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Species of *Caligus* Müller, 1785 (Copepoda: Caligidae) parasitic on marine fishes of Taiwan

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Abstract

Six species of copepods of the genus *Caligus* (Caligidae, Siphonostomatoida) parasitic on marine fishes of Taiwan are reported. They are: *C. absens* n. sp. from *Priacanthus blochii* and *P. macracanthus*; *C. epinepheli* Yamaguti, 1936 from *Scolopsis vosmeri*; *C. kanagurta* Pillai, 1961 from *Decapterus kurroides*; *C. laticaudus* Shiino, 1960 from *Lutjanus vitta* and *Parapristiopoma trilineatum*; *C. nengai* Rangnekar, Rangnekar & Murti, 1953 from *Triacanthus biaculeatus*; and *C. rotundigenitalis* Yü, 1933 from *Drepane punctata*, *Liza macrolepis* and *Terapon jarbua*. *C. distortus* Pillai & Natarajan, 1977 is relegated to a synonym of *C. nengai* and *C. multispinosus* Shen, 1957 reported by Lin et al. (1994) from the cultured sea bream *Acanthopagrus schlegeli* is a misidentification for *C. rotundigenitalis* Yü, 1933.

Introduction

Caligus Müller, 1785 is the largest genus of parasitic copepods, containing more than 250 species. So far, 43 species of this genus have been reported from the fishes of the Far East, but only eight of them are known from Taiwan. These eight species are: *C. acanthopagri* Lin & Ho, 1994; *C. coryphaenae* Steenstrup & Lütken, 1861; *C. epidemicus* Hewitt, 1971; *C. multispinosus* Shen, 1957; *C. orientalis* Gusev, 1951; *C. oviceps* Shiino, 1952; *C. polycanthi* Gnanamuthu, 1950; and *C. punctatus* Shiino, 1955 (= *C. chanos* Lin, 1989). This paucity of *Caligus* spp. from Taiwan is believed to be an artifact, due to the lack of systematic examination of marine fishes. The fact that six of the aforementioned eight species were reported from the cultured fish and not wild fish supports our speculation. Therefore, we examined for one year, from August, 1997 to July, 1998, the fishes landed at four fishing ports in Taiwan for parasitic copepods. We examined 2,214 fishes belonging to 63 species and recovered over 2,000 copepod parasites from 485 fishes belonging to 39 species. In this paper, we report on six species of *Caligus* obtained from ten species of fishes taken off the west coast of Taiwan.

In studying the specimens of *Caligus*, we made a close comparison with the species reported from China, Japan and Korea in addition to those from Taiwan. Unexpectedly, it was discovered that '*Caligus multispinosus* Shen, 1957' reported by Lin et al. (1994) from the sea bream *Acanthopagrus schlegeli* cultured in Taiwan is conspecific with *C. rotundigenitalis* Yü, 1933 found in China (Yü, 1933) and India (Rangnekar, 1959; Pillai & Natarajan, 1977). Since this species was recovered in our survey from three species of fishes caught in the wild, a treatment of this synonymy is included in this report.

Materials and methods

Fishes landed at the following fishing ports in Taiwan were selectively purchased from fishermen as they were being unloaded from the ships at: Sheng-Dah Fishing Port and Mi-Tuo Fishing Port in Kao-Hsiung County, Ma-Kong Fishing Port in Pescadores Islands, and Dong-Shih Fishing Port in Chiayi County. The fishes landed at each fishing port were all caught in the vicinity of the port.

The purchased fishes were kept in an ice-box and transported to the laboratory on the campus of National Chiayi Institute of Technology for examination. In the laboratory, the body surface, eyes and fins of each fish were examined first, then the nostrils, oral cavities and gill cavities. The copepod parasites were carefully removed and placed in a Petri dish filled with sea-water. After finishing the fish examination, the copepods in the Petri dish were examined under the dissection microscope and fish mucus and debris removed with a pair of fine point forceps. Then, the cleaned parasites were transferred to another Petri dish filled with 70% alcohol and left there for overnight before being placed in a vial for storage (in 70% alcohol).

To make a complete microscopical study of the parasitic copepods, the preserved specimens were cleared in 85% lactic acid for 1 to 2 hrs before taking measurements and making dissection in a drop of lactic acid. The removed body parts and appendages were examined under the compound microscope with a series of magnification up to × 1,500. All drawings were made with the aid of a camera lucida. The terminology for the armature of leg 1 exopod follows that employed by Kabata (1988).

***Caligus absens* n. sp.** (Figures 1–3)

Material examined: 3 ♀♀ and 2 ♂♂ from wall of gill cavities of 3 *Priacanthus bochi* Bleeker landed at Sheng-Dah Fishing Port on 11 September, 1997; 5 ♀♀, 5 ♂♂ and 4 chalimus from wall of gill cavities of 9 *Priacanthus macracanthus* Cuvier landed at same fishing port on 23 October 1997. Holotype (USNM 230429), allotype (USNM 230430) and 8 paratypes (USNM 230431; 4 ♀♀ and 4 ♂♂) deposited in the National Museum of Natural History, Smithsonian Institution, Washington, DC.

Etymology: The species name *absens* is a Latin for "absent". It alludes to the lack of sternal furca in this species.

Description

Female

Body (Figure 1A) 3.27 (3.08–3.52) mm long, excluding setae on caudal rami. Cehalothoracic shield 1.63 (1.52–1.70) mm long and 1.42 (1.34–1.48) mm wide, excluding lateral hyaline membranes. Lunules (Figure 1B) 279 μm wide; distance between lunules only slightly longer than their diameters. Genital complex trapezoidal, 0.99 (0.98–1.00) mm long and 1.05 (1.02–1.08) mm wide. Abdomen longer than wide (0.64 × 0.28 mm) and indistinctly 2-segmented, with much longer anterior somite. Strip of membrane on ventral surface of distal abdominal segment (Figure 3B). Caudal ramus (Figure 3B) slightly longer than wide (85 × 70 μm), armed with 3 short and 3 long plumose setae. Egg-sac about one-half of body length, containing c. 20 eggs.

Antennule (Figure 1C) 2-segmented; proximal segment with 27 plumose setae on anterodistal surface; distal segment with a subterminal seta on posterior margin and 11 setae plus 2 aesthetascs on distal margin. Antenna (Figure 1D) 3-segmented; proximal segment smallest, with short, blunt process at posteromedial corner; second segment rectangular and unarmed; distal segment a sharply pointed claw bearing 2 setae in proximal region. Postantennal process (Figure 1D) small but sharply pointed, bearing 2 basal papillae with each carrying 4 setules. Another similar papilla located nearby on sternum. Mandible (Figure 1E) with 13 teeth on medial margin of distal blade. Maxillule (Figure 1D) comprising small, conical process and papilla with 3 setae. Maxilla (Figure 1F) 2-segmented; proximal segment (lacertus) unarmed, slender; distal segment (brachium) carrying small subterminal hyaline membrane on outer edge and 2 unequal elements (calamus and canna) terminally. Maxilliped (Figure 1G) 3-segmented; proximal segment (corpus) robust, protruded on medial surface into large pointed cone; middle and distal segments fused to form strong claw carrying medial seta. Sternal furca absent.

Armature on rami of legs 1-4 as follows (Roman numeral indicating spines and Arabic numeral, setae):

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

Leg 1 (Figure 2A) protopod with long outer (anterior) seta and short inner (posterior) seta; endopod a small process tipped with 1 setule; first segment of exopod with row of setules on posterior edge; middle 2 of 4 terminal elements on last segment of exopod (Figure 2B) with pectinate tip and also bearing accessory process. Leg 2 (Figure 2C) coxa small, with large plumose seta on posterior edge; basis with small,

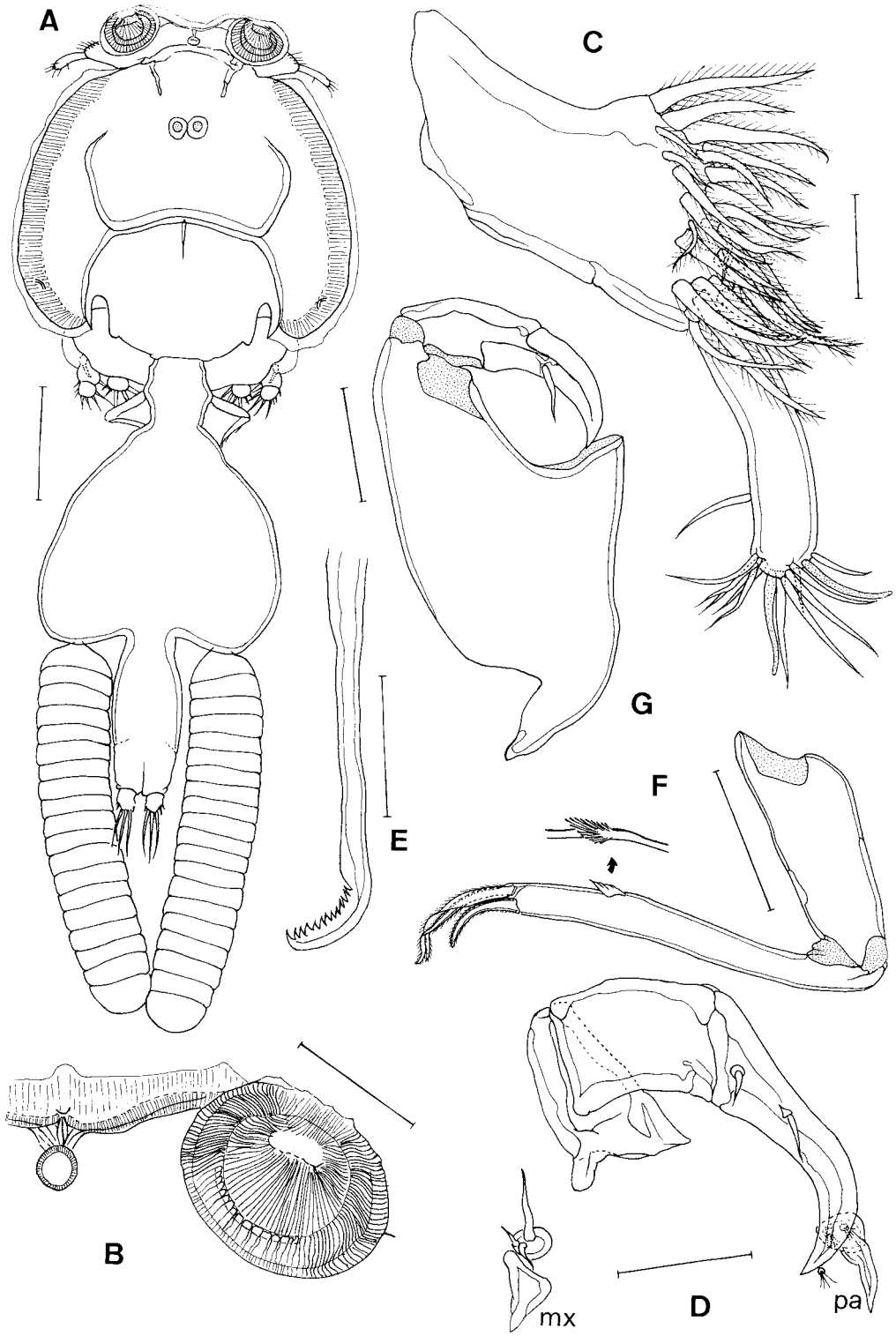

Figure 1. Caligus absens n. sp. Adult female. A. habitus, dorsal; B. frontal hyaline membrane and lunule, ventral; C. antennule, ventral; D. antenna, postantennary process (pa) and maxillule (mx); E. mandible; F. maxilla; G. maxilliped. *Scale-bars*: A, 0.5 mm; B, 0.15 mm; C,E,G, 50 μm; D, F, 0.1 mm.

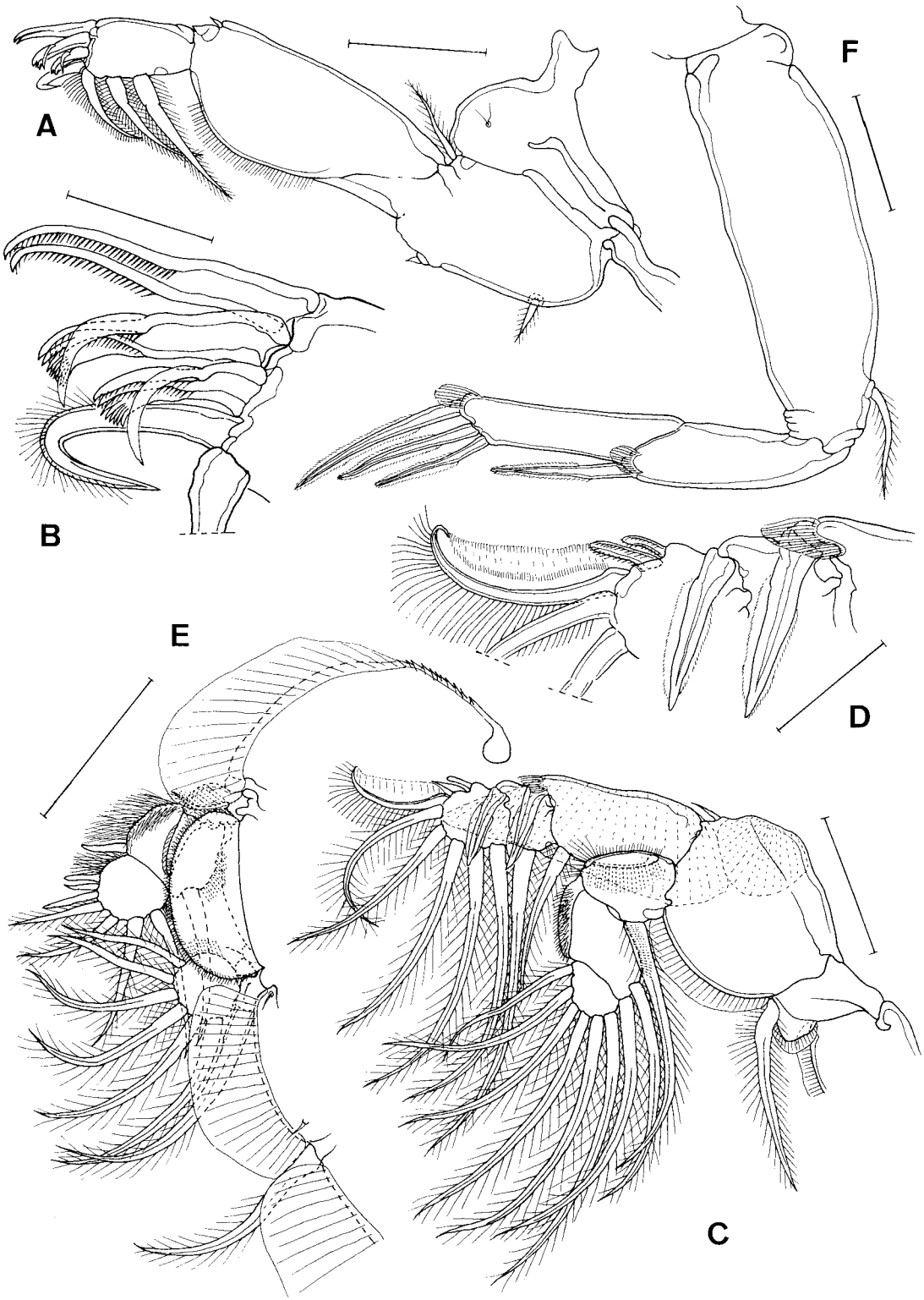

Figure 2. Caligus absens n. sp. Adult female. A. leg 1; B. tip of leg 1 exopod; C. leg 2; D. spines on outer margin of leg 2 exopod; E. leg 3, ventral; F. leg 4. *Scale-bars*: A, 0.1 mm; B, 30 μm; C,E, 0.15 mm; D, 70 μm; F, 50 μm.

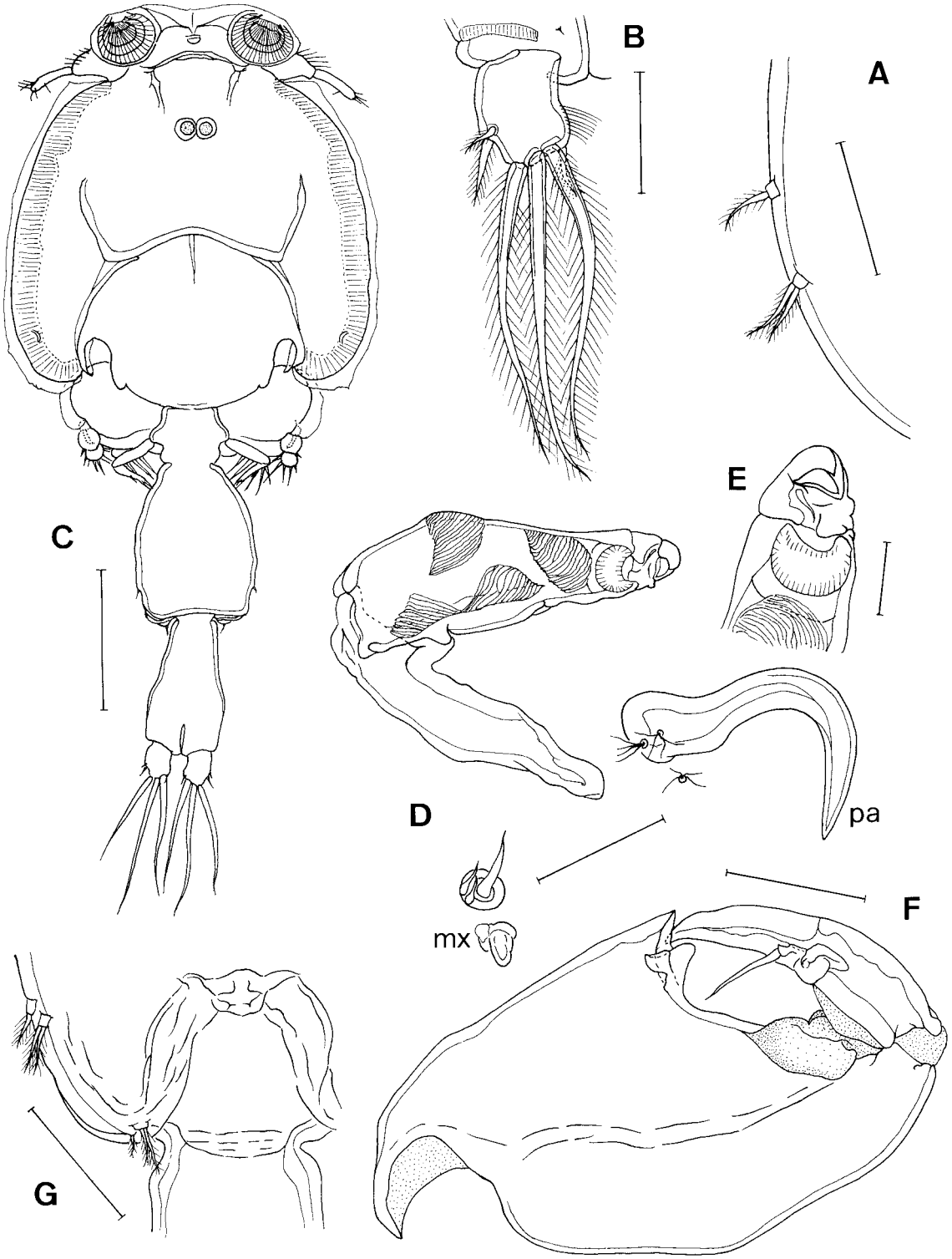

Figure 3. Caligus absens n. sp. Adult female: A. leg 5, ventral; B. caudal ramus, ventral. Adult male: C. habitus, dorsal; D. antenna, postantennary process (pa) and maxillule (mx); E. tip of antenna; F. maxilliped; G. right distal corner of genital complex, ventral. *Scale-bars*: A,B,D,F, 0.1 mm; C, 0.5 mm; E, 30 μm; G, 0.2 mm.

naked outer seta; external spines on 3 exopod segments as shown in Figure 2D; endopod first segment with row of setules on outer margin and second segment with several rows of setules on outer surface. Leg 3 (Figure 2E) protopod (apron) with row of denticles on outer edge; medial, coxal seta longer than outer, basal seta. Leg 4 (Figure 2F) protopod with long, plumose outer seta; pectens on exopod segments at insertion of first and last outer spines. Leg 5 represented by 2 small papillae on posterolateral margin of genital complex (Figure 3A), 1 tipped with small plumose seta, other with 2 similar setae.

Male

Body (Figure 3C) 2.69 (2.66–2.72) mm long. Cephalothoracic shield slightly longer than wide, 1.55 × 1.31 mm. Genital complex longer than wide, 0.51 × 0.41 mm. Abdomen 0.45 mm long and wider (0.25 mm) posteriorly. Caudal ramus longer than wide, 115 × 90 μm. Antenna (Figure 3D) 3-segmented; proximal segment slender and unarmed; middle segment largest, armed with 4 corrugated pads; terminal segment smallest, with medial seta in basal region (Figure 3E) and 3 overlapping, cuticular flaps at distal end. Postantennal process (Figure 3E) sickle-shaped. Maxillule (Figure 3D) reduced to small knob and papilla with 3 setae. Corpus of maxilliped (Figure 3F) with bifid tip at protruded medial surface. Both legs 5 and 6 (Figure 3G) represented by 2 papillae, 1 tipped with small plumose seta and other with 2 similar setae.

Remarks

The most outstanding characteristic of the present species is the absence of the sternal furca. According to Ho & Bashirullah (1977) and Pillai (1985), only *C. grandiabdominalis* Yamaguti, 1954 (among more than 250 species) lacks the sternal furca. However, the latter can be easily distinguished from *C. absens* in having an inflated abdomen and five (instead of four) outer spines on the exopod of leg 4. It is a parasite of the fusilier *Casio kuning* (Cuvier & Valenciennes) from the Celebes (Yamaguti, 1954).

The caligid copepods of the genus *Metacaligus* Thomsen, 1949 are characteristic in lacking the sternal furca. However, based on the amended definition given to this genus by Ho & Bashirullah (1977), *C. absens* cannot be placed in *Metacaligus* due to the structural difference in legs 1 and 2. Species of *Metacaligus* are characterised in bearing on leg 1 an exopod armed with bilaterally denticulate terminal spines (without accessory processes) and short plumose setae, and on leg 2 with two (instead of three) outer spines on the third exopod segment.

***Caligus epinepheli* Yamaguti, 1936**

Material examined: 4 ovigerous ♀♀ from gill filaments of 3 *Scolopsis vosmeri* (Bloch) landed at Ma-Kong Fishing Port in Pescadores Islands on 18 June, 1998.

Remarks

This is a fairly widely distributed species of *Caligus*. In addition to occurring in the Far East (Yamaguti, 1936; Shiino, 1952; Kim, 1998), it has been reported from Malaysia (Leong, 1984), India (Pillai, 1963; Rangnekar & Murti, 1963), Sri Lanka (Kirtisinghe, 1964), Australia (Kabata, 1965; Byrnes, 1987), Jamaica (Cressey, 1991) and Persian Gulf (Ho & Sey, 1996). Although it was originally described from the sea basses (Serranidae), it has been reported from several other families of fishes, such as porgies (Sparidae; Shiino, 1952; Kabata, 1965; Byrnes, 1987), jacks (Carangidae; Pillai, 1963), spadefishes (Ephippidae; Rangnekar & Murti, 1963; Kirtisinghe, 1964), threadfin breams (Nemipteridae; Leong, 1984; Ho & Sey, 1996) and smelt-whitings (Sillaginidae; Leong, 1984). The present report from Taiwan adds a new family of hosts, the scats (Scatophagidae).

Since *C. epinepheli* was redescribed by Cressey (1991) and our observation did not add new information, description of the specimens from Taiwan is thus omitted.

The division of abdomen into a 2-segmented structure seems to be not a constant feature in the present species. While a distinct suture line was illustrated in the original description, as well as in the works of Kirtisinghe (1964), Pillai (1985) and Cressey (1991), it was merely an indication of somite separation in the other reports (Shiino, 1952; Rangnekar & Murti, 1963; Kabata, 1965) and the present work.

***Caligus kanagurta* Pillai, 1961** (Figures 4–6)

Material examined: 22 ♀♀ and 1 ♂ recovered from wall of gill cavities of 5 *Decapterus kurroides* Bleeker landed at Sheng-Dah Fishing Port on 23 October, 1997; 10 ♀♀ and 1 ♂ from wall of gill cavities of 6 *D. kurroides* caught off Keelung on 5 January, 1998.

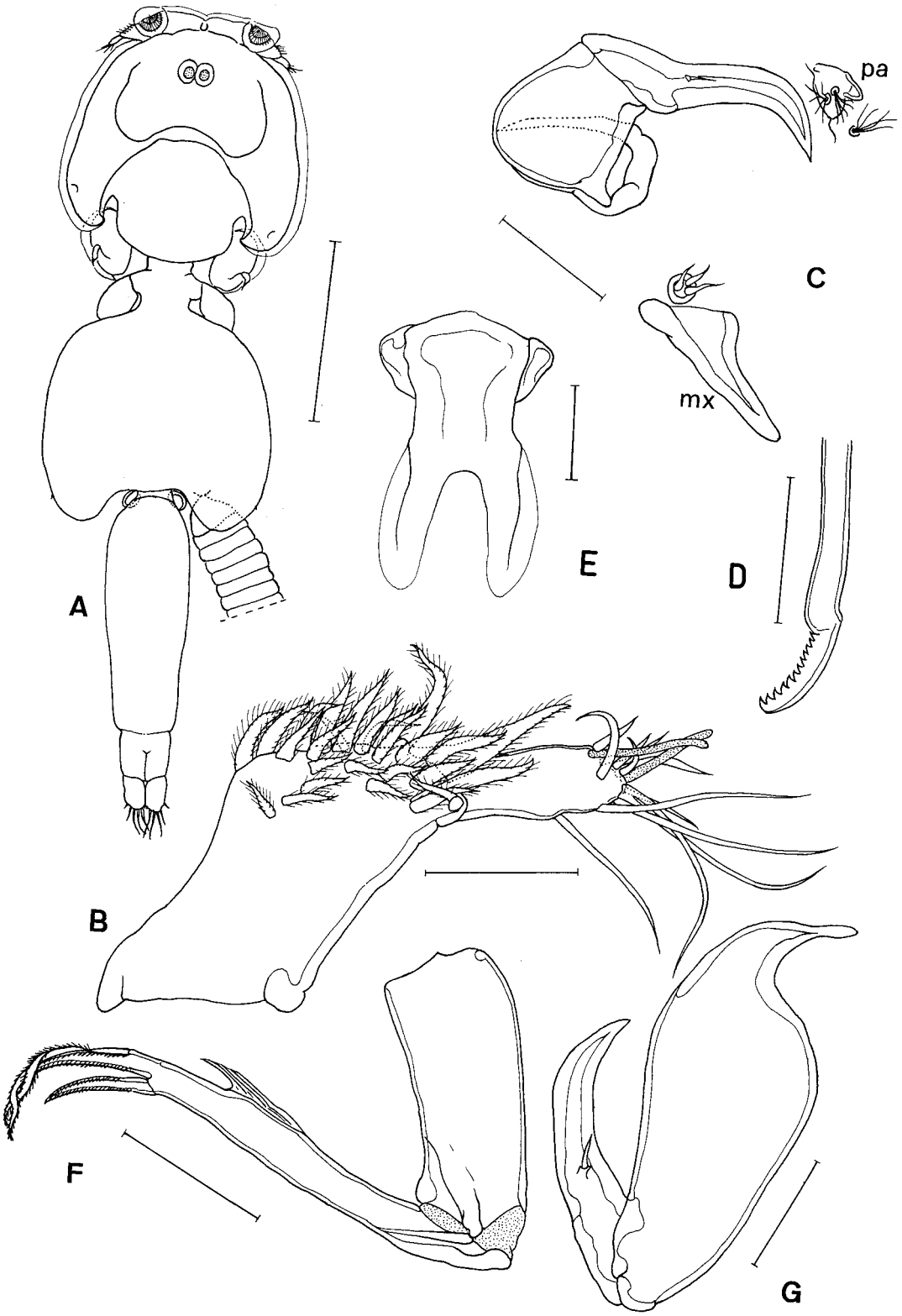

Figure 4. Caligus kanagurta Pillai, 1961. Adult female. A, habitus, dorsal; B. antennule, ventral; C. antenna, postantennary process (pa) and maxillule (mx); D, mandible; E, sternal furca; F, maxilla; GG, maxilliped. *Scale-bars*: A, 1 mm; B, 70 μm; C,F,G, 0.1 mm; D,E, 50 μm.

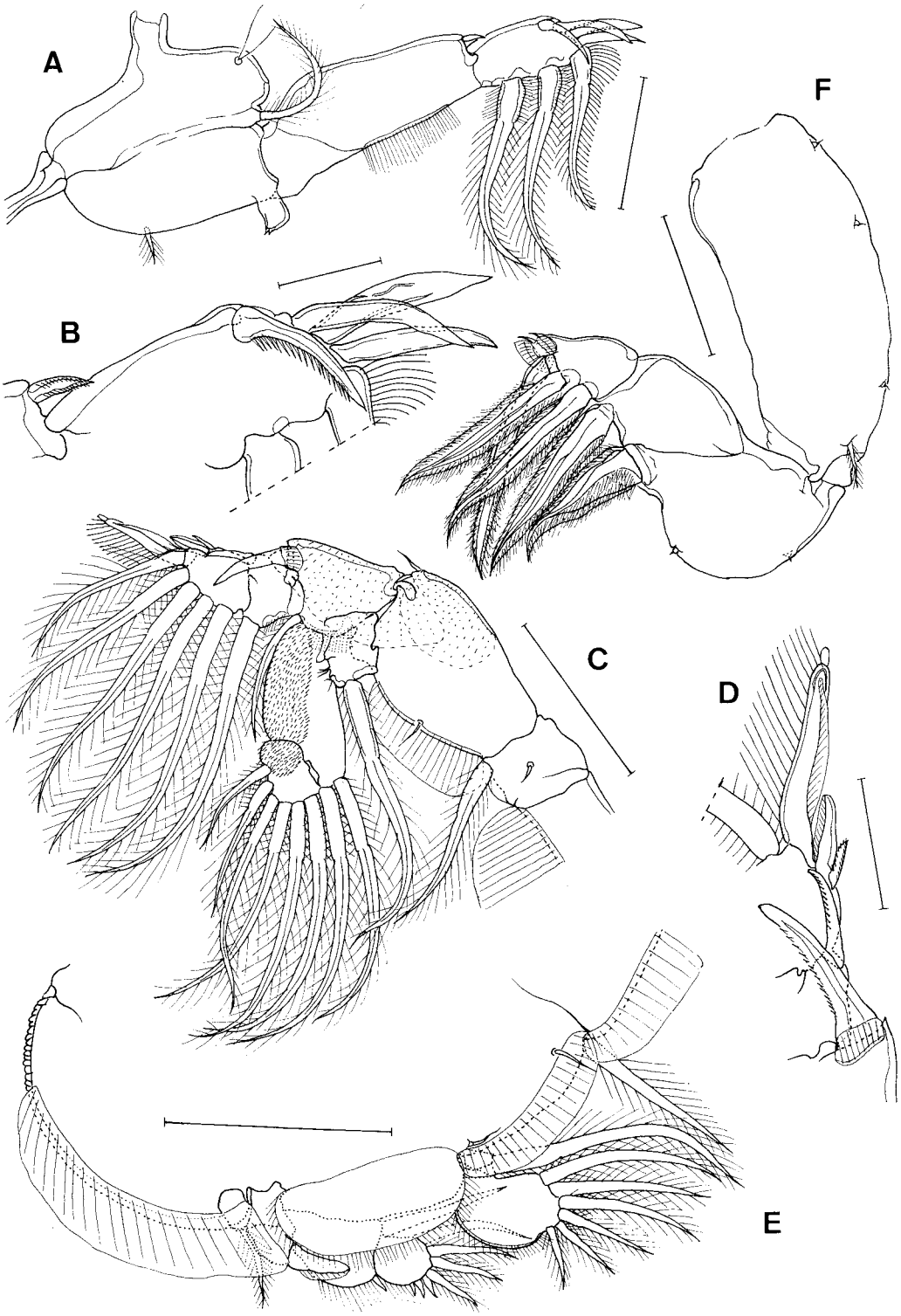

Figure 5. Caligus kanagurta Pillai, 1961. Adult female. A. leg 1; B. armature on distal margin of leg 1 exopod; C. leg 2; D. spines on outer margin of leg 2 exopod; E. leg 3, ventral; F. leg 4, posterior, dorsal. *Scale-bars*: A, 0.1 mm; B, 30 μm; C,E, 0.2 mm; D, 70 μm; F, 0.15 mm.

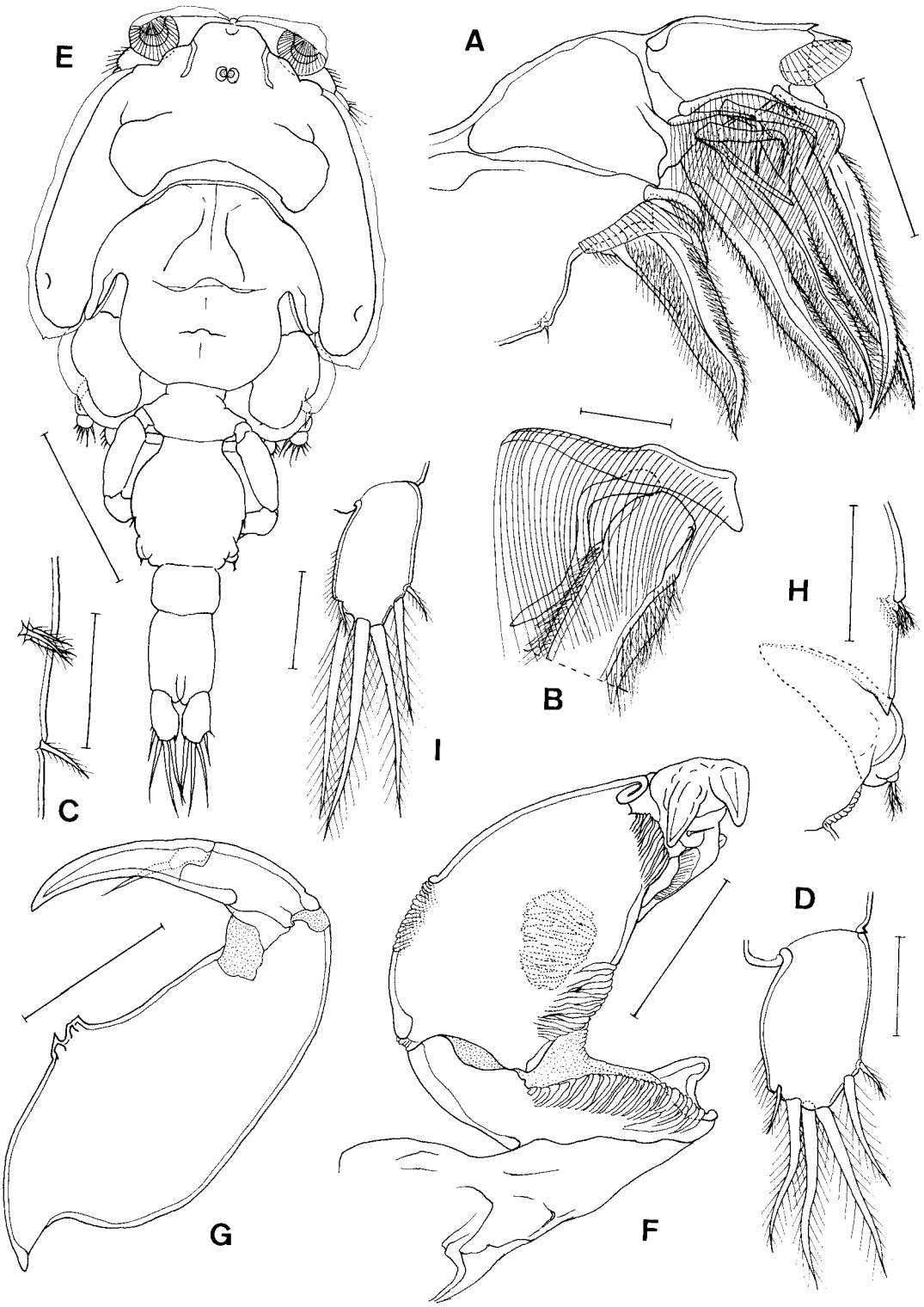

Figure 6. Caligus kanagurta Pillai, 1961. Adult female: A. distal portion of leg 4, anterior (ventral); B. ornamentations at base of seta on leg 4; C. leg 5, ventral; D. caudal ramus, dorsal. Adult male: E. habitus, dorsal; F. antenna; G. maxilliped; H. left margin of genital comoplex; I. caudal ramus, dorsal. *Scale-bars*: A,C,D,G,H,I, 0.1 mm; B, 30 μm; E, 0.5 mm; F, 70 μm.

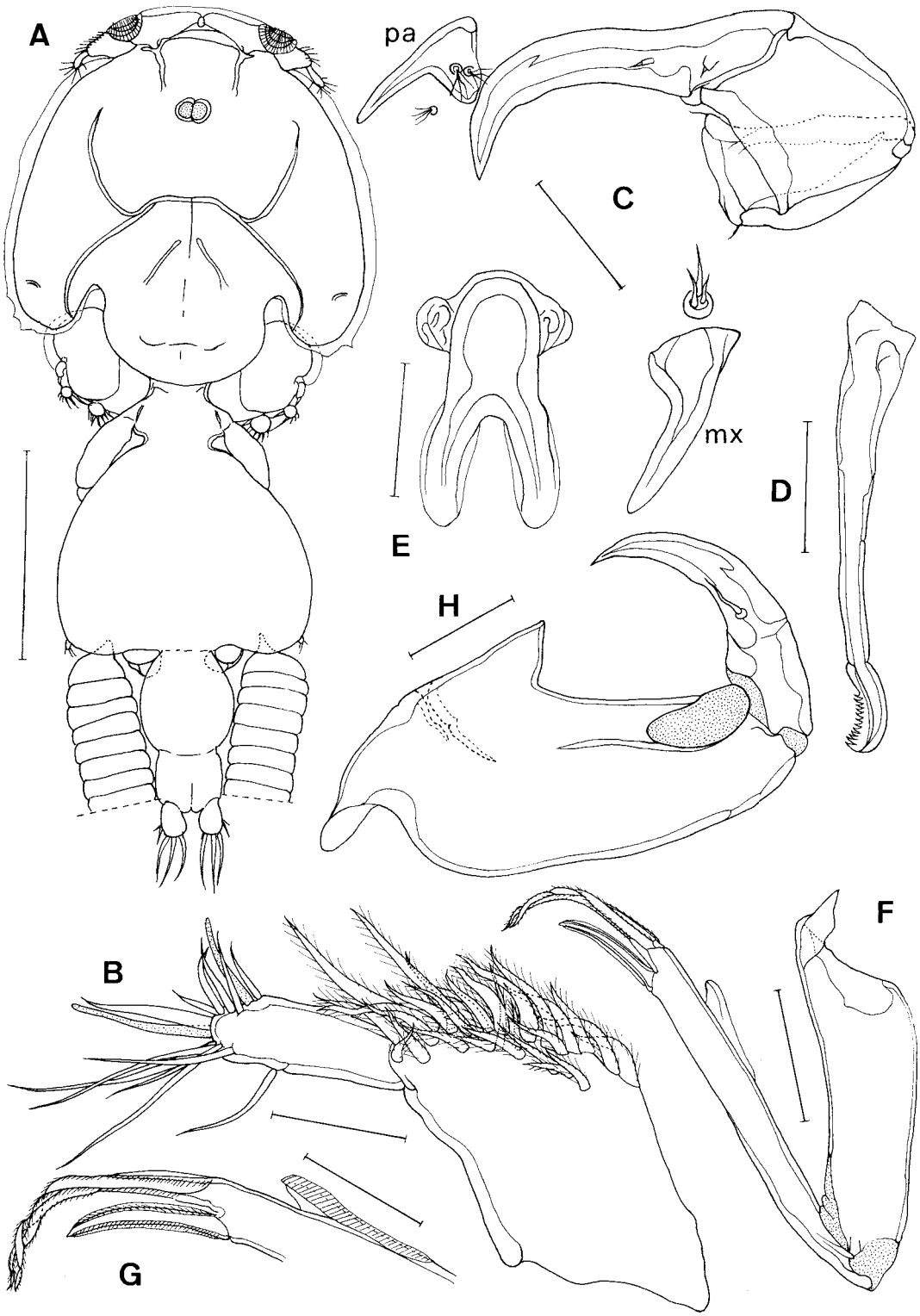

Figure 7. Caligus laticaudus Shiino, 1960. Adult female. A. habitus, dorsal; B. antennule, ventral; C, antenna, postantennary process (pa) and maxillule (mx); D. mandible; E. sternal furca; F. maxilla; G. tip of maxilla; H. maxilliped. *Scale-bars*: A, 0.5 mm; B,G, 70 μm; C,E,F,H, 0.1 mm; D, 50 μm.

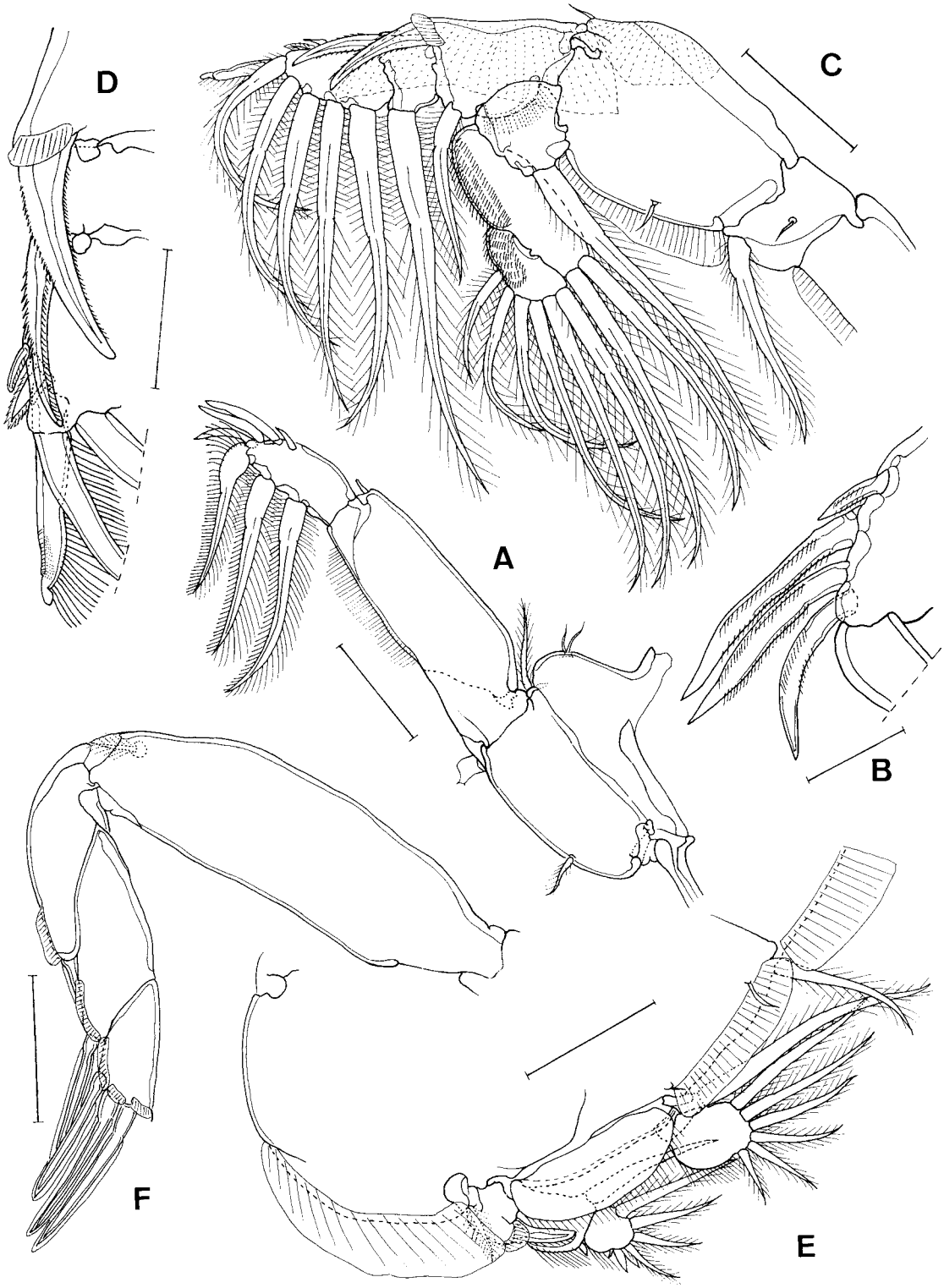

Figure 8. Caligus laticaudus Shiino, 1960. Adult female. A. leg 1; B. tip of leg 1 exopod; C. leg 2; D. spines on outer margin of leg 2 exopod; E. leg 3, ventral; F. leg 4. *Scale-bars*: A, 0.1 mm; B, 30 μm; C,E,F, 0.15 mm; D, 70 μm.

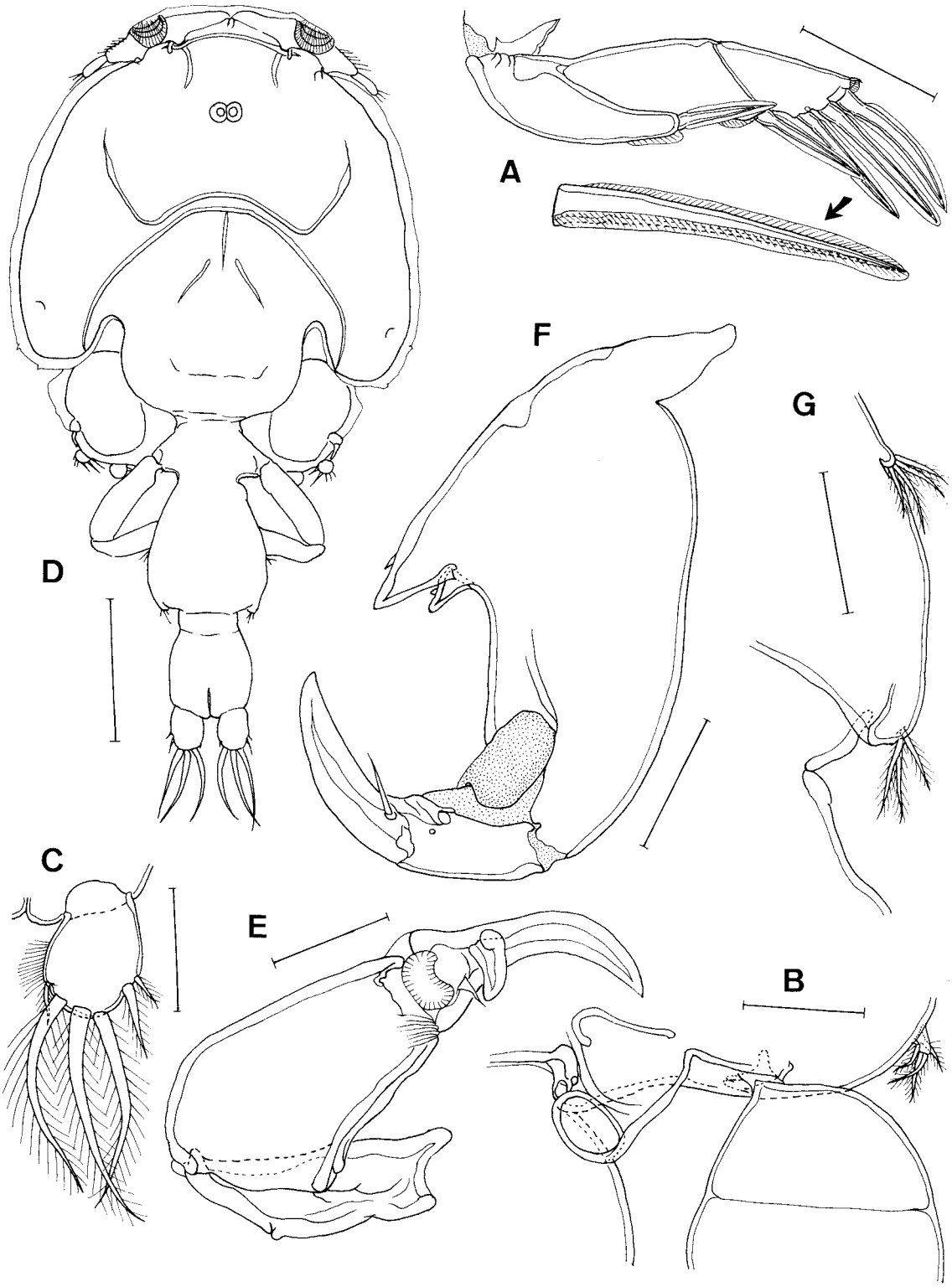

Figure 9. Caligus laticaudus Shiino, 1960. Adult female: A. exopod of leg 4; B. left egg-sac attachment area, ventral; C. caudal ramus ventral. Adult male: D. habitus, dorsal; E. antenna; F. maxilliped; G. left side of genital complex, ventral. *Scale-bars*: A,B,C, 0.15 mm; D, 0.5 mm; E, 70 μm; F,G, 0.1 mm.

Description

Female

Body (Figure 4A) 4.41 (4.30–4.70) mm long, excluding setae on caudal rami. Cephalothoracic shield 1.51 (1.42–1.62) mm long and 1.39 (1.24–1.50) mm wide, excluding lateral hyaline membranes. Lunules 190 μm wide and widely spaced. Genital complex 1.18 (1.06–1.28) mm long and 1.33 (1.22–1.46) mm wide. Abdomen 2-segmented; first segment 1.31 (1.23–1.36) mm long and second segment, 0.29 (0.27–0.31) mm long. Caudal ramus (Figure 6D) longer than wide (0.19 $\times$ 0.11 mm), armed with 2 short and 4 long setae. Egg-sac slightly shorter than body, containing up to 45 eggs.

Antennule (Figure 4B) 2-segmented; proximal segment distinctly longer than distal segment, carrying 27 plumose setae on anterodistal surface; distal segment rod-shaped, armed with 1 subterminal seta on posterior margin and 11 setae plus 2 aesthetascs on distal margin. Antenna (Figure 4C) 3-segmented; proximal segment small, unarmed; second segment with posteromedial corner protruded into spur-like process; distal segment a curved, sharply pointed claw bearing seta. Postantennal process (Figure 4C) small, bearing 2 basal papillae with each carrying 4 setules. Another similar papilla located nearby on sternum. Mandible (Figure 4D) with 12 teeth on medial margin of distal blade. Maxillule (Figure 4C) comprises pointed process and papilla bearing 3 setae. Maxilla (Figure 4F) and maxilliped (Figure 4G) as in *C. epinepheli*. Sternal furca (Figure 4E) with rounded tines, slightly divergent and shorter than box.

Armature on rami of legs 1–4 as follows (Roman numerals indicating spines and Arabic numerals, setae):

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

Leg 1 (Figure 5A) protopod with long outer (anterior) seta and short inner (posterior) seta; endopod a small process bearing 2 tiny setules at medioterminal corner; first segment of exopod with row of long setules on posterior edge; outermost terminal element on last segment of exopod (Figure 5B) with barbules on one side. Leg 2 (Figure 5C) coxa small, with large plumose seta on posterior edge and setule on ventral surface; basis with small seta on outer edge and setule on posterior edge ventral to marginal membrane; external spines on 3 exopod segments dissimilar, as shown in Figure 5D; distal 2 segments of endopod with large patches of spinules on antero-outer surface. Leg 3 (Figure 5E) protopod (apron) with corrugated outer margin anterior to hyaline membrane; both medial, coxal seta and anterior, basal seta long and plumose. Leg 4 (Figure 5F) protopod with short plumose outer seta in addition to 3 discrete marginal setules. Exopod 3-segmented; first segment with expanded outer margin carrying 2 spinules; third segment smallest and tipped with 2 pectens (Figure 6A); 2 spiniform processes on ventral (anterior) surface at insertion of middle 3 outer spines (Figure 6A), 1 simple and other bearing long hairs (Figure 6B). Leg 5 represented by 2 small papillae on posterolateral margin of genital complex (Figure 6C), one tipped with 2 small plumose setae and other with similar seta.

Male

Body (Figure 6E) 2.22 mm long. Carapace longer than wide, 1.28 $\times$ 1.00 mm. Genital complex longer than wide, 0.40 $\times$ 0.34 mm. Abdomen 2-segmented; first segment (0.12 mm) less than half length of second segment (0.26 mm). Caudal ramus (Figure 6I) more slender than in female, 140 $\times$ 90 μm. Antenna (Figure 6F) 3-segmented; proximal segment armed with corrugated pad on medial margin; middle segment large, robust and armed with 4 corrugated pads; terminal segment smallest, carrying basal seta and ending in 2 claw-like terminal spines. Corpus of maxilliped (Figure 6G) bearing 2 unequal ridges on medial surface. Leg 5 (Figure 6H) located at about midway along lateral margin of genital complex and composed of 1 small seta and papilla with 3 plumose setules. Leg 6 (Figure 6H) represented by 2 plumose setules on protuberance at posterolateral margin of genital complex.

Remarks

The most distinctive character of the present species is the nature of its leg 4. It is unusual in having on the ventral (anterior) surface two accessory spiniform processes extending from the insertion of each of the middle three outer spines, with one naked and the other bearing a row of long setules (see Figures 6A,B). A similar structure is also known for "*Caligus pelamydis* Krøyer" reported by Lewis (1967) from Hawaii and by Kim (1998) from Korea. Since Lewis (1967)

noted that Pillai's (1961) *C. kanagurta* "exhibits a very close similarity to *C. pelamydis*", Pillai (1974) made a comparative study of the specimens of *C. pelamydis* from mackerel collected in the Irish Sea with those of C. *kanagurta* found on mackerel at Trivandrum, India. Pillai (1974) concluded that the two species are not conspecific. They can be distinguished by the structure of the genital complex. It is "unlobed" in *C. pelamydis* and "lobed" in *C. kanagurta*.

Our study revealed that there is another distinction between *C. pelamydis* and *C. kanagurta*. The posterior (ventral) margin of the first exopod segment of leg 4 is evenly sloped in *C. pelamydis* but it bulges greatly in *C. kanagurta* (see Figure 5F). This feature is more reliable as a species distinction than the shape of the genital complex, which is known to vary with the state of maturation of the parasite. Taking this into consideration, we discovered that, in addition to Lewis' (1967) "*Caligus pelamydis* Krøyer", the specimens identified as "*Caligus pelamydis* Krøyer" by Hewitt (1963) from the snake mackerel *Thyrsites atun* (Euphrasen) off New Zealand and by Kim (1998) from the Japanese mackerel *Scomber japonicus* Houttuyn off Korea should also be referred to as *C. kanagurta*. With this correction, it becomes clear that *C. pelamydis* is a species confined to the Atlantic and Eastern Pacific and *C. kanagurta* to the Indo-West Pacific. Our discovery of *C. kanagurta* from the scads of Taiwan fits this pattern of distribution.

So far, only fishes of the Carangidae, Gempylidae and Scombridae in the Indo-West Pacific are known to harbour *C. kanagurta*.

Caligus laticaudus **Shiino, 1960** (Figures 7–9)

Material examined: 2 ♀♀ and 1 ♂ on inner side of gill covers of 2 *Parapristipoma trilineatum* (Risso) landed at Ma-Gong Fishing Port on 7 May, 1998; 1 ♀ and 2 ♂♂ from gill covers of 2 *Lutjanus vitta* (Quoy & Gaimard) landed at same fishing port on same day.

Description

Female

Body (Figure 7A) 3.61 (3.44–3.78) mm long, excluding setae on caudal rami. Cephalothoracic shield 1.86 (1.80–1.92) mm long and 1.58 (1.54–1.62) mm wide, excluding lateral hyaline membranes. Lunules 170 μm wide and widely spaced. Genital complex 0.91 (0.82–1.00) mm long and 1.15 (1.04–1.26) mm wide. Abdomen 2-segmented; proximal segment about as long as wide, 0.43 $\times$ 0.43 mm, but distal segment wider than long, 0.27 $\times$ 0.31 mm. Caudal ramus (Figure 9C) longer than wide (0.62 $\times$ 0.34 mm), armed with 3 short and 3 long plumose setae. Egg-sac shorter than body, containing up to 34 eggs.

Antennule (Figure 7B) 2-segmented; proximal segment diamond-shaped, carrying 27 plumose setae on anterodistal surface; distal segment rod-shaped, armed with 1 subterminal seta on posterior margin and 11 setae plus 2 aesthetascs on distal margin. Antenna (Figure 7C) 3-segmented; first 2 segments unarmed; distal segment a curved claw bearing 2 setae in basal region. Postantennal process (Figure 7C) L-shaped, carrying 2 basal papillae, each bearing 4 setules. Another similar papilla located nearby on sternum. Mandible (Figure 7D) with 12 teeth on medial margin of distal blade. Maxillule (Figure 7C) comprising pointed process and basal papilla bearing 3 setae. Maxilla (Figure 7F) generally as in *C. kanagurta* but bearing longer subterminal hyaline membrane (Figure 7G). Corpus of maxilliped (Figure 7H) with large, conical, basal protrusion and distal, corrugated pad on medial margin; other wise as in *C. kanagurta*. Sternal furca (Figure 7E) inverted U-shape; tines with round tip and shorter than box.

Armature formula of legs 1-4 as in *C. kanagurta*. Leg 1 (Figure 8A) protopod with long, coxal, outer seta and short, basal, inner seta; endopod a small process tipped with 2 setules; first segment of exopod with row of long setules on posterior edge; outermost terminal element on last segment of exopod much shorter than other 3 (Figure 8B); all elements bilaterally spinulate. Leg 2 (Figure 8C) coxa and basis armed as in *C. kanagurta*; external spines on exopod dissimilar as shown in Figure 8D; distal 2 segments of endopod with large patches of spinules on antero-outer surface. Leg 3 (Figure 8E) protopod (apron) as in *C. kanagurta* except with smooth outer margin anterior to hyaline membrane. Leg 4 (Figure 8F) protopod with short, plumose outer seta; first 2 segments of exopod with pecten proximal to insertion of outer spine, same pecten on distal segment in addition to 2 smaller ones at base of distal 2 spines. All spines with strip of hyaline membrane bilaterally (Figure 9A). Leg 5 represented by 2 small papillae (Figure 9B) on posterolateral margin of genital complex; one tipped with one plumose seta; other with 3 similar setae.

Male

Body (Figure 9D) 2.57 mm long. Cephalothoracic shield longer than wide, 1.67 $\times$ 1.39 mm. Genital

complex slightly longer than wide, 0.48 × 0.45 mm. Abdomen indistinctly 2-segmented, first segment (80 μm) much shorter than second (310 μm). Caudal ramus longer than wide, 150 × 130 μm. Antenna (Figure 9E) 3-segmented; proximal segment small and unarmed; middle segment large, robust and armed with small corrugated pad on mediodistal surface; terminal segment curved claw bearing basal, inner seta and large, basal hook. Corpus of maxilliped (Figure 9F) bearing 2 unequal processes on medial surface. Leg 5 (Figure 9G) located at about midway along lateral margin of genital complex, composed of 4 plumose setae. Leg 6 (Figure 9G) represented by 3 setae on small, posterolateral lobe on genital complex.

Remarks

As in *C. kanagurta*, the present species seems to be restricted to the Indo-West Pacific. It was first discovered in Japan (Shiino, 1960) and subsequently from India (Pillai, 1961), Eniwetok Atoll (Lewis, 1968), China (Li, 1984) and Malaysia (Leong, 1984). Although *C. laticaudus* was reported originally from the porgies (Sparidae; Shiino, 1960), later records were from threadfins (Polynemidae; Pillai, 1961), surgeonfishes (Acanthuridae; Lewis, 1968), mullets (Mugilidae; Li, 1984) and pomfrets (Apolectidae; Leong, 1984). The record from Taiwan extends this host range to include grunts (Haemulidae) and snappers (Lutjanidae).

C. laticaudus can be distinguished from its allies by a combination of the following characteristics: (1) the corpus of the maxilliped has a large, conical protrusion on the medial surface; (2) the terminal elements of the first exopod lack accessory processes; (3) element 1 of the four terminal armatures of leg 1 exopod is short, only about one third of the length of other three elements which are subequal in length; (4) the 3-segmented exopod of leg 4 has a formula of I-0, I-0, III; (5) the terminal three spines on the fourth exopod are subequal in length; and (6) the 2-segmented abdomen is short and broad, with its length less than twice the width.

***Caligus nengai* Rangnekar, Rangnekar & Murti, 1953** (Figures 10–12)

Material examined: 1 ♀ on inner wall of operculum of a *Triacanthus biaculeatus* (Bloch) landed at Dong-Shih Fishing Port on 1 April, 1998.

Description

Female

Body (Figure 10A) 2.42 mm long, excluding setae on caudal rami. Cephalothoracic shield longer than wide, 1.34 × 1.18 mm (excluding lateral hyaline membrane). Lunules 100 μm wide and widely spaced. Genital complex oval, 1.04 × 0.76 mm, with depressed central region. Abdomen small, wider than long, 0.10 × 0.16 mm. Caudal ramus (Figure 12D) wider than long, 24 × 100 μm, located subterminally on abdomen, armed with 2 short and 4 long plumose setae.

Antennule (Figure 10B) 2-segmented; proximal segment distinctly longer than distal segment, carrying 27 plumose setae on anterodistal surface; distal segment rod-shaped, armed with 1 subterminal seta on posterior margin and 11 setae plus 2 aesthetascs on distal margin. Antenna (Figure 10C) 3-segmented; proximal segment small, armed with posterior spinous process; middle segment well sclerotised but unarmed; distal segment a curved claw bearing 2 setae in proximal region. Postantennal process (Figure 10C) bluntly pointed and bearing hyaline membrane. Membrane-bearing sclerite present posterior to postantennal process. Mandible (Figure 10D) with 12 teeth on medial margin of distal blade. Maxillule (Figure 10C) comprising sharply-pointed process and basal papilla bearing 3 setae. Maxilla (Figure 1E) 2-segmented and brachiform; proximal segment (lacertus) unarmed; slender, distal segment (brachium) carrying small subterminal membrane on outer edge and 2 unequal elements (calamus and canna) terminally. Maxilliped (Figure 11A) relatively slender; proximal segment (corpus) with 4 medial protuberances on proximal half; distal 2 segments fused to form strong claw, bearing in midregion denticle and long seta. Sternal furca (Figure 10F) tines longer than box and with rounded tips.

Armature on rami of legs 1-4 as follows (Roman numeral indicating spines and Arabic numeral, setae):

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

Leg 1 (Figure 11C) protopod with long, coxal, outer seta; inner, basal seta small; endopod rod-like blunt process bearing fringe of setules on both margins and

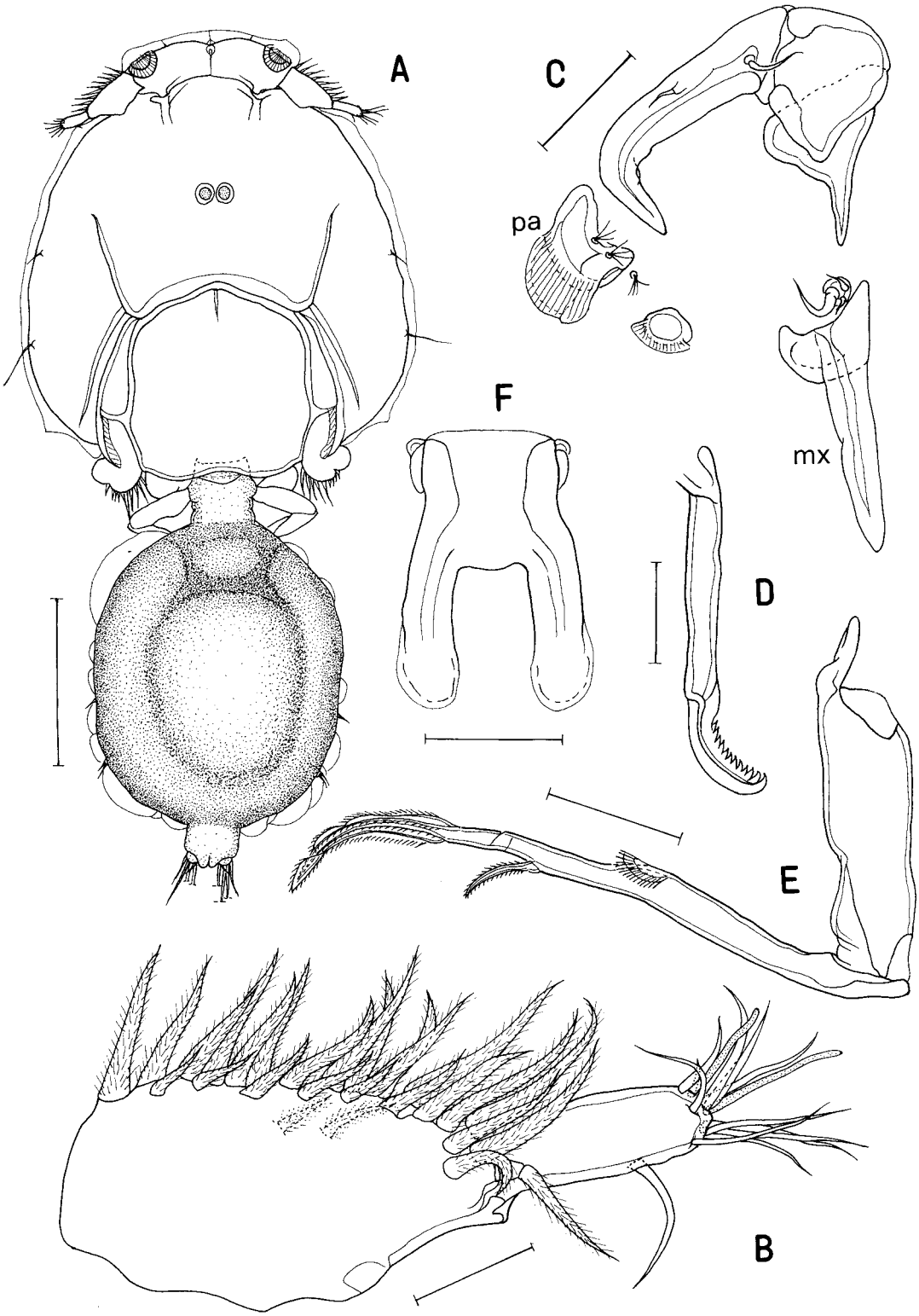

Figure 10. Caligus nengai Rangnekar, Rangnekar & Murti, 1953. Adult female. A. habitus, dorsal; B. antennule, ventral; C. antenna, postantennary process (pa) and maxillule (mx); D. mandible; E. maxilla; F. sternal furca. *Scale-bars*: A, 0.5 mm; B, 50 μm; C, 0.1 mm; D, 30 μm; E,F 70 μm.

Figure 11. *Caligus nengai* Rangnekar, Rangnekar & Murti, 1953. Adult female. A. maxilliped, ventral; B, corpus of maxilliped, anteroventral; C. leg 1; D. leg 2; E. spines on outer margin of leg 2 exopod. *Scale-bars*: A,B,E, 50 μm; C, 70 μm; D, 0.1 mm.

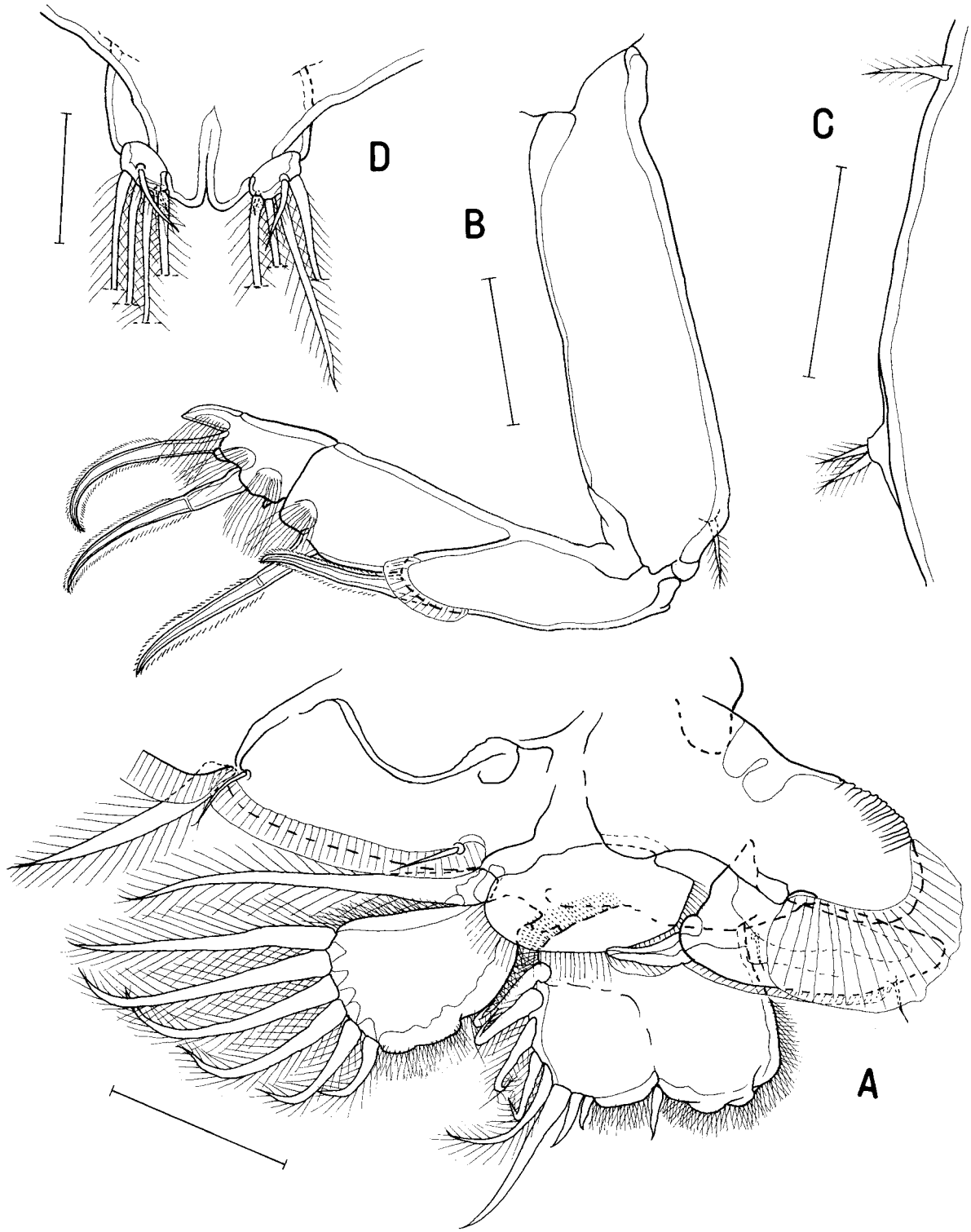

Figure 12. Caligus nengai Rangnekar, Rangnekar & Murti, 1953. Adult female. A. leg 3; B. leg 4; C. right side of genital complex, ventral; D. abdomen and caudal rami, ventral. *Scale-bars*: A,C,D, 0.1 mm; B, 70 μm.

apex; first segment of exopod with row of long spinules on posterior edge and small outer, corner spine with basal pecten; middle 2 of 4 terminal elements on last segment of exopod with accessory process. Leg 2 (Figure 11D) coxa and basis armed as in *C. kanagurta*; external spines on exopod dissimilar as shown in Figure 11D. Leg 3 (Figure 12A) protopod relatively short and wide, with corrugated outer margin anterior to hyaline membrane; other armature as in *C. kanagurta*; segmentation on exopod not clear. Leg 4 (Figure 12B) protopod with a short, plumose outer seta; 3 exopod segments with different number and structure of hyaline membrane as shown in Figure 12B; inner distal corner of terminal segment protruded into pointed process with hyaline membrane. Leg 5 represented by plumose seta and widely separated papilla, tipped with 2 plumose setae (Figure 12C).

Remarks

Caligus nengai seems to be a rare species. This is only the second sighting of the species since its discovery in 1953 in Bombay, India (Rangnekar et al., 1953). While the host of the first record was a sea catfish (Ariidae), the second record from Taiwan is a remotely related spikerfish (Triacanthidae). Even though the hosts and the localities of the parasites from these two records are so far apart phylogenetically and geographically, there is no doubt that they are conspecific. They share the following morphological features, some of them unusual for *Caligus*, such as (1) a large, oval genital complex carrying a small abdomen, (2) the caudal rami attached obliquely to the posterior margin of the abdomen, (3) the rudimentary endopod of leg 1 ornamented with setules, (4) a slender corpus of maxilliped with four protrusions in the basal region, (5) element 4 being the shortest of the four terminal elements on leg 1 exopod, and (6) the third segment of leg 4 exopod with two subequal spines.

One unusual characteristic of *C. nengai* overlooked by Rangnekar et al. (1953) is the possession of four protuberances in the basal region of the slender corpus of the maxilliped (see Figures 11A,B). It is interesting to point out that this unusual feature of slender corpus with basal protuberances is present in *C. distortus* Pillai & Natarajan, 1977. A close inspection of Pillai & Natarajan's (1977) illustrations shows that it also possesses the aforementioned unusual characteristics of *C. nengai*, except for item (1). The genital complex of *C. distortus* is, curiously, truncated on the right side. Pillai & Natarajan (1977) had only one specimen and they admitted that the growth of such a "curiously shaped genital segment" of this specimen could have been "effected by the parasite". In their figures 67 and 68, this parasite was illustrated as carrying a large, round, sessile protistan attached to the right side of the genital complex in the posteroventral region. Taking all of the above information into consideration, we strongly believe that the single specimen reported as *C. distortus* by Pillai & Natarajan (1977) is indeed a deformed specimen of *C. nengai*. Thus, the former is considered a junior synonym of the latter.

***Caligus rotundigenitalis* Yü, 1933**

Material examined: 12 ♀♀ on wall of gill cavities of 6 *Terapon jarbua* (Forskål) landed at Sheng-Dah Fishing Port on 23 October, 1997; 4 ♀♀ found on inner side of operculum of 1 *Drepane punctata* (Linnaeus) landed at same fishing port on same day; and 3 ♀♀ from wall of gill cavities of 2 *Liza macrolepis* (Smith) landed at Mi-Tuo Fishing Port on 22 January, 1998.

Remarks

In making a close comparison between our specimens with the descriptions of *Caligus* spp. from the Far East, we discovered that *C. rotundigenitalis* has the following four features in common with *C. tanago* Yamaguti, 1939 and *C. multispinosus* Shen, 1957: (1) element 1 is the shortest of the four terminal elements on the exopod of leg 1; (2) elements 2 and 3 of the terminal armature of leg 1 exopod are simple spiniform without accessory process; (3) the 3-segmented exopod of leg 4 has an armature formula of I, I, III; and (4) the first four spines on the exopod of leg 4 are covered with spinules. Since these fine structural features are generally considered significant in the distinction of *Caligus* spp., it makes one wonder if these three species reported from the fishes of Far East are conspecific. Thus, due to the inaccessibility of type-specimens, we decided to make a close comparison of the original descriptions of these three species given respectively by Yü (1933), Yamaguti (1939) and Shen (1957).

Although several distinctions can be enumerated from the inspection of original descriptions, it is difficult to determine whether the morphological differences found are genuine or simply due to the difference in the author's observation and/or technique of

illustration. For instance, the spines on the exopod of leg 4 in *Caligus* are usually arranged in such a way that the tip of the distal spine extends slightly beyond that of the spine immediately proximal to it. However, this normal feature is altered in *C. rotundigenitalis* in which the tip of the middle spine on the third segment of leg 4 exopod recedes from that of the proximal spine (Yü, 1933, plate II, figure 2). This unusual feature was not mentioned by Yü (1933) nor by Yamaguti (1939) or Shen (1957). Furthermore, when Yamaguti (1939) described *C. tanago*, he did not compare it with *C. rotundigenitalis*, and Shen (1957) did not compare his *C. multispinosus* with either *rotundigenitalis or tanago*. Therefore, we concentrated our attention only on those obvious structures that would not likely be missed during observation, or differently interpreted. Consequently, only the abdomen was found to provide reliable distinguishing characters as follows:

rotundigenitalis	*tanago*	*multispinosus*
2-segmented	1-segmented	2-segmented
$< \frac{1}{2}$ of carapace	$< \frac{1}{2}$ of carapace	$> \frac{3}{4}$ of carapace

These differences can be accepted for species discrimination only under the assumption that the form of the abdomen does not change with the state of maturity. Based on this assumption, the specimens of *Caligus* found on the black sea bream *Acanthopagrus schlegeli* Bleeker cultured in Taiwan and reported as "*Caligus multispinosus* Shen, 1957" by Lin et al. (1994, 1997) becomes a misidentification for *C. rotundigenitalis*. Since Lin et al. (1994) gave a complete redescription of this species, redescription is omitted here.

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