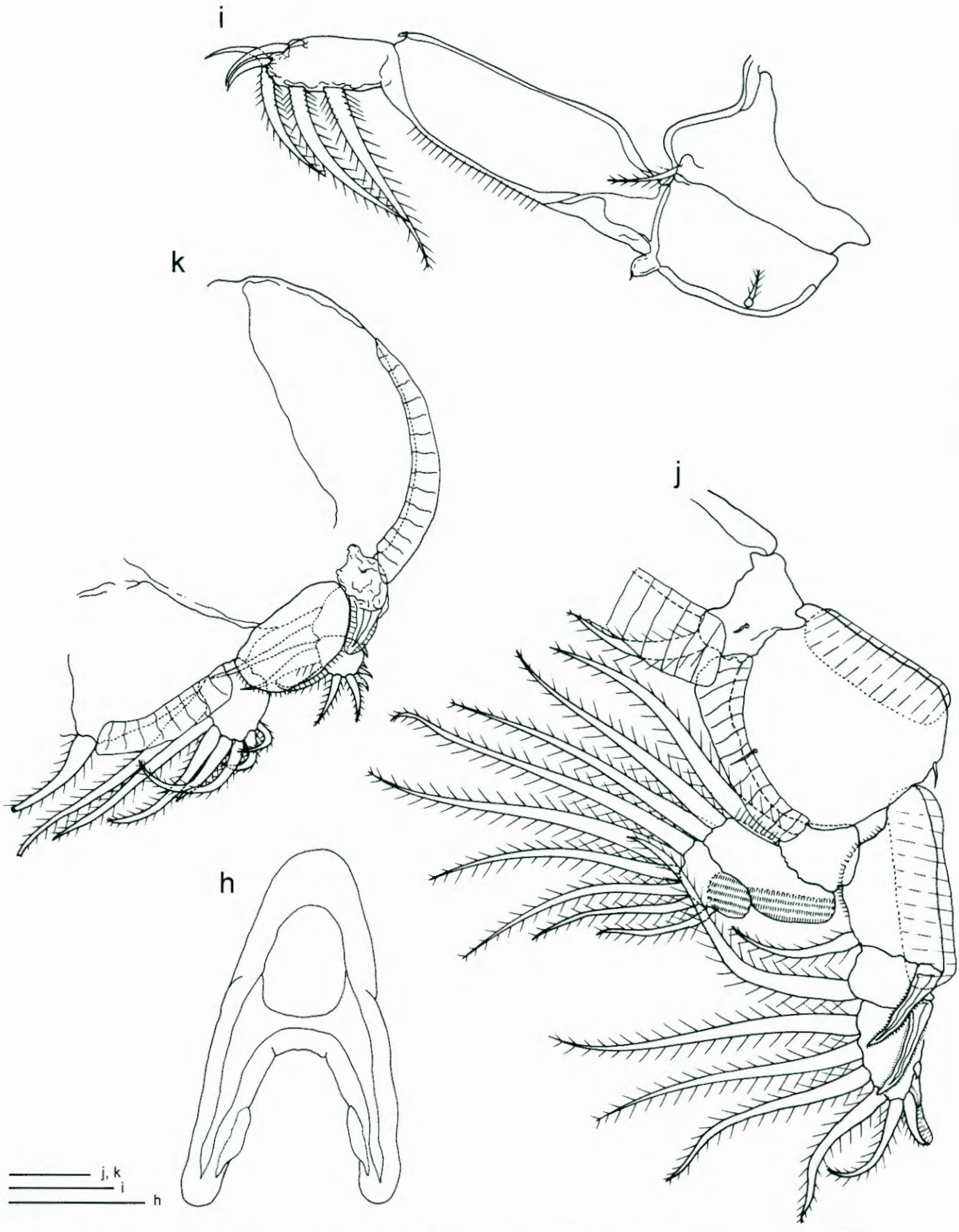


Fig. 3.14. (cont.) *Caligus penrithi* Kensley & Grindley, 1973, female. **h.** sternal furca. **i.** leg 1, ventral. **j.** leg 2, ventral. **k.** leg 3, ventral. Scale bars: 100 μm in h-k.

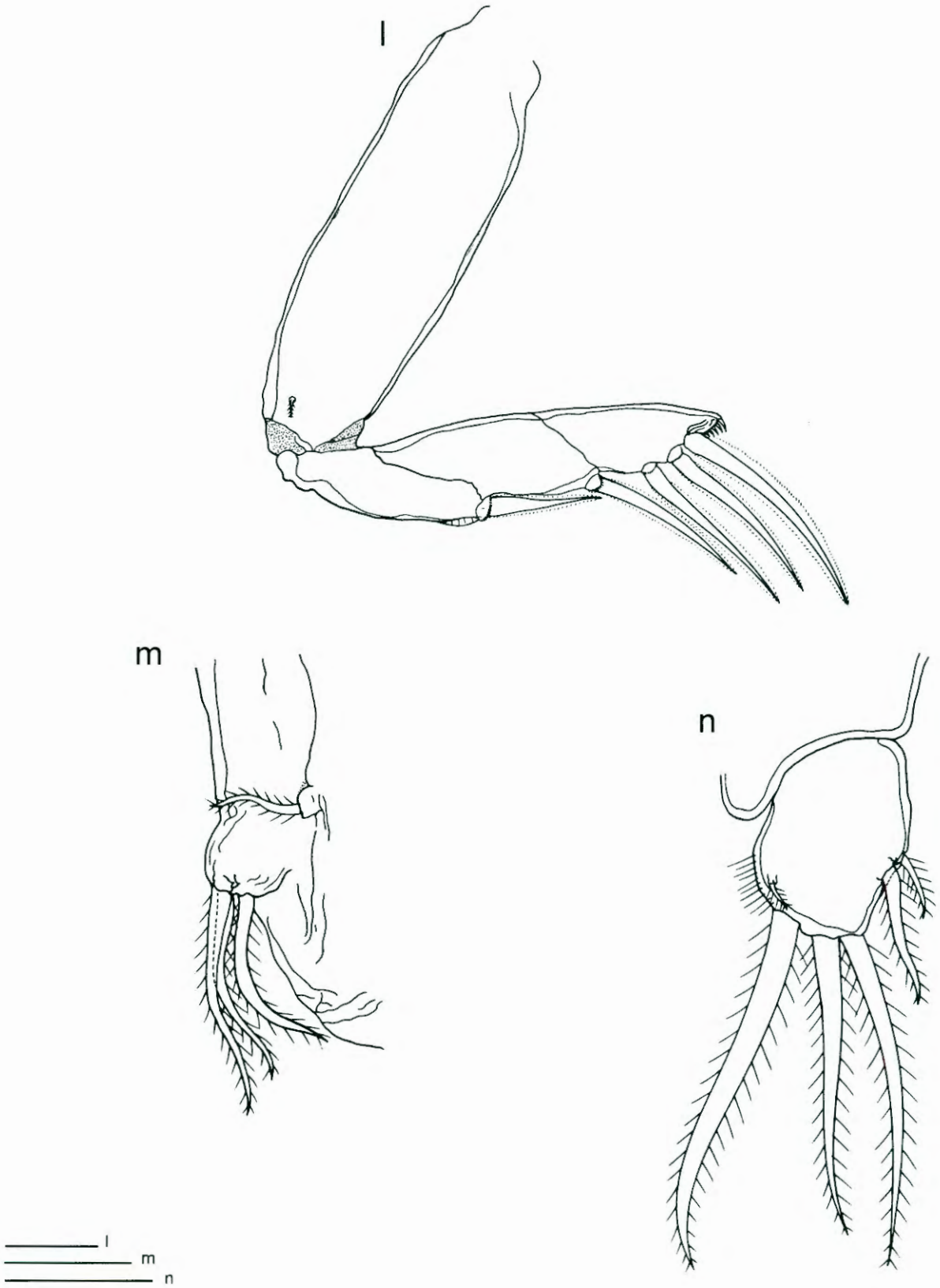


Fig. 3.14. (cont.) *Caligus penrithi* Kensley & Grindley, 1973, female. **l.** leg 4, ventral. **m.** posterolateral side of genital complex, showing leg 5, ventral. **n.** caudal ramus, ventral. Scale bars: 100 μm in l, n; 50 μm in m.

***Caligus tetrodontis* Barnard, 1948**

Figs. 3.15a-u

Caligus tetrodontis: Barnard, 1948: 245-247, fig. 4; Barnard, 1955a: 245, 247, 250, figs. 9d-f; Yamaguti, 1963: 61, plate 78 (figs. 5a-d).

Material examined.

South African Museum: SAM A3778: Two ovigerous females, two females and four males from *Torquigener hypselogeneion* (Bleeker, 1852), Port Elizabeth. Voucher specimens from present study, two ovigerous females and one male, have been deposited in the collection of the SA Museum, SAM A45165.

Present study: Voucher specimens have been deposited in the collection of the Aquatic Parasitology Research Group, Department of Zoology and Entomology, University of the Free State, Bloemfontein. Material collected in present study is listed in Table 3.5.

Table 3.5. Total number of *Caligus tetrodontis* Barnard, 1948 specimens collected from fish hosts in De Hoop Nature Reserve, including collection numbers.

Host species	# ♀♀, ♂♂ *Caligus*	Locality	Collection number
Amblyrhynchotes honckenii	2 ovig ♀♀, 2 ♂♂	De Hoop	00/11/04-01
Amblyrhynchotes honckenii	5 ovig ♀♀, 3 ♂♂	De Hoop	00/11/08-01
Amblyrhynchotes honckenii	6 ovig ♀♀, 1 ♂	De Hoop	00/11/08-02
Amblyrhynchotes honckenii	5 ovig ♀♀, 2 ♂♂	De Hoop	00/11/11-03
Amblyrhynchotes honckenii	5 ovig ♀♀, 4 ♂♂	De Hoop	00/11/11-04
Amblyrhynchotes honckenii	1 ♂	De Hoop	26/03/02-05

Description.

Female. Body (Fig. 3.15a) 5.61 (4.92-5.87) mm long. Cephalothoracic shield slightly longer than wide, 3.18 (2.75-3.31) x 3.16 (2.79-3.27) mm, excluding lateral hyaline membranes. Fourth pediger wider than long, 0.36 (0.34-0.38) x 0.79 (0.66-0.91) mm. Genital complex wider than long, 1.55 (1.48-1.61) x 1.66 (1.59-1.72) mm. Abdomen one-segmented, longer than wide, 0.62 (0.54-0.68) x 0.44 (0.41-0.47) mm. Caudal ramus (Fig. 3.15n) longer than wide, 216.2 (191.3-223.7) x 161.8 (153.3-171.4) µm. Posterior margin of each ramus armed with two small outer, one small, medial and three large terminal plumose setae.

Antennule. Two-segmented (Fig. 3.15b). Proximal segment shorter than distal segment and armed with 24 plumose setae on anterodistal surface. Distal segment rod-shaped, much longer than wide, armed with one subterminal seta on posterior margin and 10 setae and two aesthetascs on distal margin.

Antenna. Three-segmented (Fig. 3.15c). Proximal segment small with spatula-like process on posterior surface. Second segment unarmed. Distal segment a curved claw bearing one small seta in middle region.

Postantennary process. Process a curved claw (Fig. 3.15d). Basal part of process with two papillae, one bearing one setule, other bearing two setules. Another similar papilla located nearby on sternum, bearing one setule.

Maxillule. Dentiform (Fig. 3.15e), another basal process in shape of a claw. Basal papilla with two short, and one medium sized setae.

Maxilla. Two-segmented (Fig. 3.15f). Proximal segment (lacertus) unarmed. Distal segment (brachium) carrying large flabellum with both margins serrated and two unequal elements (a short canna and a longer calamus) terminally, canna and calamus with both margins serrated.

Maxilliped. Three-segmented (Fig. 3.15g). Proximal segment (corpus) largest, bearing large ridge with small denticles on medial margin. Second (shaft) and distal (claw) segments fused to form subchela. Shaft bearing small subterminal seta. Claw curved, with medium sized basal seta.

Sternal furca. Base short, with processes on lateral margins (Fig. 3.15h). Tines almost spatula-like, and flattened terminally.

Leg 1. Protopod (Fig. 3.15i) with one medium sized plumose seta on posterior margin and another small plumose seta on anterodistal margin. Endopod vestigial, naked. Exopod two-segmented. First segment with row of setules on posterior margin and small, spiniform seta on anterodistal corner. Second segment with four terminal elements (elements two and three with accessory process, elements one, two and three naked, element four longest, twice as long as first three elements, naked) and three plumose setae on posterior margin.

Leg 2. Coxa small (Fig. 3.15j), with spinule bearing papilla on ventral surface and large plumose inner seta on posterior margin. Protopod with anterodistal small, naked seta, patch of fringed anterodistal membrane, posterior margin covered by a striated membrane, with one centrally situated seta. Exopod three-segmented. First segment with one anterodistal spine, both margins of spine with striated membrane, posterior margin with one medium sized plumose seta. Second segment with one anterodistal, curved spine, both margins of spine with striated membrane, posterior margin with one long plumose seta. Third segment with three spines on anterodistal margin (first spine smallest, both margins serrated, second spine with striated membrane on inner

margin, third spine with striated membrane along outer margin and plumose inner margin) and five long, plumose setae. Second segment with crest of setules on innermost margin. Endopod three-segmented. First segment with one long, plumose seta. Second segment with two long, plumose setae and prominent crest of setules on outer and inner margin. Third segment with six plumose terminal setae and crest of setules on outer corner.

Leg 3. Anterior margin of protopod with striated membrane (Fig. 3.15k). Exopod three-segmented. First segment with large, slightly curved, terminal claw, outer margin of claw bearing striated membrane. Second segment with one anterodistal spine and one posterodistal plumose seta. Third segment with three spines of almost equal lengths and four plumose setae of different lengths. Second and third segment with rows of setules on lateral margins. Endopod two-segmented. First segment expanded laterally into velum on outer margin and bearing one long plumose seta on posterior margin. Second segment with six plumose setae of different lengths and row of setules on lateral margin.

Leg 4. Protopod (Fig. 3.15l) with small plumose anterodistal seta, two setules on outer margin. Exopod two-segmented. First segment bearing terminal spine, with both margins finely serrated. Second segment bearing three terminal spines of different lengths, all spines with both margins finely serrated. All exopod spines with basal pecten.

Armature on rami of legs 1-4:

	Exopod	Endopod
Leg 1	1-0; III, 1, 3	(vestigial)
Leg 2	I-1; I-1; II, I, 5	0-1; 0-2; 6
Leg 3	I-0; I-1; III, 4	0-1; 6
Leg 4	I-0; III	(missing)

Leg 5. Represented by two papillae (Fig. 3.15m) on posterolateral corner of genital complex, one tipped with two medium sized plumose setae, other with one similar plumose seta.

Male. Body (Fig. 3.15o) 4.02 (3.76-4.47) mm long. Cephalothoracic shield longer than wide, 2.03 (1.87-2.21) x 1.87 (1.69-2.03) mm, excluding lateral hyaline membranes. Fourth pediger wider than long, 0.21 (0.19-0.23) x 0.47 (0.41-0.52) mm. Genital complex longer than wide, 0.87 (0.78-0.94) x 0.55 (0.51-0.60) mm. Abdomen two-segmented. First segment 0.28 (0.25-0.30) x 0.30 (0.27-0.33) mm. Second segment 0.35 (0.32-0.37) x 0.30 (0.27-0.33) mm. Caudal ramus (Fig. 3.15u) one and a half times as long than wide, 226.1 (211.8-237.7) x 136.5 (128.4-145.3) µm.

Posterior margin of each ramus armed with two outer (one small, one medium), one small, medial and three long terminal plumose setae.

Antenna. Three-segmented (Fig. 3.15p). Proximal segment unarmed. Second segment with corrugated medial, ventral, and posteroventral surfaces. Distal segment bifid claw, with parts being covered by cuticular flap, and one strong basal seta.

Postantennary process. Broad base (Fig. 3.15q), process a strongly curved claw.

Maxillule. Dentiform, process sharply-pointed, (Fig. 3.15r) bearing accessory process near base.

Maxilliped. Three-segmented (Fig. 3.15s). Corpus large and robust, bearing one large conical, sclerotised ridge, and another smaller ridge on medial margin. Second segment (shaft) with long subterminal seta, and claw bearing strong basal seta.

Leg 5. Represented by two papillae (Fig, 3.15t) on posterolateral margin of genital complex, one tipped with medium sized plumose seta, other with two similar plumose setae.

Leg 6. Represented by one papilla (Fig. 3.15t) on posterolateral margin of genital complex, bearing two medium sized plumose setae.

Remarks. This species was originally collected and described from the orange-spotted toadfish, *Torquigener hypselogeneion* (Bleeker, 1852), Port Elizabeth. This species has been collected on various occasions in the present study on the south coast of South Africa, from another pufferfish species, the evil eye pufferfish, *Amblyrhynchotes honckenii* (Bloch, 1785). It seems as if this species is a parasite of toadfish and pufferfish, and future collections will confirm this finding.

Specimens of *Caligus tetrodontis* were collected from the white-spotted puffer *Arothron hispidus*, Port Elizabeth, and subsequently described as a new species, *Caligus africanus*, in the PhD thesis of Oldewage (1987). In the synopsis and host distribution of *Caligus* species from Africa, Oldewage and Van As (1989) included *Caligus africanus* as a species awaiting description, but instead this never materialised. Oldewage (1990) redescribed the female of *Caligus tetrodontis* based on the material collected from *Arothron hispidus*, without acknowledging the previous misidentification by Oldewage (1987).

Many discrepancies are found in this redescription of Oldewage (1990), and for one, he described the second exopodal segment of leg 1 in having one long spine and five shorter spines, thus, in total, six terminal elements. No species of *Caligus* have six terminal elements on the second exopodal segment of leg 1. My opinion is that the redescription of *C. tetrodontis* by Oldewage (1990) should be disregarded, as it will only add more confusion to the species of *Caligus* collected from South Africa. *Caligus africanus* as designated by Oldewage in 1987 should also be considered as species inquirenda.

Characteristic features of *C. tetrodontis* females are; 1) the accessory process at the base of the maxillule, 2) the shape of the bas and tines of the sternal furca, 3) the four terminal elements on the second exopodal segment of leg 1, and 4) the armature and details of the spines on leg 4 exopod.

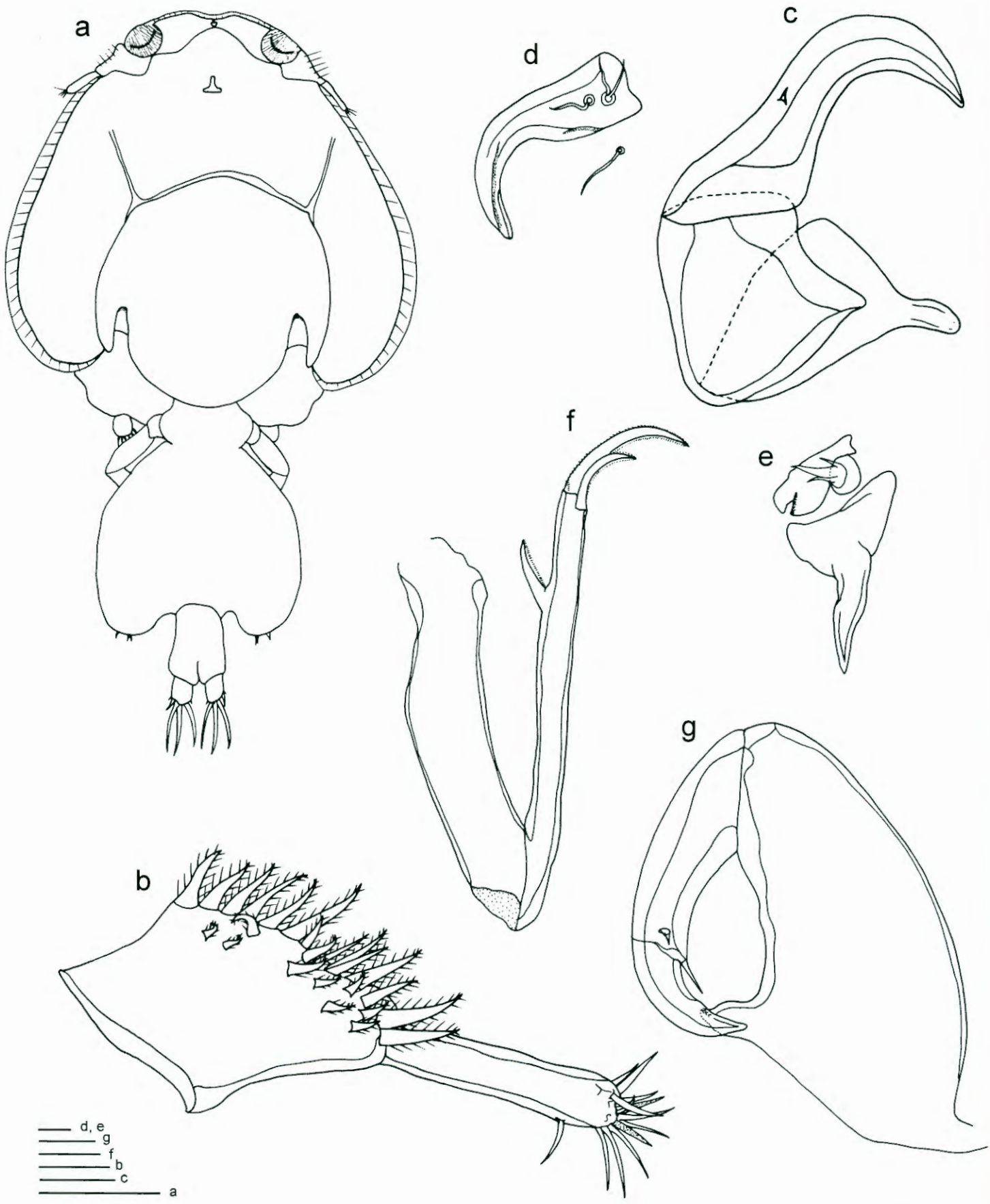


Fig. 3.15. *Caligus tetrodontis* Barnard, 1948, female. **a.** habitus, dorsal. **b.** antennule, ventral. **c.** antenna, ventral. **d.** postantennary process, ventral. **e.** maxillule, ventral. **f.** maxilla. **g.** maxilliped. Scale bars: 1 mm in a; 100 μm in b, c, f, g; 50 μm in d, e.

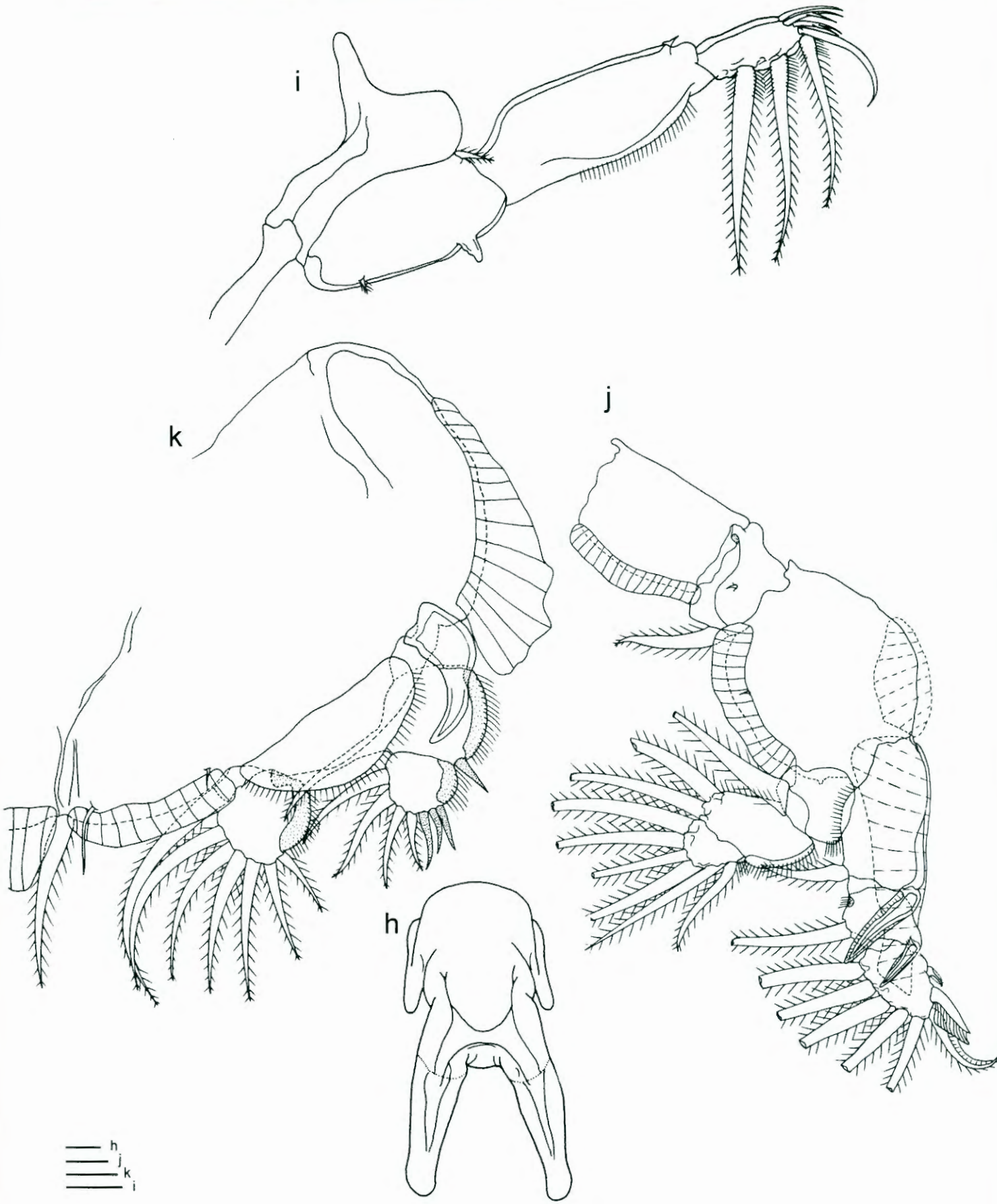


Fig. 3.15. (cont.) *Caligus tetrodontis* Barnard, 1948, female. **h.** sternal furca. **i.** leg 1, ventral. **j.** leg 2, ventral. **k.** leg 3, ventral. Scale bars: 100 μm in i-k; 50 μm in h.

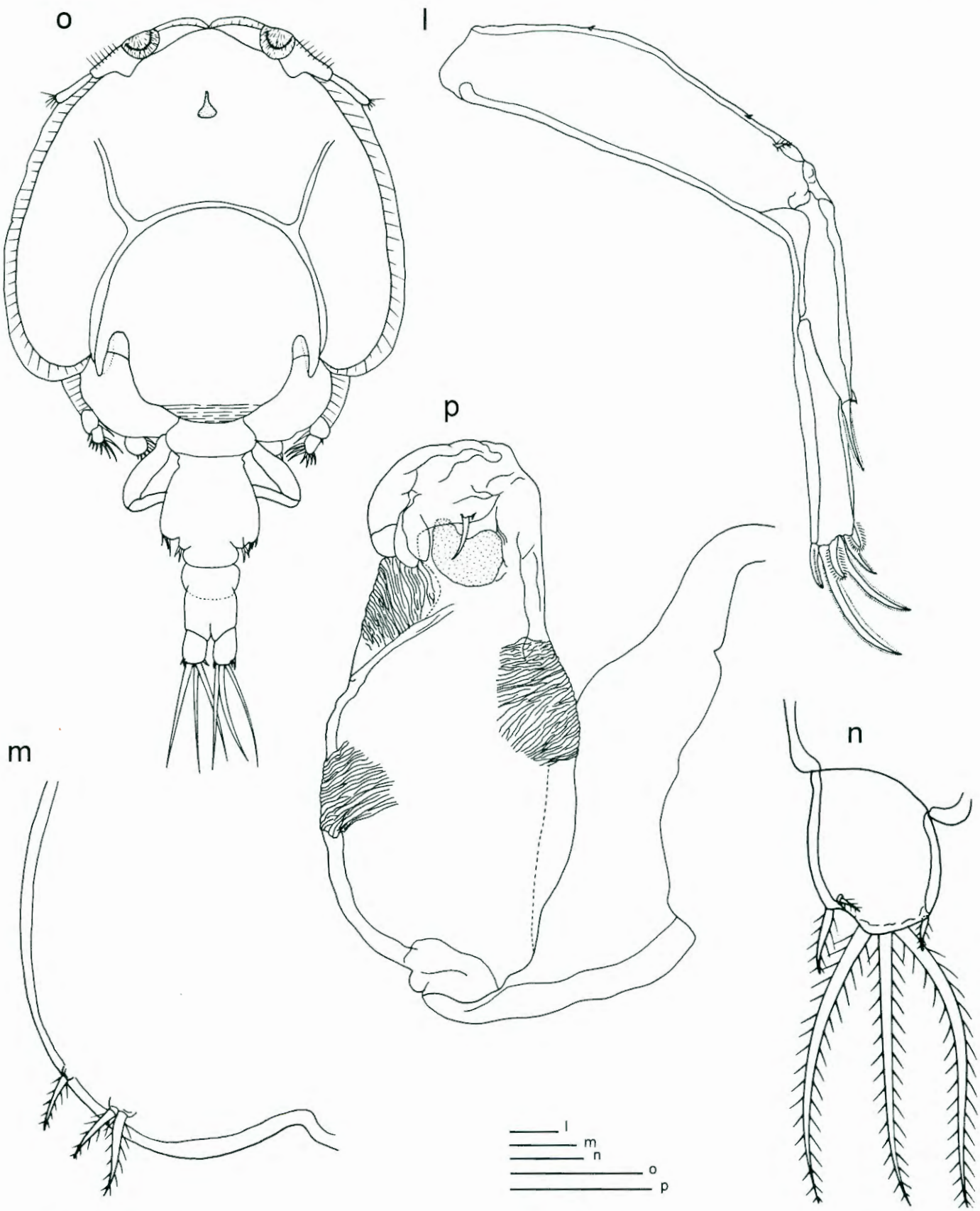


Fig. 3.15. (cont.) *Caligus tetrodontis* Barnard, 1948, female. **l.** leg 4, ventral. **m.** posterolateral side of genital complex, showing leg 5, ventral. **n.** caudal ramus, ventral. *Caligus tetrodontis*, male. **o.** habitus, dorsal. **p.** antenna, ventral. Scale bars: 1 mm in o; 100 µm in l-n, p.

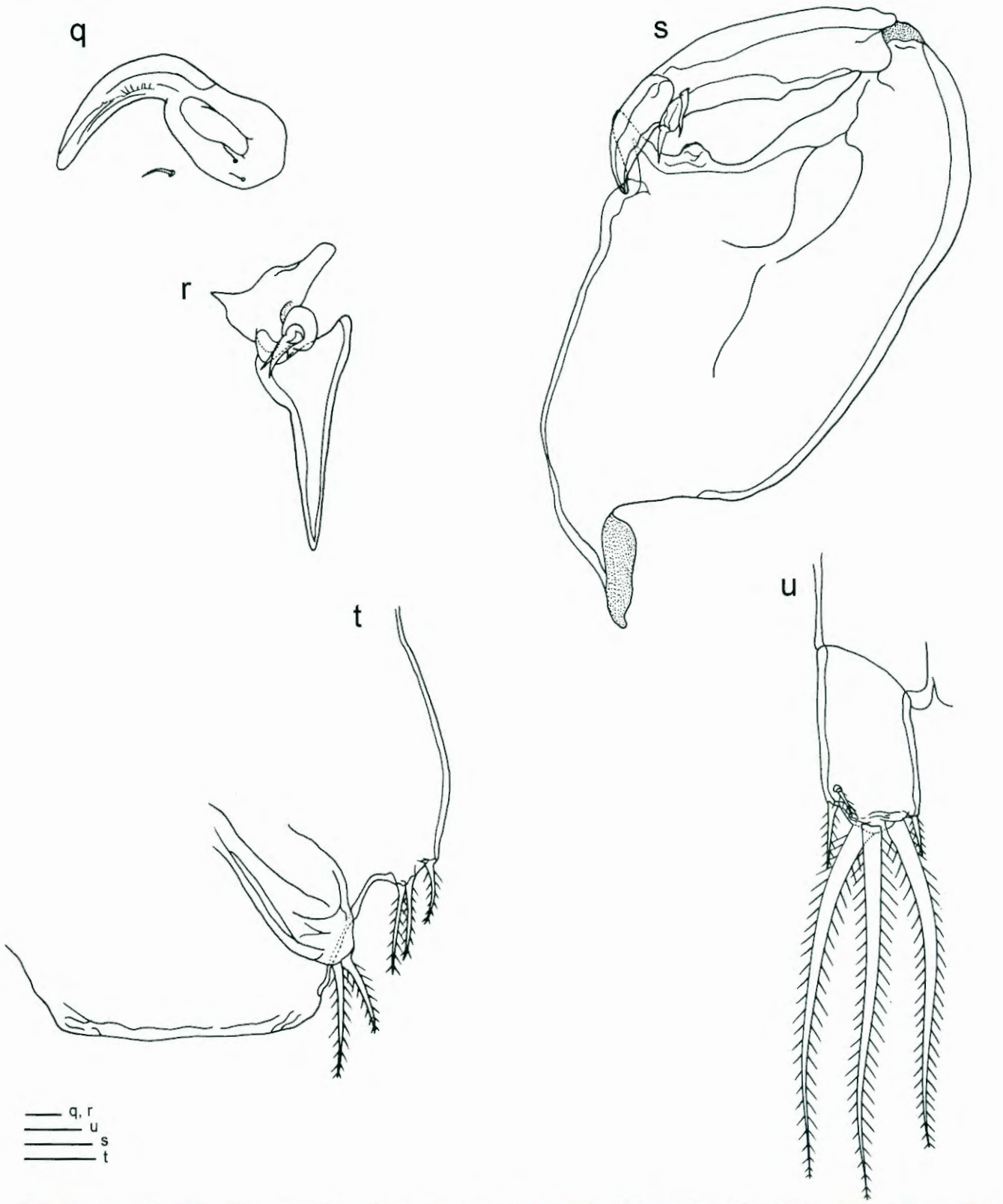


Fig. 3.15. (cont.) *Caligus tetrodontis* Barnard, 1948, male. **q.** postantennary process. **r.** maxillule. **s.** maxilliped. **t.** posterolateral side of genital complex, showing leg 5 and leg 6, ventral. **u.** caudal ramus, ventral. Scale bars: 100 μm in s-u; 50 μm in q, r.

Caligus sp. A

Figs. 3.16a-u

Caligus sp. A

Material examined.

South African Museum: Voucher specimens from present study, two ovigerous females and one male, have been deposited in the collection of the SA Museum, SAM A45166.

Present study: Voucher specimens have been deposited in the collection of the Aquatic Parasitology Research Group, Department of Zoology and Entomology, University of the Free State, Bloemfontein. Material collected in present study is listed in Table. 3.6.

Table 3.6. Total number of *Caligus* sp. A specimens collected from fish hosts in De Hoop Nature Reserve and Jeffreys Bay, including collection numbers.

Host species	# ♀♀, ♂♂ *Caligus*	Locality	Collection number
Argyrosomus japonicus	3 ovig ♀♀, 1 ♀, 2 ♂♂	Jeffreys Bay	99/01/16-02
Argyrosomus japonicus	2 ovig ♀♀, 1 ♂	Jeffreys Bay	99/01/17-03
Argyrosomus japonicus	6 ovig ♀♀	De Hoop	2001/04/03-02
Argyrosomus japonicus	2 ovig ♀♀, 1 ♂	De Hoop	2001/04/04-01
Argyrosomus japonicus	1 ovig ♀	De Hoop	2001/04/04-04
Argyrosomus japonicus	3 ovig ♀♀, 1 ♀, 2 ♂♂	De Hoop	227
Argyrosomus japonicus	7 ovig ♀♀	De Hoop	232

Description.

Female. Body (Fig. 3.16a) 6.36 (5.94-6.61) mm long. Cephalothoracic shield longer than wide, 3.28 (2.97-3.42) x 2.81 (2.59-2.98) mm, excluding lateral hyaline membranes. Fourth pediger wider than long, 0.33 (0.29-0.37) x 0.65 (0.57-0.69) mm. Genital complex longer than wide, 1.62 (1.49-1.76) x 1.51 (1.42-1.63) mm. Abdomen two-segmented. First segment 0.18 (0.16-0.19) x 0.41 (0.35-0.47) mm. Second segment 0.68 (0.59-0.77) x 0.52 (0.44-0.61) mm. Caudal ramus (Fig. 3.16n) longer than wide, 393.1 (374.5-406.8) x 216.9 (207.4-221.9) µm. Posterior margin of each ramus armed with two outer (one small, one medium), one small, medial and three large terminal plumose setae.

Antennule. Two-segmented (Fig. 3.16b). Proximal segment trapezoid, much broader than distal segment, with 26 plumose setae on anterodistal surface. Distal segment rod-shaped, much longer than wide, armed with one subterminal seta on posterior margin and 11 setae and two aesthetascs on distal margin.

Antenna. Three-segmented (Fig. 3.16c). Proximal segment with large cone-shaped posteromedial process. Second segment subrectangular and unarmed. Distal segment a curved claw bearing one small seta in middle region.

Postantennary process. Broad base (Fig. 3.16d), process a curved claw. Two basal papillae, one bearing one setule, other two setules, another similar papilla located nearby on sternum bearing two setules.

Maxillule. Dentiform, pointed process (Fig. 3.16e) with basal papilla bearing two short and one long setae.

Maxilla. Two-segmented (Fig. 3.16f). Proximal segment (lacertus) unarmed. Distal segment (brachium) carrying large flabellum with both margins serrated and two unequal elements (a short canna and a longer calamus) terminally, canna and calamus with both margins serrated. Brachium also bearing a long patch of serrated margin on inner margin, subterminally, just before base of canna.

Maxilliped. Three-segmented (Fig. 3.16g). Proximal segment (corpus) largest, unarmed. Second (shaft) and distal (claw) segments fused to form subchela. Shaft bearing medium seta posteromedially. Claw curved, with medium sized basal seta.

Sternal furca. Base rectangular (Fig. 3.16h). Tines diverging away from each other, bluntly pointed.

Leg 1. Protopod (Fig. 3.16i) with one small plumose seta on posterior margin and another small plumose seta on anterodistal margin. Endopod vestigial, naked. Exopod two-segmented. First segment with row of setules on posterior margin and small, spiniform seta on anterodistal corner. Second segment with four terminal elements (elements one, two and three equal in size, each with accessory process, appears to be naked, element four longest, appears to be naked) and three plumose setae on posterior margin.

Leg 2. Coxa small (Fig. 3.16j), with spinule bearing papilla on ventral surface and large plumose inner seta on posterior margin. Protopod with anterodistal small, naked seta, patch of fringed anterodistal membrane, posterior margin covered by a striated membrane, with one centrally situated seta. Exopod three-segmented. First segment with one anterodistal, curved spine, outer margin of spine with striated membrane, posterior margin with one medium sized plumose seta. Second segment with one anterodistal, curved spine, outer margin of spine with striated membrane,

posterior margin with one long plumose seta. Third segment with three spines on anterodistal margin (first spine smallest, both margins serrated, second spine with inner margin bearing membrane, which is finely serrated, third spine with outer margin bearing membrane, which is finely serrated, inner margin plumose) and five long, plumose setae. Endopod three-segmented. First segment with one long, plumose seta and crest of setules on outermost margin. Second segment with two plumose setae and prominent crest of setules on outer and inner margin. Third segment with six plumose terminal setae and crest of setules on outer corner.

Leg 3. Anterior margin of protopod more sclerotised than rest of segment, with striated membrane (Fig. 3.16k). Exopod three-segmented. First segment with large, slightly curved, terminal claw. Second segment with one anterodistal spine and one posterodistal plumose seta. Third segment with three spines of almost equal lengths and four plumose setae. Second and third segment with rows of setules on lateral margins. Endopod two-segmented. First segment expanded laterally into velum on outer margin and bearing one long, plumose seta on posterior margin. Second segment with six plumose setae of different lengths and row of setules on lateral margin.

Leg 4. Protopod (Fig. 3.16l) with small plumose anterodistal seta. Exopod two-segmented. First segment bearing terminal spine, with both margins very finely serrated. Second segment bearing three terminal spines of different lengths, all three spines with both margins finely serrated. All exopod spines with basal pecten.

Armature on rami of legs 1-4:

	Exopod	Endopod
Leg 1	1-0; III, 1, 3	(vestigial)
Leg 2	I-1; I-1; II, I, 5	0-1; 0-2; 6
Leg 3	I-0; I-1; III, 4	0-1; 6
Leg 4	I-0; III	(missing)

Leg 5. Represented by two papillae (Fig. 3.16m) on posterolateral corner of genital complex, one tipped with long plumose seta, other with two similar, smaller plumose setae. Two additional papillae, bearing one small naked seta each, but not part of leg 5.

Male. Body (Fig. 3.16o) 5.08 (4.78-5.21) mm long. Cephalothoracic shield longer than wide, 2.95 (2.81-3.04) x 2.36 (2.29-2.41) mm, excluding lateral hyaline membranes. Fourth pediger wider than long, 0.31 (0.28-0.33) x 0.53 (0.49-0.55) mm. Genital complex much longer than wide, 0.76 (0.72-0.81) x 0.57 (0.52-0.61) mm. Abdomen two-segmented. First segment 0.31 (0.28-0.32) x

0.35 (0.32-0.38) mm. Second segment 0.51 (0.47-0.54) x 0.39 (0.36-0.41) mm. Caudal ramus (Fig. 3.16u) one and a half times as long than wide, 358.2 (349.7-364.8) x 188.5 (185.1-193.6) µm. Posterior margin of each ramus armed with two outer (one small, one medium), one small, medial and three long terminal plumose setae.

Antenna. Three-segmented (Fig. 3.16p). Proximal segment unarmed. Second segment with corrugated medial, ventral, and posteroventral surfaces. Distal segment bifid claw, with parts being covered by cuticular flap, and one strong basal seta.

Postantennary process. Broad base (Fig. 3.16q), process a strongly curved claw. Two basal papillae with one and two setules respectively, another nearby on sternum, bearing one setule.

Maxillule. Dentiform process, slightly curved, (Fig. 3.16r) bearing large accessory process at base.

Maxilliped. Three-segmented (Fig. 3.16s). Corpus large and robust, bearing two large, sclerotised ridges on medial margin, one ridge being bifid. Claw with medium sized basal seta, and one minute seta subterminally.

Leg 5. Represented by two papillae (Fig, 3.16t) on posterolateral margin of genital complex, one tipped with one medium sized plumose seta, other with two similar plumose setae.

Leg 6. Represented by one papilla (Fig. 3.16t) on posterolateral margin of genital complex, bearing two medium sized plumose setae.

Remarks. This species was collected from the kabeljou, *Argyrosomus japonicus* (Temminck & Schlegel, 1843), at De Hoop Nature Reserve and Jeffreys Bay on the south coast of South Africa. The host species is a commercially important angling fish, and it is interesting to find that this species was not yet recovered from the host species. Characteristic features of this species are; 1) the genital complex of the female having posterolateral protrusions, 2) two-segmented abdomen, with the first segment being much smaller and thinner than the second segment, 3) the brachium of the maxilla bearing a long serrated surface subterminally of the canna, 4) the sternal furca with tines diverging away from each other, 5) the four terminal elements on leg 1 second exopodal segment, 6) the armature and details of the spines on leg 4 exopod.

This species bears closest resemblance to *Caligus longipedis* Bassett-Smith, 1898, a fairly widely distributed species of sea lice parasitic primarily on the carangid fishes (Ho & Lin, 2001). The name of this species refers to the most outstanding characteristic feature, which is the nature of the long outer spines on the exopod of leg 4. Another unusual feature of *Caligus longipedis* pointed out by Cressey (1991) is the presence of two "crescent-shaped sclerotised areas on the last segment of the endopod of the second leg". This feature is shared with only one species of *Caligus*, *C. robustus* Bassett-Smith, 1898. Ho and Lin (2001) pointed out that the latter species can be easily

distinguished from *C. longipedis* by the structure of the four terminal elements on the distal segment of the exopod of leg 1, in addition to the four long outer spines on the exopod of leg 4. In *Caligus robustus* both element one and element four are shorter than the elements two and three, which bear accessory processes. Also, *Caligus robustus* has its abdomen nearly as long as the genital complex.

As *Caligus* sp. A bears closest resemblance to *C. longipedis*, morphological differences between these two species are discussed. 1) The postantennary process in *Caligus* sp. A is a strongly curved claw, but in *C. longipedis* it is only slightly curved. 2) The process of the maxillule in *Caligus* sp. A is slightly curved, in comparison to a straight process in the maxillule of *C. longipedis*. 3) The sternal furca in *Caligus* sp. A has tines diverging away from each other, compared to the laterally expanded tines in *C. longipedis*. In the present species, the sternal furca of the female and male is exactly the same, but the sternal furca in the male of *Caligus longipedis* differs significantly from that of the female, having slender tines. 4) The four terminal elements on the second exopodal segment of leg 1 in *Caligus* sp. A appears to be naked, as very fine serrations could not be seen with the method used of Humes and Gooding (1964). The first three elements bear each accessory process, almost equal in length, with the fourth element the longest and without accessory process, but in *C. longipedis* the middle two elements have accessory processes and bear serrated membrane. 5) The present species does not bear the "crescent-shaped sclerotised areas on the last segment of the endopod of the second leg", as pointed out by Ho and Lin (2001) with their comparison of *Caligus longipedis* and *C. robustus*. 6) *Caligus* sp. A bear striated membrane on the outer margins of both the first and second exopodal spines on segments one and two of leg 2. In *Caligus longipedis* both margins of both the first and second exopodal spines on segments one and two of leg 2 bear striated membrane. 7) The only difference in the nature of the outer spines on the exopod of leg 4 is that the spines in *Caligus* sp. A is much shorter than the spines found in *C. longipedis*, an important morphological feature. 8) The male of *Caligus longipedis* bears row of denticles on the medial margin of the terminal claw of the maxilliped. This feature was not found in *Caligus* sp. A. 9) It was also found that the postantennary process in the male of *Caligus* sp. A is strongly curved, compared to a slightly curved process in *C. longipedis*. 10) The maxillule in the male of *Caligus* sp. A is slightly curved, compared to an almost straight process in *C. longipedis*, and in addition, also bear an accessory basal process in the present species.

This species will, for the time being, be referred to as *Caligus* sp. A, until the species has been accepted as a new species and published in an international journal. This parasite was included in a conference proceeding (see Appendix II) where the parasites of the kabeljou, *Argyrosomus japonicus*, were presented.

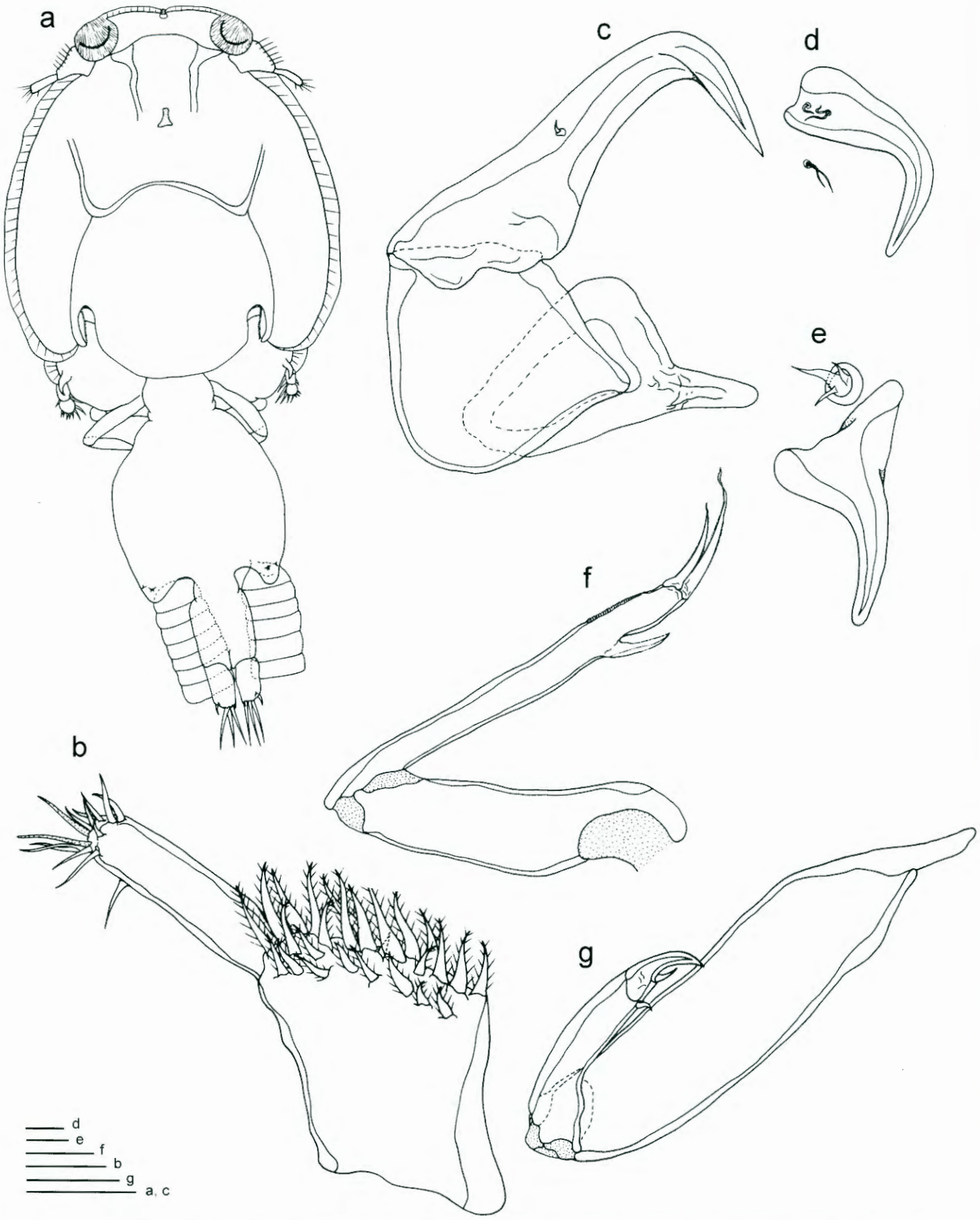


Fig. 3.16. *Caligus* sp. A, female. **a.** habitus, dorsal. **b.** antennule, ventral. **c.** antenna, ventral. **d.** postantennary process, ventral. **e.** maxillule, ventral. **f.** maxilla. **g.** maxilliped. Scale bars: 1 mm in a; 100 µm in b, c, f, g; 50 µm in d, e.

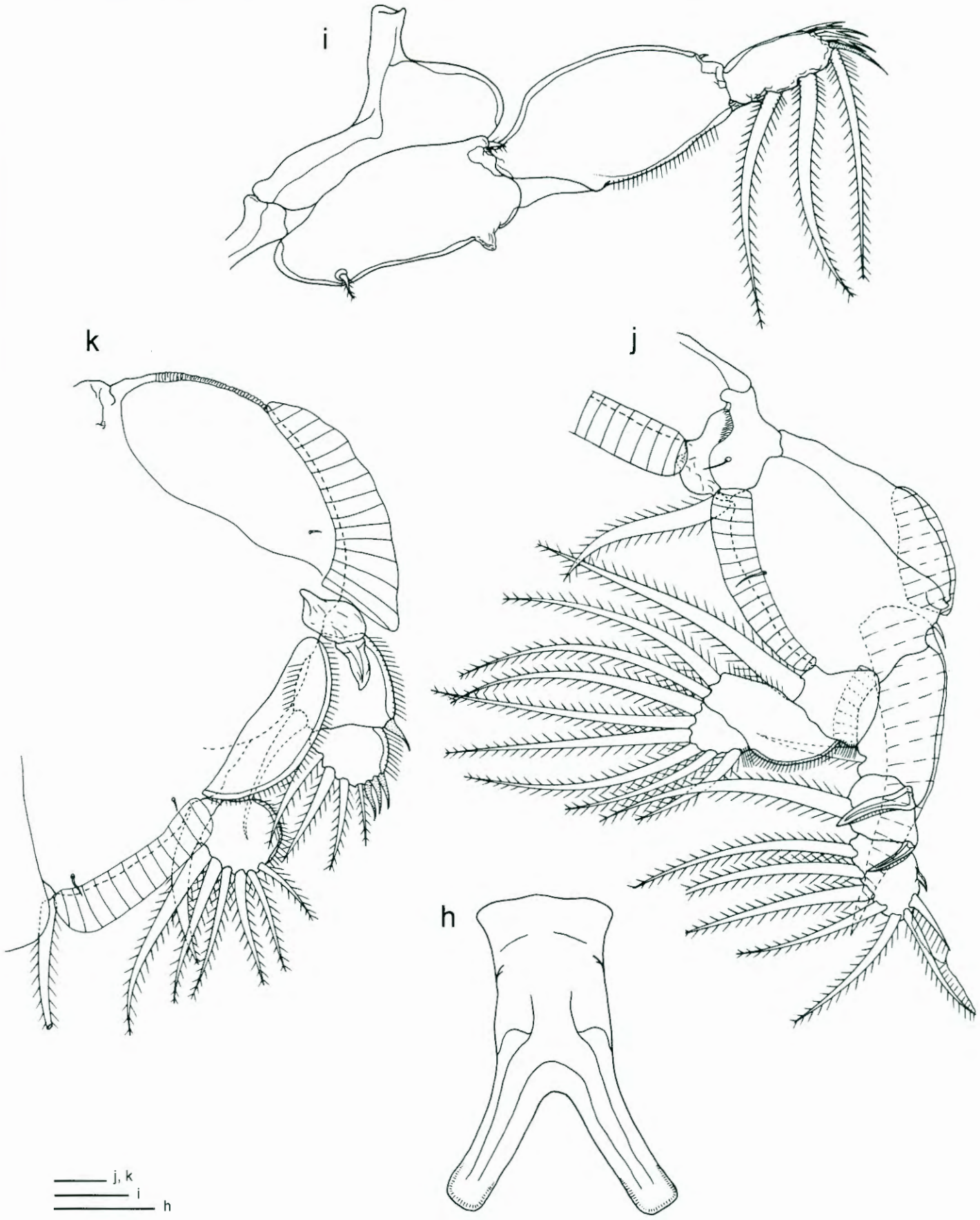


Fig. 3.16. (cont.) *Caligus* sp. A, female. **h.** sternal furca. **i.** leg 1, ventral. **j.** leg 2, ventral. **k.** leg 3, ventral. Scale bars: 100 µm in h-k.

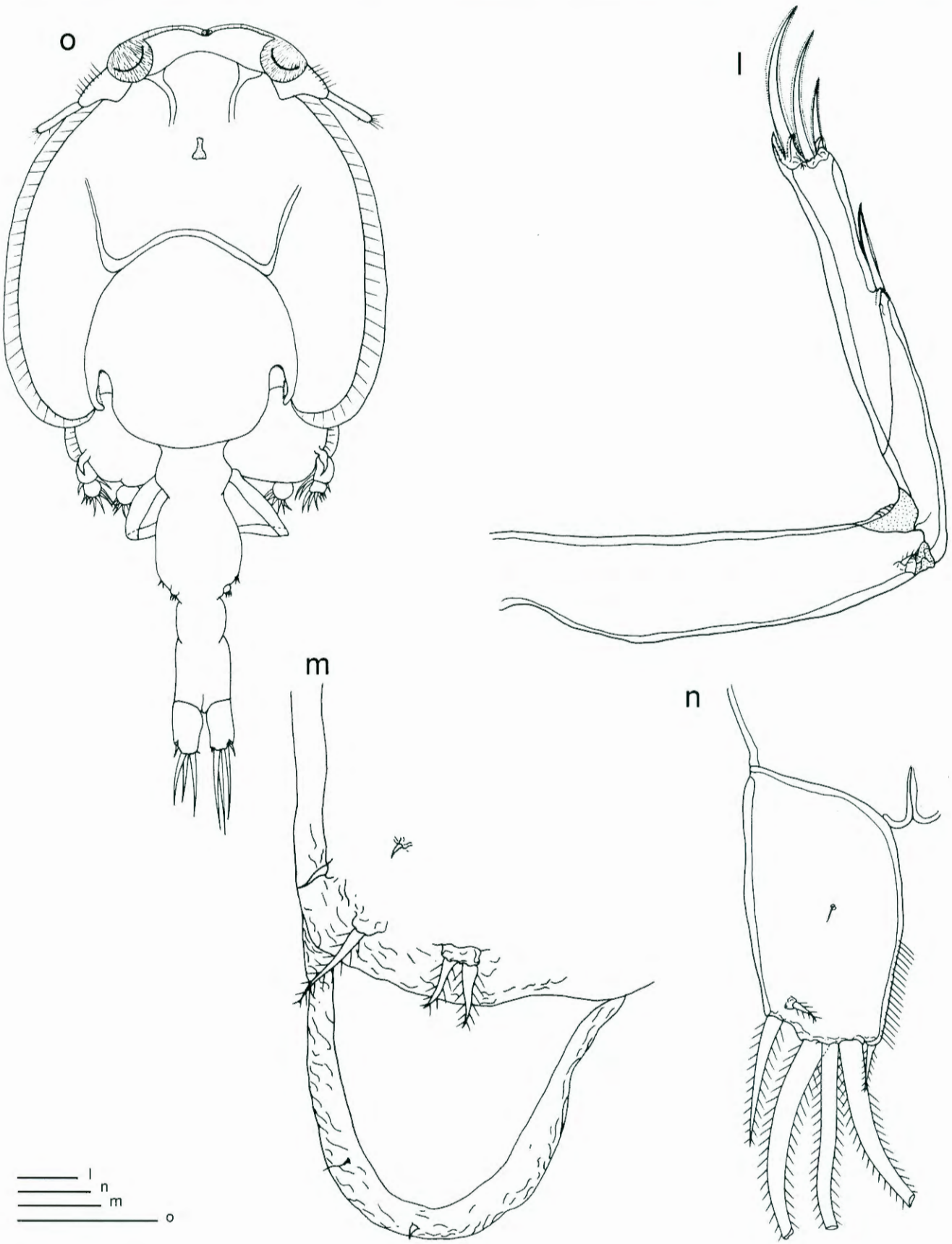


Fig. 3.16. (cont.) *Caligus* sp. A, female. **l.** leg 4, ventral. **m.** posterolateral side of genital complex, showing leg 5, ventral. **n.** caudal ramus, ventral. *Caligus* sp. A, male. **o.** habitus, dorsal. Scale bars: 1 mm in o; 100 µm in l, n; 50 µm in m.

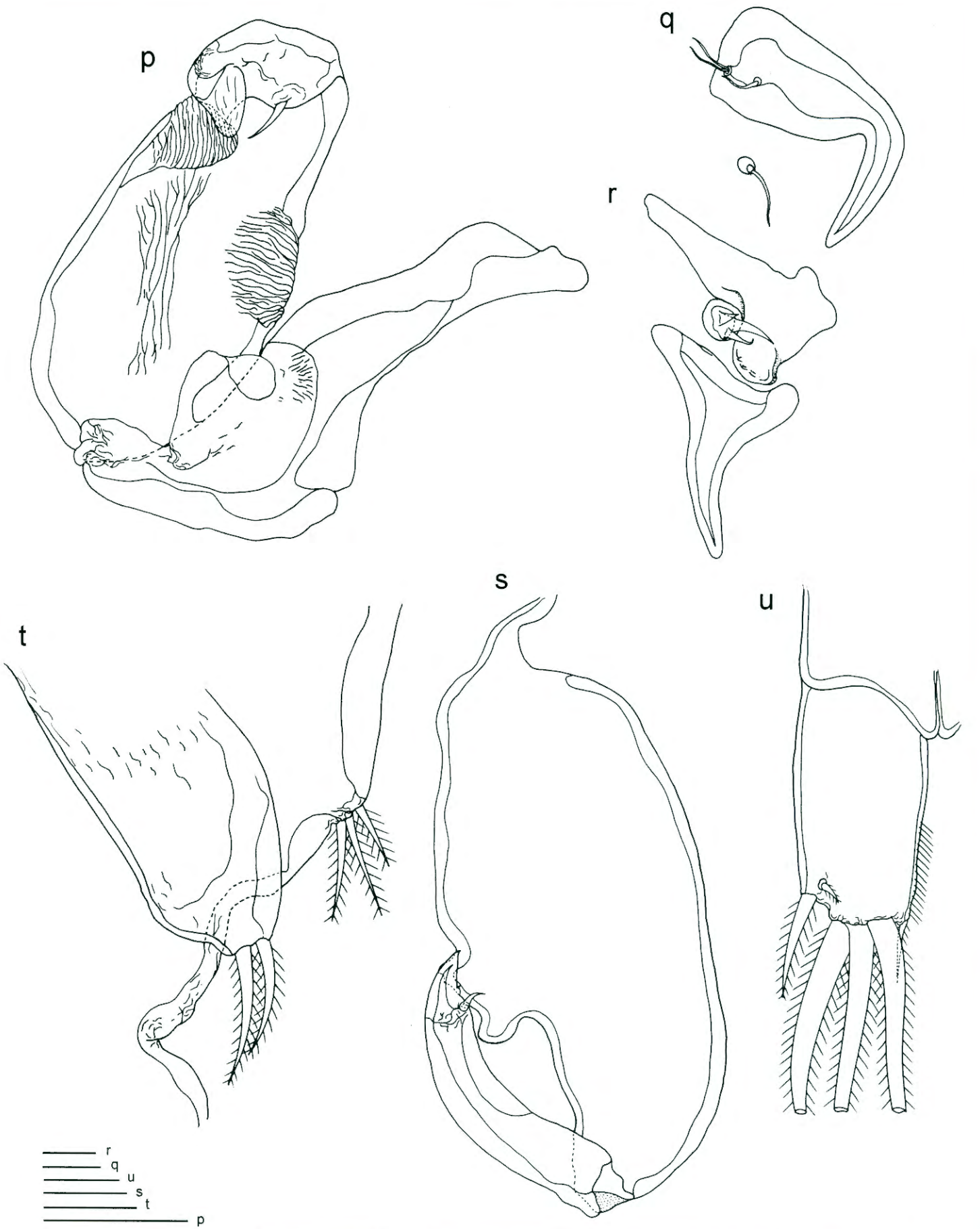


Fig. 3.16. (cont.) *Caligus* sp. A, male. **p.** antenna, ventral. **q.** postantennary process. **r.** maxillule. **s.** maxilliped. **t.** posterolateral side of genital complex, showing leg 5 and leg 6, ventral. **u.** caudal ramus, ventral. Scale bars: 100 µm in p, s, u; 50 µm in q, r, t.

Caligus sp. B

Figs. 3.17a-u

Caligus sp. B

Material examined.

South African Museum: SAM A12996: Two ovigerous females and one male collected from *Pomatomus saltatrix* (Linnaeus, 1766), Durban. Voucher specimens from present study, one ovigerous female, one female and two males, have been deposited in the collection of the SA Museum, SAM A45164.

Present study: Voucher specimens have been deposited in the collection of the Aquatic Parasitology Research Group, Department of Zoology and Entomology, University of the Free State, Bloemfontein. Material collected in present study is listed in Table 3.7.

Table 3.7. Total number of *Caligus* sp. B specimens collected from fish hosts in De Hoop Nature Reserve and Mhlatuze estuary, including collection numbers.

Host species	# ♀♀, ♂♂ *Caligus*	Locality	Collection number
Pomatomus saltatrix	1 ovig ♀♀, 5 ♀♀, 4 ♂♂	De Hoop	163
Pomatomus saltatrix	1 ovig ♀, 3 ♂♂	De Hoop	228
Pomatomus saltatrix	3 ovig ♀♀, 2 ♂♂	De Hoop	001
Pomatomus saltatrix	1 ovig ♀, 1 ♂	De Hoop	231
Pomatomus saltatrix	2 ovig ♀♀	Mhlatuze estuary	00/03/21-02
Pomatomus saltatrix	1 ♂	Mhlatuze estuary	00/12/04-01

Description.

Female. Body (Fig. 3.17a) 4.76 (3.91-5.01) mm long. Cephalothoracic shield slightly longer than wide, 2.08 (1.47-2.21) x 2.02 (1.63-2.19) mm, excluding lateral hyaline membranes. Fourth pediger wider than long, 0.24 (0.22-0.26) x 0.47 (0.37-0.52) mm. Genital complex much longer than wide, 1.71 (1.41-1.82) x 1.01 (0.86-1.08) mm. Abdomen two-segmented. First segment 0.66 (0.59-0.71) x 0.31 (0.28-0.34) mm. Second segment 0.28 (0.20-0.32) x 0.30 (0.22-0.34) mm. Caudal ramus (Fig. 3.17n) almost twice as long than wide, 176.8 (133.3-186.4) x 95.1 (83.1-103.2)

µm. Posterior margin of each ramus armed with two outer (one small, one medium), one small, medial and three long terminal plumose setae.

Antennule. Two-segmented (Fig. 3.17b). Proximal segment trapezoid, much broader than distal segment, with 29 plumose setae on anterodistal surface. Distal segment rod-shaped, much longer than wide, armed with one subterminal seta on posterior margin and nine setae and two aesthetascs on distal margin.

Antenna. Three-segmented (Fig. 3.17c). Proximal segment with cone-shaped posteromedial process. Second segment subrectangular and unarmed. Distal segment a curved claw bearing one medium sized basal seta.

Postantennary process. Broad base (Fig. 3.17d), process a curved claw. Two basal papillae each bearing four setules, another similar papilla located nearby on sternum.

Maxillule. Dentiform, pointed process (Fig. 3.17e) with basal papilla bearing two short and one long setae.

Maxilla. Two-segmented (Fig. 3.17f). Proximal segment (lacertus) unarmed. Distal segment (brachium) carrying medium sized flabellum with both margins serrated and two unequal elements (a short canna and a longer calamus) terminally, canna and calamus with both margins serrated.

Maxilliped. Three-segmented (Fig. 3.17g). Proximal segment (corpus) largest, unarmed. Second (shaft) and distal (claw) segments fused to form subchela. Shaft bearing minute seta in middle region. Claw curved, with large basal seta.

Sternal furca. Base narrow, broadening posteriorly (Fig. 3.17h). Tines slightly curved on both margins, both tines subterminally on inner margins straight.

Leg 1. Protopod (Fig. 3.17i) with one large, plumose seta on posterior margin and another medium sized plumose seta on anterodistal margin. Endopod vestigial, medium sized, bearing minute element distally. Exopod two-segmented. First segment with row of robust setules on posterior margin and small, spiniform seta on anterodistal corner. Second segment with four terminal elements (elements two and three with accessory process, elements one, two and three with both margins bearing striated membrane, element four longest with outer margin bearing hairs, inner margin naked), three plumose setae on posterior margin of this segment absent. One small subterminal, naked element on posterior margin of terminal segment.

Leg 2. Coxa small (Fig. 3.17j), with spinule bearing papilla on ventral surface and large plumose inner seta on posterior margin. Protopod with anterodistal small, naked seta, patch of fringed anterodistal membrane, posterior margin covered by a striated membrane, with one centrally situated seta. Exopod three-segmented. First segment with one anterodistal, curved spine, both margins of spine with striated membrane, posterior margin with one medium sized plumose seta.

Second segment with one anterodistal, curved spine, both margins of spine with striated membrane, posterior margin with one long plumose seta. Third segment with three spines on anterodistal margin (first spine smallest, naked, second spine with both margins serrated, third spine with striated membrane along outer margin and plumose inner margin) and five long, plumose setae. Second and third segments with crest of setules on innermost corners. Endopod three-segmented. First segment with one long, plumose seta. Second segment with two plumose setae and prominent crest of robust setules on outer margin, setules on inner margin. Third segment with six plumose terminal setae and crest of setules on outer corner.

Leg 3. Anterior margin of protopod more sclerotised than rest of segment, with striated membrane (Fig. 3.17k). Rows of denticles above exopod. Exopod three-segmented. First segment with large, slightly curved, terminal claw. Second segment with one anterodistal spine and one posterodistal plumose seta. Third segment with three spines of different lengths and four plumose setae of almost equal lengths. Second and third segment with rows of setules on lateral margins. Endopod two-segmented. First segment expanded laterally into velum on outer margin and bearing one long, plumose seta on posterior margin. Second segment with six plumose setae of different lengths and row of setules on lateral margin.

Leg 4. Protopod (Fig. 3.17l) with medium sized plumose anterodistal seta, and three setules on outer margin. Exopod two-segmented. First segment bears a terminal spine with both margins finely serrated. Second segment bearing one subterminal spine and three terminal spines, all spines with both margins finely serrated. All exopod spines with basal pecten.

Armature on rami of legs 1-4:

	Exopod	Endopod
Leg 1	1-0; III, 1, 1	(vestigial)
Leg 2	I-1; I-1; II, I, 5	0-1; 0-2; 6
Leg 3	I-0; I-1; III, 4	0-1; 6
Leg 4	I-0; I, III	(missing)

Leg 5. Represented by one papilla (Fig. 3.17m) on posterolateral corner of genital complex, tipped with three medium sized plumose setae.

Male. Body (Fig. 3.17o) 4.72 (4.51-4.93) mm long. Cephalothoracic shield slightly longer than wide, 2.81 (2.69-2.94) x 2.77 (2.68-2.85) mm, excluding lateral hyaline membranes. Fourth pediger wider than long, 0.26 (0.23-0.28) x 0.65 (0.61-0.69) mm. Genital complex longer than

wide, 0.83 (0.76-0.89) x 0.73 (0.68-0.78) mm. Abdomen two-segmented. First segment 0.24 (0.22-0.26) x 0.43 (0.40-0.45) mm. Second segment 0.30 (0.28-0.32) x 0.36 (0.33-0.38) mm. Caudal ramus (Fig. 3.17u) one and a half times as long than wide, 256.3 (239.4-266.8) x 167.2 (161.6-175.1) µm. Posterior margin of each ramus armed with two outer (one small, one medium), one small, medial and three long terminal plumose setae.

Antenna. Three-segmented (Fig. 3.17p). Proximal segment unarmed. Second segment with corrugated medial and ventral surfaces. Distal segment composed of four pointed lamellae, with the second lamella being covered by cuticular flap, and two strong basal setae on either side of distal segment.

Postantennary process. Broad base (Fig. 3.17q), process a strongly curved claw.

Maxillule. Dentiform process, slightly curved, (Fig. 3.17r) bearing tooth-like process subterminally on outer margin.

Maxilliped. Three-segmented (Fig. 3.17s). Corpus large and robust, bearing two large, sclerotised ridges on medial margin. Claw with long basal seta.

Leg 5. Represented by two papillae (Fig. 3.17t) on posterolateral corner of genital complex, one with one medium sized plumose seta, and other with two similar plumose setae.

Remarks. This species was originally collected from the shad, *Pomatomus saltatrix*, Durban. Subsequently it has been collected on various occasions in the present study on the south coast of South Africa, as well on two occasions on the east coast, from the same host species. The specimens collected in the present study are larger than those collected from Durban, but variations in size are common among parasitic copepods. Kensley and Grindley (1973) collected this species from the same host species, but identified it as *Caligus* cf. *affinis* Heller, 1866 (SAM A12996). The material for this species is missing from the South African Museum, but according to the description of Kensley and Grindley (1973), this species does not fit the description as reported by Brian (1935). I consider the reference to *Caligus affinis* as a misidentification and *C. affinis* is removed from the list of species collected from the South African coast.

Characteristic features of this species are; 1) two-segmented abdomen, with the first segment being much longer than the second segment, 2) the slightly curved tines of the sternal furca 3) the four terminal elements on leg 1 second exopodal segment, 4), the absence of the three posterior plumose setae on the terminal segment of the exopod of leg 1, 5) the presence of a small subterminal, naked element on the terminal segment of the exopod of leg 1, 6) the armature and details of the spines on leg 4 exopod, and 7) the male antenna, with the distal segment being composed of five lamellae.

Ho and Lin (2003) discussed the taxonomic confusion surrounding *Caligus epinepheli*, which was collected from whitecheek monocle bream, *Scolopsis vosmeri* (Bloch), Taiwan. Included in their study was a close comparison between specimens of *Caligus pagrosomi* Yamaguti, 1939, and *C. epinepheli*. According to the work of Yamaguti (1939), *C. pagrosomi* differs from *C. epinepheli* mainly in the presence of 1) a small subterminal seta on the posterior margin of the terminal segment of the first leg, and 2) a mammiferous projection on each side of the sternal furca. Byrnes (1987) considered these two distinguishing features as an insufficient reason for establishing a separate species and proposed to relegate *C. pagrosomi* to a junior synonym *of C. epinepheli*. Ho and Lin (2003) listed seven features, six of which these two species differ. *Caligus pagrosomi* was resurrected, and subsequently divided into two subspecies, *Caligus pagrosomi pagrosomi* (Yamaguti, 1939), and *Caligus pagrosomi schlegeli* Ho & Lin, 2003.

The species collected in the present study, *Caligus* sp. B, bears features of both subspecies, as was listed by Ho and Lin (2003). However, *Caligus* sp. B does not have sternal projections, a feature found in both subspecies. The species from the present study have the same size range for the female as *Caligus pagrosomi pagrosomi*. However, the posterior margin of the first segment of the exopod of leg 1 has a row of setules in *Caligus* sp. B and *C. pagrosomi pagrosomi*, but a row of platelets in *C. pagrosomi schlegeli*. In *Caligus* sp. B the subterminal element on the terminal segment of the exopod of leg 1 is a small, naked element, in *C. pagrosomi pagrosomi* it is a long plumose seta, and in *C. pagrosomi schlegeli* it is a minute hyaline element. The vestigial endopod of leg 1 in *Caligus pagrosomi pagrosomi* have two minute elements distally, in *C. pagrosomi schlegeli* the vestigial endopod is naked, and in *C*. sp. B the vestigial endopod has only one minute element distally. Only *Caligus pagrosomi pagrosomi* has a setule on the male maxillule dentiform process. This setule is absent in *C. pagrosomi schlegeli*, but in *Caligus* sp. B the dentiform process of the maxillule has a small tooth-like process subterminally.

According to the description of *Caligus affinis* by Brian (1935), *C. affinis* is characterised as lacking sternal projections as well as the three plumose setae on the posterior margin of the terminal segment of leg 1. These two features are found in *C. epinepheli*, but not in *Caligus* sp. B. The species from the present study does not have the essential feature (sternal projections) to be placed within the subspecies group of *Caligus pagrosomi*. It differs from *C. epinepheli* and *C. affinis* as outlined above, and is considered to be a new species. However, as Ho and Lin (2003) pointed out, there are at least seven species of *Caligus*, which can be unified under *C. affinis*, but such action is not considered appropriate before re-examination of the type material of each of these species. *Caligus epinepheli* is the only species, which has a well outlined description, and as stated by Ho and Lin (2003), is for the time being considered a valid species. The morphological features of *C.*

epinepheli were studied by Grobler *et al.* (2004), where it was also stated to be a valid species, differing from *C. affinis*.

The subterminal element on the posterior margin of the terminal segment of leg 1 in both *Caligus pagrosomi pagrosomi* and *Caligus* sp. B is translucent and detachable. If this element is detached, the parasite could be mistaken for *Caligus epinepheli*. This could have lead to Byrnes (1987) proposed synonimisation of *C. pagrosomi* with *C. epinepheli*. However, a close examination of the sternal area for the mammiferous projections should render an easy solution to this confusion (Ho & Lin 2003). These projections are found in both subspecies of *C. pagrosomi*, but are absent from *C. epinepheli* and *Caligus* sp. B. *Caligus* sp. B has been collected on numerous occasions from the shad, *Pomatomus saltatrix*, and is considered to be the type host.

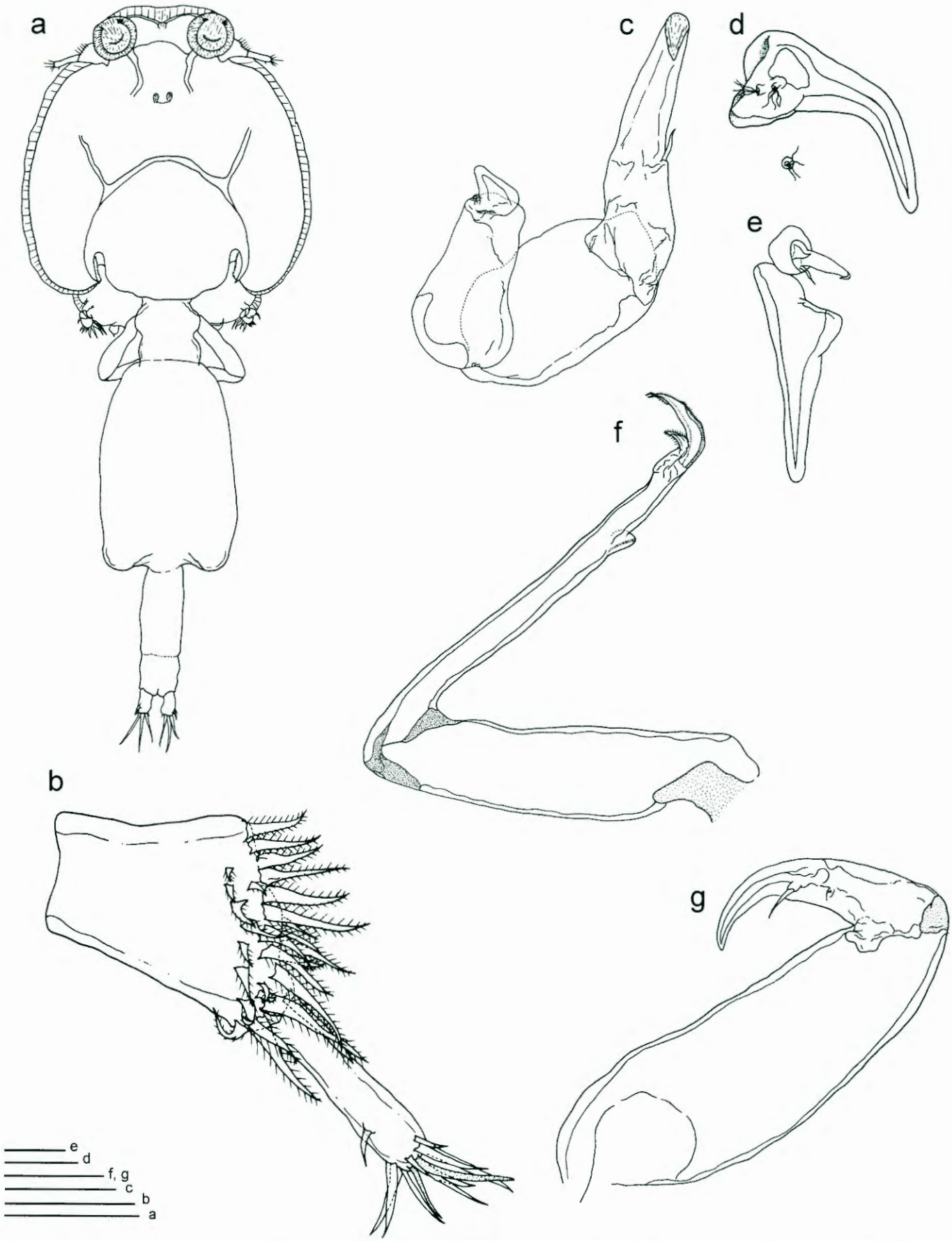


Fig. 3.17. *Caligus* sp. B, female. **a.** habitus, dorsal. **b.** antennule, ventral. **c.** antenna, ventral. **d.** postantennary process, ventral. **e.** maxillule, ventral. **f.** maxilla. **g.** maxilliped. Scale bars: 1 mm in a; 100 µm in b, c, f, g; 50 µm in d, e.

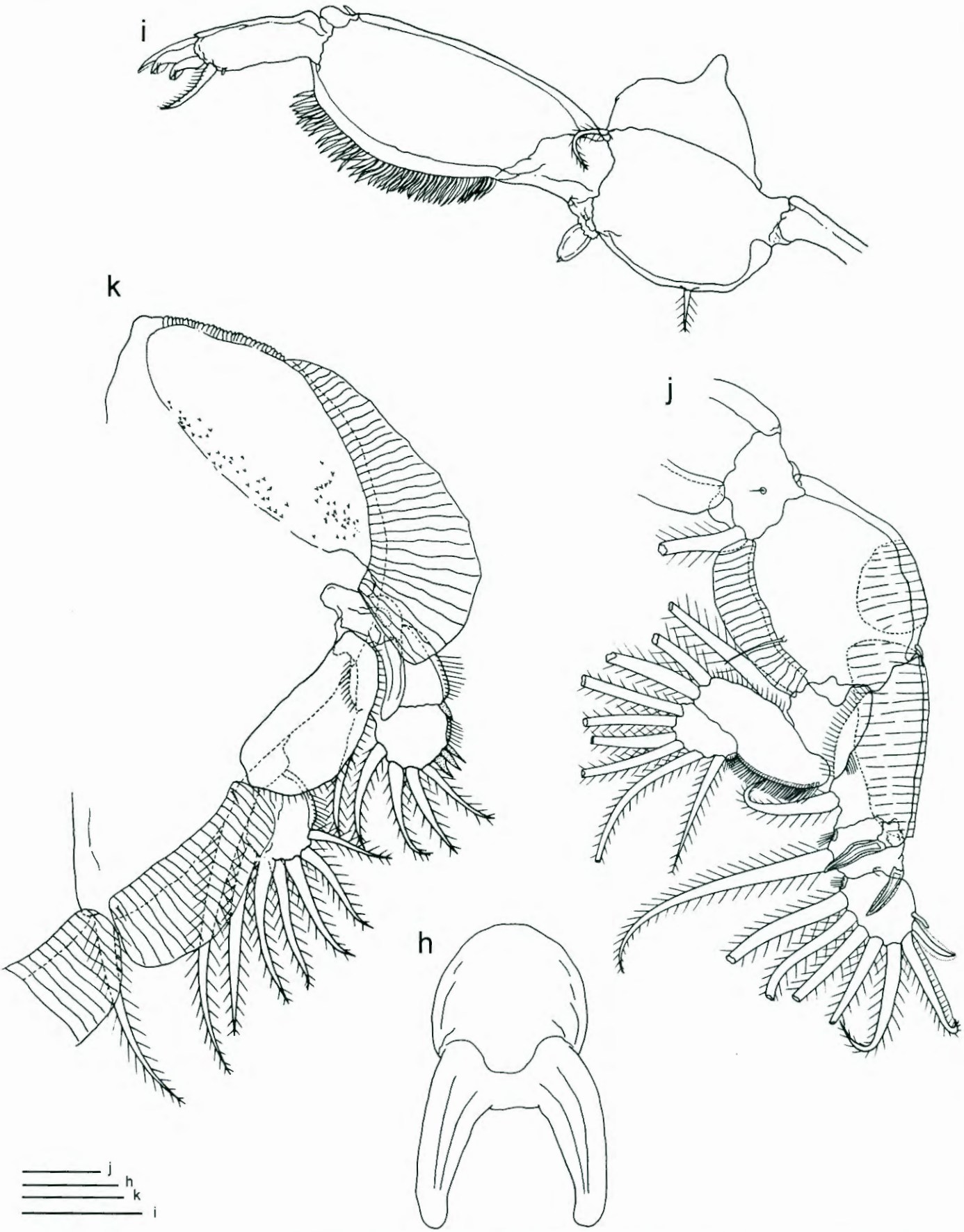


Fig. 3.17. (cont.) *Caligus* sp. B, female. **h.** sternal furca. **i.** leg 1, ventral. **j.** leg 2, ventral. **k.** leg 3, ventral. Scale bars: 100 µm in i-k; 50 µm in h.

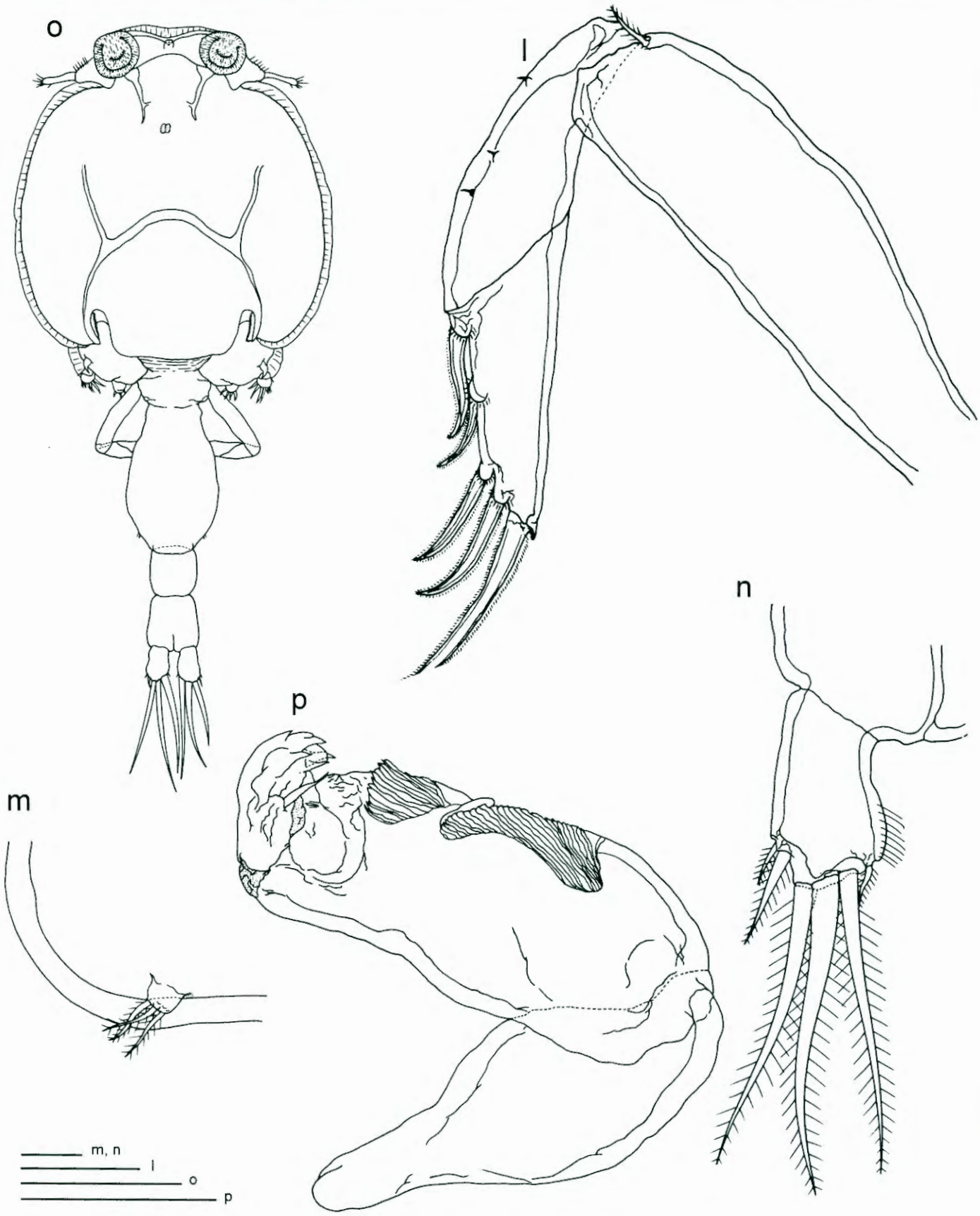


Fig. 3.17. (cont.) *Caligus* sp. B, female. **l.** leg 4, ventral. **m.** posterolateral side of genital complex, showing leg 5, ventral. **n.** caudal ramus, ventral. *Caligus* sp. B, male. **o.** habitus, dorsal. **p.** antenna, ventral. Scale bars: 1 mm in o; 100 µm in l, p; 50 µm in m, n.

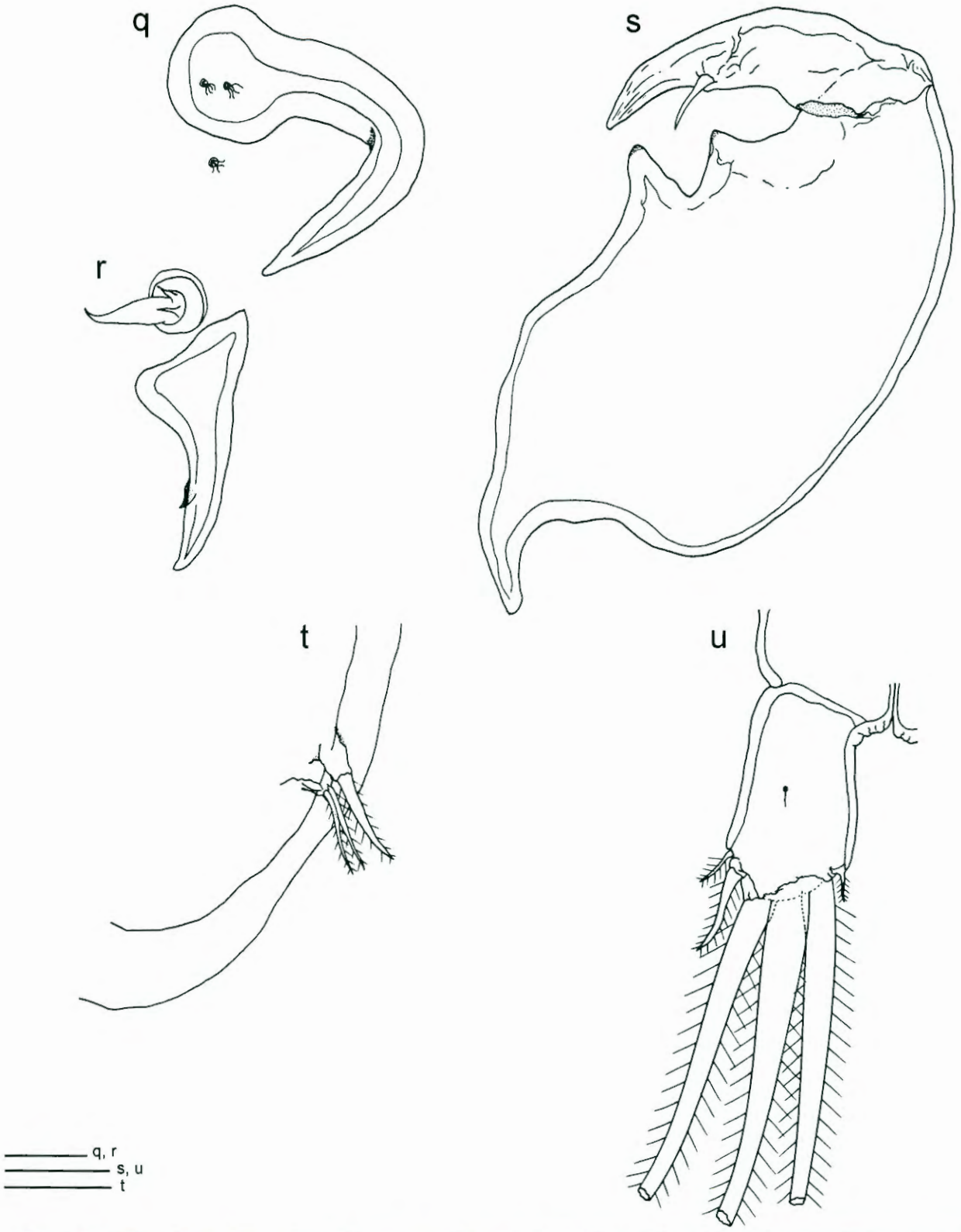


Fig. 3.17. (cont.) *Caligus* sp. B, male. **q.** postantennary process. **r.** maxillule. **s.** maxilliped. **t.** posterolateral side of genital complex, showing leg 5, ventral. **u.** caudal ramus, ventral. Scale bars: 100 μm in s, u; 50 μm in q, r, t.

***Caligus epinepheli* Yamaguti, 1936**

Figs. 3.18a-h, 3.19a-h

Caligus epinepheli: Yamaguti, 1936: 4-5, 8, 18-19, plate III (figs. 27-39); Shiino, 1952: 79-84, figs. 1A-E, 2A-I; Yamaguti, 1963: 53, plate 69 (figs. 3a-c); Kirtisinghe, 1964: 57, 127, fig. 32; Rangnekar & Murti, 1964: 87-89, figs. 2a-k; Kabata, 1965: 109, 112-114, 126, fig. 2C; Pillai, 1967: 1590, 1671, fig. 69; Ho & Lin, 2003: 256-271, figs. 1A-G, 2A-H; Grobler, Van As & Olivier, 2004: In Press.

Material examined: Material collected in present study is listed in Table 3.8. All specimens were collected from the gills of the hosts. The measurements of the female collected in Lake St Lucia is given first, followed by the measurements of the female collected at De Hoop Nature Reserve in parenthesis. As mentioned earlier, both *Caligus epinepheli* and *C. rotundigenitalis* are described, based on studies with scanning electron microscopy.

Table 3.8. Total number of *Caligus epinepheli* Yamaguti, 1936 specimens collected from fish hosts in Lake St Lucia and De Hoop Nature Reserve, including collection numbers.

Host species	# ♀♀, ♂♂ *Caligus*	Locality	Collection number
Rhabdosargus holubi	1 ♀, 1 ♂	Lake St Lucia	8/046
Diplodus sargus capensis	1 ♀	De Hoop	98/04/01-09

Description.

Female. Body 3.11 (2.82) mm long. Cephalothoracic shield 1.48 (1.34) mm long and 1.2 (1.12) mm wide, excluding lateral hyaline membranes. Genital complex slightly longer than wide, 0.82 (0.73) x 0.75 (0.66) mm wide. Abdomen more than twice as long as wide, 0.67 (0.61) x 0.29 (0.26) mm. Caudal ramus longer than wide, 116 (108) x 65 (59) µm, armed with 3 short and 3 long plumose setae. The material collected by Ho and Lin (2003) is similar to the material collected in the present study. The specimens from the present study are larger and the caudal rami slightly longer than those reported by Ho and Lin (2003), where the specimens measured between 2.20 and 2.32 mm and the caudal ramus 65 x 45 µm.

The problem surrounding the taxonomic status of *Caligus epinepheli* is tackled here, with the aim of the study is to present new and additional information with the aid of scanning electron microscopy, which will verify some of the findings by Ho and Lin (2003), as well as to establish

Caligus epinepheli as a valid species. Ho and Lin (2003) confirmed that an up-to-date revision of the genus is needed, as re-examinations of type specimens will solve many of the taxonomic problems concerning certain *Caligus* species. Seven species (including *Caligus epinepheli*) are closely related and only appropriate re-examination of type specimens will clarify whether these species are the same or not.

A small sclerotized, conical protrusion is present between the basis of the antenna and the post-antennal process (Fig. 3.18a). This process was also noted by Ho and Lin (2003). A pair of buccal stylets (Fig. 3.18b) was observed near the roof of the labrum. Grobler *et al.* (2003) discussed the function of these stylets, also observed in *Caligus confusus*. The buccal stylets found in *C. epinepheli* are much smaller than those present in *C. confusus*, but could be related to body size, as *C. confusus* is almost 2 mm longer than *C. epinepheli*. The maxillule has a basal papilla bearing three setae, two of which are small and equal in length, and one longer and robust. The latter bears spinules on both margins near the tip (Fig. 3.18c), which is unique in this species. The sternal furca has a short base and long diverging tines (Fig. 3.18d). The tines curve slightly inwards like a horseshoe, with a serrated membrane on the distal margin, which extends around the tip to the distal portion of the medial margin.

Leg 1 has some unique features that have not been observed from other species studied. The protopod of leg 1 bears a basal patch of spinules (Fig. 3.18e). This part of the leg is not usually in contact with the host, so the exact function of these spinules is not clear. The endopod (Fig. 3.18f) is rudimentary and one-segmented. A small protrusion is found on the tip of the endopod. The exopod of leg 1 is two-segmented with unique armature. The first segment bears a prominent row of setules on the posterior edge and small seta at the outer distal corner (Fig. 3.18g). The second segment lacks the usual three long plumose setae on the posterior margin. The four terminal elements on the second exopod segment of leg 1 are not identical to each other (Fig. 3.18h). Element 1 is apically bifid. Elements 2 and 3 are armed with accessory processes. The fourth element, a spine-like seta, is the longest and bears no pectinate membrane or accessory process. Pectines cover the bases of the three terminal spines. The exopod of leg 2 is three-segmented. First segment with a large, stout spine, slightly curved posteriorly and serrated on both margins (Fig. 3.19a). Pecten at base of spine. Second segment with a smaller spine (Fig. 3.19a), almost straight, serrated on both margins and without pecten at base.

Leg 4 exopod is two-segmented (Fig. 3.19b). First segment with a spine at outer distal corner, covered with pecten at base of insertion. Second segment with one spine at outer distal corner near terminal end of segment, and three terminal spines. All four spines on second segment have a pecten at the base of insertion (Fig. 3.19c). The genital complex carries the rudimentary leg 5 on

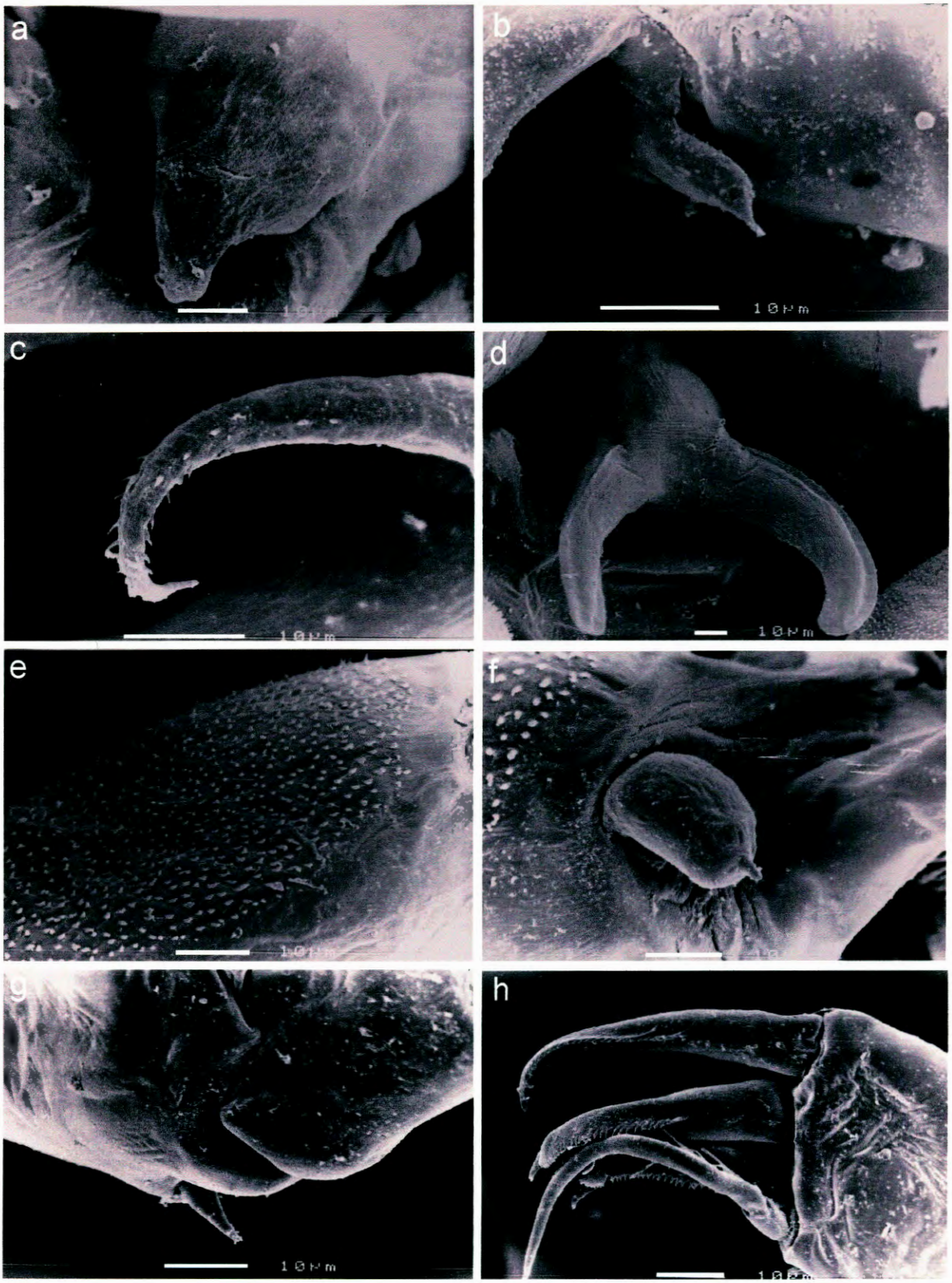
the posterolateral margin. Leg 5 (Fig. 3.19d) consists of two small papillae, one tipped with a small plumose seta, the other with two similar plumose setae. The posteroventral and distal-outer margin of the abdomen is covered with numerous spinules (Fig. 3.19e). The function of these spinules is not known, but these could aid when the copepod is in danger of slipping backwards on its host.

Small setae were observed on the marginal membrane (Fig. 3.19f). These setae are most probably sensory setae and have also been observed in *C. engraulidis.* They are most probably present on all *Caligus* species. Numerous setules are present on the dorsal shield (Fig. 3.19g), in small clusters near the marginal membrane. These setules on the dorsal shield probably have a sensory function.

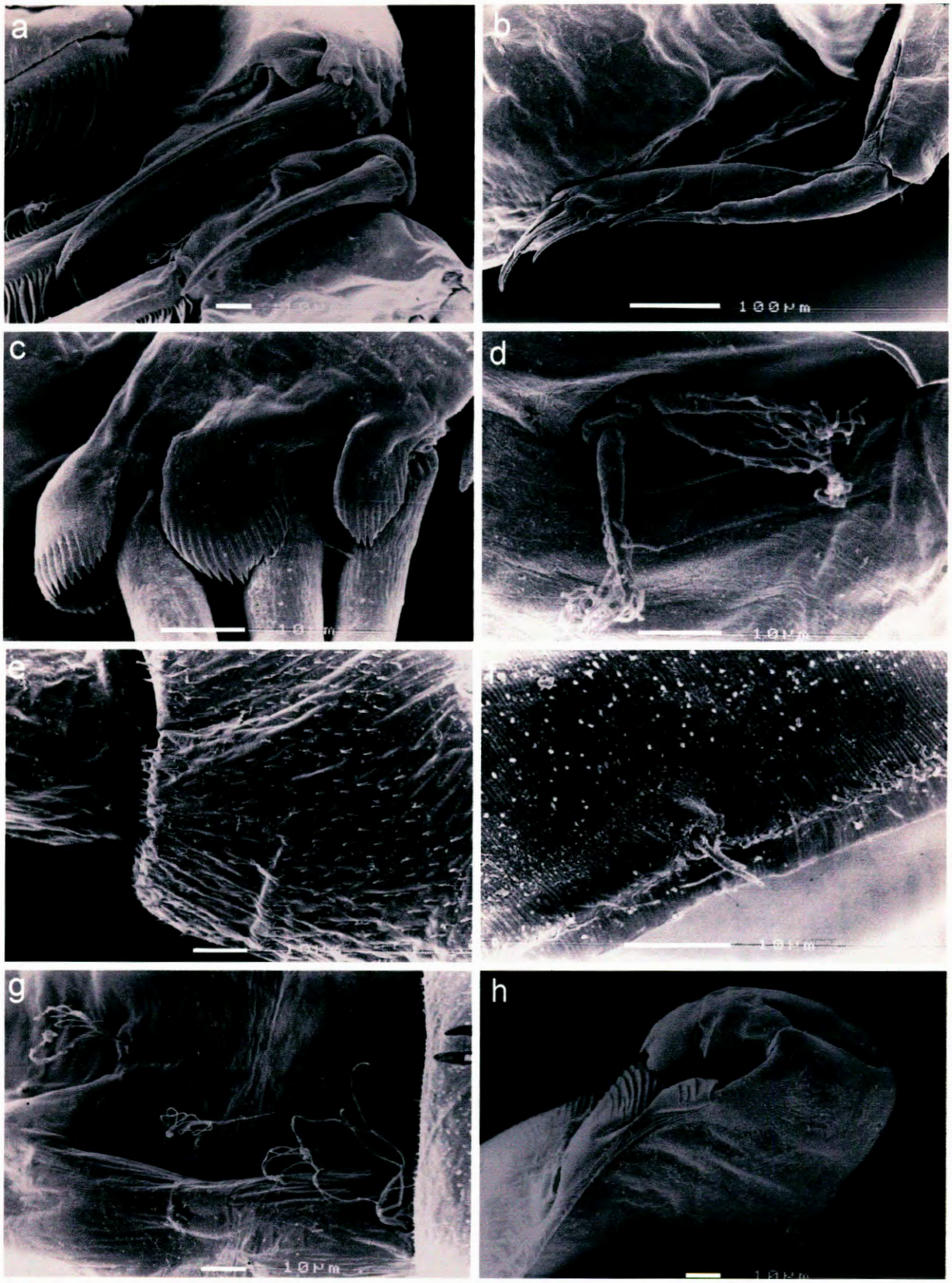
Male. Body 2.04 mm long. Cephalothoracic shield 1.19 mm long and 1.06 mm wide, excluding lateral hyaline membranes. Genital complex slightly longer than wide 0.46 x 0.43 mm. Abdomen two-segmented, sub-equal in length, one-third longer than wide, 0.36 x 0.23 mm. Caudal ramus longer than wide, 100 x 76 µm, armed with 3 short and 3 long plumose setae.

The male is one-third smaller than the female. The posteroventral and distal-outer margin of the abdomen is covered with numerous spinules similar to those in the female. The antenna bears three adhesion pads on the second segment (Fig. 3.19h), with the terminal segment bearing apically a trifid claw. Except for the sexual dimorphic characteristics, no other additional morphological features were observed from the male.

Remarks. Caligus epinepheli was described by Yamaguti (1936) from the convict grouper *Epinephelus septemfasciatus* (Thunberg, 1793) from Kuki (Mie Prefecture, Japan) and the Hong Kong grouper *Epinephelus akaara* (Temminck & Schlegel, 1842) from Tarumi (Inland Sea, Japan). Pillai (1985) included *C. epinepheli* found in Indian waters, where the length of the female was given as 4.5 mm and of the male as 4.1 mm, which indicates that the specimens found by Pillai (1985) are much larger than those described by Ho and Lin (2003) as well as those in the present study. Cressey (1991) redescribed *C. epinepheli*, but Ho and Lin (2003) renamed the species *C. cresseyi*. Ho and Lin (2003) found four morphological differences between *C. epinepheli* and *C. cresseyi*, which indicated that the species found by Cressey (1991) was not identifiable with *C. epinepheli.* Based on these morphological characters and on comparison with the original description of *C. epinepheli*, it is confirmed that *C. epinepheli* is a valid species, differing from *C. cresseyi* and *C. affinis*. This is the first report of *C. epinepheli* from South Africa and represents new host and distribution records for this species.



Figs. 3.18a-h. Scanning electron micrographs of *Caligus epinepheli* Yamaguti, 1936, female. **a.** sclerotized protrusion between bases of antenna and postantennary process. **b.** buccal stylet near roof of labrum. **c.** longer basal seta of maxillule bearing spinules on both margins. **d.** sternal furca. **e.** protopod of leg 1 bearing basal patch of spinules. **f.** endopod of leg 1. **g.** first exopod segment of leg 1 bearing small seta on outer distal corner. **h.** terminal four elements on leg 1 second exopod segment. Scale bars: 10 µm in a-h.



Figs. 3.19a-g. Scanning electron micrographs of *Caligus epinepheli* Yamaguti, 1936, female. **a.** first and second segment of leg 2 exopod with serrated spines. **b.** leg 4 exopod. **c.** pecten at base of three terminal spines on second exopod segment of leg 4. **d.** leg 5. **e.** spinules on posteroventral and distal-outer margin of abdomen. **f.** seta on marginal membrane. **g.** cluster of setules on dorsal shield near marginal membrane. **Fig. 3.19h.** *Caligus epinepheli*, male. **h.** claw of antenna. Scale bars: 100 µm in b; 10 µm in a, c-h.

***Caligus rotundigenitalis* Yu, 1933**

Figs. 3.12e-h

Caligus rotundigenitalis: Yu, 1933: 117, 118-120, 136, plate I (figs. 1-7), plate II (figs. 1-4); Rangnekar, 1959: 43-46, figs. 1a-m; Yamaguti, 1963: 59, plate 77 (figs. 2a-e); Pillai, 1967: 1592: 1671, 1672, fig. 76; Lin, Ho & Chen, 1994: 253-264, figs. 5A-F, 6A-J, 7A-G; Grobler, Van As & Olivier, 2004: In Press.

Material examined: Material collected in present study is listed in Table 3.9. All specimens were collected from the operculum of the host. The measurements of both females collected are given.

Table 3.9. Total number of *Caligus rotundigenitalis* Yu, 1933 specimens collected from fish hosts in Lake St Lucia and De Hoop Nature Reserve, including collection numbers.

Host species	# ♀♀, ♂♂ *Caligus*	Locality	Collection number
Rhabdosargus holubi	2 ♀♀	Lake St Lucia	8/019

Description.

Female. Body 2.47 (2.41) mm long. Cephalothoracic shield 1.25 (1.31) mm long and 1.02 (1.04) mm wide, excluding lateral hyaline membranes. Genital complex wider than long, 0.55 (0.49) x 0.72 (0.61) mm. Abdomen indistinctly two-segmented, more than twice as long as wide, 0.49 (0.54) x 0.19 (0.21) mm. Caudal ramus longer than wide, 129 (136) x 80 (74) µm, armed with 3 short and 3 long plumose setae. Ho *et al*. (2000) did not report measurements for the specimens collected from hosts at Sheng-Dah Fishing Port and Mi-Tuo Fishing Port. The specimens collected in the present study fit the description for *Caligus rotundigenitalis*.

Confusion on three closely related species, *C. rotundigenitalis*, *C. tanago* Yamaguti, 1939, and *C. multispinosus* Shen, 1957 were dealt with by Ho *et al.* (2000). The present study present only additional morphological information based on scanning electron microscopy. The sternal furca (Fig. 3.12e) has a short base, with tines about as long as the base. The tines are strongly flattened and medially slightly curved. The exopod of leg 2 is three-segmented. First segment with a large, stout spine, anteriorly slightly curved and serrated on both margins (Fig. 3.12f). Pecten at base of spine. Second segment with a smaller spine (Fig. 3.12f), anteriorly slightly curved, serrated on both margins and lacking a pecten at the base.

The most striking feature of this species is the ornamentation of the spines on the exopod of leg 4. The exopod of leg 4 is three-segmented (Fig. 3.12g) and has a formula of I-0; I-0; III. Four of these five spines are covered by spinules (Fig. 3.12h), a rare feature only shared by three other species, i.e., *C. multispinosus*, *C. platytarsis* Bassett-Smith, 1898, and *C. tanago*. Of these three species, only *C. multispinosus* and *C. tanago* are closely similar to *C. rotundigenitalis*. Ho *et al.* (2000) compared the three species and eluded the difficulty to determine whether the morphological differences found are genuine or simply due to differences in the author`s observation and/or technique of illustration.

The abdomen was found to provide reliable distinguishing characters. *Caligus rotundigenitalis* has a two-segmented abdomen, which is less than half the length of the carapace and *C. multispinosus* a two-segmented abdomen, more than three-quarters the length of the carapace, whereas *C. tanago* has a one-segmented abdomen, less than half the length of the carapace. Thus, the species in the present study fits the characters of the abdomen of *Caligus rotundigenitalis*. The confusion between these three species can only be sorted out when original type material will be studied, both with compound and scanning electron microscopy.

Remarks. *Caligus rotundigenitalis* was first described by Yu (1933) from *Lutjanus malabaricus* (Bloch & Schneider, 1801) from Chefoo, China. Rangnekar (1959) recorded this species from *Gnathanodon speciosus* (Forsskål, 1775) from Bombay, India, and Pillai (1985) recorded it from *Scatophagus argus* (Linnaeus, 1766) from Kerala, India. Lin *et al.* (1994) redescribed *Caligus rotundigenitalis* from the black sea bream, *Acanthopagrus schlegeli* Bleeker, 1854 from Taiwan. Lin *et al.* (1994) originally redescribed the present species as *Caligus multispinosus*, but Ho *et al.* (2000) corrected the misidentification. The major problem will be to locate the type-specimens, and our comparisons are thus based on the original descriptions.

Caligus rotundigenitalis is the most common sea louse found in Taiwanese waters. It parasitises 24 different host species of 17 families. More host species will be added to the list as this number only includes examination of fish hosts collected from fishing ports on the west coast of Taiwan, which excludes current examinations of fish hosts from the east coast of that island (J.-S. Ho, pers. comm.). This is the first report of *C. rotundigenitalis* from South Africa and represents new host and distribution records for this species.

Discussion

As one of the largest parasitic copepod genera, *Caligus* species have been reported from every major marine habitat. The genus *Caligus* comprises numerous species, but the lack of an up-to-date revision of this genus makes taxonomic work difficult. The synopsis of the genus *Caligus* published by Margolis *et al.* in 1975 bring the total number of species described until 1975 to 208, of which only 28 have been recorded off the coast of South Africa (present study). Since the synopsis was published, at least another 42 descriptions of new species were published worldwide. Most of the earlier descriptions lack much of what copepodologists now know to be essential morphological details necessary to recognise different species. These essential details will be elaborated upon and some views will be presented. Apart from essential details of each species, another important factor is to recollect specimens from the type hosts and as close to the type locality as possible to facilitate redescriptions.

Cressey (1991) divided the genus into four major groups based on the segmentation and armature of the exopod of the fourth leg. The first group has a 3-segmented exopod. The first two segments each bear a terminal spine and the last segment bears three terminal spines. This group is represented by six species from the present study, i.e. *Caligus aesopus*, *C. confusus*, *C. coryphaenae*, *C. pelamydis*, *C. penrithi* and *C. rotundigenitalis*. The second group has a 2-segmented exopod. The first segment bears a terminal spine and the last segment has a spine at the outer mid-margin (or subterminal) and three terminal spines. This group is represented by three species from the present study, i.e. *Caligus acanthopagri*, *C. epinepheli*, and *Caligus* sp. B. The third group has a 2-segmented exopod. The first segment bears a terminal spine and the last segment has three terminal spines. This group is represented by four species from the present study, i.e. *Caligus hottentotus*, *C. lalandei*, *C. tetrodontis* and *Caligus* sp. A. The fourth group has a 2-segmented exopod. The first segment bears a terminal spine and the last segment has a spine at the outer mid-margin, two prominent terminal spines and an inconspicuous outer spine usually hidden by a pecten. This group is represented by at least four known species i.e. *Caligus atromaculatus* Wilson, 1913, *C. biaculeatus* Brian, 1914, *C. kabatae* Cressey, 1991 and *C. pomacentrus* Cressey, 1991. None of these species were collected in the present study.

A fifth group is proposed, which could include eight species (two species from the present study) with the same characteristic features of the exopod of leg 4. These eight species include; *Caligus engraulidis*, *C. mortis* (the two species from the present study), *C. centrodonti*, *C. distortus*, *C. labracis*, *C. pageti*, *C. saucius* and *C. sensorius*. In this group the exopod of leg 4 is either one- or two-segmented, the first segment bears a spine at the outer mid-margin or terminal spine, but the

last segment bears only two terminal spines, without a small inconspicuous outer spine or additional pecten.

Outlined below are two different keys, the one being a key to the six genera of the family Caligidae found in South African coastal waters, the other a key to the 15 species of *Caligus* reviewed in the present study. The two species studied with the aid of scanning electron microscopy, *C. epinepheli* and *C. rotundigenitalis*, are included in the key, based on the morphological features studied. The 13 species of *Caligus* with no reference material are not included in the above mentioned groups or the key to the South African species. The main reason is that these species are doubtful species until such time that their status can be validated.

Basic key to identify six different caligid copepod genera from South Africa

The family Caligidae are represented by five genera in the South African coastal waters, i.e. *Caligus* Müller, 1785, *Hermilius* Heller, 1868, *Lepeophtheirus* von Nordmann, 1832, *Paralebion* Wilson, 1911, *Sciaenophilus* van Beneden, 1852. The following key distinguishes between females of these genera and a sixth genus, *Pseudocaligus* Scott, 1901, recently collected but as yet not published, is added.

1. Lunules absent……..…….**2**
   Lunules present……...…**4**
2. Cephalothoracic shield normal, not folded…….…….**3**
   Cephalothoracic shied longitudinally folded……...….***Hermilius***
3. Posterolateral lobes of genital complex long and pointed…….…*Paralebion*
   Genital complex without long and pointed posterolateral lobes…….... ***Lepeophtheirus***
4. Abdomen in female equal to, or more than half of body length……..…….***Sciaenophilus***
   Abdomen in female less than half of body length……...……**5**
5. Fourth leg well developed (protopod and exopod), two to four segments…….....…….***Caligus***
   Fourth leg vestigial, one-segmented……..…….…..***Pseudocaligus***

Key to the South African species of *Caligus*

1. Fourth leg (based on the five groups discussed)
   3-segmented exopod, first 2 segments each bearing terminal spine,
   last segment bearing three terminal spines……**2**
   2-segmented exopod, first segment bearing terminal spine, last segment with
   spine at outer mid-margin (or subterminal) and three terminal spines ……..…**5**

2-segmented exopod, first segment bearing terminal spine,
last segment bearing three terminal spines……..……...…....**7**
2-segmented exopod, first segment bearing terminal spine, last segment with
spine at outer mid-margin, two prominent terminal spines and an inconspicuous
outer spine hidden by a pecten……..…….….**presently no SA species**
1- or 2-segmented exopod, first segment bearing spine at outer mid-margin
or terminal spine, last segment bearing two terminal spines, without small
inconspicuous outer spine or additional pecten…….…..……**10**

2. Abdomen one-segmented……..….**3**
Abdomen two-segmented…….……..**4**
Abdomen five-segmented…….…...***coryphaenae***

3. Circlet of strong teeth (10 in total) above leg 3 endopod…….…...***aesopus***
Circlet of strong teeth (15 in total) above leg 3 endopod…….…….***confusus***

4. Four terminal elements on leg 1 exopod naked, element 1
minute, elements 2, 3 and 4 equal in length……..…....***penrithi***
Four terminal elements on leg 1 different, elements 1 and 2
serrated both margins, element 3 robust and naked, element
4 naked, all four elements almost equal in length…….…….……..***pelamydis***
Four terminal elements on leg 1 different, elements 1, 2 and
3 serrated both margins, element 4 longest and naked……....….***rotundigenitalis***

5. Abdomen one-segmented…….… ***acanthopagri***
Abdomen two-segmented…….…….……**6**

6. Terminal segment of leg 1 with four terminal elements, subterminal
element on posterior margin absent……..…...….***epinepheli***
Terminal segment of leg 1 with four terminal elements, small subterminal,
naked element on posterior margin.…….……...**sp. B**

7. Abdomen one-segmented……....….***tetrodontis***
Abdomen two-segmented…….…….…….…...**8**

8. Caudal ramus long, between 300 and 410 Φm in length……..…….……...**9**
Caudal ramus exceptionally long, between 1.01 and 1.40 mm in length.……...….***lalandei***

9. Inner, subterminal border of maxilla normal……...…….….***hottentotus***
Inner, subterminal border of maxilla serrated……....……**sp. A**

10. Fourth leg with one subterminal and one terminal spine…….…..…...…….***mortis***
Fourth leg with two terminal spines, largest spine heavily

serrated both margins……...……...….***engraulidis***

Important morphological features to distinguish species of *Caligus*

As discussed earlier, confusion in the taxonomic work of *Caligus* has resulted in the description of more than 315 nominal species. As a revision of the whole genus is vital, future studies on these parasites should be done in such a manner to cause no confusion at all. The way forward will be complete taxonomic descriptions of new species, as well as redescriptions of species, which were inadequately described. Authors such as Cressey (1991) proposed groupings of species based on the segmentation and armature of the exopod of the fourth leg. As a new group was proposed in the present study, *Caligus* species can be divided into one of five groups. Groupings within these groups are a possibility and the use of the armature of the four terminal elements on the second exopodal segment of the first leg may be used, as this morphological feature is unique to each species. However, this type of grouping will not be used in the key in the present study, but is proposed for future studies on these parasites.

The use of this second type of grouping may be more complicated than the use of the fourth leg as a group divider. I am going to propose six groups, but will not elaborate on the fine ornamentations of these elements in the proposed groups, which include serrated margins, striated membrane, setae or be naked. The first group has the four terminal elements equal or almost equal in lengths. The second group has the first element significantly smaller than the rest of the elements. The third group has the fourth element significantly longer than the rest of the elements. The fourth group has the fourth element significantly smaller than the rest of the elements. The fifth group has elements two and three each with an accessory process. The sixth group has elements one, two and three each with an accessory process.

According to the groupings of both the segmentation and armature of the exopod of the fourth leg and the armature of the four terminal elements on the second exopodal segment of the first leg, the species in the present study can be grouped as illustrated in Table 4.1.

Table 4.1. Grouping of *Caligus* Müller, 1785 species from present study according to the two different proposed groupings using the segmentation and armature of the exopod of leg 4 and the second exopodal segment of leg 1.

Leg 4 exopod	Leg 1 second exopodal segment
Group 1	Group 2
Caligus penrithi	
Caligus rotundigenitalis	
Group 1	Group 4
Caligus pelamydis	
Group 1	Group 5
Caligus aesopus	
Caligus confusus	
Caligus coryphaenae	
Group 2	Group 5
Caligus acanthopagri	
Caligus epinepheli	
Caligus sp. B	
Group 3	Group 3
Caligus hottentotus	
Group 3	Group 5
Caligus lalandei	
Caligus tetrodontis	
Group 3	Group 6
Caligus sp. A	
Group 5	Group 1
Caligus engraulidis	
Group 5	Group 5
Caligus mortis	

The use of this proposed system will be confusing, but will allow the whole genus to be divided into more groups. It may sound like a lot of groups, but with a genus comprising more than 315 nominal species, this will make taxonomic work easier, especially when this grouping system can

be used as a reference system for the whole genus. As I said earlier, this is only a proposed system, as a lot of work on the genus is still needed before a system like this proposed one can be used as a type of reference system.

A few remarks based on the present study, concerning important morphological features for species identification, are outlined. Cressey (1991) pointed out that the shape of the claw of the antenna in the female is generally a reliable character. I tend to differ from this remark, as most female specimens of different species studied in the present study could not be separated using this character. It is only in the claw of the male antenna where reliable differences can be found between male specimens of different species. As the male antenna is not used for species identification, but only as a sexual dimorphism, the use of the shape of the claw of the female antenna as a morphological feature should not be one of critical importance.

The opposite is true for the postantennary process and maxillule. It was found in the present study that the postantennary process and maxillule of different species bear different characteristics. Important to note is whether the processes of both the postantennary process and maxillule are straight or curved, and to what degree it is curved. These processes also bear outgrowths or accessory processes, or none at all. The postantennary process usually has two basal papillae and another papilla located nearby on the sternum, each bearing setules. The number of setules may differ between species, but I feel that this feature should not be used in species identifications, as it was found that specimens from the same species tend to have different numbers of setule-bearing papillae.

The sternal furca is usually a stable character, but intraspecific variations are sometimes found (Cressey 1991). The discovery of such variations should be noted and these individuals should not be described as new species unless there are substantial other differences as well. One of the most important features is the armature of the exopodal and endopodal segments of the first, second, third and fourth pair of legs and the fine ornamentations of the different segments. The most important of these being the following: 1) the four terminal elements on the second exopodal segment of the first leg, 2) the ornamentation of the spines and setae on the three exopodal segments of the second leg, in addition to the fine ornamentation of the endopodal segments of this leg, 3) the ornamentations on the protopod of the third leg, in addition to the armature and ornamentations of the exopodal and endopodal segments of this leg, and 4) the segmentation and armature of the exopod of the fourth leg.

An important trend to be explored in future studies on caligid copepods is the use of molecular work. Molecular work on the family Caligidae was done by Ho and Lin (2002). The systematic position of the caligid genera was compared using cladistic analysis. This trend may be useful

when species are found which are closely related, as was found in the present study with *Caligus epinepheli* and *C. rotundigenitalis*, or to explore phylogenetic relationships within the family to see whether a species belongs to another genus or not. Species, which have intraspecific variations due to geographical occurrences, may also be studied using molecular work, as these variations among species found on the same hosts were reported.

These ideas are stepping-stones for future studies, and could form interesting projects for postgraduate studies at various Universities. Another idea for future studies is to collect live specimens, which include ovigerous females, and rear them in culture to study the life cycles of these species. Notwithstanding the fact that more than 315 nominal species of *Caligus* are known, the complete life cycle is known for only about ten species (Lin *et al.* 1997). This will make the understanding of one of the worlds most diverse parasitic copepod genera complete.

Species of *Caligus* with questionable status

No voucher specimens

The following species have either been recorded, collected or described from the South African coastline. No voucher specimens of these species could be found in any parasite collection in South Africa, and are thus, according to me, doubtful species. These species will, however, remain as species recorded from South Africa, until such time that their status can be validated. However, for the purpose of this study, they are included as part of the South African fauna (synopses Chapter 1).

Caligus arii Bassett-Smith, 1898

The only record of this species is the original description by Bassett-Smith (1898). The specimens in the collection of the South African Museum (SAM A8518) are missing, making it difficult to compare and elaborate on this species. Original host species, *Arius acutirostris* and *Arius caelatus*, should be collected in order to clarify the status of this species.

Caligus assymmetricus Pillai, 1965

The only record of this species is the record by Oldewage and Van As (1989), where it was recorded from the host species *Scomberomorus commerson* and *Katsuwonus pelamis*. Original host species should be collected in order to clarify the status of this species.

Caligus biseriodentatus She, 1957

The only record of this species is the record by Oldewage and Van As (1989), where it was recorded from the host species *Scomberomorus commerson* and *Sarda sarda*. Original host species should be collected in order to clarify the status of this species.

Caligus bonito Wilson, 1905

This species has been recorded twice from South Africa, first by Barnard (1955b), where it was collected from the host *Sarda sarda* and included in his key. Oldewage and Van As (1989) recorded it from the host *Scomberomorus commerson*. Original host species should be collected in order to clarify the status of this species.

***Caligus brevicaudatus* Scott, 1901**

The only record of this species is the record by Barnard (1955b), where it was included in his key. No host or locality records were given, making this a doubtful record.

***Caligus curtus* Müller, 1785**

The only record of this species is the record by Oldewage and Avenant-Oldewage (1993), where it was recorded from two host species *Chelidonichthys capensis* and *Chelidonichthys queketti*. Original host species should be collected in order to clarify the status of this species.

***Caligus diaphanus* Nordmann, 1832**

The only record of this species is the record by Oldewage and Van As (1989), where it was recorded from the host species *Trachinotus botla*. Original host species should be collected in order to clarify the status of this species.

***Caligus elongatus* Nordmann, 1832**

The only record of this species is the record by Barnard (1955a), where it was included in his key. No host or locality records were given, making this a doubtful record.

***Caligus infestans* Heller, 1865**

The only record of this species is the record by Oldewage and Van As (1989), where it was recorded from the host species *Scomberomorus commerson*. Original host species should be collected in order to clarify the status of this species.

***Caligus lunatus* Wilson, 1928**

The only record of this species is the record by Barnard (1955b), where it was collected from the host *Seriola lalandi* and included in his key. Original host species should be collected in order to clarify the status of this species.

***Caligus mauritanicus* Brian, 1924**

The only record of this species is the record by Barnard (1955b), where it was collected from the following hosts; *Pomatomus saltatrix*, *Caranx rhonchus*, *Corvina cameronensis*, *Dentex gibbosus*, *Dentex* sp., *Pagrus pagrus*, and *Plectorhinchus mediterraneus*, and included in his key. Original host species should be collected in order to clarify the status of this species.

***Caligus saucius* Dojiri, 1989**

The only record of this species is the species description by Dojiri (1989), where it was collected from the host *Cirripectes castaneus* at KwaZulu reef. The species description of Dojiri (1989) is full and complete, making this a valid species from South Africa. The type specimens were deposited in the United States National Museum, one female holotype (USNM 229988) and two female paratypes (USNM 229989), but no specimens were deposited in the South African Museum. A redescription of the species was thus omitted from the present work.

***Caligus zei* Norman & Scott, 1906**

The only record of this species is the record by Barnard (1955b), where it was collected from the host *Thyrsites atun* and included in his key. Original host species should be collected in order to clarify the status of this species.

Misidentified species of *Caligus*

Three species of *Caligus* were misidentified and the errors are rectified. All three species will be removed from the South African list of *Caligus* species. However, *Caligus africanus* is not a valid species and synonymised with *C. tetrodontis*.

***Caligus* cf. *affinis* Heller, 1866**

Refer to full species description and remarks on *Caligus* sp. B in Chapter 3.

***Caligus africanus* Oldewage & Van As, 1989**

Refer to full species description and remarks on *Caligus tetrodontis* in Chapter 3.

***Caligus labracis* Scott, 1902**

The only record of this species is the record by Barnard (1955b), where it was recorded from the host species *Clinus superciliosus*. No description was given, where it was only included in his key. With multiple collections of *Caligus mortis* from *Clinus superciliosus* at various localities on the south and west coast of South Africa, I feel this is a misidentification, and *Caligus labracis* should be removed from the list of *Caligus* species from South Africa. Kabata (1979) also expressed his surprise with this record from *Clinus superciliosus*. *Caligus labracis* is known almost exclusively from around the British Isles, where it occurs apparently only on two host species, *Labrus bergylta* Ascanius, 1767, and *L. mixtus* Linnaeus, 1758.

Mixed-up specimens

As discussed earlier, many of the specimens in the collection of the South African Museum got lost on loan. A few of the returned specimens, which were on loan, got mixed-up completely. These mixed-up specimens are sorted out, some have catalogue numbers, but those without or wrong catalogue numbers will for the time being remain without any catalogue numbers. The loan numbers are 1195, 1196 and 2737.

***Caligus penrithi* Kensley & Grindley, 1973**

Three female specimens, labeled with catalogue number SAM A8517, is part of a mixed-up loan. It is labeled to be part of the original syntype series of *Caligus lalandei*. Roger Cressey, with the specimens on loan, identified the two female specimens as *C. tetrodontis*, but the fourth leg is three segmented with formula I-0, I-0, III. After examining these specimens, they were identified as *C. penrithi*. All three specimens are in a rather poor state. No host or locality record is included in the labeling of the specimens. Both these specimens will be assigned new catalogue numbers after appropriate discussion with the South African Museum.

***Caligus tetrodontis* Barnard, 1948**

Two female specimens, without any catalogue number, is also part of the mixed-up loans. The specimens have both been identified as *C. tetrodontis*. No host or locality record is included in the labeling of the specimens. Both these specimens will be assigned new catalogue numbers after appropriate discussion with the South African Museum.

***Caligus mortis* Kensley, 1970 & *C. tetrodontis* Barnard, 1948**

This vial with catalogue number SAM A12993 contains specimens of both *Caligus mortis* and *C. tetrodontis*, another mixed-up loan. The original catalogue number SAM A12993 is part of the type material of *C. mortis*, and this additional vial should be re-catalogued. However, all the specimens inside this vial are missing appendages, which makes identification rather difficult. I feel the best solution is to remove this vial from the collection, or to label it as incomplete specimens for future references. J.-S. Ho also checked these specimens in 2000 and remarked it to be unidentifiable specimens.

Vials without any specimens/wrongly identified as a species of *Caligus*

The following vials were found to have no specimens inside. The exact reason for the disappearance of these specimens is not known, but could be related to specimens, which were lost on loan.

***Caligus arii* Bassett-Smith, 1898**

The missing specimens of this species was discussed earlier (see no voucher specimens).

***Caligus confusus* Pillai, 1961**

This vial has no SAM A catalogue number. It is labeled *Caligus confusus* inside, but contains no specimens. This vial should be removed from the collection of the South African Museum, as no catalogue number with no specimens will create confusion for future refernces.

***Caligus* sp.**

This vial has the catalogue number SAM A40323, but contains no specimens. As this species was not identified and no host been recorded, this catalogue number should be removed from the list of catalogue numbers for species of *Caligus* from the South African Museum.

***Caligus* sp.**

This vial has the catalogue number SAM A40324 and contains one specimen. However, this species was identified as *Caligus* sp., but is not a species of *Caligus*. The terminal elements on the second exopodal segment of leg 1 do not resemble that of the genus *Caligus*. Another difference is found on the endopodal segments of leg 2, which bear heavy serrated spines. This caligid copepod could not be identified, no host has been recorded, and only one specimen exists, which will make a comparison with other caligids difficult.

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Abstract

The ichthyoparasitic and fish louse copepod genus, *Caligus* Müller, 1785, is the most abundant copepod genus, found in almost any part of the world's oceans, with the exception of one freshwater species. More than 315 nominal species have been described, of which only 26 species have been recorded off the coast of South Africa. Most of the information on this genus from South Africa is limited to very old and often incomplete taxonomic descriptions. Of the 26 known species of *Caligus* recorded from South Africa, only 15 species have reference material, either in the collection of the South African Museum, or in the collection of the Aquatic Parasitology Research Group, University of the Free State, Bloemfontein. These 15 species are redescribed, and the validity of each species is discussed. Additional morphological features for six species are given, based on studies with the aid of scanning electron microscopy. In addition to the species descriptions, a synopsis of host/parasite and parasite/host is given. A key to all 15 species reviewed in the present study is included. The reference material of 15 species has disappeared, mainly due to material on loan that got lost. These species will, however, remain as species recorded from South Africa, until such time that their status can be validated. However, for the purpose of this study, they are included as part of the South African fauna. Three of these 15 species, *Caligus affinis* Heller, 1866, *C. africanus* Oldewage & Van As, 1989 and *C. labracis* Scott, 1902, have been misidentified. Specimens of the misidentified *C. affinis* were subsequently collected from the same host, *Pomatomus saltatrix* (Linnaeus, 1766), in the present study, and a detailed description is included for this species (*Caligus* sp. B), but it is still uncertain whether this species is new. *Caligus africanus* is not a valid species and is therefore synonymised with *Caligus tetrodontis* Barnard, 1948. One new species (*Caligus* sp. A) has been collected from the Kob, *Argyrosomus japonicus* (Temminck & Schlegel, 1843), and a fully illustrated description is supplied. With the description of this new species, as well as the inclusion of *Caligus* sp. B, the total number of species recorded from the South African coast is 28. The genus *Caligus* can traditionally be divided into four major species groups based on the segmentation and armature of the exopod of the fourth leg. In this study, a fifth group is proposed to include eight species (two species from the present study) with the same characteristic features of the exopod of the fourth leg. In this group the exopod of leg 4 is either one- or two-segmented, the first segment bearing a terminal spine and the last segment bearing only two terminal spines. Future studies on the caligid copepods of South Africa should involve molecular work, as this trend may be useful when species are found which are close to each other, as was found in the present study with *Caligus epinepheli* Yamaguti, 1936, and *C. rotundigenitalis* Yu, 1933, or to explore phylogenetic relationships within the family to see

whether a species belongs to another genus or not. During the course of the present study, which started as an Honours project in 1997, four papers have been published in international journals. Various conference proceedings have also been published during the course of this study. This present study forms a well-outlined reference for future studies on species of *Caligus* from South Africa.

Key words. Copepod, *Caligus*, ichthyoparasitic, sea louse, description, synopsis, key, reference, South Africa

Opsomming

Die parasitiese kopepod en visluis-genus, *Caligus* Müller, 1785, is die genus met die meeste spesies en word in amper elkeen van die wêreld se oseane aangetref, met die uitsondering van een varswater spesie. Meer as 315 nominale spesies is tot dusver beskryf, waarvan slegs 26 spesies vanaf die Suid-Afrikaanse kus aangeteken is. Die meeste inligting van die genus in Suid-Afrika is tot baie ou en meestal onvolledige taksonomiese beskrywings beperk. Van die 26 bekende *Caligus* spesies wat van Suid-Afrika aangeteken is, het slegs 15 spesies verwysingsmateriaal wat óf in die versameling van die Suid-Afrikaanse Museum óf in die versameling van die Akwatiese Parasitologie Studiegroep, Universiteit van die Vrystaat, Bloemfontein, gestoor word. Hierdie 15 spesies word herbeskryf en die geldigheid van elke spesie word bespreek. Bykomende morfologiese besonderhede vir ses spesies word ook gegee wat met die hulp van skandeerelektrone-mikroskopie bestuur is. Tesame met die spesie-beskrywings word `n sinopsis van gasheer/parasiet asook een van parasiet/gasheer gegee. Al 15 spesies, wat in die studie bestudeer is, word in `n sleutel saamgevat. Die verwysingsmateriaal van 15 spesies het weggeraak, hoofsaaklik as gevolg van spesies wat uitgeleen is. Hierdie spesies sal wel deel van die Suid-Afrikaanse verwysingsmateriaal bly totdat hul status geldig gemaak word. Vir die doel van die huidige studie word hierdie spesies as deel van die Suid-Afrikaanse fauna ingesluit. Drie van hierdie 15 spesies, *Caligus affinis* Heller, 1866, *C. africanus* Oldewage & Van As, 1989 en *C. labracis* Scott, 1902, is verkeerd geïdentifiseer. Materiaal is ook versamel vanaf *Pomatomus saltatrix* (Linnaeus, 1766), dieselfde gasheer waarvan *Caligus affinis* verkry is. Die status van die spesie (*Caligus* sp. B) is nog onbekend, maar is nie *C. affinis* nie. *Caligus africanus* is nie `n geldige spesie nie en word as `n sinoniem van *Caligus tetrodontis* Barnard, 1948 beskou. Een nuwe spesie is vanaf die kob/kabeljou *Argyrosomus japonicus* (Temminck & Schlegel, 1843) versamel en `n volledige geïllustreerde beskrywing word gegee. Met die beskrywing van die nuwe spesie sowel as die insluiting van *Caligus* sp. B, is die totale getal spesies wat vanaf die Suid-Afrikaanse kus versamel is 28. Die genus *Caligus* is tradisioneel in vier groepe spesies verdeel, gebaseer op die segmentasie en armatuur van die eksopood van die vierde poot. `n Vyfde groep word in die huidige studie voorgestel, wat agt spesies (twee spesies van die huidige studie) insluit, gebaseer op dieselfde morfologiese eienskappe van die vierde poot. In hierdie vyfde groep het die eksopood van die vierde poot óf een óf twee segmente, die eerste segment het `n terminale stekel terwyl die tweede segment slegs twee terminale stekels het. Toekomstige studies op die kaligid kopepode van Suid-Afrika moet molekulêre werk insluit, want dit kan baie hulpsaam wees met spesies wat baie naby verwant is, soos in die huidige studie gevind is waar *Caligus epinepheli*

Yamaguti, 1936, en *C. rotundigenitalis* Yu, 1933, baie naby verwant is aan ander spesies. Die filogenetiese verwantskappe tussen families kan ook met molekulêre werk gedoen word. Gedurende die huidige studie, wat as my Honneurs projek in 1997 begin het, is vier wetenskaplike artikels in internasionale joernale gepubliseer. Verskeie kongresbydraes gedurende die huidige studie is ook gepubliseer. Die huidige studie is `n baie volledige verwysing vir toekomstige studies op spesies van die genus *Caligus* van Suid-Afrika.

APPENDIX I

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Description of the previously unknown male of *Caligus mortis* Kensley, 1970 (Copepoda: Caligidae), parasite of intertidal fish from South Africa

Nico J. Grobler[1], **Jo G. Van As**[1] and **Piet A.S. Olivier**[2]

[1]Department of Zoology and Entomology, University of the Free State, P.O. Box 339, Bloemfontein, 9300, South Africa;

[2]School of Molecular and Life Sciences, University of the North, Private Bag X1106, Sovenga, 0727, South Africa

Key words: Copepoda, Caligidae, *Caligus mortis*, South Africa, intertidal fish

Abstract. *Caligus mortis* Kensley, 1970 was originally described from females collected from intertidal pools along the coast of Namibia. During surveys at Jeffreys Bay and De Hoop Nature Reserve in South Africa, both females and males of *C. mortis* were collected from intertidal pool fish hosts. Based on this material a full description of the male is given, and a comparison with the female reveals the sexual dimorphic characteristics.

The genus *Caligus* Müller, 1785 comprises numerous species, but the lack of an up-to-date revision of this genus makes taxonomic work difficult. The synopsis of the genus *Caligus* published by Margolis et al. (1975) bring the total of species described until 1975 to 208, of which 39 have been recorded off the coast of Africa. Since the synopsis was published, at least 38 descriptions of new nominal species were published. Kensley (1970) described the female of *Caligus mortis* Kensley, 1970 from intertidal rock pools at Rocky Point and Torra Bay, Namibia. Dojiri (1989) redescribed the species based on the holotype and other specimens from the collection of the South African Museum. The male of *C. mortis* has remained hitherto unrecorded. During fish parasitological surveys carried out in March and April of 1997, 1998 and 1999 at Jeffreys Bay and De Hoop Nature Reserve on the south coast of South Africa, specimens of *C. mortis* were found on three different resident intertidal fish species. Based on this material a full description of the male is given, and a comparison with the female reveals the sexual dimorphic characteristics. All comparisons with the female are based on the excellent redescription by Dojiri (1989).

MATERIALS AND METHODS

Fishes were collected with hand nets in intertidal pools. Caligid copepods were removed from the hosts and fixed in 70% ethanol. All preserved specimens were cleared in 85% lactic acid for at least 24 h before measurements were taken. The specimens were then dissected according to the wooden slide procedure of Humes and Gooding (1964). All drawings were made with the aid of a drawing tube. Specimens for scanning electron microscopy were dehydrated to absolute ethanol, critical-point dried, sputter coated with gold and studied in a JEOL WinSEM JSM 6400 at 10 kV. Mean body measurements are given in millimetres, followed by the range in parentheses. Measurements of appendages are given in micrometres.

RESULTS

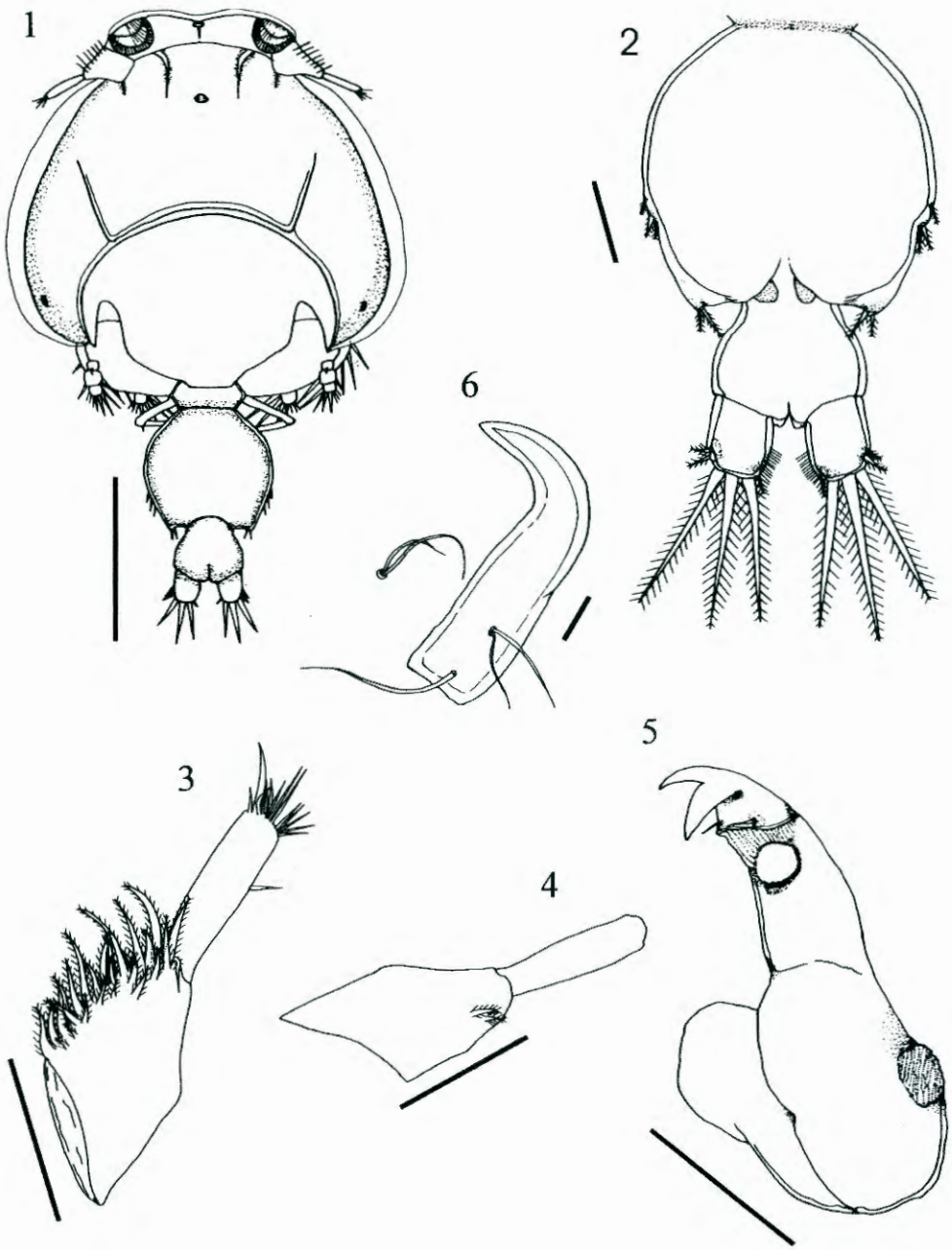
Caligus mortis Kensley, 1970

Adult male Figs. 1-23

Description: Body typically caligiform (Fig. 1). Total length of male (excluding setae on caudal rami) 1.88 mm (1.66-1.93; n = 5). Adult male much smaller than female. Cephalothorax suborbicular, less than 1.1 times wider than long. Frontal plates well developed; lunules large. Posterior sinuses deep; lateral zones not reaching fourth pediger; posterolateral corner of lateral zone with conspicuous sensory pit. Tip of antennule not reaching lateral limit of dorsal shield. Fourth pediger wider than long, distinctly separated from genital complex. Genital complex (Fig. 2) with slightly rounded posterolateral corners. Abdomen (Fig. 2) one-segmented, wider than long. Caudal rami longer than wide, shorter than abdomen. Posterior margin of each ramus armed with two outer, one small, medial and three large terminal plumose setae (Figs. 2, 21).

Antennule two-segmented (Fig. 3); proximal segment trapezoid, much broader than distal segment, with 14 large, stout, marginal setae, 13 short, plumose ventral setae and two short, plumose dorsal setae (Fig. 4); distal segment rod-shaped, much longer than wide, armed with 13 terminal setae and one subterminal seta on posterior margin. Antenna three-segmented (Fig. 5); proximal segment unarmed; second segment large, robust, armed with two corrugated patches; terminal segment smallest; claw bifid (Fig. 16); strong seta on each side of claw, close to base. Postantennary process hook-like (Fig. 6) with two basal papillae, bearing one

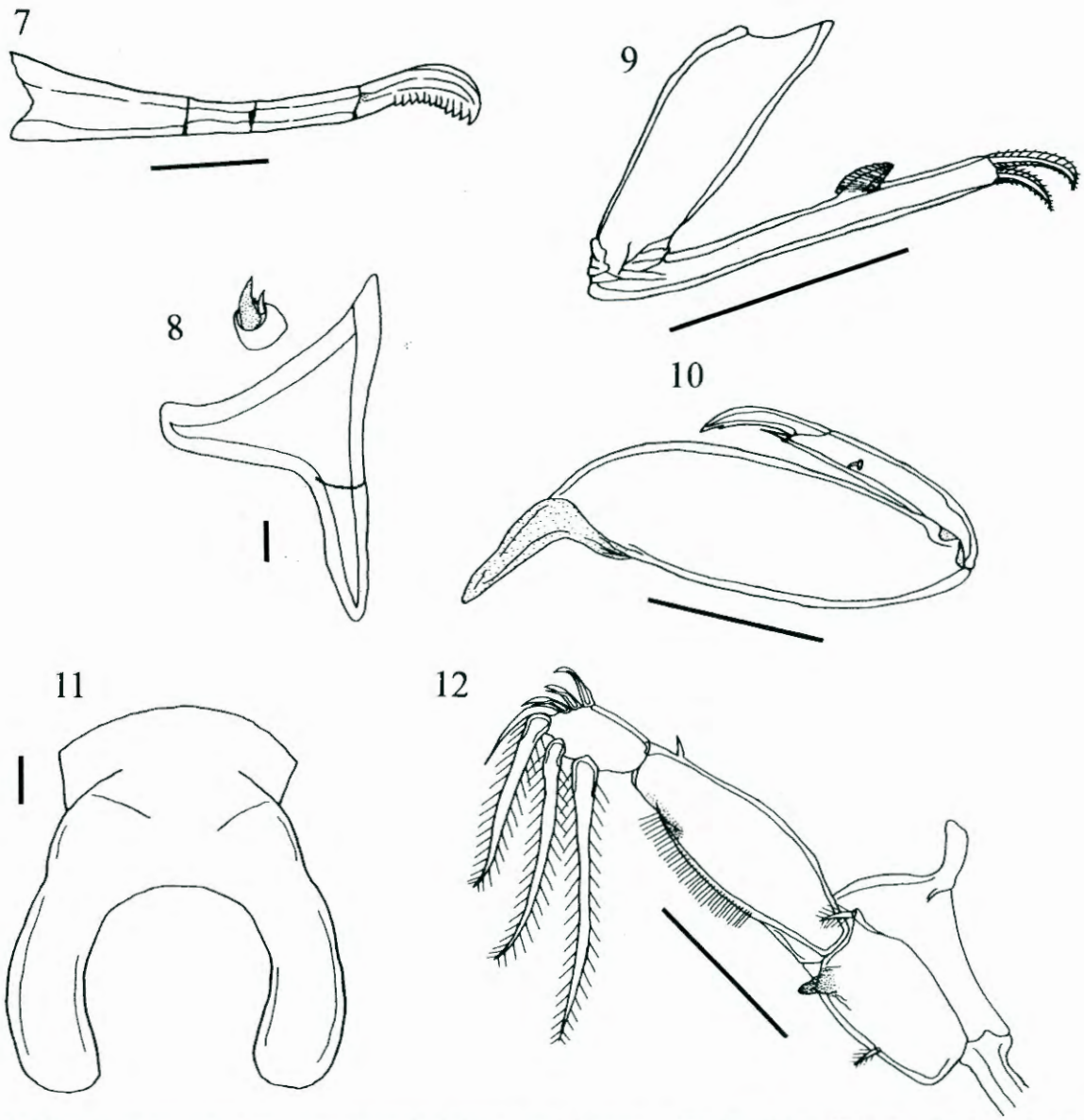
Address for correspondence: J.G. Van As, Department of Zoology and Entomology, University of the Free State, P.O. Box 339, Bloemfontein, 9300, South Africa. Phone: ++27 51 401 2427; Fax: ++27 51 448 8711; E-mail: vanasjg@sci.uovs.ac.za



Figs. 1-6. Microscope projection drawings of a male *Caligus mortis* Kensley, 1970. **Fig. 1.** Dorsal view. **Fig. 2.** Urosome. **Fig. 3.** Ventral view of antennule. **Fig. 4.** Antennule, showing only armature on dorsal surface. **Fig. 5.** Antenna. **Fig. 6.** Postantennary process. Scale bars: Fig. 1 = 500 μm; Figs. 2-5 = 100 μm; Fig. 6 = 10 μm.

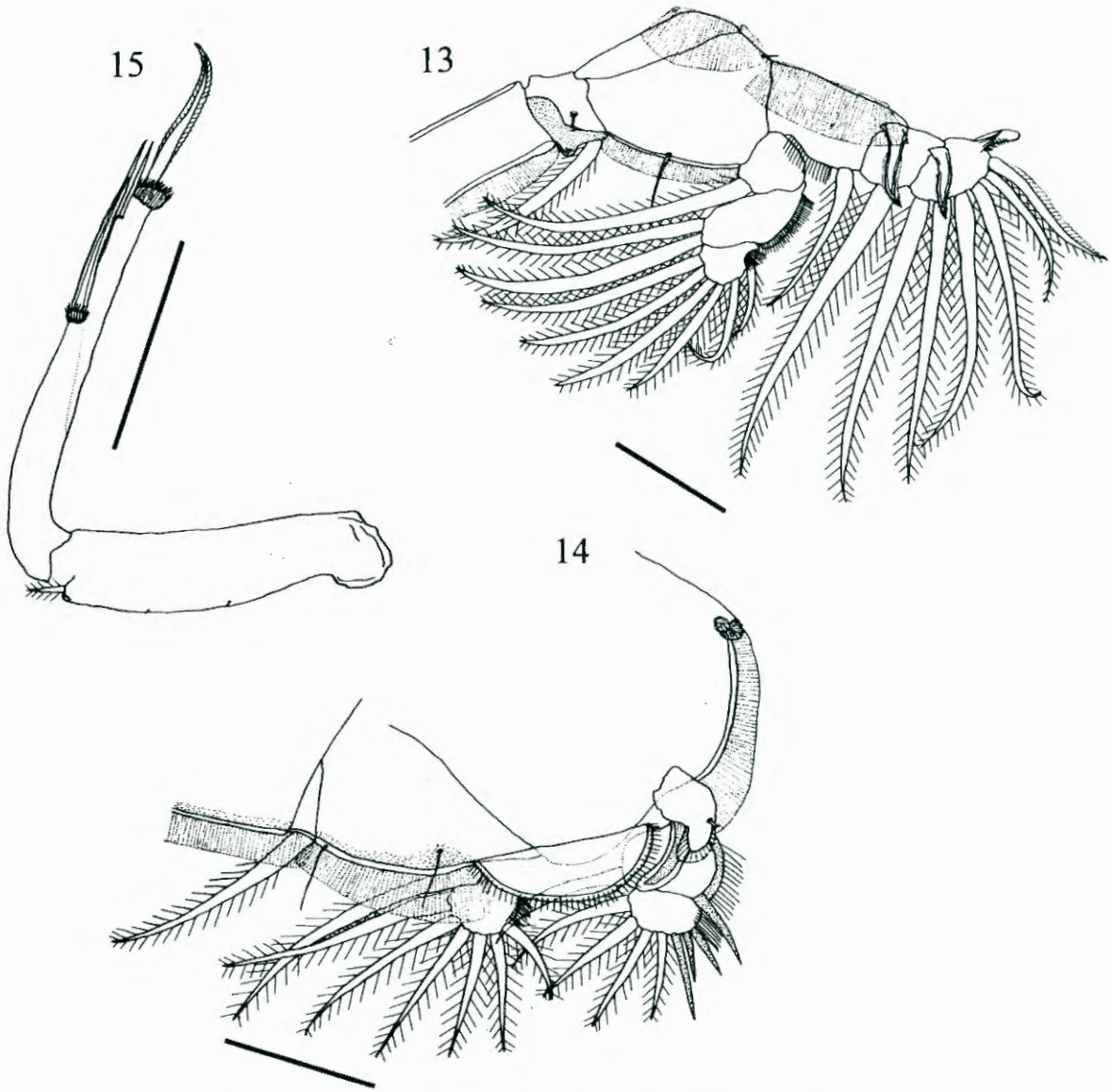
and two long setules respectively and one similar papilla located nearby on sternum bearing two long setules.

Mouth tube longer than wide (Fig. 17). Mandible (Fig. 7) with 12 teeth on mediodistal margin. Maxillule dentiform (Fig. 8), sharply hook-like with papilla bearing three setae; small band of striatious on middle of process. Maxilla two-segmented, brachiform (Fig. 9); proximal segment (lacertus) unarmed; distal segment (brachium) slender with flabellum on medial margin bearing hyaline membrane; calamus with three rows of tiny spinules; canna with two rows of tiny spinules, shorter than calamus. Maxilliped three-segmented (Fig. 10); proximal segment stout, unarmed; second and terminal segments fused, forming strong claw; second segment with small, hyaline, setiform process in small pit and one naked seta on inner distal corner; terminal segment with minute accessory tooth near inner distal end. Sternal furca with small base (Figs. 11, 18); tines not tapered, curving inward, slightly flared, and truncate at tip.



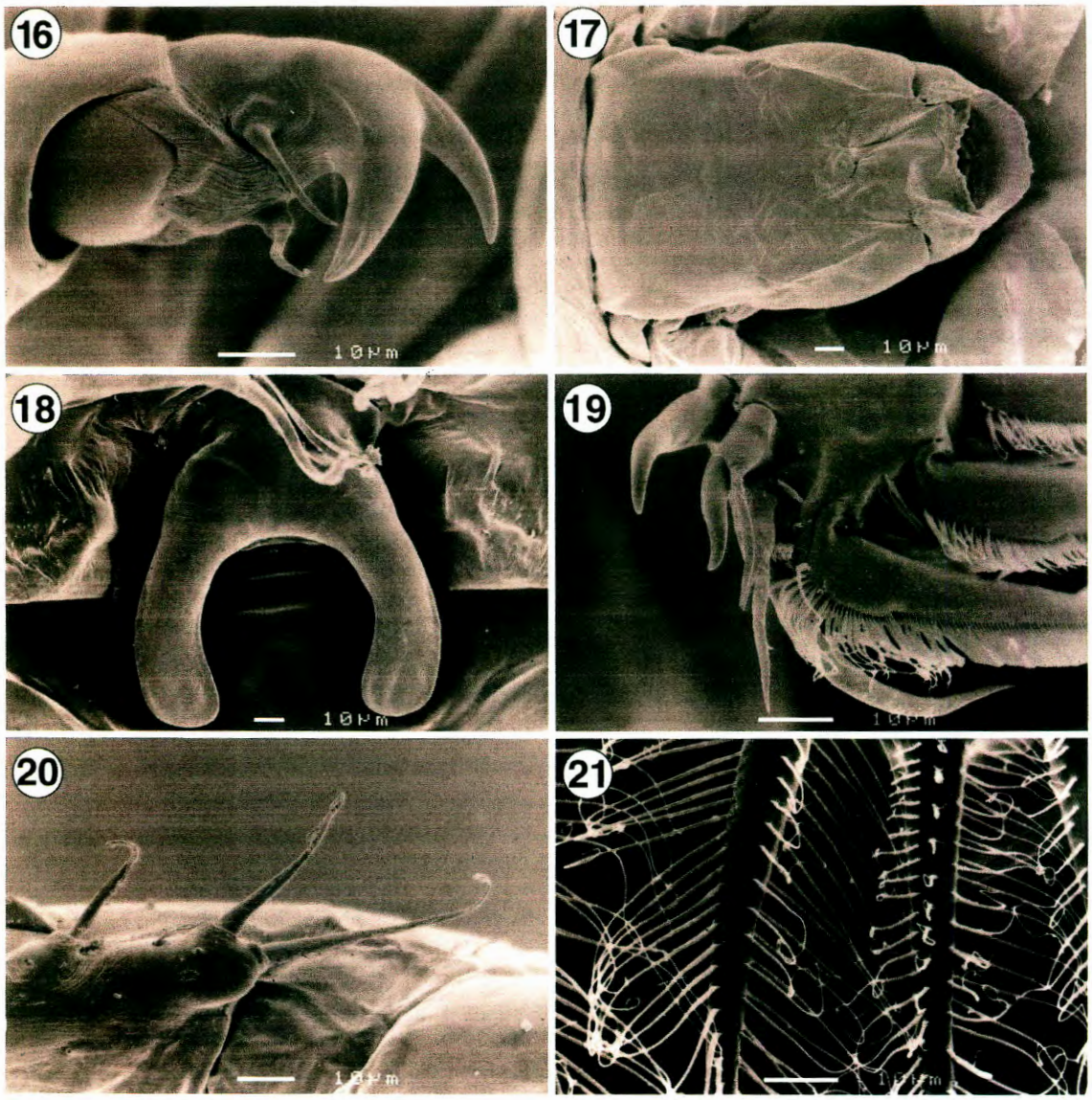
Figs. 7-12. Microscope projection drawings of a male *Caligus mortis* Kensley, 1970. **Fig. 7.** Mandible. **Fig. 8.** Maxillule. **Fig. 9.** Maxilla. **Fig. 10.** Maxilliped. **Fig. 11.** Sternal furca. **Fig. 12.** Leg 1. Scale bars: Figs. 7, 9, 10, 12 = 100 μm; Figs. 8, 11 = 10 μm.

Leg 1 biramous (Fig. 12); protopod with one inner and one outer short, plumose seta; exopod two-segmented; first segment with lateral distal spine and medial row of setules; second segment with four terminal elements; first spine simple and slightly longer than spines 2 or 3; spines 2 and 3 with spiniform secondary process, equaling the length of spines (Fig. 19); spine 4 two times as long as spine 1, robust, tapering and unarmed; three long, plumose setae on posterior margin of same segment, different in size; endopod rudimentary, unarmed. Leg 2 coxa with large plumose seta and one setule near intercoxal plate (Fig. 13); basis with one long medial setule and striated membrane along medial margin, and one setule on anterolateral margin; exopod three-segmented; first segment with one outer slightly curved spine and one long, plumose inner seta; second segment with one outer spine and one long, plumose inner seta; both spines with serrated membranes along distal two-thirds of outer and inner margins; third segment with three spines on anterolateral margin (first spine minute; second spine with hyaline membrane and row of hairs on inner margin; third spine with striated membrane along outer margin and setules on inner margin) and five long, plumose setae; endopod three-segmented; first segment with one long, plumose inner seta; second segment with two long, plumose inner setae and a crest of prominent hairs on outer margin; third segment with six long, plumose terminal setae and patch of hairs on outer margin. Leg 3 with small adhesive pad on



Figs. 13-15. Microscope projection drawings of a male *Caligus mortis* Kensley, 1970. **Fig. 13.** Leg 2. **Fig. 14.** Leg 3. **Fig. 15.** Leg 4. Scale bars: Figs. 13-15 = 100 μm.

ventrolateral surface and striated marginal membranes (Fig. 14); exopod three-segmented; first segment with large basal claw-like spine situated subterminally on basal swelling which bears terminal striated membrane and lateral setule; second segment with one outer spine and one plumose inner seta; third segment with three spines of different lengths and four plumose setae of equal length; both segments with rows of setules on lateral margins; endopod two-segmented; first segment expanded laterally into velum on outer margin and bearing one long, plumose seta on medial margin; second segment with five long, plumose setae of different lengths and rows of hair on lateral margin. Leg 4 protopod bearing two setules (Fig. 15); outer seta on protopod short and plumose; long and slender exopod, indistinctly two-segmented; first segment with spine, almost as long as terminal spine, naked and bearing pectinate membrane at base; second segment with two spines of different size; first spine relatively short, naked, not highly sclerotised, without pectinate membrane; terminal spine with two rows of serrated membranes and equipped with pectinate membrane at base. Leg 5 rudimentary (Figs. 2, 20), on lateral margin of genital complex, represented by three plumose setae. Leg 6 rudimentary (Fig. 2), on rounded posterolateral corner of genital complex, represented by two plumose setae.



Figs. 16-21. Scanning electron micrographs of a male *Caligus mortis* Kensley, 1970. **Fig. 16.** Bifid claw of antenna. **Fig. 17.** Mouth tube. **Fig. 18.** Sternal furca. **Fig. 19.** Tip of leg 1 exopod showing spines 2 and 3 with spiniform secondary process. **Fig. 20.** Leg 5. **Fig. 21.** Plumose setae on caudal ramus. Scale bars: Figs. 16-21 = 10 μm.

Armature on rami of legs 1-4:

Leg 1	Exp 1-0; III, 1, 3	Enp (rudimentary)
Leg 2	Exp I-1; I-1; I, II, 5	Enp 0-1; 0-2; 6
Leg 3	Exp I-0; I-1; 3, 4	Enp 0-1; 6
Leg 4	Exp I-0; I, I	Enp (absent)

Material examined: Thirteen females and eight males collected from the body surface of *Clinus superciliosus* (Linnaeus, 1758). Three females from *Clinus cottoides* Valenciennes, 1836, three females from *Chorisochismus dentex* (Pallas, 1769). A single female collected from the body surface of *Liza richardsonii* (Smith, 1846) and another from *Sarpa salpa* (Linnaeus, 1758). Infestation statistics are summarised in Table 1.

Deposition of voucher specimens: In the collection of the Aquatic Parasitology Research Group, Department of Zoology and Entomology, University of the Free State, Bloemfontein, South Africa (2 males, 5 females, 97/04/07–03); (2 males, 3 females, 98/04/07–07); (2 males, 3 females, 98/04/10–02); (3 females, 99/01/18–02); (3 females, 99/03/22–04). In the collection of the Institute of Parasitology, ASCR, České Budějovice, Czech Republic (1 male, 1 female, PaÚ AVČR 1987) and in the collection of the South African Museum, Cape Town, South Africa (1 male, 1 female, SAM A44115).

Table 1. Infestation statistics of *Caligus mortis* Kensley, 1970, from intertidal fish species collected at two localities on the southern coast of South Africa.

Fish host		N	S (mm)	Inf.	TP	P (%)	I	MI
Jeffreys Bay (1997, 1998 and 1999)								
Clinus superciliosus (Linnaeus, 1758)	R	18	86-182 (124)	5	5	27.7	1	1
Clinus cottoides Valenciennes, 1836	R	3	98-107 (102)	1	1	33.3	1	1
Chorisochismus dentex (Pallas, 1769)	R	4	143-264 (203)	2	2	50	1	1
Liza richardsonii (Smith, 1846)	T	9	110-141 (127)	0				
Sarpa salpa (Linnaeus, 1758)	T	8	49-74 (58)	0				
De Hoop Nature Reserve (1997, 1998 and 1999)								
Clinus superciliosus (Linnaeus, 1758)	R	31	73-219 (129)	7	16	51.6	1-8	2.29
Clinus cottoides Valenciennes, 1836	R	13	57-173 (90)	2	2	15.38	1	1
Chorisochismus dentex (Pallas, 1769)	R	1	135	1	1	100	1	1
Liza richardsonii (Smith, 1846)	T	171	33-210 (99)	1	1	0.58	1	1
Sarpa salpa (Linnaeus, 1758)	T	44	107-214 (122)	1	1	2.27	1	1
Rhabdosargus holubi (Steindachner, 1881)	T	25	54-121 (78)	0				

N – total number of fish collected; S – total length of hosts and mean size; Inf. – number of hosts infested; TP – total number of parasites; P – prevalence expressed as a percentage; I – intensity; MI – mean intensity (parasites per host); R – residential tidal pool species; T – transient tidal pool species

Other material: Two females collected from *Liza richardsonii* and *Sarpa salpa*, in the collection of the Aquatic Parasitology Research Group, Department of Zoology and Entomology, University of the Free State, Bloemfontein, South Africa.

Voucher material locality: Off the south coast, De Hoop Nature Reserve (34°28'S, 20°30'E).

Other localities: Off Jeffreys Bay (34°2.2'S, 24°56.5'E).

DISCUSSION

The most characteristic features of *Caligus mortis* are the shape of the sternal furca and the two-segmented exopod of leg 4 bearing an armature of I-0; I, I. The majority of *Caligus* species possess three terminal spines on the exopod of leg 4. Only nine species of the over 300 known species of this genus have been described as bearing two spines at the tip of leg 4. They are: *C. atromaculatus* Wilson, 1913, *C. centrodonti* Baird, 1850, *C. distortus* Pillai et Natarajan, 1977, *C. engraulidis* Barnard, 1948, *C. labracis* Scott, 1902, *C. mortis*, *C. pageti* Russell, 1925, *C. saucius* Dojiri, 1989, and *C. sensorius* Heegaard, 1962. Only five species have a two-segmented exopod of leg 4 with the formula I-0; I, I. They are: *C. centrodonti*, *C. labracis*, *C. mortis*, *C. pageti*, and *C. sensorius* (Dojiri, 1989). *Caligus mortis* can be distinguished from the other four species by the shape of the sternal furca, and the morphology and relative lengths of the exopodal spines of leg 4, particularly the setiform nature of spine 2, and spine 1 almost equal in length to the terminal spine.

The male differs from the female in being smaller as well as in the following: Antenna: male antenna with two corrugated patches and well-developed adhesion pads which are absent in the female; terminal segment of male antenna with bifid claw and two strong setae on each side of claw, whereas the terminal segment of the female antenna forms a strongly curved hook, bearing one basal and one marginal seta and two minute hyaline papillae. Maxillule: male maxillule similar to female maxillule, but with a small band of striations on the middle of the process.

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Additional morphological information on two species of *Caligus* (Copepoda: Caligidae) parasitic on South African marine and estuarine fish

N.J. Grobler[1], J.G. Van As[1*] & P.A.S. Olivier[2]

[1]*Department of Zoology and Entomology, University of the Free State, P.O. Box 339, Bloemfontein, 9300 South Africa*

[2]*School of Molecular and Life Sciences, University of the North, Private Bag X1106, Sovenga, 0727 South Africa*

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Two species of *Caligus* that are parasitic on fish were collected from Lake St Lucia, South Africa. Specimens of *C. confusus* Pillai, 1961, were removed from the gill chambers of both *Caranx sexfasciatus* Quoy & Gaimard, 1825, and *Rhabdosargus holubi* (Steindachner, 1881), and *Caligus acanthopagri* Lin, Ho & Chen, 1994, from the skin of both *Acanthopagrus berda* (Forsskål, 1775) and *R. holubi*. Except for the occurrence of *Caligus confusus* on *Caranx sexfasciatus*, all of the remaining host records are new in South Africa. *Caligus acanthopagri* is recorded for the first time from South African waters. The morphological features of these two species were studied with scanning electron microscopy. Patterns were observed on the dorsal side of the cephalothorax of the male *C. confusus*. Such patterns have not previously been observed. The fine structures on the exopod of leg 4 of both species were studied, as these features are important for distinguishing species.

Key words: **Crustacea, *Caligus confusus, C. acanthopagri,* external morphology, SEM.**

INTRODUCTION

A total of 25 species of the genus *Caligus* Müller, 1785, has previously been recorded from marine fishes from the coast of South Africa. More than 300 species have been assigned to this genus worldwide, and the number of *Caligus* species for South Africa may increase over time. In this paper we add one more species of *Caligus, C. acanthopagri* Lin, Ho & Chen, 1994, to the list of caligid copepods of South Africa, bringing the total to 26.

During surveys carried out in Lake St Lucia on the east coast of South Africa, two species of caligid copepods were collected from different fish hosts. Specimens of *C. confusus* Pillai, 1961 were collected from the gills of *Caranx sexfasciatus* Quoy & Gaimard, 1825, and *Rhabdosargus holubi* (Steindachner, 1881). Pillai (1961) described *Caligus confusus* from *Caranx sansun* (Forsskål, 1775) from South India. It has since then been recorded from *Caranx hippos* (Linnaeus, 1766), *C. melampygus* Cuvier, 1833, *Coryphaena hippurus* Linnaeus, 1758, and *Seriola* sp. The first record of *C. confusus* from South Africa dates back to 1973, when Kensley & Grindley collected specimens of *C. confusus* from the gill chambers of *Alepes djedaba* (Forsskål, 1775), off Durban on the east coast of South Africa.

Many specimens of *Caligus acanthopagri* were collected from the body surface of two sparid fish hosts, *Acanthopagrus berda* (Forsskål, 1775) and *Rhabdosargus holubi,* in the present study. This species was first described by Lin *et al.* (1994) from the black sea bream *Acanthopagrus schlegeli* Bleeker, 1854, taken from a culture pond at the Tainan Branch of the Taiwan Fisheries Research Institute in Chi-Ku Village of Tainan County, Taiwan. The present study is the first report of *C. acanthopagri* from South Africa and additional morphological information for both species are given, based on studies with scanning electron microscopy. Previous studies based on scanning electron microscopy were done by Oldewage & Van As (1989) and Oldewage (1990). This paper deals with the first scanning electron microscopy study for both *Caligus acanthopagri* and *C. confusus.*

MATERIALS & METHODS

Fishes were collected with gill nets at Fanies Island and Charters Creek in Lake St Lucia during fish parasitological studies in 1992, 1993, 1994 and 1997. Caligid copepods were carefully removed from the hosts and fixed in 70 % ethanol. Specimens for scanning electron microscopy were first hydrated from 70 % ethanol to fresh water. The caligids were washed for one day in fresh water in order to get rid of salt crystals and debris. After

*Author for correspondence. E-mail: vanasjg@sci.uovs.ac.za

washing, the specimens were again cleaned using a soft hair brush to remove excess debris. Specimens were then placed in 0.1 M phosphate buffer (pH 7.3) to remove any excess mucus and debris, without damaging the tegument. Clean specimens were dehydrated to absolute ethanol, critical-point dried, sputter-coated with gold and viewed in a Jeol WinSEM JSM 6400 at 10 kV. Mean body measurements are given in millimetres followed by the range in brackets. For both the females and males the total length was measured from the anterior border of the frontal plate to the posterior border of the caudal rami, excluding the setae on the caudal rami.

Material examined. Caligus confusus Pillai, 1961 – A total of 13 males and eight females was collected from the gill rakers of four *Caranx sexfasciatus* at Fanies Island and Charters Creek in 1992 and 1993. Two females and one male were collected from the gills of a single *Rhabdosargus holubi* at Fanies Island in 1992.

Caligus acanthopagri Lin, Ho & Chen, 1994 – A total of 480 adult specimens were collected from the body surface of *Acanthopagrus berda* and *Rhabdosargus holubi* at Hell's Gate and Fanies Island in 1993, 1994 and 1997. This included a very high infestation of 241 adult specimens from a single *R. holubi* host (total length of 330 mm) from Fanies Island. A few developmental stages were also collected and include nauplius larvae and chalimus stages.

Voucher specimens have been deposited in the collection of the Aquatic Parasitology Research Group, Department of Zoology and Entomology, University of the Free State, Bloemfontein, South Africa – *Caligus confusus* (6/046; 8/044; 8/046; 10/12; 10/13), and *C. acanthopagri* (14/64-66; 15/029; 16/017; 16/022; 16/023; 16/030; 16/047; 16/078; 97/01/21-01; 97/01/21-02; 97/01/21-03; 97/01/21-08; 97/01/21-10; 97/01/21-11).

Voucher material locality. Off the east coast, Lake St Lucia (34°28 S, 20°30 E).

RESULTS AND DISCUSSION

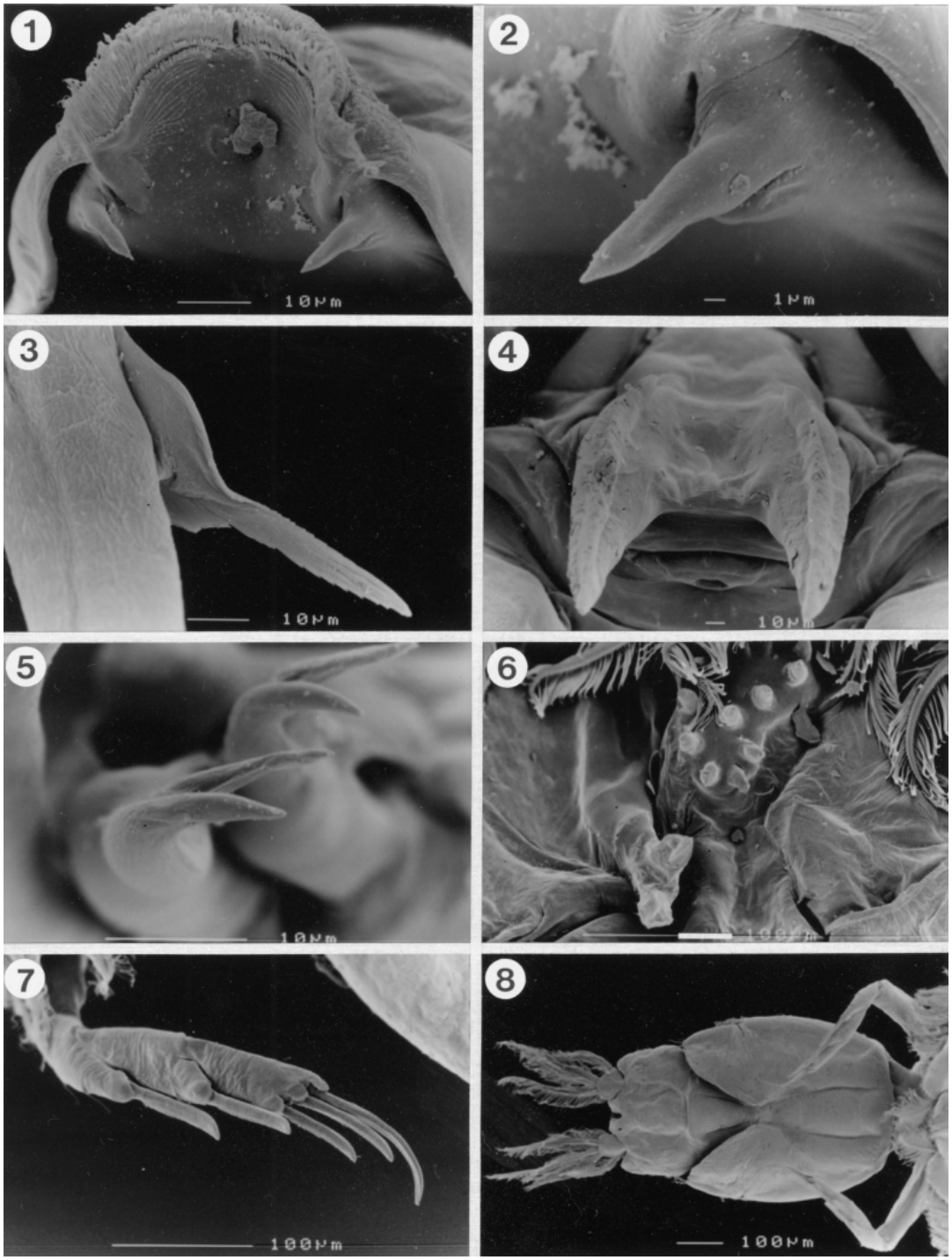
Remarks on *Caligus confusus*

Average length of female 5.03 mm (4.79–5.24; n = 8) and male 2.51 mm (2.39–2.68; n = 8).

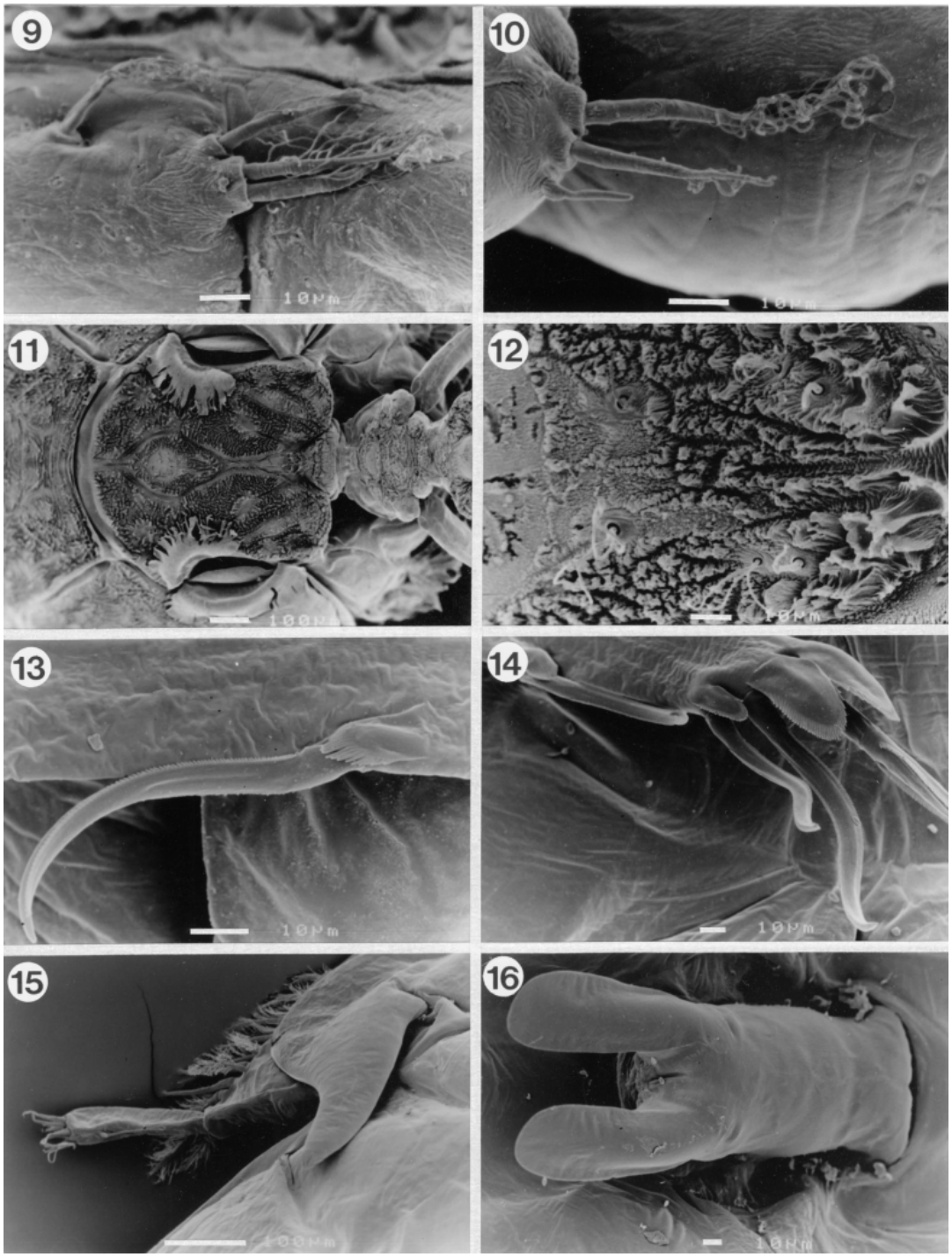
The roof of the labrum carries a pair of buccal stylets (Figs 1 & 2). These stylets are found in only three of the siphonostome families, namely Pennelidae, Lernaeopodidae and the Caligidae. Kabata (1979) only mentioned the buccal stylets and no direct function of these structures were given. It is suggested that it may be used to pierce the skin of the host when the mouth tube is attached to the hosts' skin for feeding or act as a holdfast for the mouth when the strigil is used to rasp off skin debris with its sawing movements. On the mid-length of the brachium of the maxilla a flap of striated membrane is situated. This flap is known as the flabellum and is finely serrated on both margins (Fig. 3). The sternal furca has a squarish base (Fig. 4). Its tines are about the length of the base, with outer borders parallel and inner borders diverging. The second segment of leg 1 exopod has four dissimilar terminal spines. Spines 2 and 3 (Fig. 5) are armed with a spiniform accessory process, equalling half the length of spines. The strong teeth and bifid projecting rib (Fig. 6) on the protopod of leg 3 that are used for accessory adhesion is characteristic of this species. These structures are also found in *Caligus constrictus* Heller, 1968, but the teeth patch is much longer than in *C. confusus.* The exopod of leg 4 is three-segmented (Fig. 7). The first segment bears two outer setules and one spine, with the second segment bearing one spine. The third segment bears three terminal spines of different lengths.

The male is remarkably smaller than the female. The genital complex (Fig. 8) carries the rudimentary leg 5 (Fig. 9) and leg 6 (Fig. 10) on the posterolateral margin. Leg 5 (Fig. 9) consists of four setae and leg 6 (Fig. 10) of three setae. The abdomen is only one-segmented and is wider than long (Fig. 8). The caudal rami are larger than in the female. The posterior margin of each ramus is armed with one outer, one small medial, one dorsal subterminal, and three longer terminal setae. Patterns on the dorsal shield of the male of *C. confusus* were also observed (Figs 11 & 12). No such patterns were observed in any other *Caligus* species studied to date. Small setae (Fig. 12) were also observed. These patterns and setae were observed only in the male, and the function of these secondary features are not fully understood.

Caligus confusus was described by Pillai (1961) from *Caranx sansun.* Kensley & Grindley (1973) collected three female *C. confusus* specimens from the gill chambers of *Alepes djedaba* from Durban, with a total length of 4.0 mm. These South African specimens were much larger than the Indian specimens described by Pillai (1961), where the female was only 2.9 mm in length and the male 1.8 mm. Differences in size have, however, no significance since such variations are common among parasitic



Figs 1–8. Scanning electron micrographs of female *Caligus confusus*. **1**, Pair of buccal stylets on roof of labrum; **2**, buccal stylet; **3**, serrated flabellum on brachium of maxilla; **4**, sternal furca; **5**, spine 2 and 3 with spiniform secondary process of leg 1 exopod; **6**, teeth and bifid projecting rib on protopod of leg 3; **7**, leg 4 exopod. Scanning electron micrographs of male *Caligus confusus*. **8**, genital complex, abdomen and caudal rami, ventral view. Scale bars: Figs 6, 7, 8 = 100 µm; Figs 1, 3, 4, 5 = 10 µm; Fig. 2 = 1 µm.



Figs 9–16. 9–12: Scanning electron micrographs of a male *Caligus confusus*. **9,** leg 5; **10,** leg 6; **11**, patterns on dorsal side; **12**, patterns with small sensory setae. **13–16**: Scanning electron micrographs of a male *Caligus acanthopagri*; **13,** outer spine on the first segment of leg 4; **14**, three terminal spines on leg 4 exopod; **15**, posterior extension of the proximal segment of the antennule; **16**, sternal furca. Scale bars: Figs 11, 15 = 100 µm; Figs 9, 10, 12, 13, 14, 16 = 10 µm.

copepods. The females in the present study are even larger than those collected by Kensley & Grindley (1973). *Caligus confusus* has been found on many different *Caranx* species, but has not been recorded from the host *Caranx sexfasciatus.* These caligids were found in the gill chambers of both *C. sexfasciatus* and *Rhabdosargus holubi* in the Lake St Lucia system during surveys in 1992 and 1993, and represents a new host record for South Africa.

Remarks on *Caligus acanthopagri*

Average length of female 3.61 mm (3.22–3.73; n = 20) and male 5.05 mm (4.29–5.28; n = 20).

Caligus acanthopagri displays an unusual feature for copepods in that the males are on average distinctly larger than the female. The most characteristic features of *C. acanthopagri* are the possession of a short abdomen, an accessory process on the middle two of the terminal four elements on the exopod of leg 1, and a slender, two-segmented exopod bearing an armature of I; IV on leg 4. Leg 4 has a long, slender exopod. The outer spine on the first segment of leg 4 bears a hyaline membrane (Fig. 13). The bases of the three terminal spines of leg 4 exopod are also covered by a hyaline membrane (Fig. 14). A posterior extension of the proximal segment of the antennule on the dorsal side in the male of *C. acanthopagri* is shown in Fig. 15. Lin *et al.* (1994) did not refer this extension, but from the drawing it is evident that their specimen did have the extension of the antennule. This feature has not been observed in any other *Caligus* species studied. The sternal furca (Fig. 16) has parallel and bluntly pointed tines. The tines are just more than half the length of the base.

Caligus acanthopagri bears closest resemblance to *C. latigenitalis* that was first recorded by Shiino (1954) from the body surface of *Acanthopagrus schlegeli* in Japan. The only discernible morphological difference between these two closely allied species is the fine structure on the distal end of the exopod of leg 4. In *C. acanthopagri* the distal end of the exopod of leg 4 is equipped with two corner processes with two hyaline membranes, but in *C. latigenitalis* there are two short, but heavy, digital processes.

Although this material was first collected in 1983 from black sea bream from Taiwan, it was only described as a new species by Lin *et al.* (1994). The present species was found on *Acathopagrus berda* and *Rhabdosargus holubi* in the Lake St Lucia system during the surveys made in 1993, 1994 and 1997, and represents a new parasite and host record for South Africa.

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Short communications

Observations on the development of *Udonella caligorum* Johnston, 1835 (Monogenea: Polyonchoinea) on a parasitic copepod species of *Caligus* (Copepoda: Caligidae), collected from Lake St Lucia, South Africa

N.J. Grobler[1], K.W. Christison[1], P.A.S. Olivier[2] & J.G. Van As[1*]

[1] *Department of Zoology and Entomology, University of the Free State, P.O. Box 339, Bloemfontein, 9300 South Africa*

[2] *School of Molecular and Life Sciences, University of the North, Private Bag X1106, Sovenga, 0727 South Africa*

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The hyperparasitic monogenean *Udonella caligorum* Johnston, 1835, was recorded from the ichthyoparasitic copepod of the genus *Caligus* Müller, 1785, a first record from South Africa. Different developmental stages, including filamentous eggs, egg capsules, emergent non-ciliated worms and adults of *U. caligorum,* were found associated with a *Caligus* species. Scanning electron micrographs and observations on the development of *U. caligorum* are given together with different morphological features of the developmental stages.

Key words: Udonellidae, Platyhelminthes, development, ectoparasites.

Members of the copepod genus *Caligus* Müller, 1785, parasitize the surface of fishes and are able to move freely, feeding on mucus and sloughed tissues. These ichthyoparasitic copepods resemble free-living copepods and unlike most other ichthyoparasitic copepods are capable of swimming and can switch hosts. To date, 39 species of the genus *Caligus* have been recorded off the coast of Africa. Both female and male specimens of an unknown species of *Caligus* were removed from the flathead mullet *Mugil cephalus* Linnaeus, 1758, from Lake St Lucia on the east coast of South Africa. A hyperparasite of the genus *Udonella* Johnston, 1835, was found attached to these copepods. The systematics of *Udonella* is controversial. The genus is included currently in the Gyrodactylidae of the subclass Monopisthocotylea (now referred to as Polyonchoinea) (Littlewood *et al.* 1998). These monogeneans have previously been thought of as being hyperparasites of their crustacean hosts, which are in turn parasitic on marine and estuarine fishes. However, recent evidence suggests that *Udonella* species only use their crustacean hosts for transport and hence derive their nutrition from the fish host (Kabata 1973; Aken`Ova & Lester 1996; Olivier *et al.* 2000).

Five species of the genus *Udonella* have been described from caligid copepods parasitizing marine and estuarine fishes. These species are *Udonella caligorum* Johnston, 1835, *U. myliobati* (Guberlet, 1936), *U. ophiodontis* Kay, 1945, *U. papillifera* van der Land, 1967, and *U. murmanica* Kornakova & Timofeeva, 1981. According to Hendrix (1994), *U. caligorum* has a cosmopolitan distribution, having been recorded along both the Pacific and Atlantic coasts of North America, the coasts of Europe, Australia and New Zealand. Although Olivier *et al.* (2000) reported *U. myliobati* from another caligid, *Lepeophtheirus natalensis* Kensley & Grindley, 1973, on the east coast of South Africa, this paper presents the first record of *U. caligorum* from South Africa, together with observations on its developmental stages.

The fish host, *Mugil cephalus* (flathead mullet), was collected in August 1994 from Lake St Lucia on

*Author for correspondence. E-mail: vanasjg@sci.uovs.ac.za

the East Coast of South Africa. Ectoparasitic copepods of the genus *Caligus* were removed from the fish and fixed in 70% ethanol. Upon examination of these copepods, different developmental stages of *U. caligorum* were found attached to the caligid hosts. Observations on udonellid development were studied using scanning electron microscopy (SEM). Specimens for SEM were dehydrated in a series of ethanol concentrations, critical-point dried, sputter-coated with gold and studied in a Jeol WinSEM JSM 6400 at 10 kV. Measurements are given in micrometres as indicated.

In total only three females and four males of a *Caligus* species were removed from the body surface of a single specimen of *Mugil cephalus* (537 mm). Different developmental stages comprising filamentous eggs, egg capsules, emergent non-ciliated worms and adult worms of *U. caligorum* were found attached to four of the *Caligus* specimens. Only two mature *U. caligorum* specimens were found, both occurring on the same copepod host. Many filamentous eggs and newly hatched non-ciliated worms were found attached to another *Caligus*. The remaining two *Caligus* had filamentous eggs attached to either the genital complex or caudal rami, but no emergent or adult worms were found on them.

Both adult udonellids (785 μm long $\times$ 167 μm wide) were found on the lateral margin of the dorsal shield and genital complex (Fig. 1a), attached to the host by means of a rounded posterior haptor (193 μm) (Fig. 1b). The filamentous eggs (161 μm long $\times$ 76 μm wide) attached by a filament (120 μm long) (Fig. 1c) were found attached to the genital complex of the caligid host. This is consistent with Kabata's (1973) findings that suggested that the attachment of *U. caligorum* is not permanent and some movement on the surface of the host is evident. The filamentous eggs are attached to the surface of the copepod host by means of a basal disc 55 μm in diameter (Fig. 1d).

The genital complex and abdomen of *Caligus* species are raised above the surface of the fish, when the latter is in motion. Suspended in midwater, they are bathed on all sides by the current, unlike any other parts of the copepod. Conditions created by this uninterrupted flow are optimal for the processes of development and hatching of the udonellid eggs (Kabata 1973). On hatching (Fig. 1e), the young worm attaches itself to the copepod in the vicinity of the permanently anchored egg capsule from which it has emerged. The emergent non-ciliated worms resemble miniature adults (Fig. 1f).

Aken'Ova & Lester (1996) stated that the filamentous eggs of *U. myliobati* were non-operculate. Schell (1972) illustrated a filamentous egg of *U. caligorum* with an operculum on which the emerging non-ciliated worm exerts pressure prior to hatching. The filamentous eggs found in the present study were operculate (measuring 55 μm in diameter) which is consistent with the observations of Schell (1972) (Fig. 1g). The empty egg capsules left by newly hatched worms were neatly severed at the site of the operculum (measuring 37 μm in diameter) (Fig. 1h).

Aken'Ova & Lester (1996) divided the species of the genus *Udonella* into two groups on the basis of the length of the filament. The first group, comprising *U. caligorum, U. ophiodontis, U. papillifera* and *U. murmanica,* have egg filaments which are longer than the egg capsule. The second group, which is represented by *U. myliobati* has a filament shorter or equal to the length of the egg capsule. However, Byrnes (1986) and Schram & Haug (1988) reported specimens of *U. caligorum* with filaments of eggs shorter than the capsule itself. Similarly, the St Lucia population of *U. caligorum* possessed an egg filament that was shorter than the capsule of the egg. Thus, the validity of this character for the purpose of sub-dividing the genus is in question.

Kabata (1973) proposed that *U. caligorum* obtains its food directly from the fish and not the copepod. The preferred attachment sites on the lateral margin of the dorsal shield as observed in the St Lucia population, and by Kabata (1973), give them easy access to the epidermis of the fish. This is consistent with Olivier *et al.* (2000), who proposed that *U. myliobati* feeds directly on the epithelial cells of the spotted ragged tooth shark, *Carcharias taurus* Rafinesque, 1810.

The preferred attachment site of *U. caligorum* is also ideal with respect to its transmission from one copepod host to another. Kabata (1973) suggested that the transmission of *U. caligorum* between copepod hosts requires direct contact between various copepods, which may be frequent when they are present in high densities. As the entire life-cycle of *U. caligorum* is completed on the body surface of a single caligid copepod, as observed in the present study, transmission of *U. caligorum* from one fish host to another is dependent on the mobility of *Caligus* copepods between their various fish hosts.

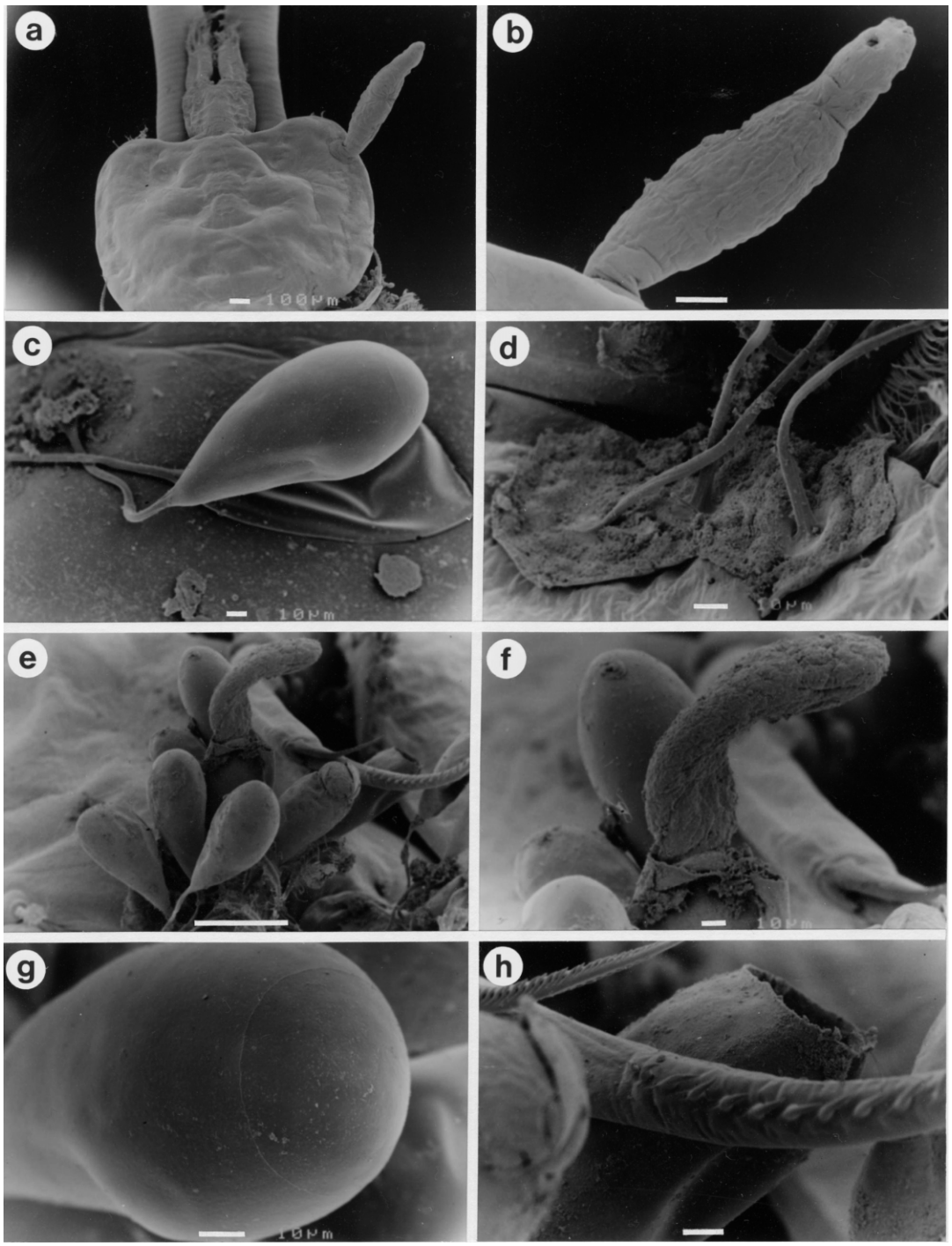

Fig. 1. Scanning electron micrographs of different developmental stages of *Udonella caligorum* attached to a *Caligus* species. **a**, Adult udonellid on dorsal side of genital complex; **b**, attachment to host with rounded posterior haptor; **c**, filamentous egg; **d**, basal disc of filamentous egg; **e**, cluster of filamentous eggs, egg capsules and emergent, non-ciliated worm; **f**, non-ciliated worm; **g**, operculated filamentous egg; **h**, empty egg capsule of hatched worm. Scale bars: a, b, e, 100 µm; c, d, f, g, h, 10 µm.

Deposition of voucher specimens: In the collection of the Aquatic Parasitology Research Group, Department of Zoology, University of the Free State, Bloemfontein, South Africa – *Caligus* sp. with attached udonellids (94/08/09-01).

Voucher material locality: Off the east coast, Lake St Lucia (28°10′S, 32°30′S).

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Biometrics of dusky indigobirds in Pietermaritzburg, KwaZulu-Natal, in 2000 and 2001

Mark Brown

School of Botany and Zoology, University of Natal, Private Bag X01, Scottsville, 3209 South Africa
E-mail: brownma@nu.ac.za

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Dusky indigobirds (*Vidua funerea*) were studied at a feeding site in Pietermaritzburg in the summers of 2000 and 2001. Eighty-five individuals were trapped, ringed and detailed biometric data recorded during this period. Birds were counted monthly, and presence or absence of both males and females at the site is discussed. The only significant morphometric difference between the sexes is wing length, with some overlap. Descriptions of male breeding dress, based on observations of all birds captured, is also presented. This study also recorded the longest movement for the species, a distance of 87 km.

Key words: biometrics, plumage, moult, movement.

Large numbers of dusky indigobird (*Vidua funerea*) males congregated at a feeding site in Pietermaritzburg in the summers of 2000/01 and 2001/02. A literature search revealed that very little published data exist on the sexual differences in biometrics and moulting patterns of dusky indigobirds. This study reports biometrics and moult data for both male and female dusky indigobirds that were ringed when visiting the feeding site. Movement patterns are also briefly discussed.

The study was conducted at the School of Botany and Zoology, University of Natal, where large flocks gathered at a seed-feeding site in an *Acacia xanthophloea* tree. Up to 52 and 79 males were counted during the first and second years, respectively. Birds were captured mainly using walk-in traps baited with wild bird seed (48 individuals), by mistnetting (25 individuals) and using handnets (12 individuals). Handnets were used when birds were trapped inside bird enclosures housing suspended cages. A total of eighty-five individuals were caught between 2 November 2000 and 31 December 2001. Additional morphometric data from eight individuals trapped between November 1994 and January 2000 have also been included. Wing length was measured using the flattened, straightened wing method (de Beer *et al.* 2000) while culmen length was taken from the

NEW MORPHOLOGICAL INFORMATION ON THE PARASITIC COPEPODS CALIGUS EPINEPHELI YAMAGUTI, 1936 AND CALIGUS ROTUNDIGENITALIS YU, 1933 (COPEPODA, CALIGIDAE) FROM SOUTH AFRICA

BY

N. J. GROBLER[1]), J. G. VAN AS[1,3]) and P.A.S. OLIVIER[2])

[1]) Department of Zoology and Entomology, University of the Free State, P.O. Box 339, Bloemfontein 9300, South Africa

[2]) School of Molecular and Life Sciences, University of the North, Private Bag X1106, Sovenga 0727, South Africa

ABSTRACT

Caligus epinepheli were collected from De Hoop Nature Reserve along the south coast and from Lake St Lucia along the east coast of South Africa. Caligus rotundigenitalis were collected from Lake St Lucia. Two females, one male, and one chalimus of C. epinepheli were removed from the gill chambers of Diplodus sargus capensis and Rhabdosargus holubi. Only two females of C. rotundigenitalis were removed from inside the operculum of Rhabdosargus holubi. Both species represent new host and distribution records for South Africa. The morphological features of these two species were studied with the aid of scanning electron microscopy. Numerous small setae were observed on the marginal membrane as well as on the dorsal shield of C. epinepheli, probably with a sensory function. Another interesting feature is the long basal seta of the maxillule bearing spinules on both margins. All other known Caligus species studied so far have a smooth, long basal seta of the

maxillule. In C. rotundigenitalis the first four spines on the second segment of the exopod of leg 4 are covered with spinules.

[3]) Author for correspondence; e-mail: vanasjg.sci@mail.uovs.ac.za

INTRODUCTION

More than 200 valid species of the parasitic copepod genus Caligus Müller, 1785, parasites of marine and estuarine fish, have been recorded from the oceans of the world. Of these, 26 species have been recorded from South African waters (Grobler et al., 2003). In this paper, we add two more species of Caligus, i.e., C. epinepheli Yamaguti, 1936 and C. rotundigenitalis Yu, 1933 to the list of caligid copepods of South Africa, bringing the total to 28.

Parasitological surveys were carried out at De Hoop Nature Reserve on the south coast of South Africa, as well as in Lake St Lucia on the east coast of South Africa. At De Hoop Nature Reserve, intertidal species of pool fish were targeted, where the male of Caligus mortis Kensley, 1970 was collected for the first time from Clinus superciliosus (Linnaeus, 1758) and was subsequently described (Grobler et al., 2002). A wide variety of marine and estuarine fish species were collected at Lake St Lucia and found to be infested with caligid copepods.

Grobler et al. (2002) eluded the problem parasitic copepodologists have with the lack of an up-to-date revision of the genus Caligus. This problem was tackled by Ho & Lin (2003), where the taxonomic confusion of C. epinepheli was dealt with. Ho & Lin (2003) mentioned that seven Caligus species (including C. epinepheli) might have to be unified under C. affinis Heller, 1866, as these seven species share the same morphological characteristics, which are based on incomplete descriptions. Such action is not considered appropriate before re-examination of the type material of each of these species (Ho & Lin, 2003). As C. epinepheli

were collected in the present study, additional morphological information is given for this species as well as for C. rotundigenitalis, and the taxonomic confusion regarding C. epinepheli is sorted out, confirming C. epinepheli as a valid species. The present study is the first report of both C. epinepheli and C. rotundigenitalis from South Africa and additional morphological information for both species is given, based on studies with scanning electron microscopy.

MATERIALS AND METHODS

Intertidal fish species were collected with handnets during low tide at De Hoop Nature Reserve. Larger blacktail hosts were caught with handlines in larger pools. At Lake St Lucia, fish hosts were collected with gill nets at Fanies Island in November 1992 and at Charters Creek in March 1993. Copepods were carefully removed from the hosts and fixed in 70% ethanol. Specimens were prepared for scanning electron microscopy using standard techniques (Grobler et al., 2003).

Mean body measurements are given in millimeters, except for the caudal ramus where the measurements are given in micrometers. Measurements of additional specimens are given in parentheses. In both the females and males, the total length was measured from the anterior margin of the frontal plate to the posterior margin of the caudal rami, excluding the setae on the caudal rami.

Voucher specimens have been deposited in the collection of the Aquatic Parasitology Research Group, Department of Zoology and Entomology, University of the Free State, Bloemfontein, South Africa: Caligus epinepheli (9/033; 98/04/01-09), and C. rotundigenitalis (8/019). Localities: off the east coast of South Africa, Lake St Lucia (28°10′S 32°30′E), C. epinepheli and C. rotundigenitalis; off the south coast of South Africa, De Hoop Nature Reserve (34°28′S 20°30′E), C. epinepheli.

RESULTS AND DISCUSSION

Caligus epinepheli Yamaguti, 1936 (figs. 1-16)

Material examined. – One female, one male, and one chalimus from the gills of Lichia amia (Linnaeus, 1758) (total length 520 mm) at Charters Creek, Lake St Lucia, March 1993. One female from the gill rakers of Diplodus sargus capensis (Smith, 1844) (total length 300 mm) at Koppie Alleen, De Hoop Nature Reserve, April 1998.

Female. - Body 3.11 (2.82) mm long. Cephalothoracic shield 1.48 (1.34) mm long and 1.2 (1.12) mm wide, excluding lateral hyaline membranes. Genital complex 0.82 (0.73) mm long and 0.75 (0.66) mm wide. Abdomen more than twice as long as wide, 0.67 (0.61) x 0.29 (0.26) mm. Caudal ramus longer than wide, 116 (108) x 65 (59) µm, armed with 3 short and 3 long plumose setae. The material collected by Ho & Lin (2003) is similar to the material collected in the present study. The specimens from the present study are larger and the caudal rami slightly longer than those reported by Ho & Lin (2003), where the specimens measured between 2.20 and 2.32 mm and the caudal ramus 65 x 45 µm.

Ho & Lin (2003) referred to the taxonomic confusion surrounding Caligus epinepheli. The present authors will not elaborate on these findings. The aim of the study is to present new and additional information with the aid of scanning electron microscopy, which will verify some of the findings by Ho & Lin (2003), as well as to establish Caligus epinepheli as a valid species. Ho & Lin (2003) confirmed that an up-to-date revision of the genus is needed, as re-examinations of type specimens will solve many of the taxonomic problems concerning certain Caligus species. Seven species (including Caligus epinepheli) are closely related and only appropriate re-examination of type specimens will clarify whether these species are the same or not. Caligus affinis Heller, 1866, one of the seven species in question, has also been

collected by the authors and will subsequently be redescribed and confirmed to be a valid species, differing from C. epinepheli.

A small sclerotized, conical protrusion is present between the basis of the antenna and the post-antennal process (fig. 1). This process was also noted by Ho & Lin (2003). A pair of buccal stylets (fig. 2) was observed near the roof of the labrum. Grobler et al. (2003) discussed the function of these stylets, also observed in C. confusus Pillai, 1961. The buccal stylets found in C. epinepheli are much smaller than those present in C. confusus, but could be related to body size, as C. confusus is almost 2 mm longer than C. epinepheli. The maxillule has a basal papilla bearing three setae, two of which are small and equal in length, and one longer and robust. The latter bears spinules on both margins near the tip (fig. 3), which is unique in this species. The sternal furca has a short base and long diverging tines (fig. 4). The tines curve slightly inwards like a horseshoe, with a serrated membrane on the distal margin, which extends around the tip to the distal portion of the medial margin. Leg 1 has some unique features that have not been observed from other species studied. The protopod of leg 1 bears a basal patch of spinules (fig. 5). This part of the leg is not usually in contact with the host, so the exact function of these spinules is not clear. The endopod (fig. 6) is rudimentary and one-segmented. A small protrusion is found on the tip of the endopod. The exopod of leg 1 is two-segmented with unique armature. The first segment bears a prominent row of setules on the posterior edge and small seta at the outer distal corner (fig. 7). The second segment lacks the usual three long plumose setae on the posterior margin. The four terminal spines on the second exopod segment of leg 1 are not identical to each other (fig. 8). Spine 1 is apically bifid. Spines 2 and 3 are armed with accessory processes. The fourth element, a spine-like seta, is the longest and bears no pectinate membrane or accessory process. Pectines cover the bases of the three terminal spines. The exopod of leg 2 is three-segmented. First segment with a large, stout spine, slightly curved posteriorly and

serrated on both margins (fig. 9). Pecten at base of spine. Second segment with a smaller spine (fig. 9), almost straight, serrated on both margins and without pecten at base. Leg 4 exopod is two-segmented (fig. 10). First segment with a spine at outer distal corner, covered with pecten at base of insertion. Second segment with one spine at outer distal corner near terminal end of segment, and three terminal spines. All four spines on second segment have a pecten at the base of insertion (fig. 11). The genital complex carries the rudimentary leg 5 on the posterolateral margin. Leg 5 (fig. 12) consists of two small papillae, one tipped with a small plumose seta, the other with two similar plumose setae. The posteroventral and distal-outer margin of the abdomen is covered with numerous spinules (fig. 13). The function of these spinules is not known, but these could aid when the copepod is in danger of slipping backwards on its host.

Small setae were observed on the marginal membrane (fig. 14). These setae are most probably sensory setae and have not been observed in previous studies on the genus Caligus. They are most probably present on all Caligus species. Numerous setules are present on the dorsal shield (fig. 15), in small clusters near the marginal membrane. These setules on the dorsal shield probably have a sensory function.

Male. - Body 2.04 mm long. Cephalothoracic shield 1.19 mm long and 1.06 mm wide, excluding lateral hyaline membranes. Genital complex 0.46 mm long and 0.43 mm wide. Abdomen two-segmented, sub-equal in length, one-third longer than wide, 0.36 x 0.23 mm. Caudal ramus longer than wide, 100 x 76 µm, armed with 3 short and 3 long plumose setae.

The male is one-third smaller than the female. The posteroventral and distal-outer margin of the abdomen is covered with numerous spinules similar to those in the female. The antenna bears three adhesion pads on the second segment (fig. 16), with the terminal segment

bearing apically a trifid claw. Except for the sexual dimorphic characteristics, no other additional morphological features were observed from the male.

Remarks. - Caligus epinepheli was described by Yamaguti in 1936 from the convict grouper Epinephelus septemfasciatus (Thunberg, 1793) from Kuki (Mie Prefecture, Japan) and the Hong Kong grouper Epinephelus akaara (Temminck & Schlegel, 1842) from Tarumi (Inland Sea, Japan). Pillai (1985) included C. epinepheli found in Indian waters, where the length of the female was given as 4.5 mm and of the male as 4.1 mm, which indicates that the specimens found by Pillai (1985) are much larger than those described by Ho & Lin (2003) as well as those in the present study. Cressey (1991) redescribed C. epinepheli, but Ho & Lin (2003) renamed the species C. cresseyi. Ho & Lin (2003) found four morphological differences between C. epinepheli and C. cresseyi, which indicated that the species found by Cressey (1991) was not identifiable with C. epinepheli. Based on these morphological characters and on comparison with the original description of C. epinepheli, it is confirmed that C. epinepheli is a valid species, differing from C. cresseyi and C. affinis. This is the first report of C. epinepheli from South Africa and represents new host and distribution records for the South African coastline.

Caligus rotundigenitalis Yu, 1933 (figs. 17-20)

Material examined. – Two females from inside the operculum of Rhabdosargus holubi (Steindachner, 1881) (total length 348 mm) at Fanies Island, Lake St Lucia, November 1992.

Female. - Body 2.47 (2.41) mm long. Cephalothoracic shield 1.25 (1.31) mm long and 1.02 (1.04) mm wide, excluding lateral hyaline membranes. Genital complex wider than long, 0.55 (0.49) mm long and 0.72 (0.61) mm wide. Abdomen indistinctly two-segmented, more than twice as long as wide, 0.49 (0.54) x 0.19 (0.21) mm. Caudal ramus longer than

wide, 129 (136) x 80 (74) µm, armed with 3 short and 3 long plumose setae. Ho et al. (2000) did not report measurements for the specimens collected from hosts at Sheng-Dah Fishing Port and Mi-Tuo Fishing Port. The specimens collected in the present study fit the description for Caligus rotundigenitalis.

Confusion on three closely related species, C. rotundigenitalis, C. tanago Yamaguti, 1939, and C. multispinosus Shen, 1957 were dealt with by Ho et al. (2000). The authors present only additional morphological information based on scanning electron microscopy. The sternal furca (fig. 17) has a short base, with tines about as long as the base. The tines are strongly flattened and medially slightly curved. The exopod of leg 2 is three-segmented. First segment with a large, stout spine, anteriorly slightly curved and serrated on both margins (fig. 18). Pecten at base of spine. Second segment with a smaller spine (fig. 18), anteriorly slightly curved, serrated on both margins and lacking a pecten at the base. The most striking feature of this species is the ornamentation of the spines on the exopod of leg 4. The exopod of leg 4 is three-segmented (fig. 19) and has a formula of I-0; I-0; III. Four of these five spines are covered by spinules (fig. 20), a rare feature only shared by three other species, i.e., C. multispinosus, C. platytarsis Bassett-Smith, 1898, and C. tanago. Of these three species, only C. multispinosus and C. tanago are closely similar to C. rotundigenitalis. Ho et al. (2000) compared the three species and eluded the difficulty to determine whether the morphological differences found are genuine or simply due to differences in the author`s observation and/or technique of illustration. The abdomen was found to provide reliable distinguishing characters. Caligus rotundigenitalis has a two-segmented abdomen, which is less than half the length of the carapace and C. multispinosus a two-segmented abdomen, more than three-quarters the length of the carapace, whereas C. tanago has a one-segmented abdomen, less than half the length of the carapace. Thus, the species in the present study fits the characters of the abdomen of Caligus rotundigenitalis. The confusion between these three

species can only be sorted out when original type material will be studied, both with compound and scanning electron microscopy.

Caligus rotundigenitalis was first described by Yu in 1933 from Lutjanus malabaricus (Bloch & Schneider, 1801) from Chefoo, China. Rangnekar (1959) recorded this species from Gnathanodon speciosus (Forsskål, 1775) from Bombay, India, and Pillai (1985) recorded it from Scatophagus argus (Linnaeus, 1766) from Kerala, India. Lin et al. (1994) redescribed Caligus rotundigenitalis from the black sea bream, Acanthopagrus schlegeli Bleeker, 1854 from Taiwan. Lin et al. (1994) originally redescribed the present species as Caligus multispinosus, but Ho et al. (2000) corrected the misidentification. The major problem will be to locate the type-specimens, and our comparisons are thus based on the original descriptions. Caligus rotundigenitalis is the most common sea louse found in Taiwanese waters. It parasitises 24 different host species of 17 families. More host species will be added to the list as this number only includes examination of fish hosts collected from fishing ports on the west coast of Taiwan, which excludes current examinations of fish hosts from the east coast of that island (J.-S. Ho, pers. comm.). The present study is the first report of C. rotundigenitalis from South Africa, and also represents a new host record.

ACKNOWLEDGEMENTS

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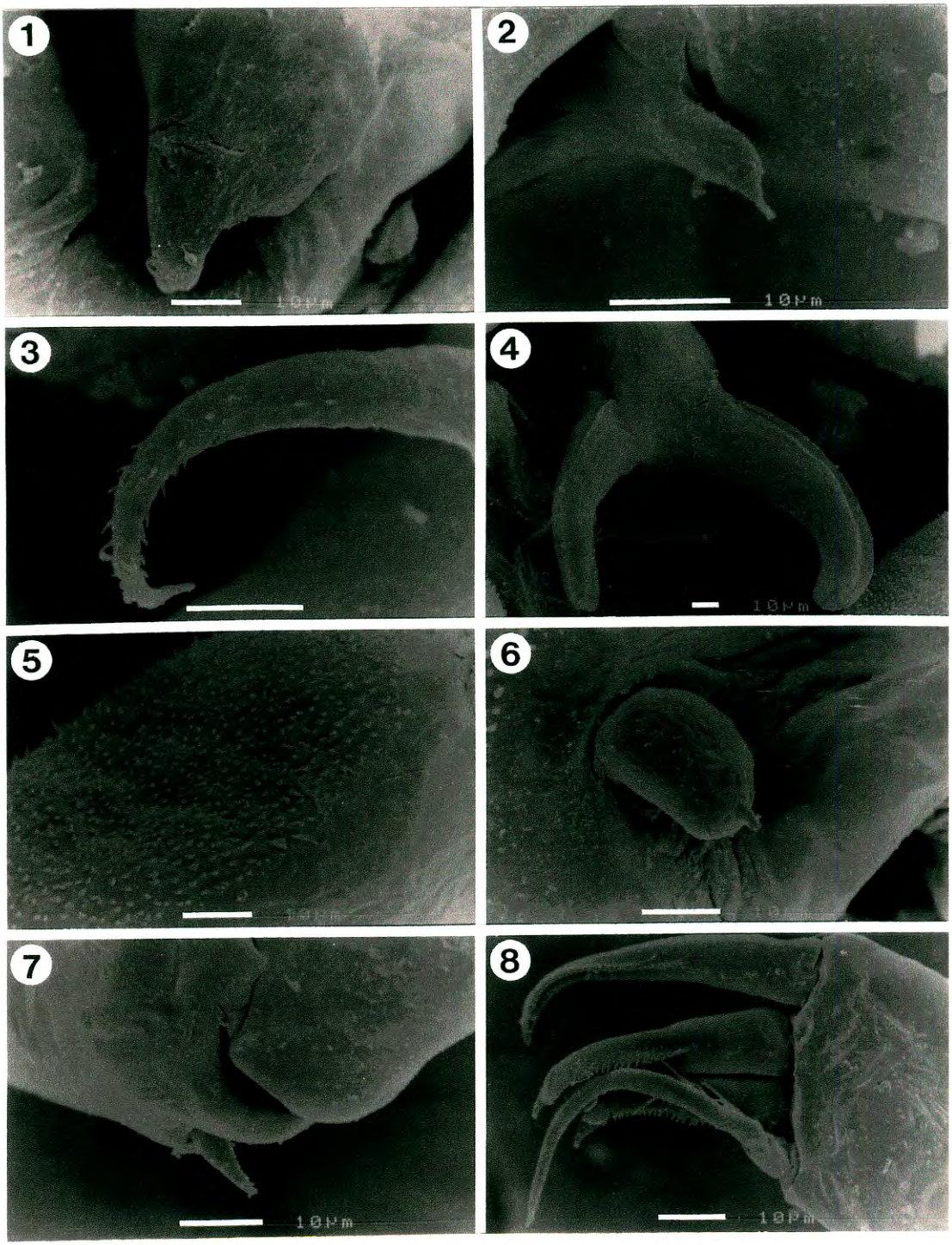
Legends

Figs. 1-8. Scanning electron micrographs of a female Caligus epinepheli Yamaguti, 1936. 1, sclerotized protrusion between bases of antenna and postantennal process; 2, buccal stylet near roof of labrum; 3, longer basal seta of maxillule bearing spinules on both margins; 4, sternal furca with short base and long diverging tines; 5, protopod of leg 1 bearing basal patch of spinules; 6, endopod of leg 1; 7, first exopod segment of leg 1 bearing small seta on outer distal corner; 8 terminal four elements on leg 1 second exopod segment. Scale bars equal 10 µm.

Figs. 9-15. Scanning electron micrographs of a female Caligus epinepheli Yamaguti, 1936. Fig. 16. Scanning electron micrograph of a male Caligus epinepheli Yamaguti, 1936. 9, first and second segment of leg 2 exopod with serrated spines; 10, leg 4 exopod; 11, pecten at base of three terminal spines on second exopod segment of leg 4; 12, leg 5 consisting of two small papillae; 13, spinules on posteroventral and distal-outer margin of abdomen; 14, seta on marginal membrane; 15, cluster of setules on dorsal shield near marginal membrane; 16, antenna with three adhesion pads. Scale bars: 10 = 100 µm; 9, 11-16 = 10 µm.

Figs. 17-20. Scanning electron micrographs of a female Caligus rotundigenitalis Yu, 1933. 17, sternal furca with short base and strongly flattened tines; 18, first and second segment of leg 2 exopod with serrated spines; 19, leg 4; 20, leg 4 exopod - four of five spines covered with spinules. Scale bars: 19 = 100 µm; 17, 18, 20 = 10 µm.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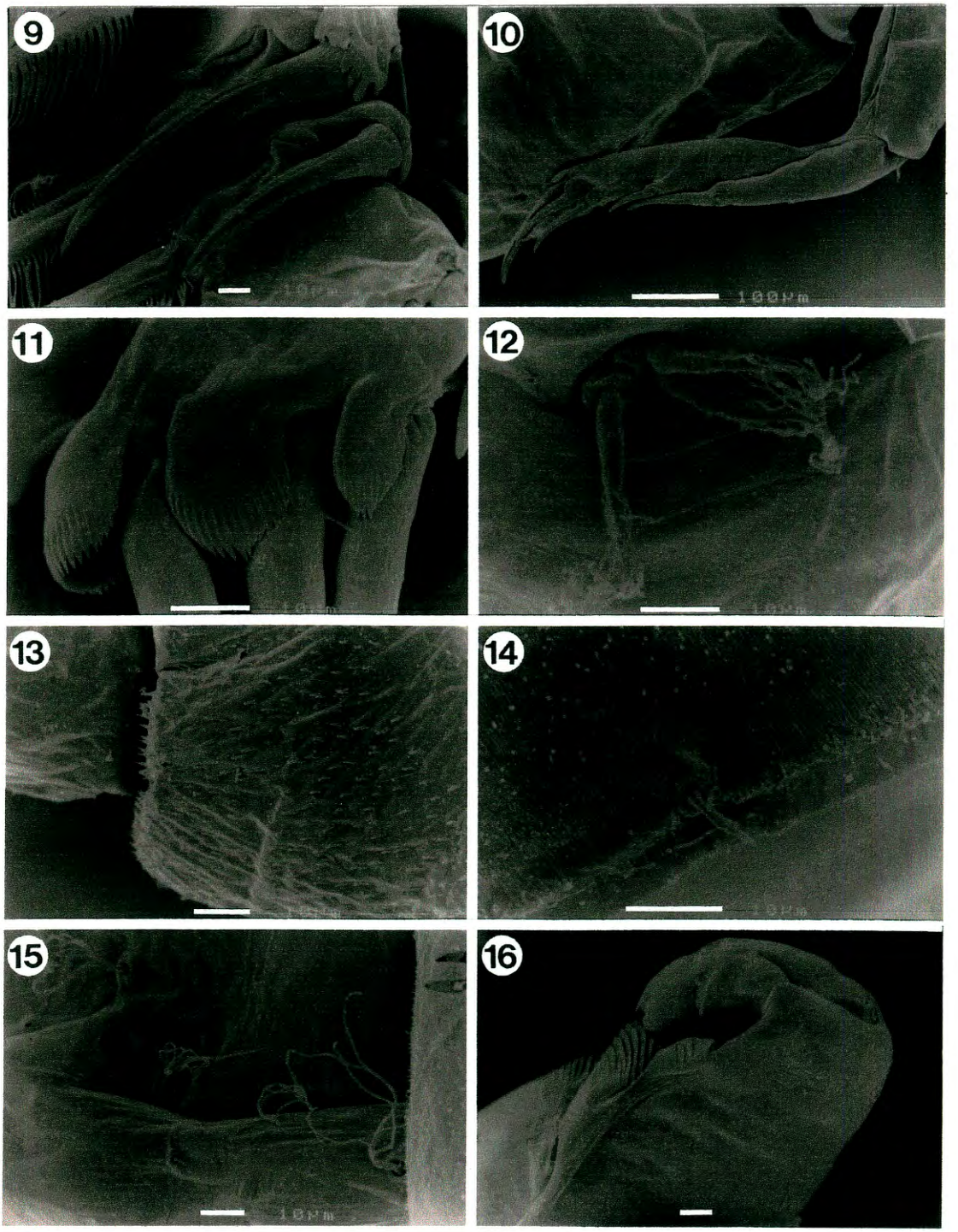
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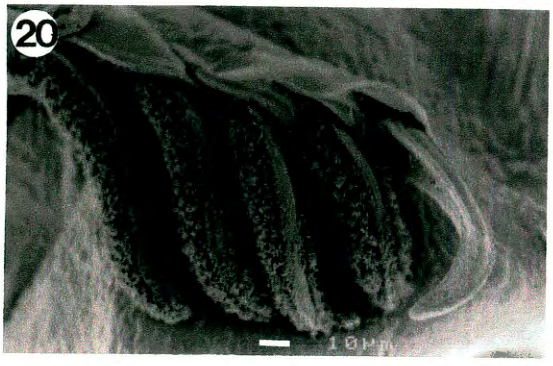
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APPENDIX II

Integrated vector management in Africa

J Githure
International Centre of Insect Physiology and Ecology, Nairobi, Kenya; jgithure@icipe.org

The WHO African Regional Office recognises the need to improve capacity for choosing and implementing vector control methods appropriate to various types of environments in Africa. There is an increasing body of evidence on the efficacy and effectiveness of insecticide-treated materials and indoor residual spraying in specific epidemiological settings. Information on other vector control methods and the conditions in which such methods can be considered cost-effective and sustainable in terms of both entomological and epidemiological impact is less available. There are a number of groups individually engaged in operations research for vector control and environmental management. Some are working in areas of seasonal transmission by *Anopheles arabiensis*, others in areas with perennial transmission by *An. gambiae* s.s., and others working primarily with *An. funestus*. Some projects are rural, others are peri-urban, or on agricultural estates or in industrial areas. Some employ chemical and bacterial larvicides while others investigate the use of environmental management. Given the renewed interest created by the resurgence of malaria and other diseases, it is necessary to optimise vector control by using a rational mix of several tactics with proven effectiveness. This presentation highlights the need to adopt an integrated approach to vector control and management that is cost-effective and sustainable in different ecological settings in Africa.

Reversing sequestration in *Plasmodium falciparum* malaria with antibodies does not work in the treatment of severe malaria

J P D Goldring
Biochemistry, University of Natal, Pietermaritzburg, South Africa; goldringd@nu.ac.za

Malaria is a serious disease infecting some 200 million people annually. Many of the fatalities are children who have cerebral malaria. *Post mortem* studies in these children have revealed the blood vessels supplying the brain and other organs to be packed with malaria-infected erythrocytes cyto-adhering to venous endothelial cells. Cyto-adherence involves the parasite ligands Pfalhesin, sequestrin, adherin and modified band 3 and the host receptors ICAM-1, CD-36, VCAM-1, TRAP, E-selectin and chondroitin sulphate. Adherence can be reproduced in the laboratory. Reversing adherence in humans with anti-malarial antibodies was investigated as an attractive adjunct to the treatment of cerebral malaria. The reversal of cyto-adherence by antibodies both *in vitro* and *in vivo* suggested that a pool of high titre anti-malarial antibodies, shown to contain antibodies to the surface of infected erythrocytes and to reverse adherence *in vitro*, may reverse adherence *in vivo*. The double blind, placebo controlled administration of the antibodies as an adjunct to quinine (the best available antimalarial at the time) had no measurable observed effect on adherence, and did not alter patient recovery. This study evaluates the predicted antibody concentrations required to reverse cyto-adherence. Antibody concentrations were calculated from *in vitro* adherence experiments; the levels of malaria adherence ligands expressed on the surface of infected erythrocytes; the levels of adherence receptors expressed on the surface of endothelial cells and the concentrations of antibodies required to reverse the adherence of cyto-adherent cells in animal models. Results suggest that insufficient antibody was administered in the immunotherapy trial and hence the anticipated reversal of adherence and improved outcome were not seen. The results further suggest that immunotherapy to reverse cyto-adherence is not appropriate as the required concentrations of antibodies are likely to have adverse side-effects.

Functional micromorphology of the slender pigeon louse *Columbicola columbae*

E D Green[1], F C Clarke[2] and M L Turner[3]
[1]*Department of Anatomy, Medical University of Southern Africa, MEDUNSA, 0204 South Africa; edward@medunsa.ac.za*
[2]*Department of Biology, Box 232, Medical University of Southern Africa, MEDUNSA, 0204 South Africa*
[3]*Electron Microscope Unit, Medical University of Southern Africa, MEDUNSA, 0204 South Africa*

Infestations with the chewing louse *Columbicola columbae* are common in pigeons worldwide, resulting in feather destruction, weight loss and decreased egg production. This scanning electron microscope (SEM) study aimed at investigating the micromorphology of these lice to obtain some understanding of how they attach to, orientate and feed on their hosts. The lice were collected live from infested pigeons and fixed in 70 % ethanol. After ultrasonic cleaning, they were routinely prepared for SEM, sputter-coated with gold, and viewed in a Leica Stereoscan 420 SEM at 5–10 kV. The head of *C. columbae* is particularly dorsoventrally flattened and lacks the medial groove for holding the barbules seen in many other feather lice. It is further elongated by a flattened anterior plate with specialised sensoria to move between the barbs of the feather. The mouthparts include robust mandibles that grasp a group of barbules to firmly attach the louse to a feather. The terminal surface of each mandible is deeply notched with the inner surface angled to form a sharp cutting surface to shear off pieces of feather for ingestion. A pair of labial palps each bear 6 peglike sensory setae. The thoracic and abdominal spiracles both have slit-shaped luminal openings, which is a unique feature compared to the round spiracular openings of other species of lice. Each leg has 2 tarsal claws. The larger curved claw closes between 4 opposing robust setae of the pretarsal sclerite to firmly grasp the barbules of the feather. The 2nd slightly curved horn-like claw was not observed to close against the pretarsal sclerite but remained open at an angle to the large claw. The mandibles and legs are specialised to prevent the lice from being detached during the rigours of preening and flight. This study confirmed the sexual dimorphism of the 5-segmented antennae. The 1st antennal segment of the male is enlarged while the 3rd segment has a hooklike process for attaching to the female during copulation. Three specialised sensoria were observed on the antennae. These consist of a peg organ with ten uniquely grooved sensillae on the distal tip of the 5th segment while a pore organ with an associated plate organ were observed on the posterolateral surfaces of each of the distal 2 segments. These chemosensory sensoria enable the eyeless lice to orientate on their host, as well as for feeding, mate location and ovipositing.

Caligus parasites collected from marine and estuarine fish in KwaZulu-Natal, South Africa

N J Grobler[1], J G van As[1] and D P Cyrus[2]
[1]*Department of Zoology and Entomology, University of the Free State, PO Box 339, Bloemfontein, 9300 South Africa; groblenj@sci.uovs.ac.za*
[2]*Department of Zoology, University of Zululand, Private Bag X1001, Kwadlangezwa, 3886 South Africa*

Lake St Lucia, on the east coast of South Africa, is the largest estuarine area in southeast Africa and occupies about 80 % of the estuarine area of KwaZulu-Natal. It is 300km^2 in area and has a mean depth of only 1 metre. Lake St Lucia is subject to extreme long-term salinity fluctuations due to its shallow nature and irregular inflow of freshwater, making it a unique estuarine system. Mhlatuzi Estuary is situated about 100 km south of Lake St Lucia and is a much smaller estuary compared to Lake St Lucia. It receives freshwater only from the Mhlatuzi River and its tributaries. Lake St Lucia receives freshwater from 5 different rivers as well as ground-water seepage along the eastern shore. Fish parasitological studies were carried out during 1992, 1993, 1994 and 1997 in Lake St Lucia and in 2001 in the Mhlatuzi Estuary. Many different species of the genus *Caligus* were removed from a wide variety of fish hosts. This genus comprises more than 300 species worldwide, valid or otherwise, of which only 28 species have been recorded from South Africa. Most of the information on this genus from South Africa is limited to very old, more than often incomplete, taxonomic descriptions. These ectoparasites have well-adapted appendages to parasitise a broad host range, contributing to their cosmopolitan distribution. At least 6 different species of *Caligus* parasites were collected during the Lake St Lucia and Mhlatuzi Estuary surveys, *i.e. Caligus acanthopagri, C. confusus, C. epinepheli, C. pageti, C. rotundigenitalis*, as well as an unknown species.

routinely processed for SEM and viewed in a Leica Stereoscan 420 SEM at 5–7 kV. The SEM study revealed several specialisations not clearly visible on traditional slide-mounted specimens. On the ventral surface of the broad shovel-shaped head, the lateral folds of the carina forms a deep medial groove that contains the membranous pulvinus that surrounds the oral cavity. The feather barbules are pushed into this groove by the mandibles when the louse attaches to the feathers. The mandibles frequently has double-notched cutting edges for feeding by scraping the host's epidermis. A pair of labial palps, each bearing 6 terminal peg-like sensory sensilla, lie just posterior to the mandibles. Several specialised sensoria were observed on the antennae. The terminal peg organ consists of 12 sensilla of varying lengths. Two sensory pore organs and their associated plate organs on the 4th and 5th segments are reported here in *R. gracilentus* for the first time. Each pore organ contains a tuft organ as well as an adjacent plate organ with radiating slits. These sensoria are reported to be chemosensory, enabling the lice to orientate on their host. The luminal surfaces of both the abdominal spiracles and the larger thoracic spiracles are lined by irregular lamellae that may function to filter the air passing through the spiracles into the tracheae. Each leg has 2 terminal tarsal claws. The larger anterior curved claw closes between the 3 opposing conical setae of the pretarsal sclerites to firmly grasp the barbules of the feather. The 2nd, slightly curved claw remains open at an angle to the large claw to easily grasp adjacent barbules. The 3 spinous setae on each of the paired tubercles on the terminal gonopods of the female confirms the identification of this louse as *R. gracilentus* according to Clay (1972). In this study the everted aedeagus with its laterally directed, leaf-shaped parameres, which protrude from the genital opening of some of the males, was observed for the first time.

Tissue-burrowing copepod parasites of *Hilsa kelee*

N J Grobler[1] and D P Cyrus[2]
[1]*Department of Zoology and Entomology, University of the Free State, PO Box 339, Bloemfontein, 9300 South Africa; groblenj@sci.uovs.ac.za*
[2]*Department of Zoology, University of Zululand, Private Bag X1001, Kwadlangezwa, 3886 South Africa*

The Pennellidae represents a peculiar family of siphonostome copepods that are known almost exclusively from female specimens. This is due to the fact that an intermediate host is involved in their life cycles and the adult males die soon after mating while they are on or in the intermediate host. The post-mated adult females leave the intermediate host, seek out a final teleost host, bore into the tissues or organs of the host, and leave only the tremendously enlarged and/or elongated genital and abdominal portions of the body exposed. The family is known from these mesoparasitic adult females on the teleosts, the ephemeral males having seldom been reported. *Lernaeenicus* sp. was found on 5 *Hilsa kelee* fish hosts collected during fish surveys carried out in the Mhlatuzi Estuary in Richards Bay on the east coast of South Africa. All the hosts with copepods were fixed in 10 % formalin, and later transferred to 70 % ethanol. The copepods were carefully dissected out of the tissue of the hosts and placed in 70 % ethanol. The site of insertion is usually variable, but all the copepods found in the present study were found inserted just beneath the pectoral fin, with the head buried in the host's tissue, never hanging free in the host's body cavity. The trunk of the parasite is not wrapped by a 'host tissue band', as is seen in some other pennelid genera. Nominal species abound in *Lernaeenicus*, many of which have been very poorly described. Some are known only from single records. A thorough revision of the genus is badly needed to piece the life history of these burrowing parasitic copepods together. The parasite represents a new host and distribution record for South Africa.

Skin and gill parasites of the Kob, *Argyrosomus japonicus* (Temminck & Schlegel, 1843) collected at the De Hoop Nature Reserve, South Africa

N J Grobler[1], N J Smit[2], C C Reed[1] and L Basson[1]
[1]*Department of Zoology and Entomology, University of the Free State, PO Box 339, Bloemfontein, 9300 South Africa; groblenj@sci.uovs.ac.za*
[2]*School of Life Sciences, Kingston University, Penrhyn Road, Kingston upon Thames, Surrey, KT1 2EE, United Kingdom*

The kob, *Argyrosomus japonicus*, is 1 of the best known and widely spread sport fishes in southern Africa and is also commercially exploited by line-boat fisherman. This shoaling predator occurs at depths of up to 400 metres and is also common in shallower coastal areas, particularly along the sandy edges of reefs and estuaries where the water is often turbid. During a recent investigation of the parasites of surf zone fishes at the De Hoop Nature Reserve, 4 kob were collected by means of rod and line. Fish were identified, measured and examined for parasites. Ecto- and endoparasites found were removed and fixed according to standard methods required for each specific group. The genus *Caligus* (Copepoda) was found abundantly on the skin, with prevalence of 100 % and up to 8 specimens on a single fish host. Three different parasites, *i.e.* 2 copepods from the genera *Neobrachiella* and *Sciaenophilus* and 1 unique monogenean from the genus *Benedenia* were found in the branchial areas. Another monogenean of the genus *Udonella* was found associated not with the kob, but with the caligid copepod. These hypersymbionts feed mainly on the epithelial tissue of the fish host and do not cause any harm to the copepod host.

Applying the parasite index (PI) as a bio-indicator of water quality in the Selati River, Limpopo Province: preliminary results

A Jooste, W J Luus-Powell and L Polling
School of Molecular and Life Sciences, Discipline of Zoology, University of the North, Limpopo Province, South Africa; joostea@unorth.ac.za

Water quality monitoring in South Africa has in the past focused mainly on measuring physical and chemical variables. The value thereof is well established, but these methods cannot on their own provide an accurate measure of the general 'health' of an aquatic ecosystem. Subsequently the fish Health Assessment Index (HAI) and associated Parasite Index (PI) have been applied and adapted for local conditions through various studies in the Olifants and Vaal River Systems. The HAI proved to be a relatively rapid and inexpensive method to detect changes in a fish population. These studies also showed that the presence of parasites *per se* was an indicator of the deteriorated health of the fish and consequently a deteriorated environment and that fish parasites are extremely sensitive to changes in the aquatic environment. The Ga-Selati River, which originates in the Drakensberg Mountain, was selected for this study owing to the mining activities on its banks before its confluence with the Olifants River. Four sampling sites in the lower Selati River were selected: 3 sites in the vicinity of the mines and 1 site representing an 'unpolluted' part of the river, 30 km upstream from the mines. Thus far 2 seasonal surveys have been conducted which included the water quality constituents and the HAI and PI. Two species of fish, *Oreochromis mossambicus* and *Clarias gariepinus*, were collected by gill netting and angling. Hosts were examined for mobile ectoparasites and dissected to examine internal organs using the revised HAI method. All parasites collected were fixed and preserved using standard methods. Preliminary results indicate that the water quality is very poor at the sampling sites at the mines, with a very high salinity and conductivity caused by the calcium, sodium, potassium and magnesium salts. The sampling site upstream from the mines, with a much better water quality, showed lower TDS values. The PI correlates with these findings, with more ectoparasites being present at this sampling site and more endoparasites at the mining sites where water quality was poor. The use of parasites in the HAI, or individually as indicators of pollution (PI), has potential and should be applied in more water bodies of South Africa.

New information on the location of Bruce's laboratory at Ubombo as a basis for possible archaeological studies

J J Joubert[1], D J Irons[2] and P H de Rycke[3]
[1]*Department of Medical Virology, University of Stellenbosch, South Africa; johanjoub@mweb.co.za*
[2]*PO Box 6, Ubombo, South Africa*
[3]*Laboratory of Zoophysiology, University of Gent, Belgium*

By means of recent surveys, the site where *Trypanosoma brucei brucei* was discovered in 1895 by Major General Sir David Bruce (KCB, DSc, LLD, FRCP, FRS, Late AMS), could be determined with more accuracy. A GPS reading of S 27° 33.681' and 32° 05.114' can

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