MORPHOLOGICAL FEATURES OF THE FISH ECTOPARASITE *MUGILICOLA SMITHAE* JONES & HINE, 1978 (COPEPODA) AND DISTRIBUTION OF THE GENUS *MUGILICOLA*

BY

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ABSTRACT

Female specimens of the copepod *Mugilicola smithae* were collected from a new locality in northern Kwazulu Natal from *Liza alata*, *L. macrolepis*, *Myxis capensis* and *Valamugil seheli*, all four species constituting new host records. Studies of whole mounts cleared in 90% lactic acid and of scanning electron microscopy were conducted. The morphological features of *Mugilicola smithae* are reviewed. The distribution of the genus *Mugilicola* and host preferences are discussed.

RÉSUMÉ

Des femelles du copépode *Mugilicola smithae* ont été collectées dans une nouvelle localité au nord du Kwazulu Natal, sur *Liza alata*, *L. macrolepis*, *Myxis capensis* et *Valamugil seheli*, les quatre espèces représentant de nouveaux hôtes. Une étude de montages complets, éclaircis dans l'acide lactique à 90%, et une étude au S.E.M. ont été effectués. Les caractères morphologiques de *Mugilicola smithae* sont revus. La distribution du genre *Mugilicola* et les hôtes préférentiels sont discutés.

INTRODUCTION

At present four species of *Mugilicola* Tripathi, 1960 are known. Of these only *Mugilicola smithae* Jones & Hine, 1978 has been recorded from Southern Africa, embedded in the buccal cavities of freshwater eels, *Anguilla mossambica* Peters, 1852, in the Keiskamma and Umtata Rivers (Jones & Hine, 1978).

The present study has been prompted by recent findings of *Mugilicola* specimens on the gills of adult specimens of four mullet species, occurring in northern Kwazulu Natal. In addition to the new morphological features of the collected

copepods, the authors have noticed regularities in the geographical distribution of the representatives of the genus *Mugilicola* and the host fishes.

Distribution of the infested host fishes showed that they are mainly restricted to rivers and estuaries connected with the Indian Ocean, with only one species occurring elsewhere.

In the present study *M. smithae* is redescribed and a comparison with other species is presented. This is complemented by a table and map showing the distribution of the genus.

MATERIALS AND METHODS

Surveys were carried out at Nhlabane Estuary (32°10′S 28°25′E) approximately 22 km north-east of Richards Bay in Kwazulu Natal. The copepods were collected from mullets sampled in one of the following manners: by monofilament gill nets, seine nets, and with an electro-shocking device.

Fish were killed by a single cut through the spinal cord. The gills were dissected out and examined with the aid of a dissection microscope. When present, the parasites were carefully dissected from the gill-arches. The parasites were treated in one of the following manners: (i) specimens for SEM studies were placed directly in 70% ethanol; (ii) the remainder was fixed in cold 10% neutral phosphate buffered formalin (Humason, 1979) for a minimum of 24 hours. Copepods fixed in formalin were washed in running tap water for 24 hours and dehydrated to 70% ethanol. Specimens for light microscopy were cleared in 90% lactic acid, mounted, and observed with a Zeiss model 18 microscope. Drawings were made with the aid of a drawing tube attachment. Specimens for SEM studies were hydrated, freeze-dried with an Edwards Tissue Drier, and sputter-coated with gold. In cases where certain structures, i.e., mouthparts, were covered by other structures and thus not visible, microdissections were carried out to uncover these structures.

Type specimens of *Mugilicola smithae* are supposedly stored at the South African Museum (Cape Town, SAM A 15679), the New Zealand National Museum (Wellington, Cr.2171), the Institute of Ichthyology (Rhodes University, RUSI 929) and in one of the describing author's (JBJ) collection. However, only the holotype (Cape Town) could be located. This specimen is distorted and the antennules are folded. Comparison was therefore limited to the species description. New voucher specimens are in the Albany Museum (Grahamstown) collection (RAU 4A-4I) and in the South African Museum (Cape Town) (No. SAM A43140).

RESULTS

Total numbers of hosts and *M. smithae* collected are as follow: 53 *Liza alata* (Steindachner, 1892), 31 parasites; 47 *Liza macrolepis* (Smith, 1846), 22 parasites; 13 *Valamugil seheli* (Forsskål, 1775), 6 parasites; and 7 *Myxis capensis* (Valenciennes, 1836), 10 parasites.

REDESCRIPTION

Mugilicola smithae Jones & Hine, 1978 (figs. 1-6)

Body showing no external segmentation, transparent except for abdomen and egg-sacs which are distinguished by their white colour. Three pairs of legs present on genital trunk. Total length, excluding egg-sacs (fig. 3d), 4.3 mm ($N = 9$). Length of juvenile female, 1.75 mm ($N = 2$) (fig. 4c, d).

Cephalon small (0.47 mm long and 0.44 mm wide, $N = 9$) with trilobic process occurring on each postero-lateral margin (fig. 1c). Appearance of trilobic process variable, from well developed to not visible (fig. 4a-d). Mouth and associated structures present medially on ventral side of cephalon, and when trilobic processes occur, mouth structures present between these two lobes. Antennae and antennulae anterior on head and antennae curved from dorsal to ventral side (figs. 2c, 5a). Minute sensory openings present antero-dorsally on head (fig. 6a). No other cephalic ornamentation present.

"Neck" cylindrical and without any appendages; comprising 50-60% of total body length ($N = 5$). "Neck" merging with trunk without visual segmentation. In many cases "neck" covered by connective tissue capsule produced by host (fig. 6c).

Trunk oval, bearing three pairs of legs ventrally. First pair of legs situated centrally whilst second and third pair located near posterior margin (fig. 3d). Genito-abdomen consists of fused segments and posterior segment is bearing caudal rami. Bases of furcal rami surrounded by single row of setae (fig. 6g, h).

Three pairs of fine setal rows present ventrally, and group of setae present anterior to rows of setae (figs. 1d, f, 6a, d). Minute sensory openings present on ventral surface of genito-abdomen (fig. 6a, b). Each caudal ramus terminating with three setae, with central setae shorter (fig. 1b).

Antennule five-segmented, segments progressively smaller from base to apex (fig. 1a), each bearing setae ventrally, variable in length and number (fig. 1a). First segment longer than wide and longer than successive segments, with 13 setae present anteriorly. Second segment also longer than wide. Four setae present, one situated apart from other three. Third segment wider than long,

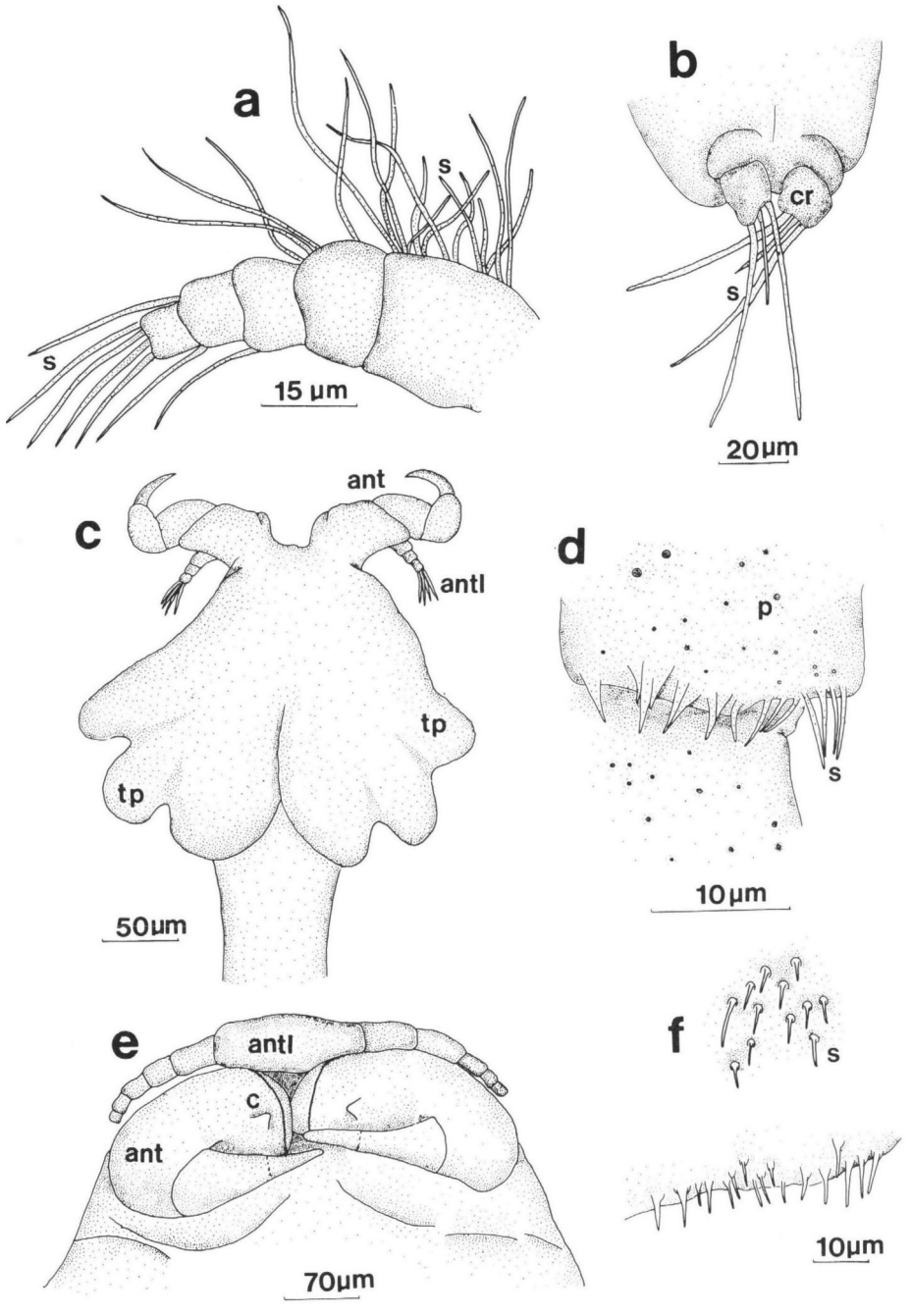


Fig. 1. External structures of *Mugilicola smithae* Jones & Hine, 1978, female. a, antennule with setae (s); b, genito-abdomen, showing caudal rami (cr) with setae (s); c, dorsal view of cephalon with antennules (antl), antennae (ant) and trilobic processes (tp); d, setal structures (s) and pores (p) on ventral side of genito-abdomen; e, ventral side of cephalon with antennules (antl), and antennae (ant) with conical process (c); f, setal structures on ventral side of genito-abdomen.

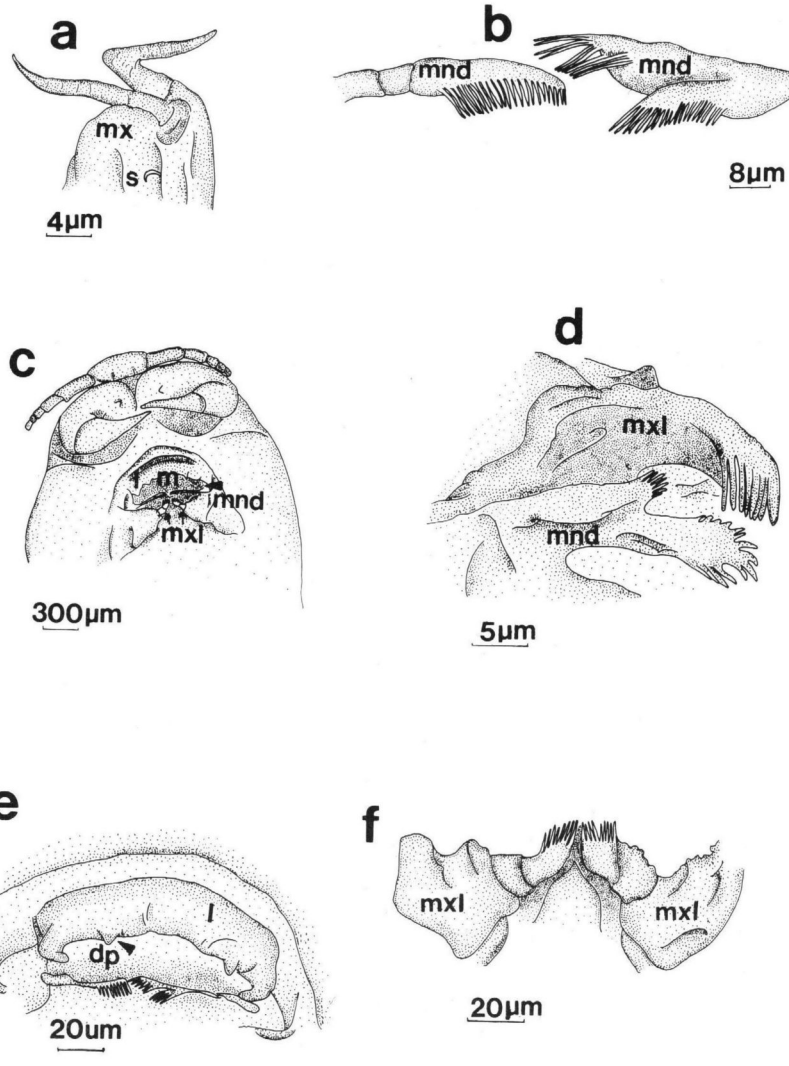
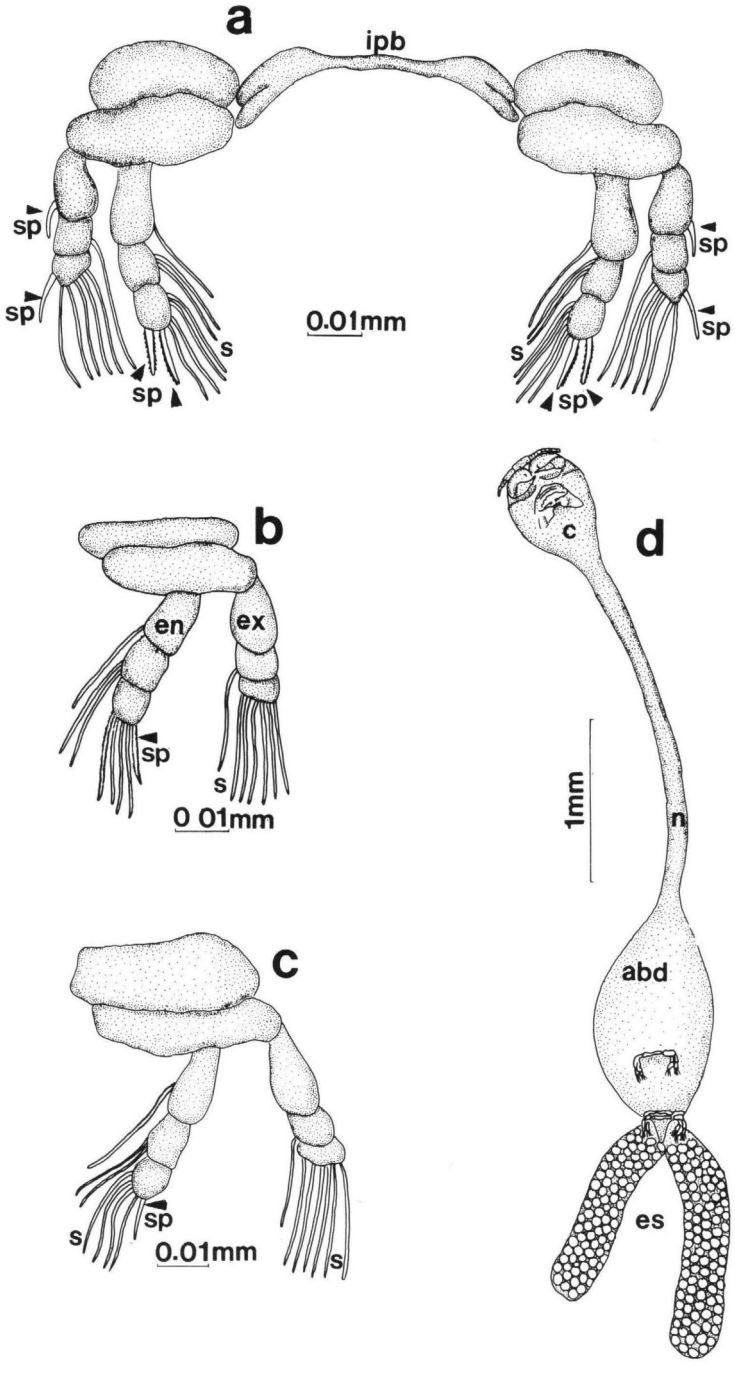


Fig. 2. Oral appendages of *Mugilicola smithae* Jones & Hine, 1978, female. a, maxillule (mx) with seta (s); b, mandible (mnd); c, ventral view of cephalon with slit-like mouth (m), labrum (l), mandibles (mnd), and maxillae (mxl); d, lateral view of maxilla (mxl) and mandibles (mnd); e, labrum (l) with denticle-like projections (dp); f, posterior view of maxillae (mxl).

Fig. 3. *Mugilicola smithae* Jones & Hine, 1978, female habitus and legs. a, first pair of legs showing interpodal bar (ipb) and spines (sp) on podomeres; b, second pair of legs showing setae and spines (sp) on endopod (en) and exopod (ex); c, third pair of legs with setae (s) and spine (sp); d, ventral view of female with cephalon (c), neck (n), genito-abdomen (abd) and egg-sacs (es).


a
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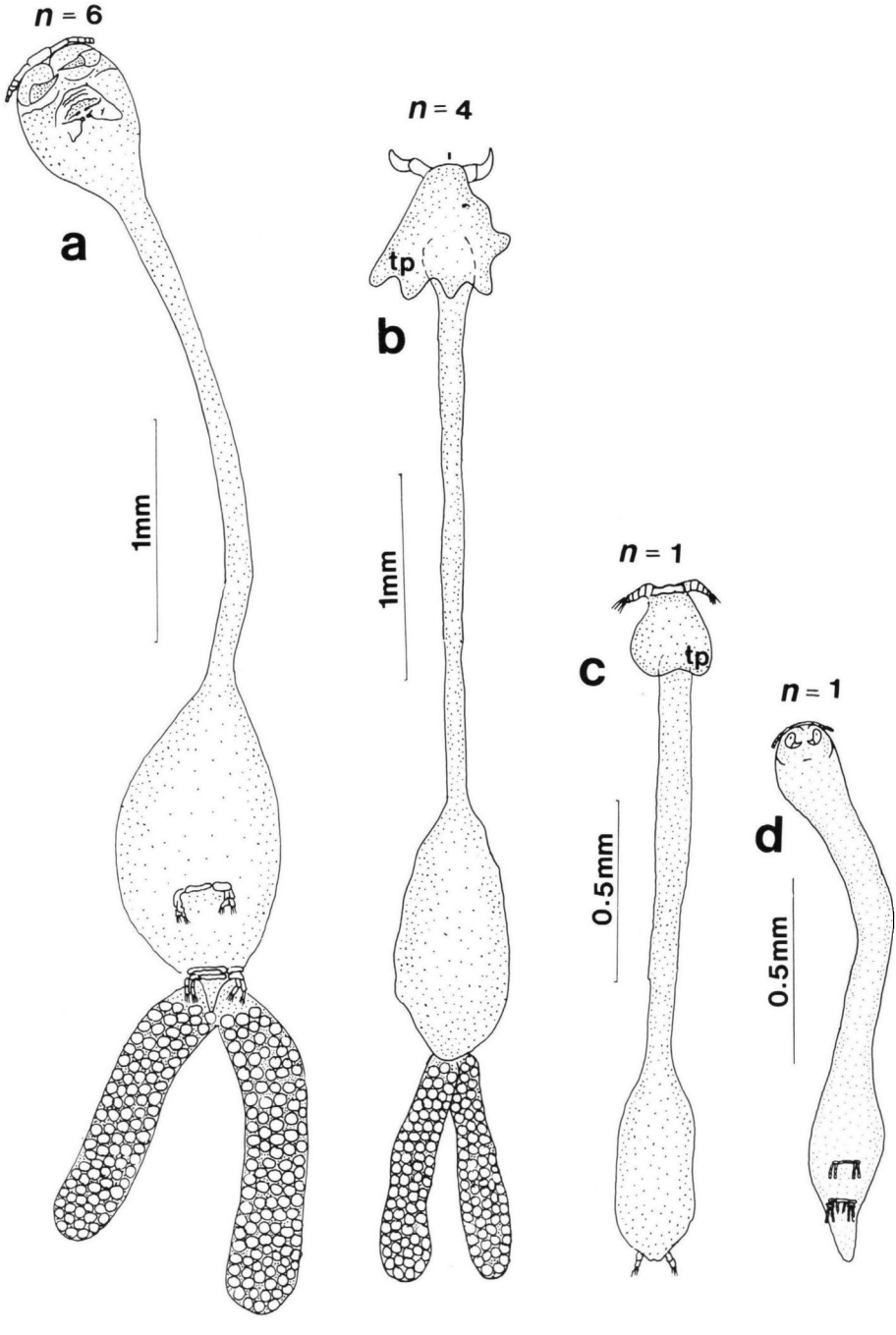
n = 6
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tp
c
0.5mm
n = 1
d
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bearing one seta. Fourth segment bearing two setae on opposite sides. Fifth segment bearing four setae. Antenna consisting of three segments (fig. 1e). First segment is wider than long and no ornamentation visible. Second segment with curved distal margin. Conical projection present medially on inner margin of second segment (figs. 1e, 5a). Third segment terminating in claw-like structure closing towards second segment. Minute opening present dorsally near segment base.

Mouth situated on ventral side of head (figs. 2c, 5a), consisting of a slit-like opening bordered anteriorly by labrum, mandibles, maxillules, and maxillae. Labrum situated anterior to the mouth and covering mouth and mandibles (figs. 2c, e, 5c), bearing four distinct dental projections (figs. 2d, 5c), on its anterior curved margin.

Mandible consisting of broad basal segment dividing into two blade-like structures. Each of these two structures contains a row of fine spines on the inner margin, giving it a comb-like appearance (figs. 2b, 5d, e). Maxillules small conical structures with two apical setae. Small curved seta present medially on conical structure (figs. 2a, 5b). Maxilla consisting of three segments. Terminal segment round, with distal margin bearing many small spines (figs. 2d, f, 5f).

First leg biramous, rami consisting of three segments each. First segment of endopod containing single seta on distal margin. Second segment bearing two setae on medial margin and many minute denticle-like protrusions on distal margin. Third segment bearing four setae on medial margin and two straight spine-like setae covered with small denticle-like structures on distal margin (figs. 3a, 6f). First segment of exopod bearing no setae but single, short, curved spine-like structure laterally (fig. 3a). Second segment with single seta on medial margin. Third segment bearing five setae terminally and single spine on lateral margin (fig. 3a). First pair of legs connected by well-developed interpodal bar (figs. 3a, 6e).

Second leg similar to first leg but with different number of setae and spines. Third segment of endopod containing one spine. First segment of the exopod unarmed. The third segment bearing six setae and no spines (fig. 3b). Interpodal bar also well developed.

Fig. 4. *Mugilicola smithae* Jones & Hine, 1978, females showing variation in length and shape of trilobic process. a, ventral view of whole body, trilobic process poorly developed, total length 4.30 mm; b, dorsal view of whole body showing well developed trilobic process (tp), total length 4.20 mm; c, dorsal view of juvenile female showing development of trilobic process, total length 1,8mm; d, ventral view of juvenile female showing almost no signs of trilobic process, total length 1.4 mm.

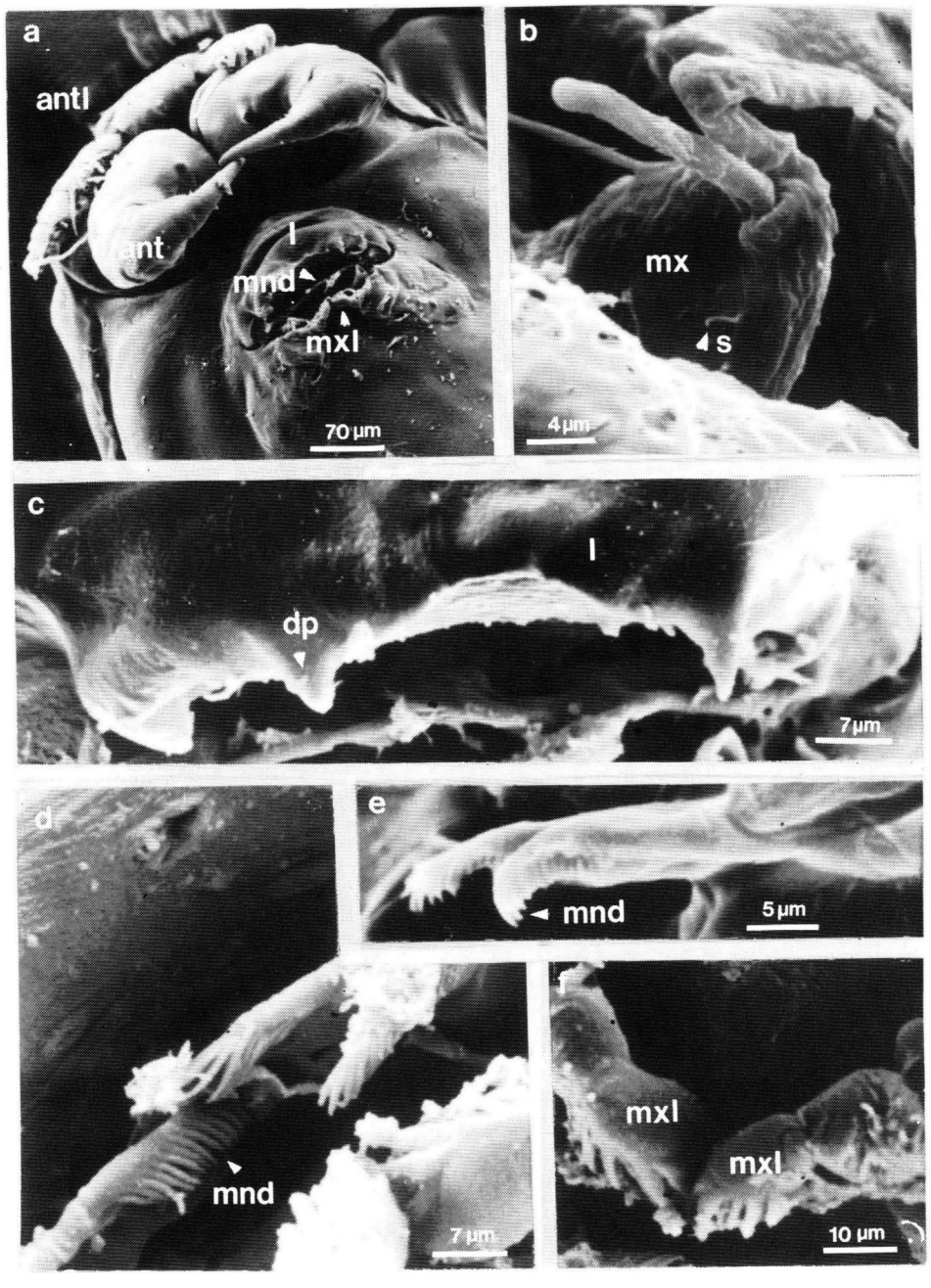

Fig. 5. *Mugilicola smithae* Jones & Hine, 1978, female, SEM micrographs of oral appendages. a, ventral view of cephalon showing antennules (antl), antennae (ant), labrum (l), mandibles (mnd), and maxillae (mxl); b, maxillule (mx) with seta (s); c, labrum (l) with denticle-like projections (dp); d, mandibles (mnd); e, lateral view of mandibles (mnd); f, maxillae (mxl), dorsal view.

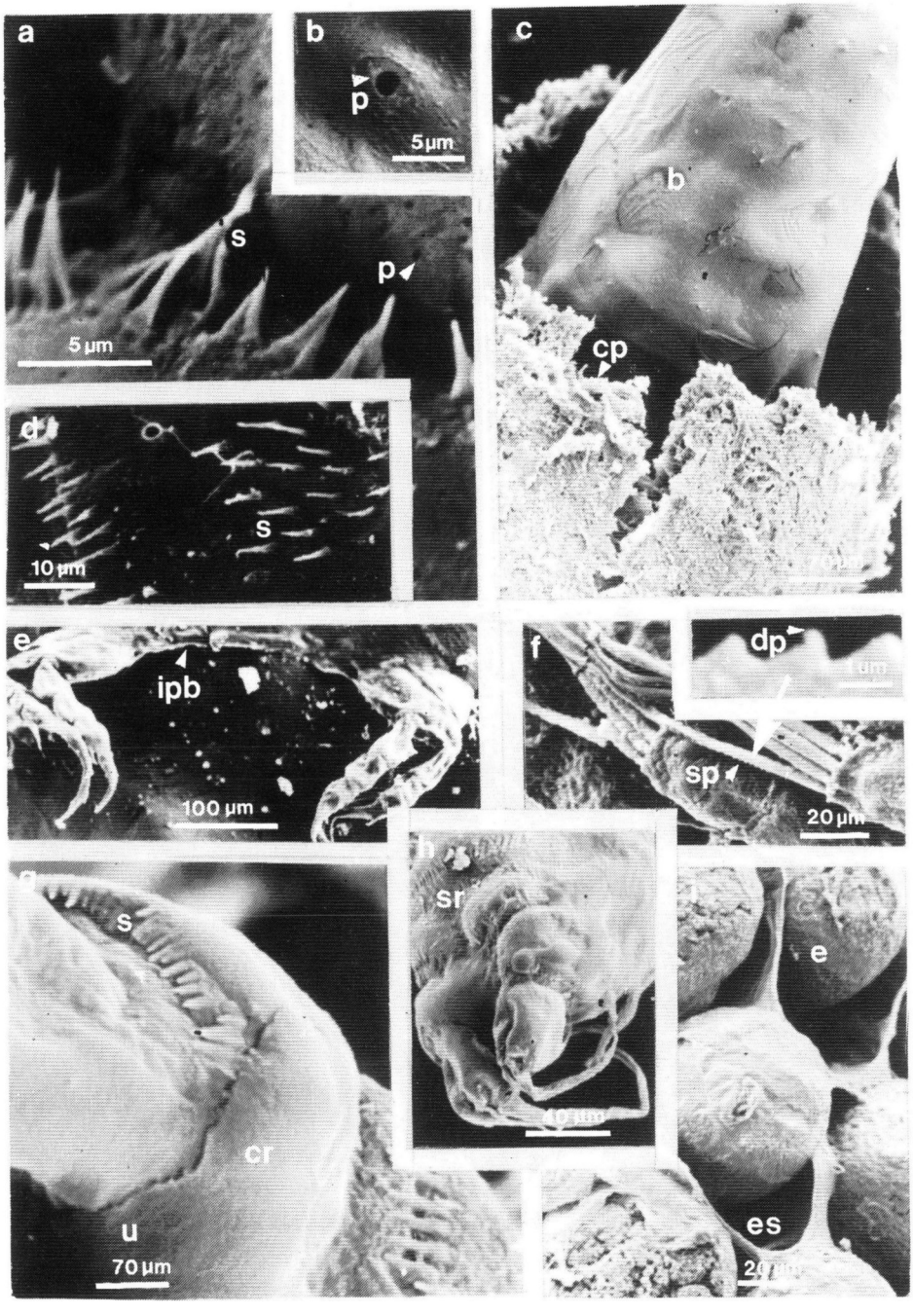

Fig. 6. SEM micrographs of *Mugilicola smithae* Jones & Hine, 1978, female. a, d, setae and pores (p) on ventral side of cephalon; b, pore (p) on ventral side of cephalon; c, body (b) partially covered by capsule (cp); e, first pair of legs showing interpodal bar (ipb); f, spine (sp) showing denticle-like protrusions (dp); g, caudal rami (cr) showing single row of setae (s) near base; h, genito-abdomen with caudal rami showing setal rows (sr) on ventral side; i, eggs (e) in egg-sac (es).

Third leg similar to above-mentioned legs. First segment of exopod unarmed. Second segment bearing one seta on medial margin. Third segment with six setae terminally but no spines. Setae and spines on endopod similar to those of second leg (fig. 3c).

Occurrence of setae and spines on legs 1-3 as follows (spines represented by Roman numerals and setae represented by Arabic numerals):

	Coxa	Basis	Endopod	Exopod
First pair	0-0	0-0	0-1;0-2;II-4	I-0;0-1;I-5
Second pair	0-0	0-0	0-1;0-2;I-4	0-0;0-1;0-6
Third pair	0-0	0-0	0-1;0-2;I-4	0-0;0-1;0-6

Juvenile female with appendages same as in adult female (fig. 4c, d).

DISTRIBUTION

Viewing the global distribution of the genus *Mugilicola*, three species are present in rivers and estuaries located on three continents bordering the Indian Ocean (fig. 7). The fourth species, i.e., *Mugilicola australiensis* Boxshall, 1986, however, occurs in a river bordering the Pacific Ocean (fig. 7).

Mugilicola kabatai Piasecki, Khamees & Mhaisen, 1991 occurs in the southern part of Iraq (fig. 7), in the Abu-Al-Khaseb Creek, a branch of the Shatt-Al-Arab River (Piasecki et al., 1991). *Mugilicola bulbosa* Tripathi, 1960 was collected on a fish farm near Port Canning and in the Matla River (fig. 7) in the northern part of India (Tripathi, 1960) and *Mugilicola australiensis* was caught off Arrawarra Beach (fig. 7), New South Wales, Australia (Boxshall, 1986), making it the only species so far collected in a location not bordering the Indian Ocean. *Mugilicola smithae*, the only species recorded in South Africa, was initially collected from the Keiskamma and Umtata Rivers (fig. 7) in the Eastern Cape (Jones & Hine, 1978), and in the course of the present studies, specimens were also collected from Nhlabane and Siaya Estuaries located near Richards Bay, Kwazulu Natal (fig. 7).

All species of *Mugilicola* were found on estuarine fishes. Although there are only four species of *Mugilicola*, nine host species have been recorded. Mullets seem to be the preferred host, as three of the four species of *Mugilicola* were collected from fishes belonging to the family Mugilidae, and only two of the nine host species are not related to mullets (table I). *Mugilicola australiensis* occurs on *Sillago ciliata* Cuvier & Valenciennes, 1829, an estuarine fish belonging to the family Sillaginidae, and *Mugilicola smithae* was first recorded on *Anguilla*

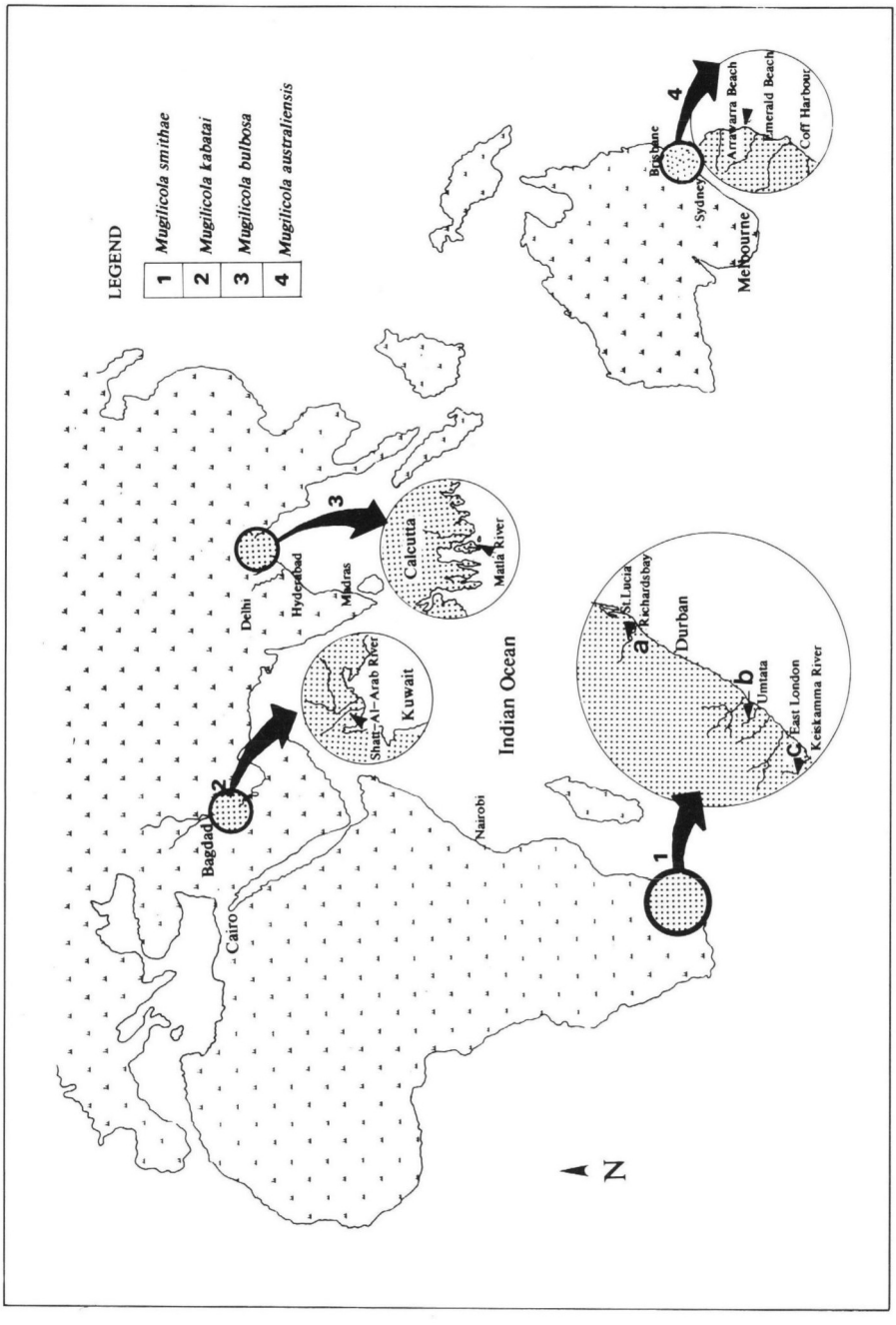

Fig. 7. Map showing global distribution of the genus *Mugilicola* (small arrows indicate localities where specimens were collected). a-c, the three localities in Southern Africa where *Mugilicola smithae* has been collected. Nos. 1-4 correspond with table I, indicating the four species of *Mugilicola*.

TABLE I

Geographical distribution and host species of *Mugilicola* spp.

Mugilicola spp.	Location	Host species	Reference
1 *M. smithae* Jones & Hine, 1978	Keiskamma & Umtata Rivers, South Africa	*Anguilla mossambica* Peters, 1852	Jones & Hine, 1978
	Nhlabane & Siaya Estuaries near Richards Bay, South Africa	*Liza alata* (Steindachner, 1892) *Liza macrolepis* (Smith, 1846) *Valamugil seheli* (Forsskål, 1775) *Myxis capensis* (Valenciennes, 1836)	Unpublished records
2 *M. kabatai* Piasecki, Khamees & Mhaisen, 1991	Shatt-Al-Arab River, Iraq	*Liza abu* (Heckel, 1843)	Piasecki et al., 1991
3 *M. bulbosa* Tripathi, 1960	Fish farm near Port Canning, River Tade, India	*Mugil tade* Forsskål, 1775	Tripathi, 1960
	Port Canning, India	*Mugil parsia* Hamilton-Buchanan, 1822	
4 *M. australiensis* Boxshall, 1986	Arrawarra Beach, Australia	*Sillago ciliata* Cuvier & Valenciennes, 1829	Boxshall, 1986

mossambica, also known as fresh water eel, belonging to the family Anguillidae (table I).

DISCUSSION

Specimens examined showed that the diagnostic features of *M. smithae* correspond in general with the features of specimens used during this study. Certain features differ from Jones & Hine's (1978) description, whilst previously unrecorded ultrastructures have been seen with the aid of a scanning electron microscope.

In our material, the structure of the trilobic process on the lateral sides of the head varies from well developed and clearly visible in some specimens, to nearly absent in others (fig. 4a-d). The absence/presence is not related to the size of the specimen, and it is suggested that this is not a constant feature. Such a process is absent on *M. australiensis*, *M. bulbosa*, and *M. kabatai*.

The antennule in *Mugilicola smithae* differs from that of *M. kabatai*, in the number of setae on the segments. *M. smithae* bears 13 setae on the first segment whereas *M. kabatai* bears only ten. The second segment bears one seta less than *M. kabatai* whilst the third podomere has two fewer setae. *M. kabatai* carries one more seta on segments four and five. No information was found on the antennule of *Mugilicola australiensis* nor *M. bulbosa*, and no comparison can thus be made between those species and *M. smithae*.

The conical structure present on the antenna was not reported by Jones & Hine (1978). A similar structure has also been found on *M. kabatai* and *M. australiensis*. A minute opening on the dorsal side of the third segment of the antenna was seen for the first time.

The minute openings on the ventral surface of the head and abdomen were not noticed by Jones & Hine (1978).

Jones & Hine (1978) claimed that the second segment of the endopod the second leg bears only one seta. Boxshall (1986) attributed this to an error in labeling the legs by Jones & Hine (1978), stating that it is very unusual for legs one and three to have two setae on this segment, while only the second leg bears one seta. In our study it became clear that *M. smithae* indeed does bear two setae on the second segment of the endopod of the second leg, thus proving the statement of Boxshall (1986) to be correct.

The term "maxilliped" used by Jones & Hine (1978), is here replaced by the term "maxilla" for the following reasons: (1) Tripathi (1960), based the family Therodamasidae (which is no longer valid, cf. Boxshall, 1986) on the genus *Therodamas*. According to Kabata (1979), no maxillipedes are known for either sexes of *Therodamas*. (2) Boxshall (1986) holds the opinion that the genera *Mugilicola*, *Therodamas*, and *Paeonodes* should rather be seen as highly transformed species of the family Ergasilidae for they possess typical ergasilid cephalic appendages. No maxilliped is present in the females of Ergasilidae. According to Boxshall (1986), these are diagnostic apomorphies of the family Ergasilidae. (3) The term second maxilla is used by Kabata (1979) as well as Piasecki et al. (1991), in their species descriptions of *Mugilicola* spp. Their studies were conducted more recently than those of Jones & Hine (1978).

Electron microscopical observations showed that the genito-abdomen of *M. smithae* bears three pairs of fine setal rows ventrally as is the case in *M. kabatai*. A group of setae anterior to the three pairs of setal rows on the genito-abdomen were observed for the first time as no such structures were mentioned by either Jones & Hine (1978), Boxshall (1986), or Piasecki et al. (1991), in their descriptions of *Mugilicola* species.

It is accepted that the specimens found in the present study belong to *M. smithae*, since most of the features correspond to the data provided by Jones & Hine (1978).

As mentioned, three species of *Mugilicola* occur in regions bordered by the Indian Ocean (table I) and this could possibly be attributed to the continental drift phenomena following the separation of Gondwana. As these parasites are host specific, a possible correlation could be drawn between the occurrence of mullets and species of *Mugilicola*.

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