

# Parasitic copepods on immigrant and native clupeid fishes caught in Egyptian coastal waters off Alexandria

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**Abstract** Three species of parasitic copepods, one each from the siphonostomatoid families Lernanthropidae and Lernaepodidae and one from the cyclopoid family Bomolochidae, are redescribed based on material collected from the gills of four fish species belonging to the family Clupeidae caught from coastal waters off Alexandria, Egypt. The recorded parasites are: *Mitrapus oblongus* (Pillai, 1964), found on *Etrumeus teres* (Dekay), an immigrant species from the Red Sea, and on *Sardinella aurita* Valenciennes, a native Mediterranean species; *Clavellisa ilishae* Pillai, 1962 found only on *S. aurita*; and *Nothobomolochus fradei* Marques, 1965 found on *Herklotsichthys punctatus* (Rüppell), an immigrant species from the Red Sea, and on *Sardina pilchardus* (Walbaum), a native Mediterranean species. The first two of these copepods have been reported before on clupeid hosts from the Indian Ocean. The third was known from the eastern South Atlantic and the Arabian Gulf. None of the copepods has previously been recorded in the Mediterranean. All of the parasites reported here constitute new records for these hosts. Two of the hosts are Erythrean (=Lessepsian) immigrants and were caught

in Mediterranean waters off the Egyptian coast. The original description of *N. fradei* (Marques, 1965) is inadequate by modern standards. This species is fully described here for the first time. The male of *M. oblongus* was briefly described by Pillai (1964), but its mouthparts are described in detail here for the first time.

## Introduction

Fishes of the Mediterranean Sea are known to host a rich fauna of parasitic copepods, with a total of 226 species listed in the survey by Raibaut et al. (1998). However, the marine fauna of the Eastern Mediterranean is undergoing a profound and rapid change due to sustained Erythrean immigration (defined here as the migration of Red Sea species through the Suez Canal into the Mediterranean). The term Lessepsian migration was proposed for this phenomenon by Por (1978) and has been widely used, but we prefer the alternative term, because it is more informative (in making reference to the geographical origin of the immigrants). As a result the fish fauna is changing (see reviews by Golani et al., 2002; Zenetos et al., 2008), but the impact of these changes in the composition of the fish community upon the parasitic copepod community has yet to be fully analysed. Here we present new data on three fish parasites that are new to the Mediterranean. One was previously known from the southeastern Atlantic and the Arabian Gulf, whereas

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the other two were known only from the Indo-Pacific. We infer that these latter two parasites have been carried into the Mediterranean on their Erythrean immigrant hosts. This phenomenon of co-invasion of a parasite and its host has been reported before for gill-parasitic monogeneans and for endoparasitic digeneans on fish hosts (Fischthal, 1980; Diamant et al., 1999; Pasternak et al., 2007). Co-invasion has also been documented before for crustaceans, such as the rhizocephalan parasite *Heterosaccus dollfusi* Boschma, 1960 on its portunid crab host, *Charybdis longicollis* Leene. This is an example of a Red Sea parasite that has subsequently entered the Mediterranean Sea via the Suez Canal, following its host which invaded the Mediterranean prior to 1954 (Galil & Lutzen, 1995; Galil & Innocenti, 1999). *H. dollfusi* has not been recovered from any native Mediterranean crabs, however.

In addition to reporting the discovery of the three parasitic copepods from the Mediterranean for the first time, we found two of these parasite species on Mediterranean hosts as well as on Erythrean immigrant hosts. Such host-switching had not been reported for Erythrean immigrants before (El-Rashidy & Boxshall, 2009). The potential impacts of such host-switching events on the populations of the native hosts are profound, especially when the hosts are important commercial species, such as pilchards. This paper is the first of a series of studies looking at this fascinating regional issue, as we aim to quantify the extent of the parasitological invasion of the fishes of the Mediterranean.

## Materials and methods

Parasites were collected from the gills and branchial chambers of four species of sardines which were purchased, freshly-caught, from the local fish market in Alexandria. Specimens of *Mitrapus* Song & Chen, 1976 were collected from the gill filaments of *Sardinella aurita* Valenciennes and *Etrumeus teres* (Dekay) caught off the Alexandria coast. Specimens of *Clavellisa* Wilson, 1915 were removed from the gill rakers of *S. aurita* and specimens of *Nothobolochus* Vervoort, 1962 recovered from the gill-cavity of *Herklotsichthys punctatus* (Rüppell) and *Sardina pilchardus* (Walbaum). The copepods were preserved in 70% ethyl alcohol. They were then

dissected and mounted in lactophenol as temporary slide preparations and examined on an Olympus compound microscope. Measurements were made using an ocular micrometer and drawings were made with the aid of a drawing tube. Morphological terminology follows Boxshall (1990) and Huys & Boxshall (1991). Host names were validated against FishBase (Froese & Pauly, 2009).

## Family Lernanthropidae Kabata, 1979

### Genus *Mitrapus* Song & Chen, 1976

#### *Mitrapus oblongus* (Pillai, 1964)

Syn. *Lernanthropus oblongus* Pillai, 1964

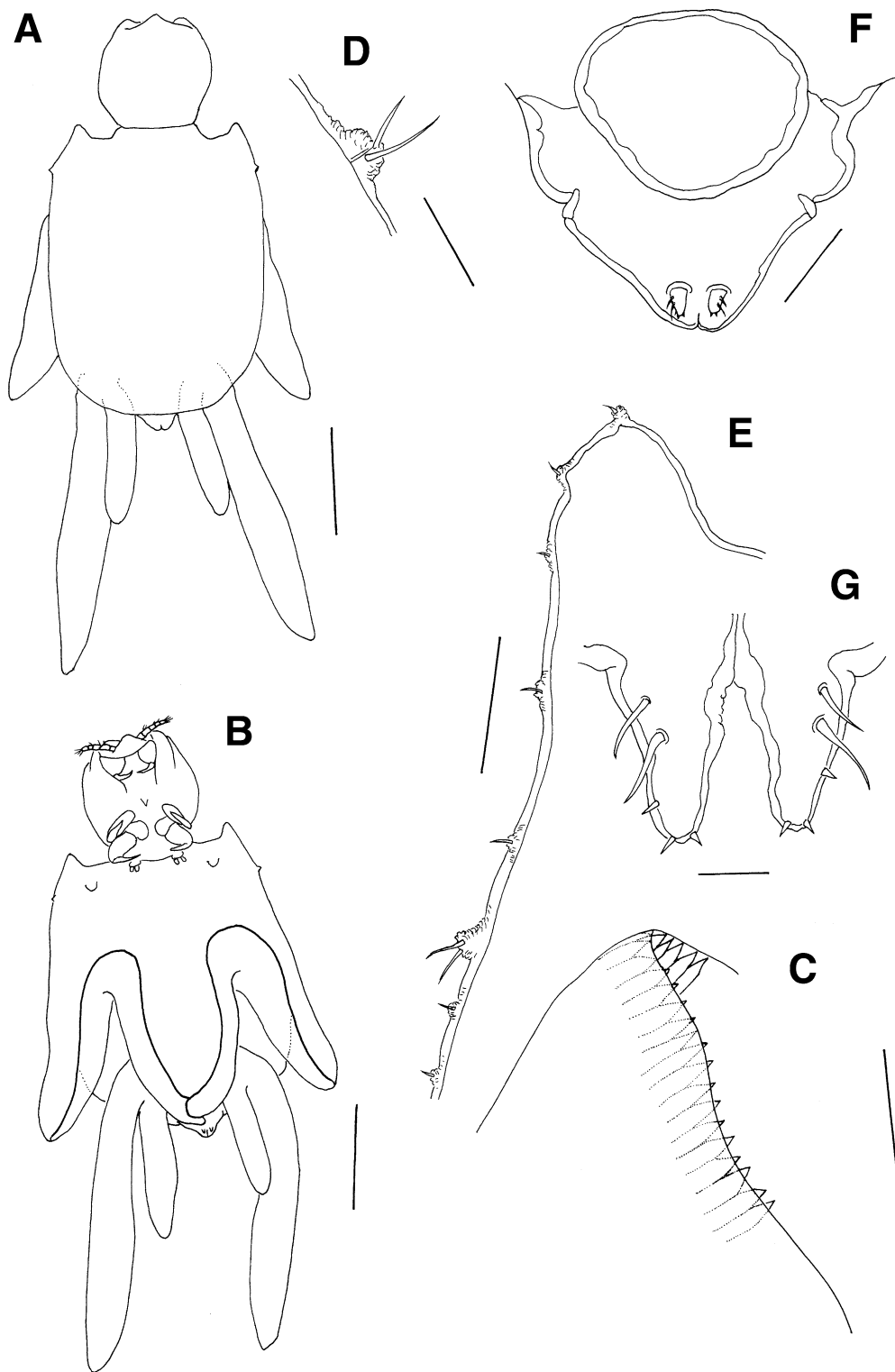
*Material examined*: 18 ♀♀ and 5 ♂♂ from gill filaments of 14 *Sardinella aurita* Valenciennes and 43 ♀♀ and 12 ♂♂ from gill filaments of 35 *Etrumeus teres* (Dekay), all caught in waters off the Egyptian coast near Alexandria. 6 ♀♀ and 1 ♂ deposited in the Natural History Museum, London, BMNH Reg. Nos 2009.238-244; remaining material in the collection of the first author.

Description (Figs. 1–6)

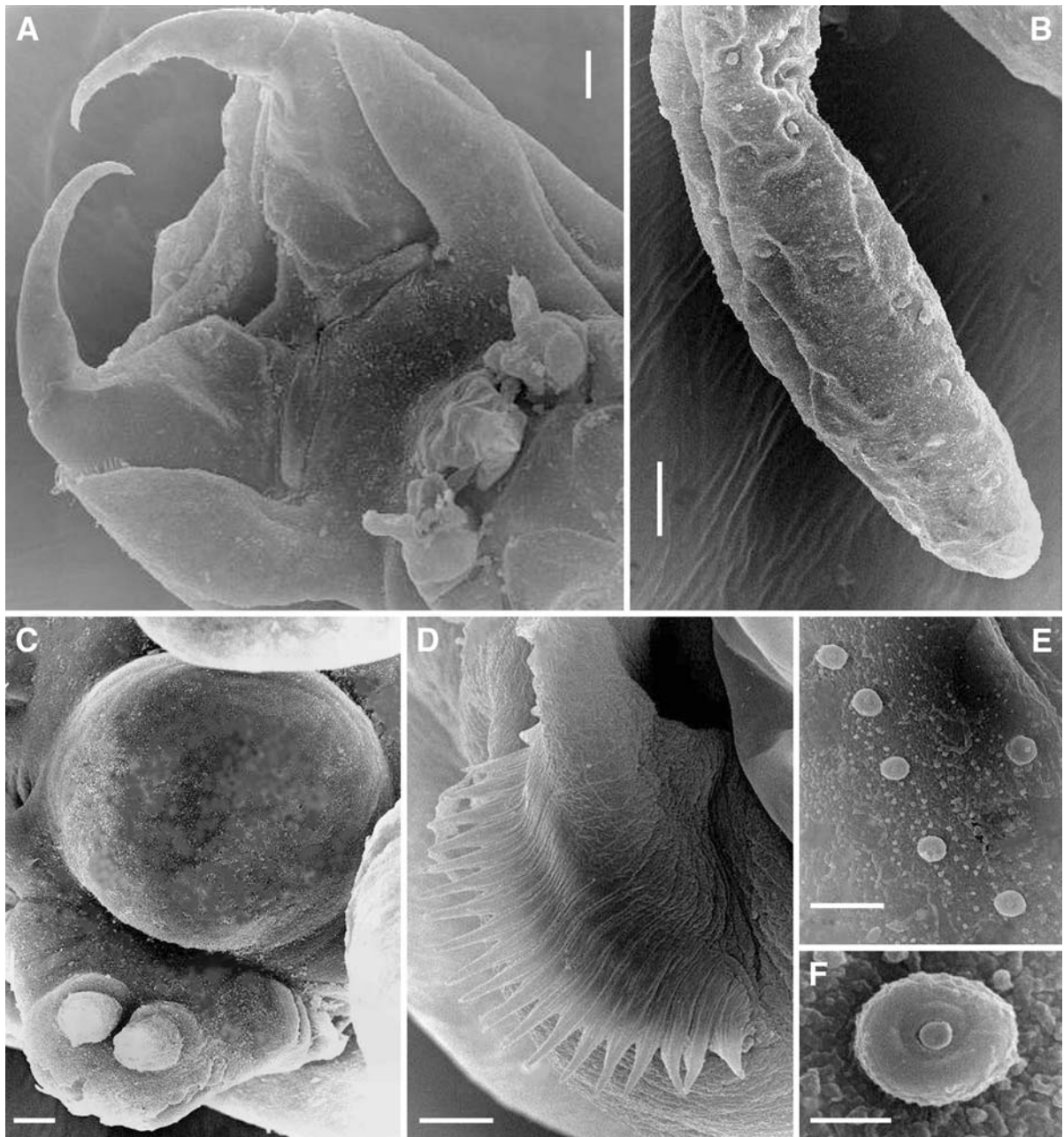
#### *Female*

Body comprising cephalothorax and trunk (Fig. 1A, B). Cephalothorax oval; anterolateral margins of cephalothorax folded downward to encircle base of antenna laterally (Fig. 2A); anterior margin of crescentic fold ornamented with semicircular array of spinules (Figs. 1C, 2D). Trunk *c.*1.4 times longer than wide, covered with dorsal plate extending posteriorly to overlap basal part of bilobed leg 4 (Fig. 1A, B); posterior margin of dorsal plate entire and evenly convex. Anterior corners of trunk produced to form conspicuous, paired, knob-like protrusions (Fig. 1A, B). Lateral margin of trunk ornamented with numerous small papillae (Fig. 1D, E). Abdomen small, with conspicuous hemispherical swelling ventrally (Fig. 2C), not clearly differentiated from genital complex, bearing caudal rami on ventral surface (Fig. 1F). Each caudal ramus armed with 2 setae and 3 spiniform setal elements (Fig. 1G).

Antennule (Fig. 3A) 5-segmented; setal formula: 4: 3: 1: 3 + ae: 8 + ae. Antenna (Fig. 3B) 3-segmented; small coxa and robust basis incompletely separated, together forming massive corpus, bearing papilliform



**Fig. 1** *Mitrapus oblongus*, female. A. Habitus, dorsal; B. habitus, ventral; C. cephalic fold with spinules around antenna; D. lateral knob on trunk; E. lateral side of trunk showing lateral papillae; F. genito-abdomen; G. caudal rami. Scale-bars: A, B, 0.5 mm; C–E, 50  $\mu$ m; F, 100  $\mu$ m; G, 25  $\mu$ m



**Fig. 2** *Mitraps oblongus*, SEM photomicrographs. A. Anterior extremity of cephalothorax of female, ventral view showing paired antennae encircled by crescent-shaped cephalic fold, plus oral cone and maxillules in situ; B, male leg 4; C, female genital complex and abdomen; D, spinule array located on internal surface of crescent-shaped fold surrounding female antenna; E, detail of ornamentation on male body surface; F, detail of ornamentation papilla. Scale-bars: A–C, 10  $\mu\text{m}$ ; D–E, 5  $\mu\text{m}$ ; F, 1  $\mu\text{m}$

process on medial surface; subchela armed with 2 small setae on surface; small bifid process present in region of arthrodial membrane in articulation between corpus and subchela. Oral cone (Fig. 3C) tapering to acute tip, housing slender mandible. Mandible as in

male (Fig. 5J), bearing 8 or 9 marginal teeth subapically. Maxillule (Fig. 3D) bilobate; smaller outer lobe (palp) tipped with unequal 2 setal elements; larger inner lobe (praecoxal arthrite) tipped with 3 unequal setal elements. Maxilla (Fig. 3E) 2-segmented,

comprising massive lacertus (syncoxa) and long brachium (basis) terminating in apical claw-like element; brachium ornamented with patch of spinules and single bifid process distally; terminal claw armed with 2 rows of sharp denticles on inner surface. Maxilliped (Fig. 4A) well developed, comprising proximal corpus ornamented with surface denticles and armed with papilliform element on medial surface; distal subchela subdivided into proximal part representing endopod and armed with single tiny spine, and distal claw.

Leg 1 biramous (Fig. 4B), with outer seta and inner spine (derived from basis) on undivided protopod; exopod broad, 1-segmented, ornamented with 4 spinules distally and 2 sensillae, armed with 5 stout spinulose spines on distal margin; endopod 1-segmented, pear-shaped, ornamented with surface spinules distally and bearing single terminal seta. Leg 2 (Fig. 4C) with outer seta on protopod, both rami 1-segmented; exopod ornamented with single sensilla plus pore and armed with 4 stout spinulose spines along distal margin; endopod tapering distally, ornamented with surface spinules and armed with delicate terminal seta (easily detached in dissected specimens). Leg 3 (Fig. 1B) large fleshy and bilobed; inner lobe extending ventrally and posteriorly; inner lobes of members of leg pair fused posteriorly in mid-line; outer lobes extend posteriorly, visible lateral to margin of dorsal plate of trunk (in dorsal view); leg 3 armed with outer basal seta (Fig. 4D). Leg 4 (Figs. 1A, B, 4E) modified forming bilobate process; outer lobe (exopod) elongate, with outer seta at base (Fig. 4F); inner lobe (endopod) 42–52% of length of exopodal lobe. Leg 5 absent.

#### Male

Body small (Fig. 5A–C), cephalothorax large, nearly as long as trunk, broadest at mid-length, tapering anteriorly and posteriorly (Fig. 5A, B), ornamented with numerous papillae distributed over lateral surface of cephalothorax (Figs. 2E, F, 5D). Postcephalic trunk showing only traces of segmental articulations between pedigerous somites (Fig. 5A, B). Genito-abdomen small (Fig. 5B, C), fully fused in dorsal view (Fig. 5E); posterolateral margins with 2 rounded processes on each side (Fig. 5F). Caudal rami bearing 2 long setae dorsally and 3 short setae ventrally (Fig. 5F).

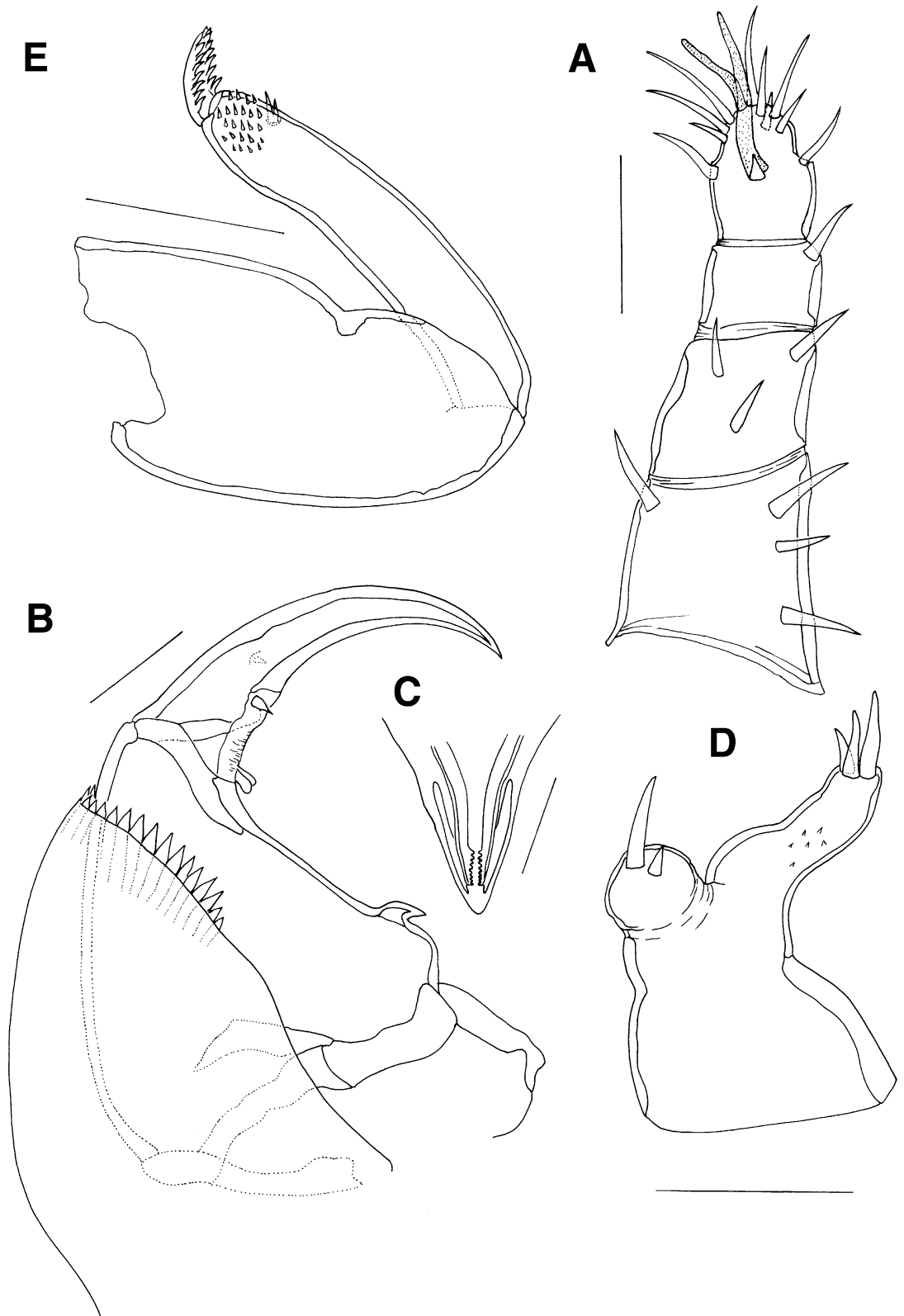
Antennule 6-segmented (Fig. 5G); setal formula: 1: 3: 3: 1: 3 + ae: 8 + ae. Antenna (Fig. 5H) subchelate,

comprising coxa and basis, bearing distal subchela. Basis armed with spine medially and ornamented with small spinules scattered over medial surface; subchela with 2 setal elements. Oral cone (Fig. 5I) tapering distally as in female, housing mandibles armed with 8 marginal teeth subapically (Fig. 5J). Maxillule (Fig. 6A), maxilla (Fig. 6B) and maxilliped as in female, except corpus of maxilliped more densely ornamented with spinules in male (Fig. 6C).

Legs 1 and 2 (Figs. 5C, 6D, E) with same basic structure and segmentation as for female, except for 2-segmented exopod of leg 2; both rami and undivided protopods of legs 1 and 2 more densely ornamented with spinules than in female. Leg 3 (Fig. 6F) reduced to fleshy, tapering lamella protruding ventrally from trunk, not extending backward; small outer seta present on protopodal part; ventral surface of leg 3 ornamented with spinules and with small papillae; tip of leg 3 with 2 small spines. Leg 4 (Fig. 6G) unilobate; outer protopodal seta present laterally at base of lobe; small spine located near mid-lateral margin of lobe; surface of leg 4 lobe ornamented with numerous papillae (Fig. 2B) similar to those found on leg 3.

#### Remarks

The family Lernanthropidae currently comprises eight genera, including *Mitrapus*, which was erected by Song & Chen (1976). The genus consists of four species parasitising hosts belonging to the families Clupeidae and Engraulidae (see Boxshall & Halsey, 2004). All known species of *Mitrapus* have thus far been recorded only from the Pacific and Indian Oceans. The type-species, *M. heteropodus* (Yü, 1933), was originally recorded from a clupeid host, *Konosirus punctatus* (Temminck & Schlegel), off China (Yü, 1933). It was subsequently recorded from the same host off Japan by Ho & Do (1985). *M. engraulis* (Tripathi, 1962) was recorded from the anchovy *Setipinna phasa* (Hamilton) in India (Tripathi, 1962) and *M. rubiginosus* (Redkar, Rangnekar & Murti, 1949) was recorded from the clupeid *Nematalosa nasus* (Bloch) off India (Redkar et al., 1949). *M. oblongus* was first recorded on the clupeid *Sardinella fimbriata* (Valenciennes) collected at Trivandrum in India (Pillai, 1964). We redescribe *M. oblongus* here from material of both sexes collected from two clupeid species, *Etrumeus teres* an immigrant



**Fig. 3** *Mitrapus oblongus*, female. A. Antennule; B. antenna surrounded with anterior cephalic fold; C. tip of mouth tube and mandibles; D. maxillule; E. maxilla. Scale-bars: A, C, 25  $\mu$ m; B, D–E, 50  $\mu$ m

species from the Red Sea, and *Sardinella aurita*, a Mediterranean species.

*M. oblongus* differs from *M. heteropodus* in the shape of the female cephalothorax and the shape of the anterolateral processes of the trunk. Most noticeably, the endopodal lobe of leg 4 is markedly shorter than the exopodal lobe in *M. heteropodus*, extending only to about 20% of the length of the exopodal lobe, whereas in *M. oblongus* it is almost half (42%–52%) its length. *M. oblongus* also differs in the ornamentation of the cephalic fold encircling the base of the antenna, which comprises a row of about 20 (19 to 22) spinules in *M. oblongus*, but at least double this number in *M. heteropodus* (see Ho & Do, 1985, fig. 80). We do not make comparisons with *M. rubiginosus* because we consider it to be indistinguishable from *M. heteropodus* – both species having similar relative lengths of the lobate rami of the female leg 4. We tentatively treat *M. rubiginosus* as a junior subjective synonym of *M. heteropodus*.

There are many minor differences in the detail of the appendages of both sexes between Pillai's (1964) description of *M. oblongus* and the present account. For example, the tip of the outer lobe of the maxillule bears two unequal setal elements rather than the single seta figured by Pillai (1964, fig. 11F); the endopod of leg 2 is tipped with a single delicate seta, which was not illustrated in the original description (Pillai, 1964, fig. 11K); and the caudal rami have two long setae and three smaller setae instead of the four setae shown by Pillai (1964, fig. 11L). All of these differences are minor and probably reflect the state of the material studied by Pillai. We found that the seta on the tip of the endopod of leg 2, for example, is easily detached or broken during handling.

The male of *M. oblongus* was briefly described by Pillai (1964), but this is the first detailed description of the appendages of the male. Most of the appendages resemble those of the female, except for the antennules and legs 2, 3 and 4. In the male, the antennule comprises six segments, with the first two equivalent to the compound proximal segment of the female. The exopod of leg 2 is 2-segmented in the male, and the first segment is small and unarmed but well sclerotised. Leg 3 is represented by a triangular lamella covered with

numerous small papillae and tipped with two vestigial spines. Leg 4 is represented by a single lobe, probably derived from the exopod since it bears an outer margin setal element. As the male grows the posterior part of the trunk and the rounded ventrolateral process become more differentiated.

*M. oblongus* was recorded during the present study on two species of clupeid hosts collected from coastal waters off Alexandria. Its body size in specimens recovered from *E. teres* and from *S. aurita* is smaller than that of the Indian material:

Host	Locality	Female body length	Male body length
<i>Sardinella fimbriata</i>	India*	2.3 mm (2.9–3.2 mm)	1.2 mm (0.86 mm)
<i>Etrumeus teres</i>	Alexandria	1.55–2.22 mm	0.62–0.86 mm
<i>Sardinella aurita</i>	Alexandria	1.44–2.24 mm	0.55–0.84 mm

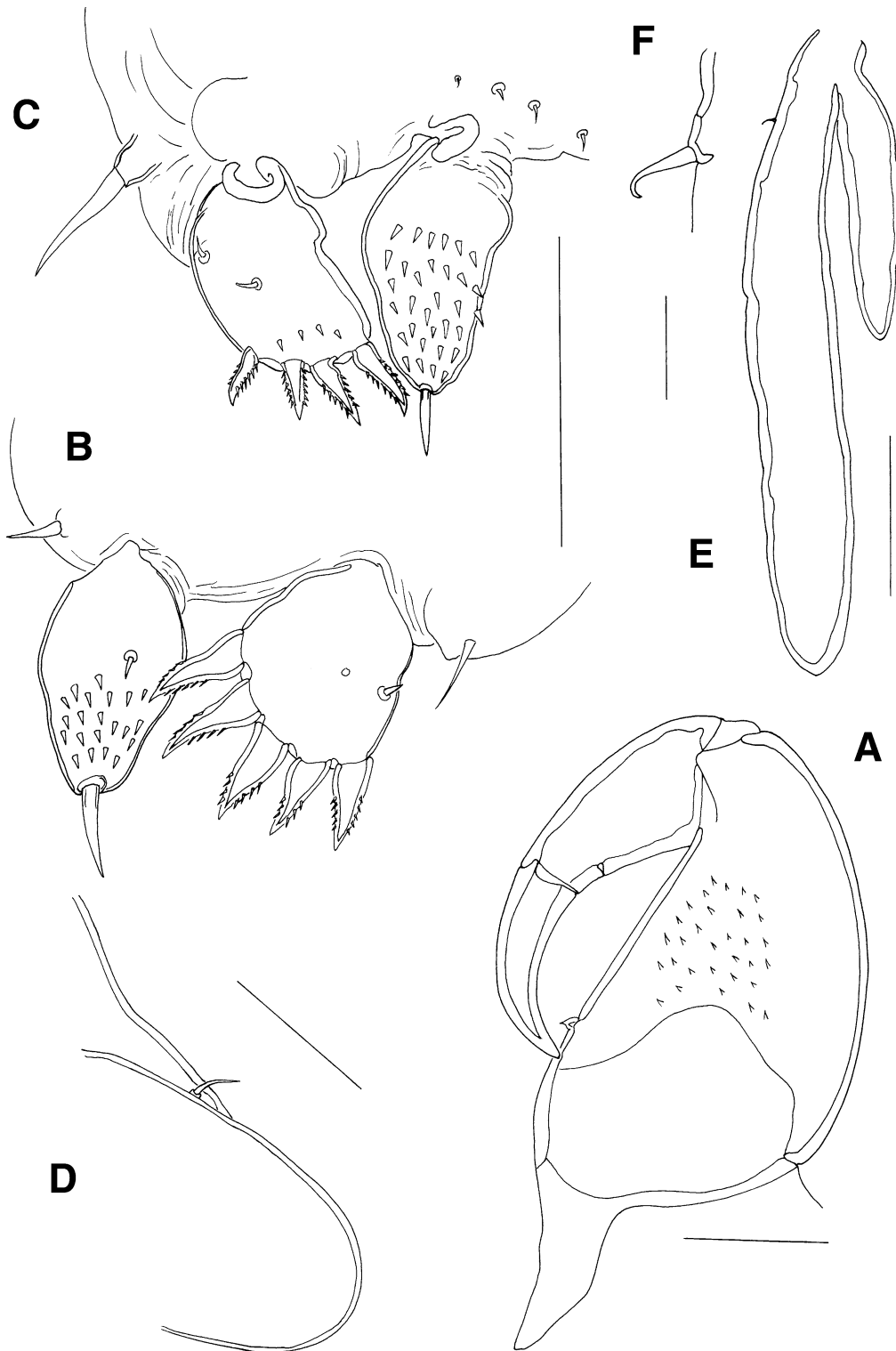
\* The size of the female and the male are as cited in the text of Pillai (1964), but the measurements given in parentheses exclude leg 4 and are based on calculations from Pillai's figure 11 using the scale-bar.

The prevalence of *Mitrapus* on *E. teres* was 62%, whereas on *S. aurita* it was only 23.3% (El-Rashidy & Boxshall, 2009). *Mitrapus* parasitises several clupeid and engraulid hosts in the Pacific and Indian Oceans and is host-specific for these families. *E. teres* is an immigrant species from the Red Sea into the Mediterranean Sea. The presence of *M. oblongus* on *E. teres* indicates that its distributional range has expanded to include the Eastern Mediterranean Sea because of dispersal on its clupeid hosts from the Red Sea, as they co-invaded the Mediterranean through the Suez Canal. The occurrence of *M. oblongus* on *S. aurita*, which is a Mediterranean clupeid species, suggests that *Mitrapus* was able not only to acclimatise to the Mediterranean but also succeeded in colonising a new Mediterranean clupeid host, although with a lower prevalence than for its Red Sea host (El-Rashidy & Boxshall, 2009).

#### Family Lernaepodidae Milne Edwards, 1840 Genus *Clavellisa* Wilson, 1915

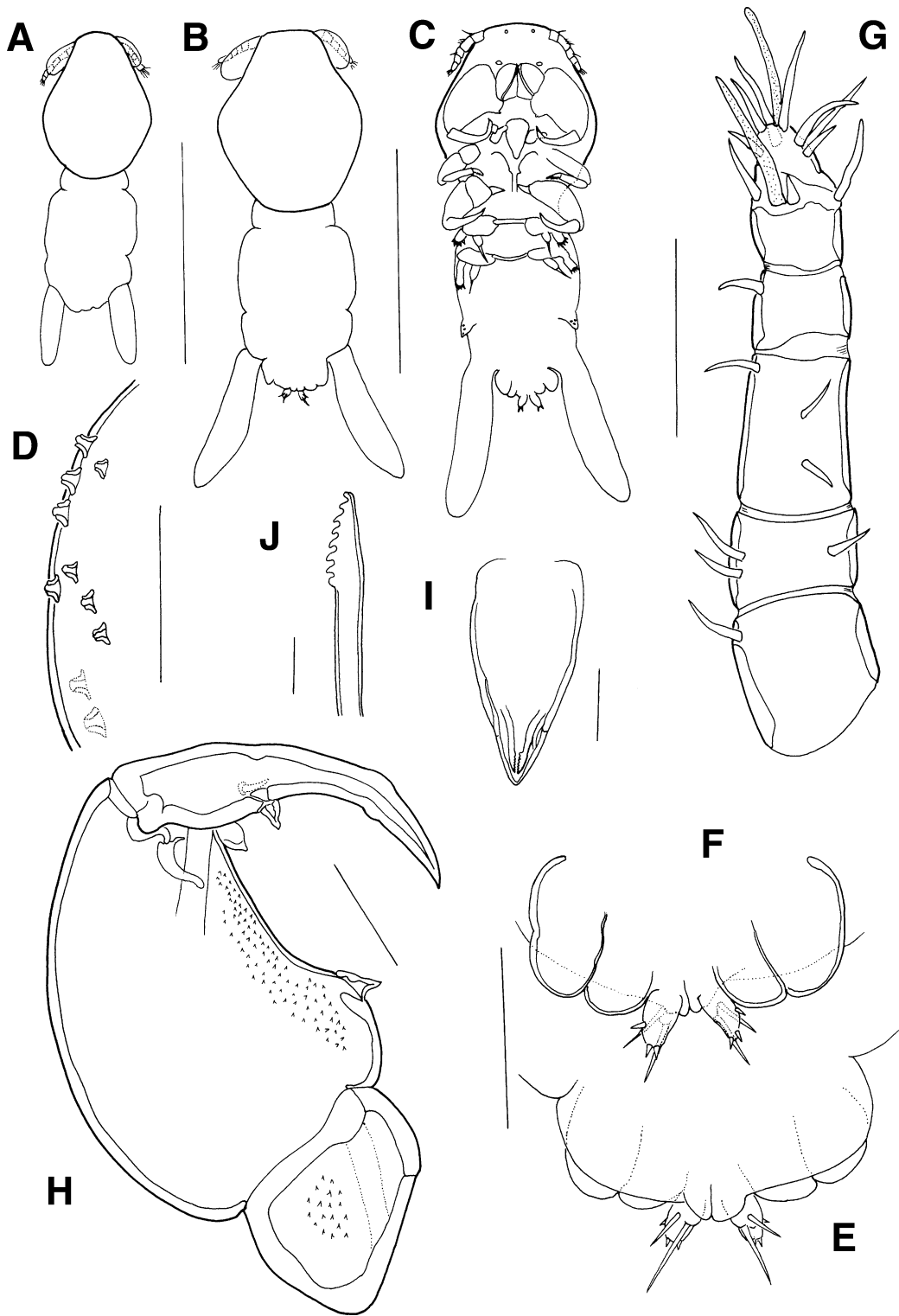
##### *Clavellisa ilishae* Pillai, 1962

Syns *Clavellisa hilsae* Tripathi, 1962, *C. cf. ilishae* of Kensley & Grindley (1973)

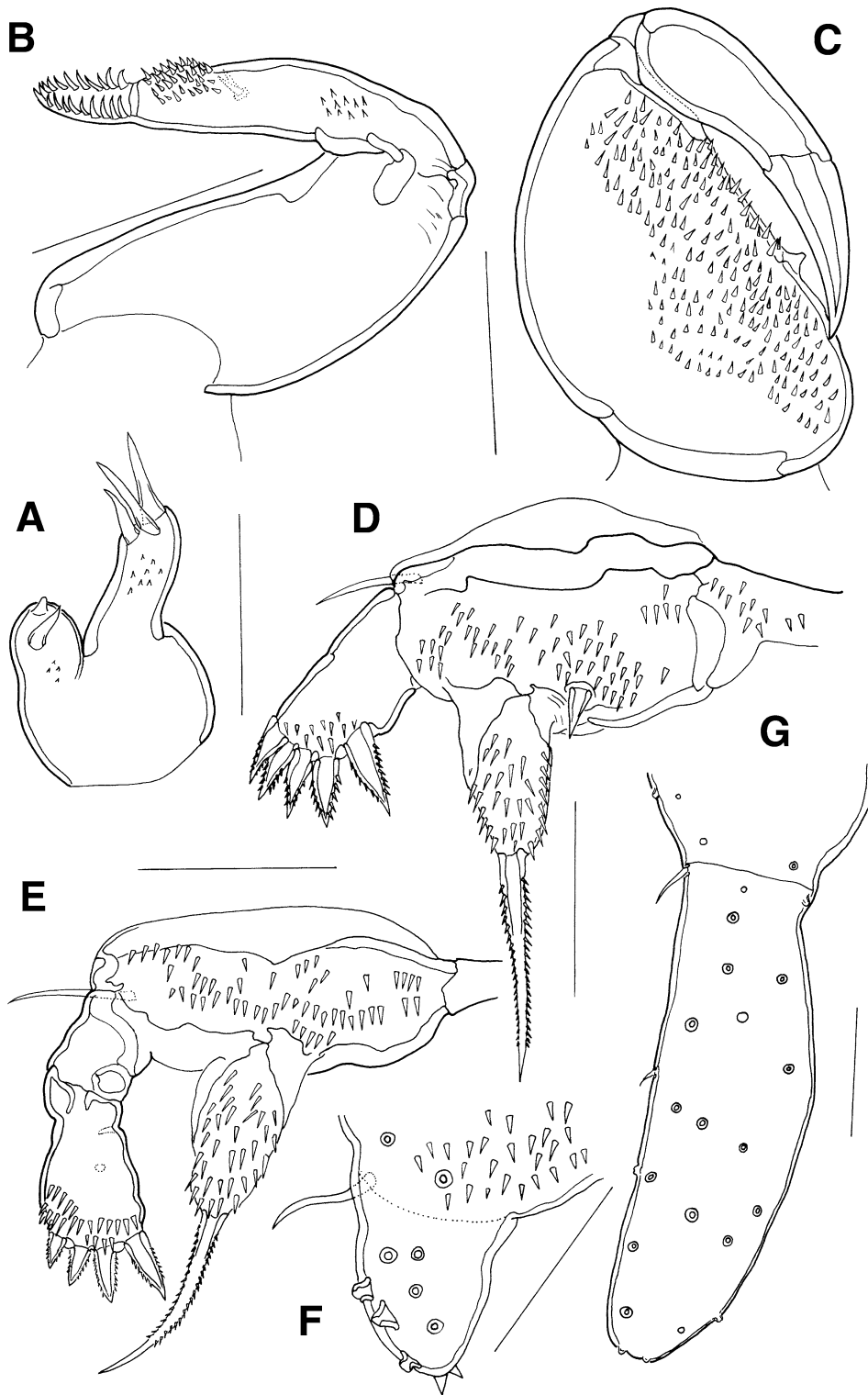


**Fig. 4** *Mitrapus oblongus*, female. A. Maxilliped; B. leg 1; C. leg 2; D. basal seta of leg 3; E. leg 4; F. lateral seta on exopod of leg 4. Scale-bars: A–C, 50  $\mu$ m, D, 100  $\mu$ m; E, 0.5 mm; F, 25  $\mu$ m





**Fig. 5** *Mitrapus oblongus*, male. A. Habitus of small male, dorsal; B. habitus of large male, dorsal; C. habitus ventral; D. lateral side of cephalothorax showing papillae; E. genito-abdomen, dorsal; F. genito-abdomen, ventral; G. antennule; H. antenna; I. mouth tube; J. mandible. Scale-bars: A–C, 0.5 mm; D, G–H, 50  $\mu$ m; E–F, 100  $\mu$ m; I, 25  $\mu$ m; J, 10  $\mu$ m



**Fig. 6** *Mitrapus oblongus*, male. A. Maxillule; B. maxilla; C. maxilliped; D. leg 1; E. leg 2; F. leg 3; G. leg 4. Scale-bars: 50  $\mu$ m

**Material examined:** 10 ♀♀ from gill-rakers of *Sardinella aurita* Valenciennes caught off Alexandria, Egypt. 8 ♀♀ deposited in the Natural History Museum, London, BMNH Reg. Nos 2009.225–232; remaining material deposited in the collection of the first author.

## Description (Figs. 7, 8)

### Female

Body (Fig. 7A) comprising ovoid trunk incorporating genito-abdomen and elongate cephalothorax, attached by means of short maxillary arms. Cephalothorax subcylindrical, considerably longer (2.0–2.8 mm) than trunk, distally carrying small dorsal cephalothoracic shield ornamented with marginal sensillae (Fig. 7B). Trunk unsegmented, ovoid (Fig. 7C), broader (0.73–1.08 mm) than long (0.50–0.72 mm), with evenly rounded lateral margins, bearing short maxillary arms. Posterior margin of trunk straight, bearing paired anal laminae, flanked by small caudal rami, each tipped with single seta (Fig. 7D).

Antennule (Fig. 8A) short, distinctly 3-segmented; basal segment slightly inflated, about as long as middle segment; basal and middle segments each armed with distal seta; apical segment armed with 8 terminal setal elements. Antenna (Fig. 8B) biramous, comprising large, unarmed protopod bearing 1-segmented, inflated exopodal lobe armed with 2 stout, curved, outer terminal setae; endopodal lobe armed with 2 setae and blunt digitiform element. Mandible small, with subapical marginal teeth as (Fig. 8C). Maxillule bilobed (Fig. 8D); large inner lobe (praecoxal arthritis) bearing 3 unequal setae, each with swollen papillate base; outer lobe (palp) small, with convex dorsal margin, bearing 2 setae. Maxilla (Fig. 7E) forming arms serving as primary attachment organ; each maxillary arm very short, tapering and closely opposed to opposite member, but apparently not fused; bulla ovoid. Maxilliped (Fig. 8E) short, comprising unarmed coxa; massive corpus (basis) bearing small inflated process on medial margin; subchela curved, tapering distally, armed with long seta proximally; concave inner margin ornamented with row of small spinules; claw with accessory barb, nearly as long as claw.

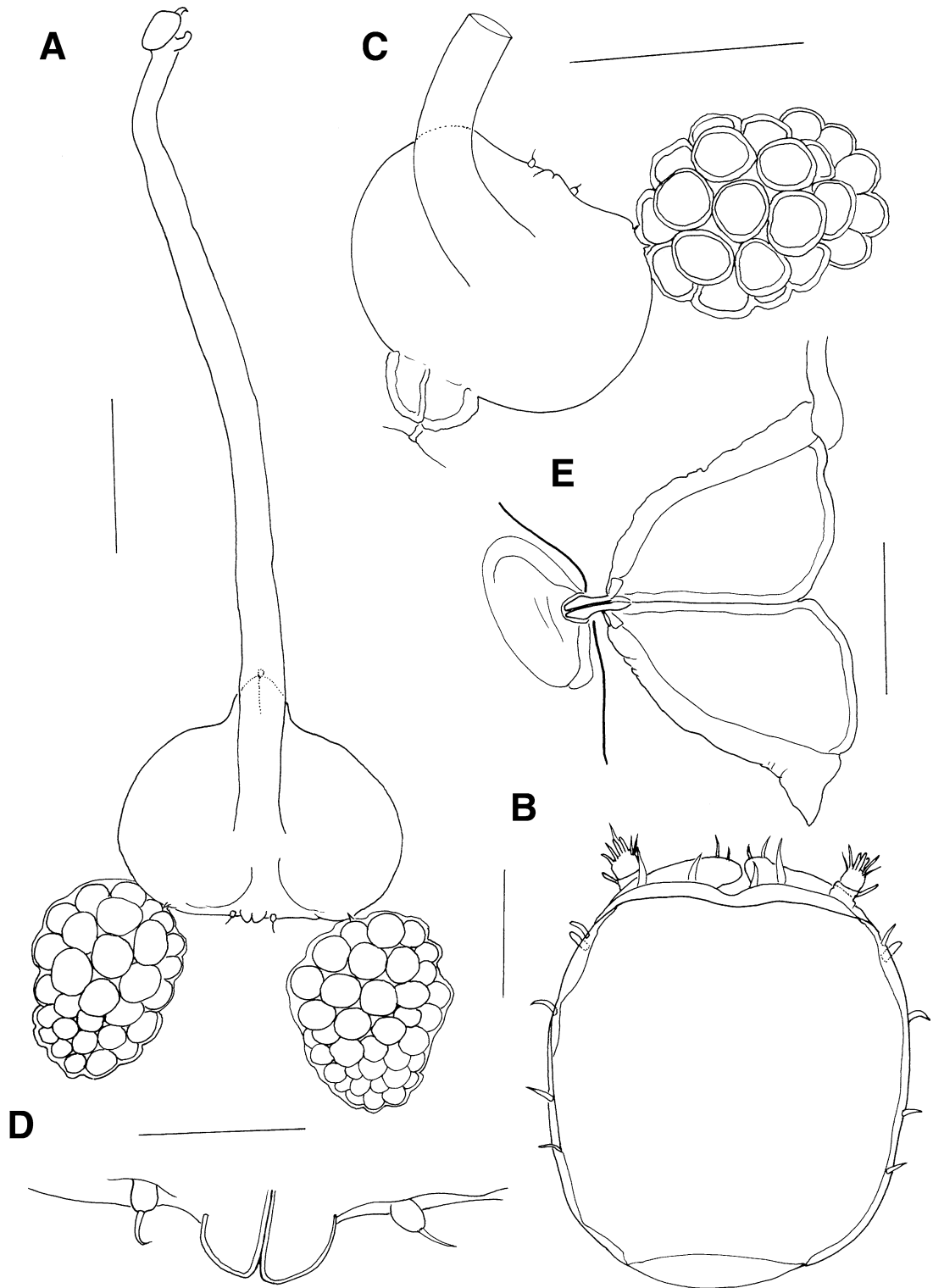
## Remarks

The Lernaepodidae is a large and diverse family, currently comprising 48 genera including *Clavellisa* Wilson, 1915, which consists of 12 nominal species (Boxshall & Halsey, 2004). Many species of *Clavellisa* are associated with clupeiform fishes, particularly from Indian waters, including: *C. ilishae* [hosts: *Ilisha filigera* (Valenciennes) and *I. melastoma* (Bloch & Schneider) – as *Euplatygaster indica* (Swainson) and *Tenualosa ilisha* (Hamilton)], *C. obcordata* Rangnekar, 1957 [host: *Nematalosa nasus* (Bloch)], *C. pellone* Tripathi, 1962 [hosts: *Ilisha filigera* and *I. melastoma* – as *Euplatygaster indica*] and *C. phasa* Tripathi, 1962 [hosts: *Coilia dussumieri* Valenciennes and *Setipinna phasa* (Hamilton)] (see Kabata, 1979).

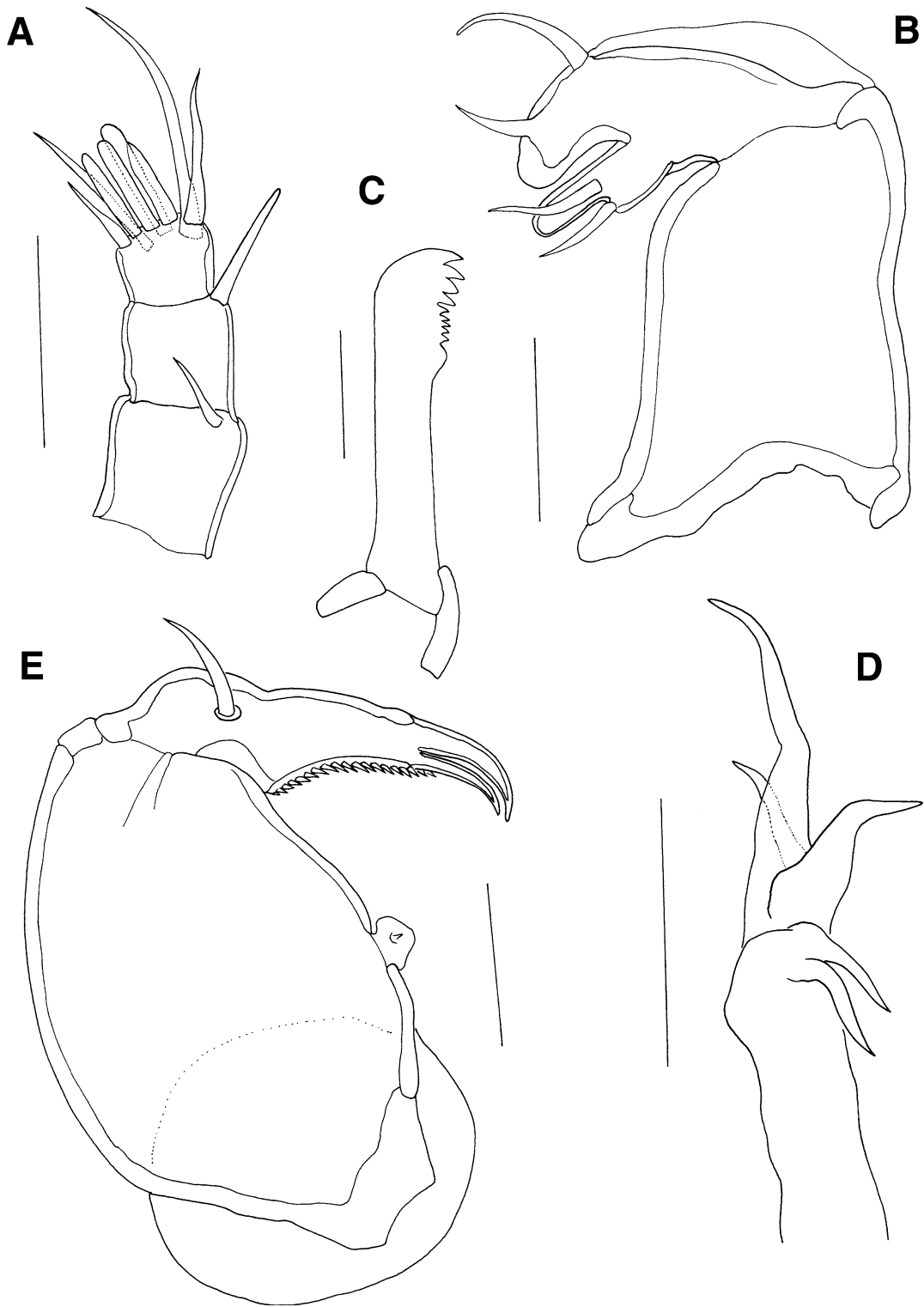
The synonymy of *C. ilishae* and *C. hilsae* Tripathi, 1962 was suggested by Kabata (1979) and accepted by Pillai (1985), who noted that *C. ilishae* and *C. hilsae* are ‘the same’. Pillai (1985, p. 794) used the name *C. hilsae* but stated that ‘Regarding priority no firm decision can be taken until the actual date of publication of the works of Pillai and Tripathi is ascertained’. According to the carefully researched bibliography of Vervoort (1986), the description of *C. ilishae* by Pillai was published in April 1962 and this takes priority over Tripathi’s name for the same taxon, *C. hilsae*, which was published in July 1962.

Another two of the four species reported and described from Indian fishes by Pillai (1962) have been re-identified: the material identified as *C. emarginata* (Krøyer, 1837) from *Thryssa malabarica* (Bloch) is now re-identified as *C. obcordata* (see Pillai, 1985) and *C. cordata* Wilson, 1915 [from *Ariomma indica* (Day)] is now considered as a probable synonym of *C. pellone* (see Kabata, 1979; Pillai, 1985). Pillai’s (1962) report of *C. dussumieriae* Gnanamuthu, 1947 (from *Dussumieria elopsoides* Bleeker) still stands.

Two species of *Clavellisa* are known from Mediterranean fishes (Raibaut et al., 1998): *C. emarginata* and *C. scombri* (Kurz, 1877). According to Kabata (1979), the former occurs on fishes of the genus *Alosa* Linck and related genera, such as *Caspialosa* Berg and *Clupeonella* Kessler. It also has a distinctive trapezoidal trunk which is longer than wide and can be readily distinguished from our new material. *C. scombri* has been recorded from the Mediterranean



**Fig. 7** *Clavellisa ilishae*, female. A. Habitus; B. cephalic shield, dorsal; C. trunk, dorsal; D. anal laminae; E. maxillae attached to bulla. Scale-bars: A, C, 0.5 mm; B, D–E, 100  $\mu$ m



**Fig. 8** *Clavellisa ilishae*, female. A. Antennule; B. antenna; C. mandible; D. maxillule; E. maxilliped. Scale-bars: A–B, D–E, 50  $\mu$ m; C, 10  $\mu$ m

Sea on *Scomber japonicus* Houttuyn, *S. colias* Gmelin and *S. scombrus* Linnaeus (see Kabata, 1979; Benmansour, 1995; Raibaut et al., 1998). According to Kabata (1979), it lacks caudal rami on the posterior margin of the trunk. It also differs from our material in the shape and size of the setae on the outer lobe of the maxillule – the two recurved setae are relatively larger than those on the outer lobe of *C. scombri*. The exopod of the antenna of the present species is armed with two stout curved setae, whereas two short conical papilliform processes are present on the exopod of *C. scombri*. We conclude that our material from *Sardinella aurita* represents a species not previously found in the Mediterranean and we identified it as *C. ilishae* Pillai, 1962 which we recognise as the senior synonym of *C. hilsae* Tripathi, 1962.

*Clavellisa ilishae* closely resembles *C. dussumieriae*, which was originally reported from Indian waters and the parasites reported as *C. cf. ilishae* from *Sardinops sagax* (Jenyns) collected in False Bay, South Africa (Kensley & Grindley, 1973). Our material has a laterally rounded trunk, whereas *C. dussumieriae* has angular lateral margins to the trunk (Pillai, 1962), and there are other differences in the armature of the maxillule and in the setation of the caudal rami. The posterior margin of the trunk has anal laminae, flanked by small caudal rami, each tipped with a small seta, which were not mentioned for *C. cf. ilishae*, as described by Kensley & Grindley (1973). These small structures could easily have been overlooked. The dimensions of the present specimens are comparable with those given by Pillai (1962) and by Kensley & Grindley (1973):

Host	Locality	Cephalothorax	Trunk length	Trunk width
<i>Ilisha filigera</i> *	India	1.9 mm	0.6 mm	1.0 mm
<i>Sardinops sagax</i> **	South Africa	1.5–2.0 mm	–	0.80–1.0 mm
<i>Sardinella aurita</i>	Egypt	2.0–2.75 mm	0.50–0.73 mm	0.73–1.06 mm

\* Data from Pillai (1962)

\*\* Data from Kensley & Grindley (1973)

**Family Bomolochidae Sumpf, 1871**  
**Genus *Nothobomolochus* Vervoort, 1962**

***Nothobomolochus fradei* Marques, 1965**

*Material examined*: 44 ♀♀ from the gills of *Herklotsichthys punctatus* (Rüppell) and 11 ♀♀ from the gills of *Sardina pilchardus* (Walbaum), caught in coastal waters off Alexandria, Egypt. 5 ♀♀ deposited in the Natural History Museum, London, BMNH Reg. Nos 2009.233–237; remaining material in the collection of the first author.

Description (Figs. 9–11)

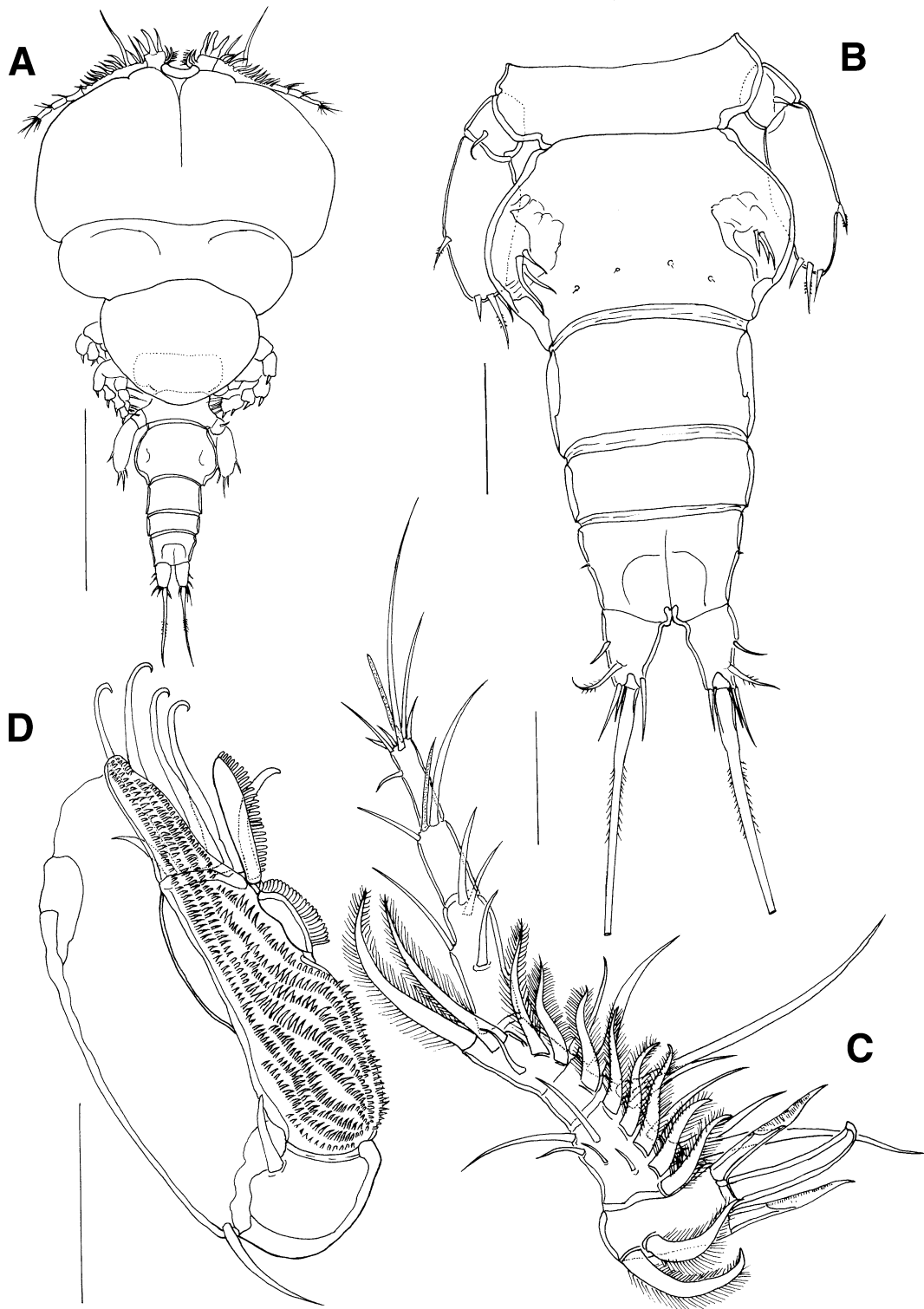
*Female*

Body (Fig. 9A) 1.41 mm (1.38–1.52 mm) in length; prosome 0.92 mm long and 0.89 mm (0.80–0.89 mm) maximum width, comprising broad cephalothorax, free second pedigerous somite, free third pedigerous somite with large tergite completely concealing fourth pedigerous somite in dorsal view (Fig. 9A), and fourth pedigerous somite. Urosome (Fig. 9B) 0.54 mm long, comprising fifth pedigerous somite, genital double-somite and 3 free abdominal somites. All urosomites wider than long; second free abdominal somite shortest; anal somite not ornamented with spinules ventrally, deeply incised dorsally and bearing paired sensillae laterally. Caudal rami (Fig. 9B) longer than width at base, tapering, bearing single principal seta plus 5 small setae.

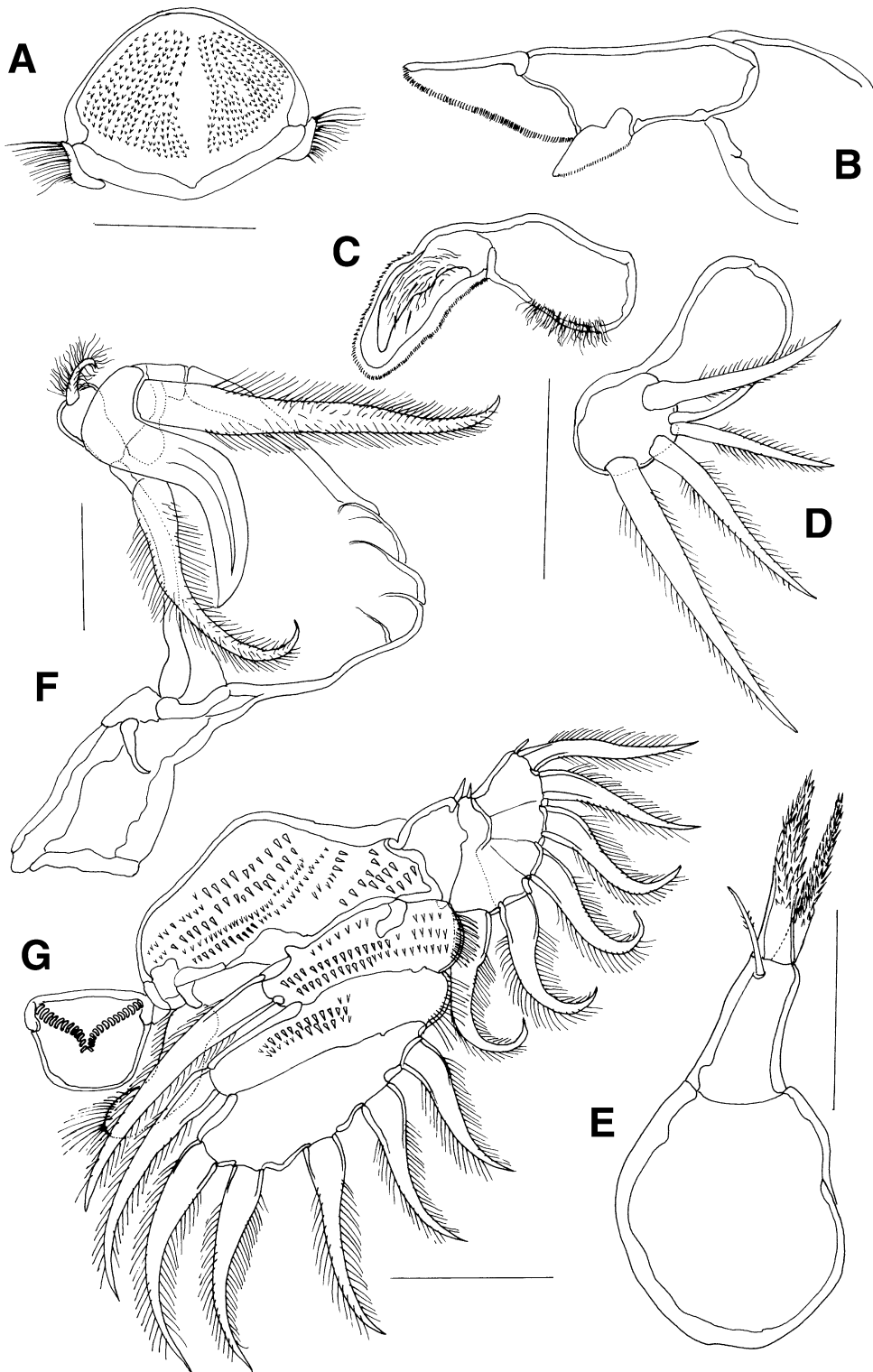
Antennule (Fig. 9C) with heavily sclerotised proximal part comprising 4 segments; first segment bearing 2 plumose setae plus 3 subequal, modified setae on pedestal; second to fourth segments carrying total of 10 stout plumose setae and 13 slender setae of different sizes; terminal part of antennule 3-segmented with setal formula: 4: 2 + 1 ae: 7 + 1 ae.

Antenna (Fig. 9D) uniramous, 3-segmented; comprising long proximal segment (coxobasis) bearing single seta, short first endopodal segment armed with one seta, and compound apical segment bearing blunt process distally plus 2 pectinate processes medially and posterior claw-like element; distal armature comprising 4 curved hooks and single small seta; ventral surface of segment and distal process ornamented with numerous rows of spinules.

Labrum (Fig. 10A) entire, ornamented with patches of spinules on ventral surface and with patches of long setules on each side. Mandible (Fig. 10B) bearing 2 unequal unilaterally-spinulate blades. Paragnath

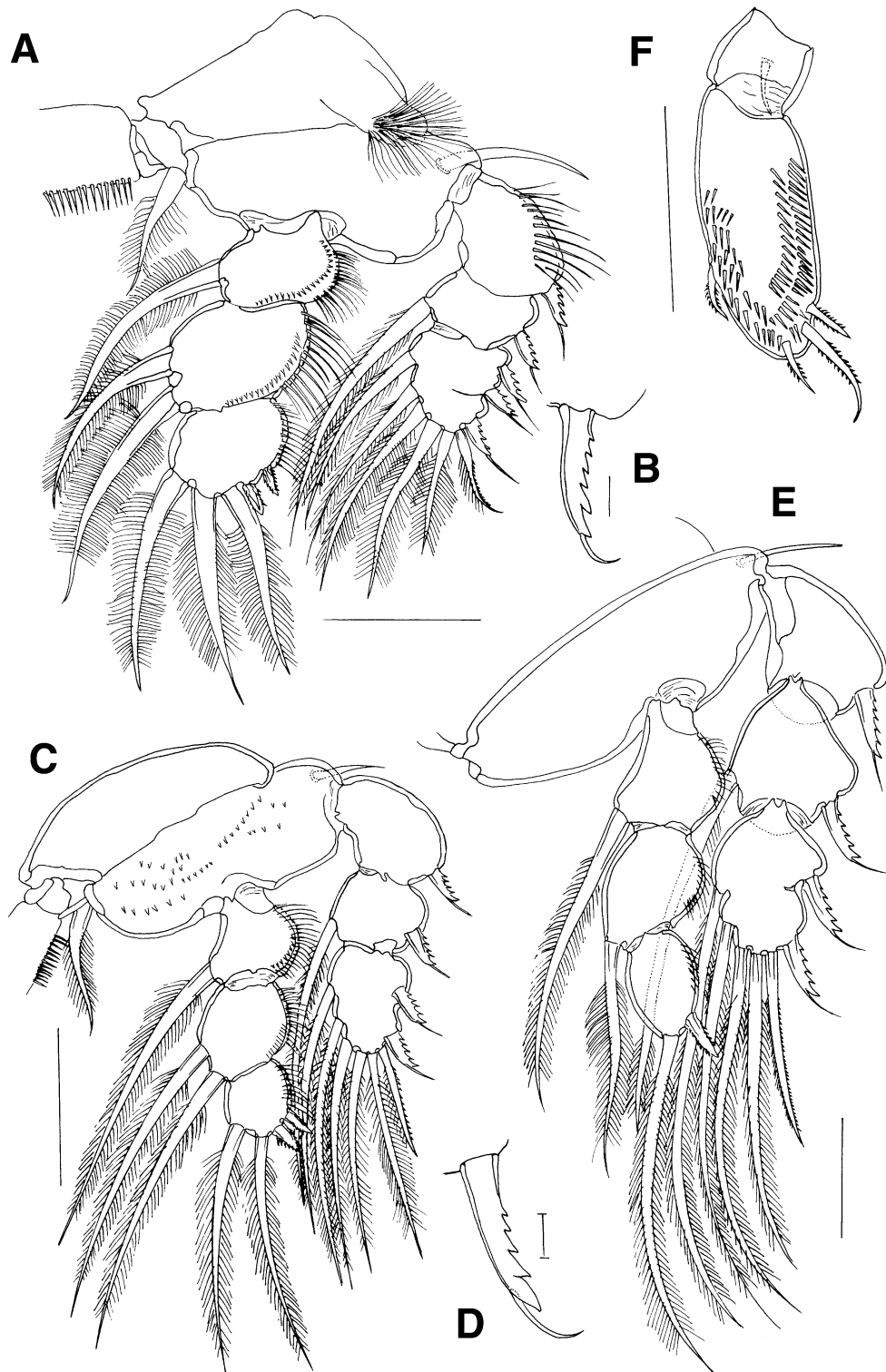


**Fig. 9** *Nothobomolochus fradei*, female. A. Habitus, dorsal; B. urosome, dorsal; C. antennule; D. antenna. Scale-bars: A, 0.5 mm; B–C, 100  $\mu$ m; D, 50  $\mu$ m



**Fig. 10** *Nothobomolochus fradei*, female. A. Labrum; B. mandible; C. paragnath; D. maxillule; E. maxilla; F. maxilliped; G. leg 1. Scale-bars: A, G, 100  $\mu$ m; B–F, 50  $\mu$ m





**Fig. 11** *Nothobomolochus fradei*, female. A. Leg 2; B. outer spine on exopod leg 2; C. leg 3; D. outer spine on exopod of leg 3; E. leg 4; F. leg 5. Scale-bars: A, C, F, 100  $\mu\text{m}$ ; E, 50  $\mu\text{m}$ ; B, D, 10  $\mu\text{m}$

(Fig. 10C) forming long blunt process fringed distally with short spinules and basally with long setules. Maxillule (Fig. 10D) forming rounded lobe bearing 4 unequal plumose setae. Maxilla (Fig. 10E) 2-segmented; proximal syncoxa large, unarmed; basis tapering, terminating in spinulate apical process bearing accessory process and spinulate seta. Maxilliped (Fig. 10F) comprising syncoxa armed with single seta; basis armed with 2 large plumose setae; free endopodal segment incorporated into claw bearing posterior hirsute seta; convex margin of claw smooth, lacking auxiliary process.

Leg 1 (Fig. 10G) biramous, modified with flattened rami; protopod ornamented with numerous rows of surface spinules; inner seta of protopod transformed into flattened element fringed with long setules; interpodal sclerite small, slightly longer than wide, ornamented with V-shaped row of short curved spinules. Exopod incompletely 3-segmented; outer spines weakly developed and easily detached in some specimens; first segment with spine at outer distal corner; segments 2 and 3 partly fused ventrally, bearing 2 small outer spines and 6 setae in total. Endopod 3-segmented; first and second segments each with inner seta and ornamented with patch of outer setules. Legs 2 to 4 (Fig. 11A–E) biramous with 3-segmented rami; each outer spine on exopod of legs 2 to 4 with denticulate outer margin and bearing subterminal flagellum (Fig. 11B, D). Ornamentation of long setules present on outer margins of endopodal segments of legs 2 to 4. Coxa and basis of legs 2 to 4 each with outer basal seta and inner coxal seta, except coxa of leg 4 lacking inner seta. Leg 2 coxa with patch of long setules at outer distal angle; long setules also present on outer margin of first exopodal segment: interpodal plate with row of spinules posteriorly in legs 2 to 4. Armature of swimming legs as follows:

	Coxa	Basis	Exopod	Endopod
Leg 1	0-1	0-0	I-0; II,6	0-1; 0-1; 5
Leg 2	0-1	1-0	I-0; I-1; III,1,5	0-1; 0-2; II,3
Leg 3	0-1	1-0	I-0; I-1; II,1,5	0-1; 0-2; II,2
Leg 4	0-0	1-0	I-0; I-1; II,1,4	0-1; 0-1; I,1

Leg 5 (Fig. 11F) 2-segmented; protopodal segment small, armed with outer seta; distal segment (exopod) ornamented with rows of spinules, armed with small lateral seta and 3 spinulate terminal setae. Leg 6

(Fig. 9B) represented by 3 short setae located in egg-sac attachment area.

#### Remarks

The family Bomolochidae currently comprises 19 genera (Boxshall & Halsey, 2004; Ho & Lin, 2006), the largest of which is *Nothobomolochus* Vervoort, 1962 containing 32 species (Ho & Lin, 2005), many of which parasitise clupeid hosts (see Boxshall & Halsey, 2004). According to Raibaut et al. (1998) *Nothobomolochus* is represented in the Mediterranean by only two species: *N. cornutus* (Claus, 1864) recorded on a range of host species including *Sardina pilchardus* (Walbaum), *Scomberesox saurus saurus* (Walbaum), *Hirundichthys rondeleti* (Valenciennes) and *Luvarus imperialis* Rafinesque; and *N. scomberesocis* (Krøyer, 1864) recorded from *S. saurus saurus*. The Egyptian material of *Nothobomolochus* differs from both of these species, and from the majority of its congeners, by the presence of only one spine and one seta on the terminal endopodal segment of leg 4. Only four species in the genus share this characteristic: *N. lateolabracis* (Yamaguti & Yamasu, 1959), *N. fradei*, *N. saxagi* Avdeev, 1986 and *N. lizae* Ho & Lin, 2005.

*N. lateolabracis*, *N. lizae* and *N. saxagi* all have an armature formula of III, I, 5 on the distal exopodal segment of leg 2, whereas Marques' figure of *N. fradei* shows a formula of II, I, 5 (Marques, 1965, fig. 3b). However in the text, Marques (1965) gives the formula as IV + 5 for this segment. We consider it likely that the illustrated specimen was incomplete and we are assuming the text is correct. So we suspect that the four species cannot be distinguished on the leg 2 exopodal setation. The armature formula for the distal exopodal segment of leg 4 is II, I, 5 in *N. saxagi*, compared with II, I, 4 in *N. lizae*, *N. fradei* and *N. lateolabracis*. *N. lizae* can be distinguished by the presence of a conspicuous auxiliary hook on the outer margin of the claw on the female maxilliped. In *N. lateolabracis* the claw has only a tiny auxiliary process, whereas *N. fradei* lacks any process on the claw. These latter two species also differ in the setation of leg 5; in the former the longest setae is about as long as the exopodal segment, whereas in *N. fradei* it is only half the length of the segment.

Comparison between the material collected from *H. punctatus* and *S. pilchardus* off Alexandria with

the description of *N. fradei* given by Marques (1965) from *Sardinella maderensis* (Lowe) collected from off Sao Tome in the Gulf of Guinea suggests that they are conspecific. The tergite of the third pedigerous somite extends posteriorly to completely cover the fourth pedigerous somite dorsally (as shown in Marques, 1965, fig. 2e). The outer spines on the exopod of legs 2 to 4 are ornamented with five or six conspicuous outer margin denticles. The outer spines on the exopod of leg 1 are small, delicate and weakly developed, and are easily detached. This is probably the explanation for their absence from Marques' figure (1965, fig. 2d). The hirsute seta located posterior to the claw of the maxilliped was overlooked in the original description (Marques, 1965). The material collected from Egyptian waters is slightly smaller and wider than the specimens collected from the Gulf of Guinea.

Host	Locality	Body length	Width
<i>Sardinella maderensis</i>	Gulf of Guinea	1.68 mm	0.65 mm
<i>Herklotsichthys punctatus</i>	Alexandria, Egypt	1.36–1.49 mm	0.80–0.89 mm
<i>Sardina pilchardus</i>	Alexandria, Egypt	1.16–1.43 mm	0.60–0.78 mm

The prevalence of *Nothobomolochus* on the Red Sea immigrant host *H. punctatus* was 85%, whereas its prevalence on the native Mediterranean host *S. pilchardus* was only 9.8% (El-Rashidy & Boxshall, 2009).

The original host of *N. fradei* was *Sardinella maderensis* (Marques, 1965), a species with a range extending northwards from the Gulf of Guinea into the Mediterranean Basin (Froese & Pauly, 2009). However, *N. fradei* has not previously been reported from this host in the Mediterranean (Raibaut et al., 1998). *N. fradei* was reported from the Arabian Gulf by Ho & Sey (1996) on an atherinid host *Atherinomorax lacunosus* (Forster) (as *Allanetta forskali*). This atherinid is widely distributed in the Indo-Pacific and was first recorded in the Mediterranean in 1924 (Norman, 1927). The discovery of *N. fradei* in Mediterranean on the Erythrean immigrant *H. punctatus* was a new host record, but we are unable to determine whether colonisation of *H. punctatus* as a

host took place prior to, or after, its immigration into the Mediterranean. On the basis of its absence from the Western Mediterranean, El-Rashidy & Boxshall (2009) inferred that the presence of *N. fradei* on *S. pilchardus* off Alexandria probably resulted from a host colonisation event which took place within the Eastern Mediterranean.

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