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Two Species of *Caligus* (Copepoda: Caligidae) Parasitic on Black Sea Bream (*Acanthopagrus schlegeli*) Cultured in Taiwan

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Two species of parasitic copepods are described based on the materials obtained from the pond-cultured black sea bream (*Acanthopagrus schlegeli*) in Tainan County, Taiwan. They are: *Caligus acanthopagri* n. sp. found on the host's body surface and *Caligus multispinosus* on the host's gills and in the gill cavities. The new species is very close to *Caligus latigenitalis* but can be distinguished from it by the fine structures on the exopod of leg 4. This study shows that *Caligus dieuzeidei* reported by Shiino in 1954 from *Sparus macrocephalus* (=*Acanthopagrus schlegeli*) was a misidentification for *C. latigenitalis*.

More than 200 species of the copepod genus *Caligus* are currently known. However, only four species of this largest genus of parasitic copepods (Caligidae, Siphonostomatoida) have been so far reported from Taiwan. Those species are: *Caligus coryphaenae* Steenstrup & Lütken on the body surface of *Coryphaena hippurus* L. reported by Ho (1963), *C. polycanthi* Gnanamuthu on the fins of *Aluterus scriptus* (Osbeck) reported by Ho (1966), *C. chanos* Lin on the body surface of *Chanos chanos* (Forskal) reported by Lin (1989), and *C. epidemicus* Hewitt on the body surface of *Oreochromis mossambicus* (Peter) reported by Lin & Ho (1993). In this paper we add two more species of *Caligus* to this meager list of caligid copepods of Taiwan. Both were recovered from the pond-cultured black sea bream (*Acanthopagrus schelegeli* Bleeker) from southern Taiwan.

In March, 1983 a pond-cultured black sea bream at the Tainan Branch of the Taiwan Fisheries Research Institute in Chi-Ku Village of Tainan County showed an abnormal condition in decreasing feed consumption with a daily mortality of five to ten fishes. At that time, three moribund fishes swimming at the edge of the pond were caught for examination. Their bodies were thin, black and infected by numerous copepods of the genus *Caligus*. The same abnormal phenomenon was found again in November, 1992 in a black sea bream culture pond located in Pei-Men Village of Tainan County. Most fishes were blackened and swimming in the corners of the pond at the windward side. About 10 to 30 fishes died daily with the mortality rate rising day after day. *Caligus* copepods were found on four moribund fishes in the gill cavities and on the gills. The infected gills showed congestion, mucus proliferation and damages. The copepods found in Chi-Ku Village are new to science and those found in Pei-Men Village are identified as *Caligus multispinosus* Shen, 1957.

The preserved specimens of *Caligus* examined in this study were cleared in 85% lactic acid for at least 24 hours before taking measurements and making dissection. All drawings were made with the aid of a camera lucida. In the following, a full description is given of the female and only the sexual dimorphic characteristics are mentioned for the male. All measurements are given in mm unless specified otherwise.

Descriptions

Caligus acanthopagri n. sp.

(Figs. 1-4)

Material examined—713 adults from body surface

of 3 moribund black sea bream, *Acanthopagrus schlegeli* Bleeker, taken from a culture pond at the Tainan Branch of the Taiwan Fisheries Research Institute in Chi-Ku Village of Tainan County, Taiwan on March 1, 1983. The holotype (USNM 268265), allotype (USNM 268266), and 10 paratypes (5 females and 5 males) (USNM 268267) have been deposited in the Division of Crustacea, National Museum of Natural History, Smithsonian Institution, Washington, D. C. Another 10 paratypes (TMCC 1) have been deposited in the Department of Zoology, Taiwan Museum, Taipei, Taiwan.

Female—Body (Fig. 1A, B) with typical appearance of *Caligus*, measuring 3.79 (3.52–4.18) long excluding setae on caudal rami, based on 20 specimens. Carapace about 2.21 (2.07–2.28) long and 2.11 (1.92–2.29) wide, excluding lateral hyaline membrane. Lunule (Fig. 1E) 0.91 (0.17–0.20) in diameter. Fourth pediger wider than long, 0.25 (0.23–0.27)×0.49 (0.41–0.54). Genital complex slightly wider than long, 0.96 (0.88–1.03)×1.02 (0.88–1.26) and distinctly separated from fourth pediger. Abdomen (Fig. 3H) short, 1-segmented and slightly longer than wide, 0.04 (0.37–0.42)× 0.28 (0.24–0.31). Caudal rami (Fig. 3H) about as long as wide, 0.10 (0.10–0.11)×0.09 (0.08–0.10), with strongly slanted anterior border. Posterior border of each ramus armed with 2 outer and 1 medial small setae and 3 large terminal setae. Egg sac (Fig. 1A) 1.49 to 2.31 long, containing 30 to 55 eggs.

Antennule (Fig. 1C) 2-segmented, proximal segment trapezoid, much broader than distal segment, carrying 14 large, stout, marginal setae, another 14 short, plumose setae on ventral surface, and 2 short, plumose setae on dorsal surface (see Fig. 1D). Distal segment rod-shaped, much longer than wide, 0.13 (0.11–0.16)×0.04 (0.04–0.05), and armed terminally with 12 setae and 1 aesthete and subterminally on posterior margin with 1 seta. Antenna (Fig. 1F) 3-segmented; proximal segment smallest, with pointed posteromedial corner; middle segment largest, robust; and terminal segment a strongly curved hook bearing a basal seta and a marginal seta. Postantennal process (Fig., 1F) hook-like, carrying 2 basal papillae with each bearing 3 long setules. Another similar papilla located nearby on sternum.

Mouth tube (Fig. 2E) longer than wide. Distal margins of labium and labrum fringed with a hyaline membrane. Labrum with a submarginal row of denticles. Mandible (Fig. 2E) with 12 teeth on mediodistal margin. Maxillule (Fig. 1F) comprising of a sharply pointed hook-like process and a papilla bearing 3 setae. Maxilla (Fig. 1H) 2-segmented and brachiform; proximal segment (lacertus) unarmed; slender distal segment (brachium) carrying a short process bearing hyaline membrane (Fig. 1I) on medial margin and 2 unequal terminal elements (calamus and canna, see Fig. 2D). Maxilliped (Fig. 2F) 3-segmented; proximal segment stout but unarmed, middle and terminal segment fused to form a strong claw and carrying a subterminal, medial seta. Base of sternal furca (Fig. 1G) longer than wide, with parallel and bluntly pointed tines.

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

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

Fine ornamentations on legs 1–4 as in typical *Caligus*. Protopod of leg 1 (Fig. 2G) carrying 1 outer and 1 inner short, plumose seta. Four terminal elements on leg 1 exopod (Fig. 2H) appeared differently. Leg 2 (Fig. 2A) with a large, plumose seta on coxa and a small, simple seta on basis. External spines on exopod of leg 2 (Fig. 2B, C) constructed unequally. Leg 3 (Fig. 3E) with an adhesive pad on ventrolateral surface. Spine on first segment of leg 3 exopod (Fig. 3F) bearing an outer membrane. Leg 4 (Fig. 3A) with long, slender exopod; outer seta on protopod (Fig. 3A) short and plumose. Bases of three outer spines on exopod (Figs. 3B, C, D) covered by a hyaline membrane, and mediodistal corner of exopod (Fig. 3D) protruded into two processes bearing a hyaline membrane, respectively. Leg 5 (Fig. 3G) represented by 3 short, plumose setae on posterolaterl corner of genital double somite.

Male—Body (Figs. 4A, B) distinctly larger than female, 5.35 (4.76–5.78) long, based on 20 specimens measured by excluding setae on caudal rami. Carapace 3.44 (3.38–3.53) long and 3.12 (2.86–3.31) wide, excluding hyaline lateral membranes. Fourth pediger wider than long, 0.33 (0.24–0.40)×0.67 (0.60–0.75). Genital double somite (Fig. 4F) 0.96 (0.81–1.30) long and 0.88 (0.82–0.95) wide, carrying rudimentary leg 5 (represented by outer 3 setae) and leg 6 (represented by inner 2 setae) on posterolateral margin. Abdomen (Fig. 4F) 2-segmented;

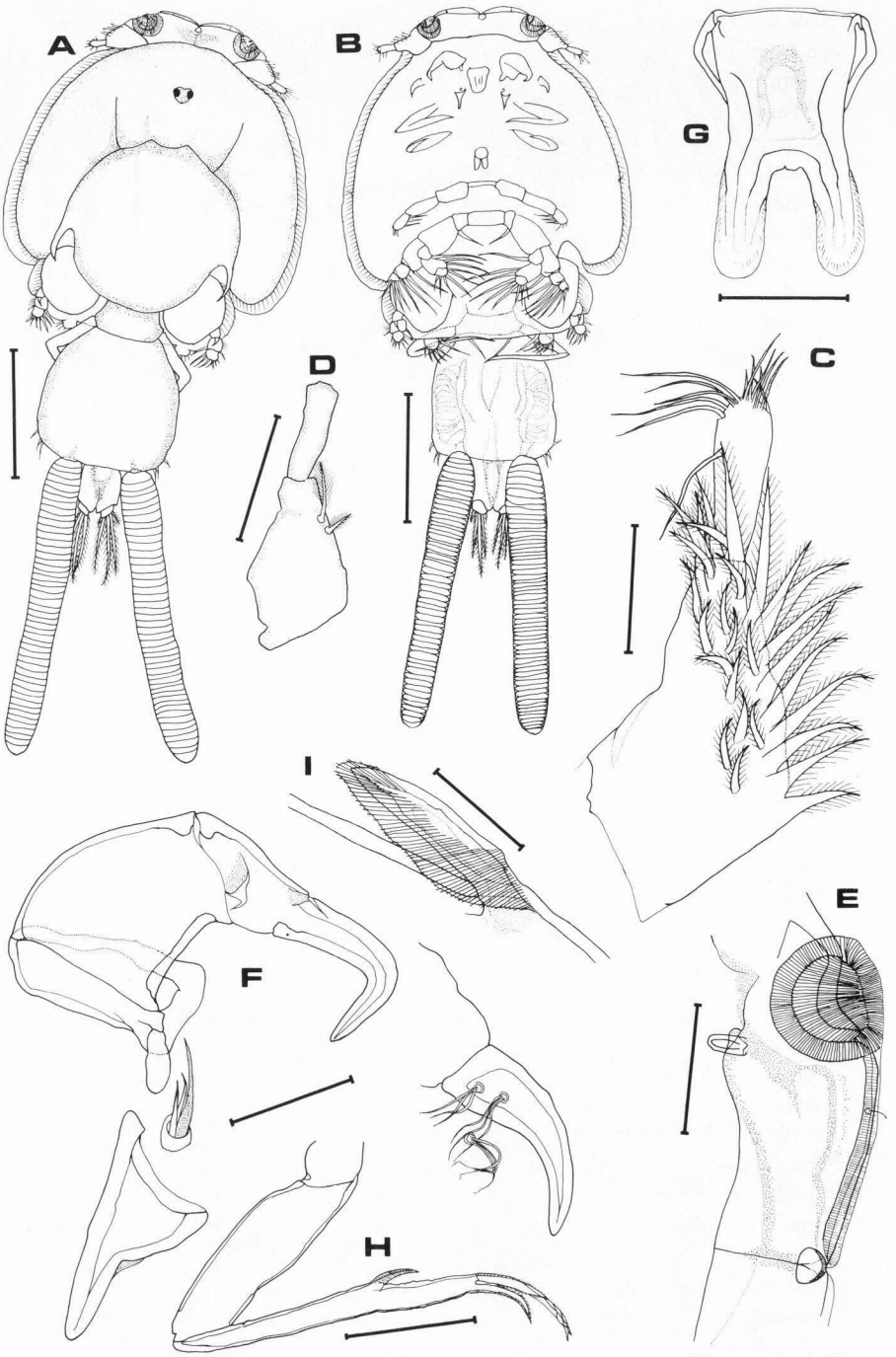

Fig. 1. *Caligus acanthopagri* n. sp., female: A. habitus, dorsal; B. same, ventral; C. antennule, vental; D. antennule, showing only armature on dorsal surface; E. frontal plate and lunule, ventral; F. antenna, postantennary process and maxillule; G. sternal furca; H. maxilla; I. medial seta on brachium of maxilla. Scale bars: 1 mm in A, B; 0.1 mm in C, F, G: 0.2 mm in D, E, H; 0.03 mm in I.

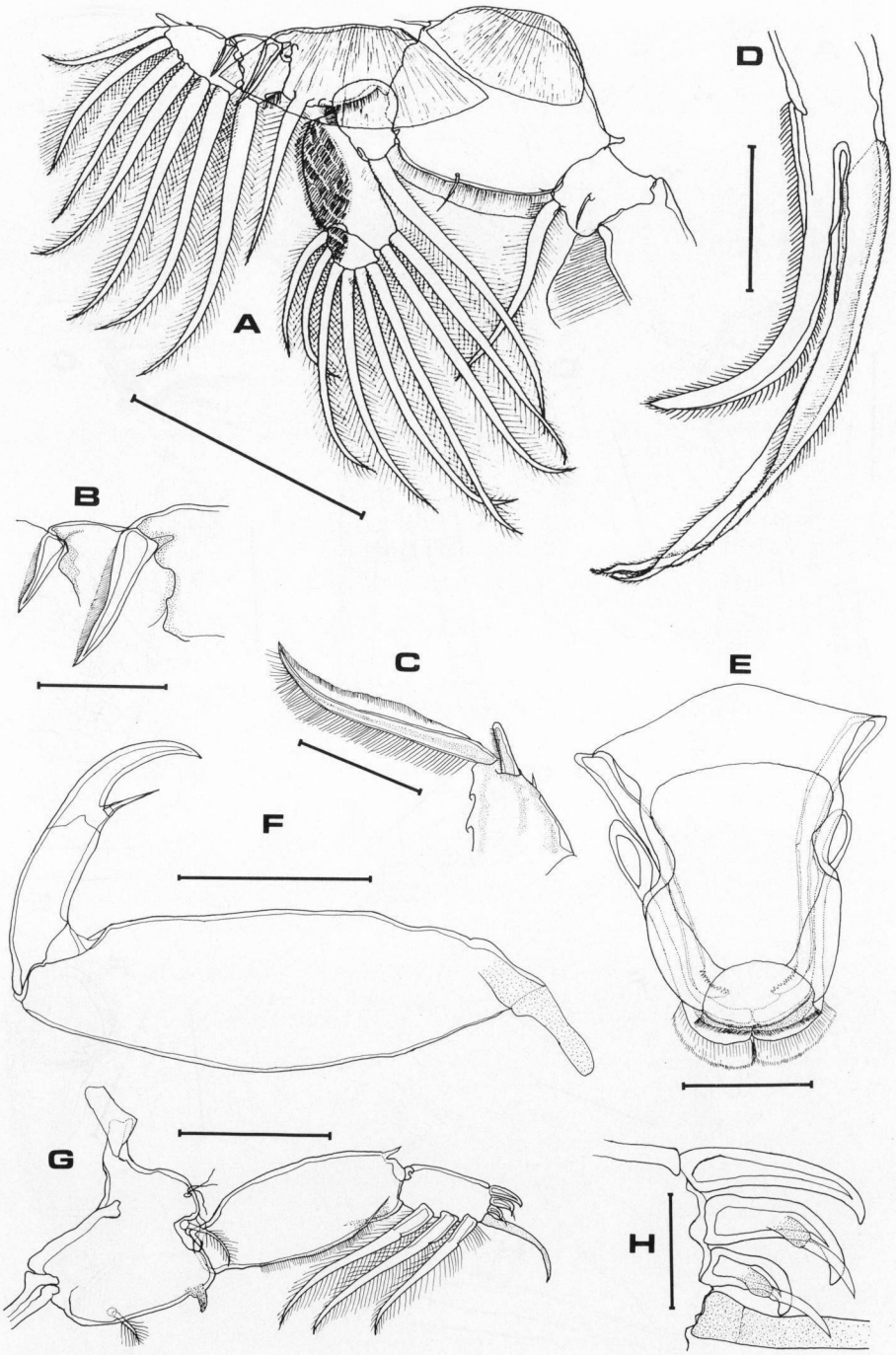

Fig. 2. *Caligus acanthopagri* n. sp., female: A. leg 2; B. spines on first two segments of leg 2 exopod; C. armature on outer surface of terminal segment of leg 2 exopod; D. calamus and canna of maxilla; E. mouth tube with mandibles; F. maxilliped; G. leg 1; H. tip of leg 1 exopod. Scale bars: 0.4 mm in A; 0.1 mm in B, C, E; 0.05 mm in D; 0.15 mm in F; 0.2 mm in G; 0.03 mm in H.

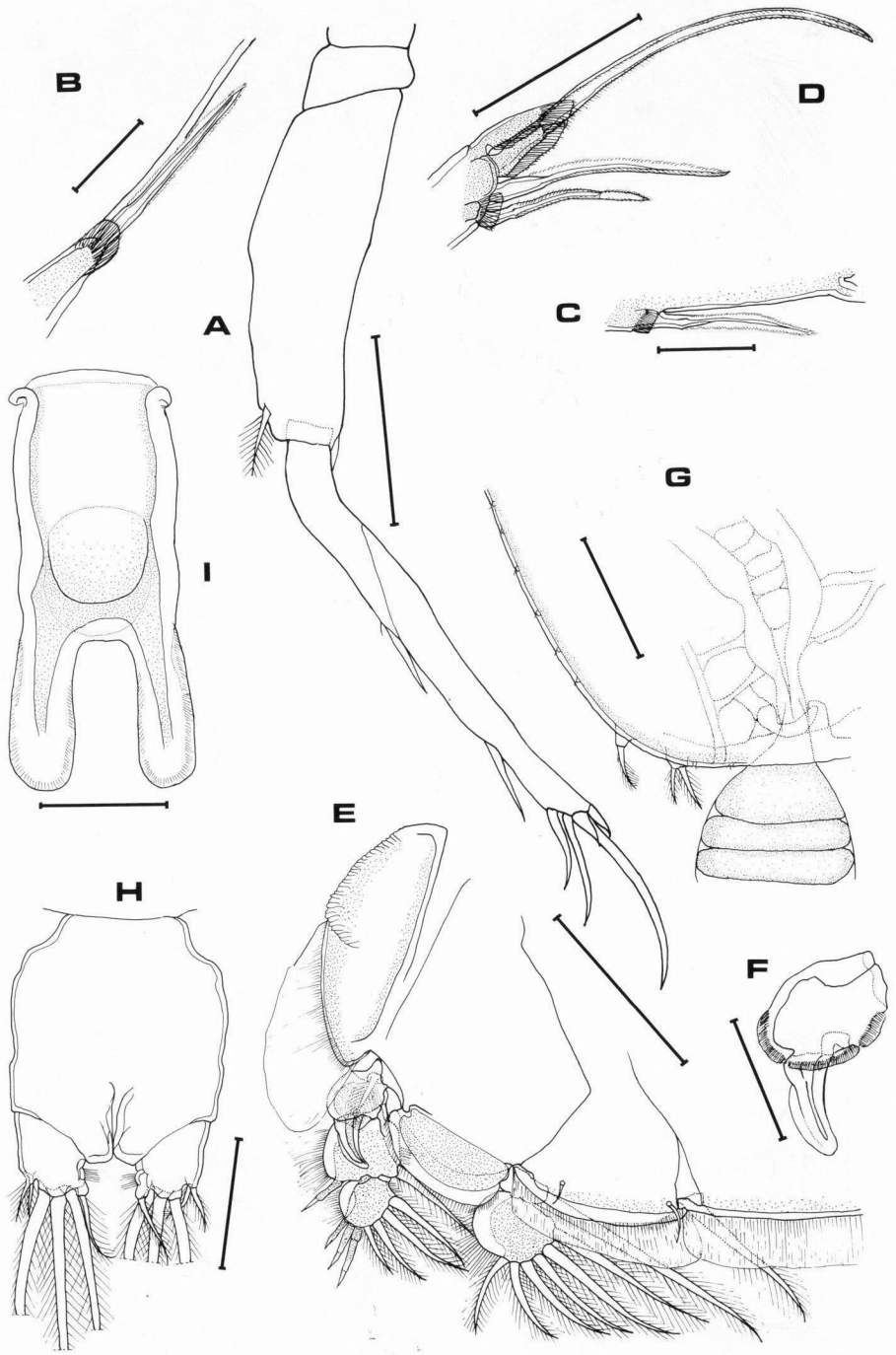

Fig. 3. *Caligus acanthopagri* n. sp., female; A. leg 4; B. outer spine of first segment of leg 4 exopod; C. subterminal spine on leg 4 exopod; D. terminal spines on leg 4 exopod; E. leg 3, ventral; F. outer spine on first segment of leg 3 exopod; G. leg 5 and egg sac attachment area; H. abdomen and caudal rami, dorsal. Male: I. sternal furca. Scale bars: 0.2 mm in A, G, H; 0.05 mm in B, C; 0.1 mm in D, F, I; 0.3 mm in E.

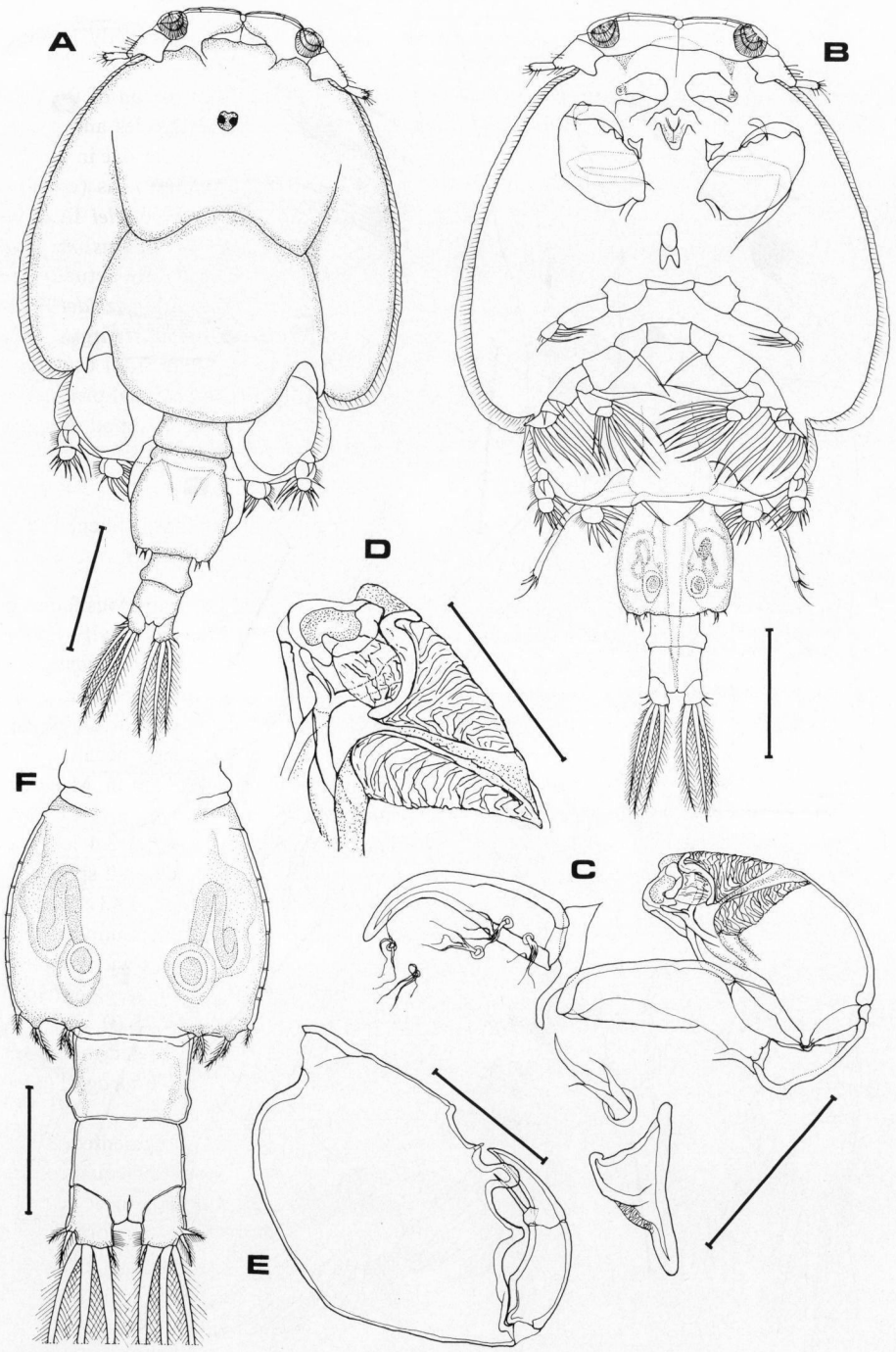

Fig. 4. *Caligus acanthopagri* n. sp., male: A. habitus, dorsal;; B. same, ventral; C. antenna, postantennary process and maxillule; D. tip of antenna, E. maxilliped; F. urosome. Scale bars; 1 mm in A, B; 0.3 mm in C, E; 0.15 mm in D: 0.4 mm in F.

proximal segment wider than long, 0.26 (0.24–0.29) ×0.43 (0.38–0.48), with laterally protruded distal margin; anal segment slightly wider than long, 0.31 (0.23–0.36)×0.39 (0.36–0.46). Caudal ramus (Fig. 4F) armed as in female but different in size, 169 (146–186) μm long and 167 (154–178) μm wide.

Antenna (Fig. 4C) 3-segmented; proximal segment unarmed; middle segment large, robust, and armed distally with two corrugated patches; distal segment smallest, armed terminally a seta and a hyaline plate (Fig. 4D). Corpus of maxilliped bearing 4 unequal ridges on medial surface (Fig. 4E). Sternal furca (Fig. 3I) with longer base.

Remarks—The most characteristic features of the present new species are the possession of (1) a short abdomen, (2) an accessory process on the middle two of the terminal four elements on the exopod of leg 1, and (3) a slender, 2-segmented exopod bearing an armature of I; IV on leg 4. With the combination of these three characteristics, *C. acanthopagri* is easily separated from its over 200 congeners except from the following five species: *C. dieuzeidei* Brian, *C. glandifer* Shiino, *C. latigenitalis* Shiino, *C. russellii* Kurian, and *C. willungae* Roubal. However, the new species is distinguishable from *C. dieuzeidei* in the structures of the postantennal process, maxillule, and caudal ramus; from *C. glandifer* in the size of the genital double somite (as large as the carapace in *C. glandifer*); from *C. latigenitalis* in the fine structures of the terminal end of the leg 4 exopod; from *C. russellii* in the structures of the maxilliped and sternal furca; and from *C. willungae* in the structures of the carapace and caudal ramus.

Of these five closely allied congeners, *C. acanthopagri* bears the closest resemblance to *C. latigenitalis*. *Caligus latigenitalis* was first recorded by Shiino (1954a) from the body surface of "*Sparus macrocephalus* (Basilewsky)" [=*Acanthopagrus schlegeli* (Bleeker)] obtaind at Momotori, Mie Prefecture in Japan. It was recorded again by Shiino (1960) from the shark (*Mustelus manazo* Bleeker) and ray [*Rhinobatos schlegelii* (Müller & Henle)] landed at Hamazima, Japan. As stated above, the only discernible morphological difference between these two closely allied species is the fine structure on the distal end of the exopod of leg 4. In the present species it is equipped with two corner processes with two hyaline membrane (see Fig. 3D), but in *C. latigenitalis* there are two short, but heavy, digital processes instead. Additionally, *C. acanthopagri* is unusual for copepods in having the male distinctly larger than the female.

In making a close comparison of the morphology between the present new species and the species of *Caligus* reported from the Sparidae in the Far East, it was discovered that the specimens (one female and three males) of "*Caligus dieuzeidei* Brian" reported by Shiino (1954b) from "*Sparus macrocephalus*" (=*Acanthopagrus schlegeli*) are actually identifiable with *C. latigenitalis*. *Caligus dieuzeidei* is also a parasite of sparid fish [*Diplodus sargus* (Linnaeus)] (Brian, 1933), but it differs from *C. latigenitalis* in the structures of the postantennal process, maxillule, the terminal lamellae on the exopod of leg 4, and the caudal ramus.

Caligus multispinosus Shen, 1957
(Figs. 5–7)

Material examined—16 ovigerous females, 6 males and many juveniles from gill cavity and gills of 4 moribund black sea bream, *Acanthopagrus schlegeli* Bleeker, taken from a culture pond at Pei-men Village of Tainan County, Taiwan on November 17, 1992. Voucher specimens have been deposited in the Department of Zoology, Taiwan Museum, Taipei, Taiwan (TMCC 2).

Female—Body (Fig. 5A, B) 3.4 long (excluding setae on caudal rami), based on 2 specimens. Carapace slightly wider than long, 1.43×1.51 (excluding marginal hyaline membrane). Lunule (Fig. 5C) 0.14 in diameter. Genital complex wider than long, 0.88 ×1.12. Abdomen (Fig. 7A) 2-segmented, moderately long, 0.57 (0.46–0.66)×0.31 (0.29–0.35). Caudal ramus (Fig. 7A) slightly longer than wide, 0.13× 0.11, armature as in *C. acanthopagri*. Egg sac 1.15 long, containing 12 eggs.

Antennule (Fig. 5C) 2-segmented; proximal segment armed with 17 stout, subequal, plumous setae on outer margin, 10 short, plumose setae on ventral surface, and 2 short setae on dorsal surface (Fig. 5D); distal segment rod-shaped, 0.1 long and 0.04 wide, and carrying terminally 14 setae and 1 aesthete and subterminally 1 long seta on posterior margin. Antenna (Fig. 6A) 3-segmented; first two segments unarmed, terminal segment sickle-shaped, and carrying in basal region a tubercle tipped with a short seta. Postantennary process (Fig. 6A) a slightly curved stout hook carrying 2 basal papillae with each bearing 4 long setules. Another similar papilla located

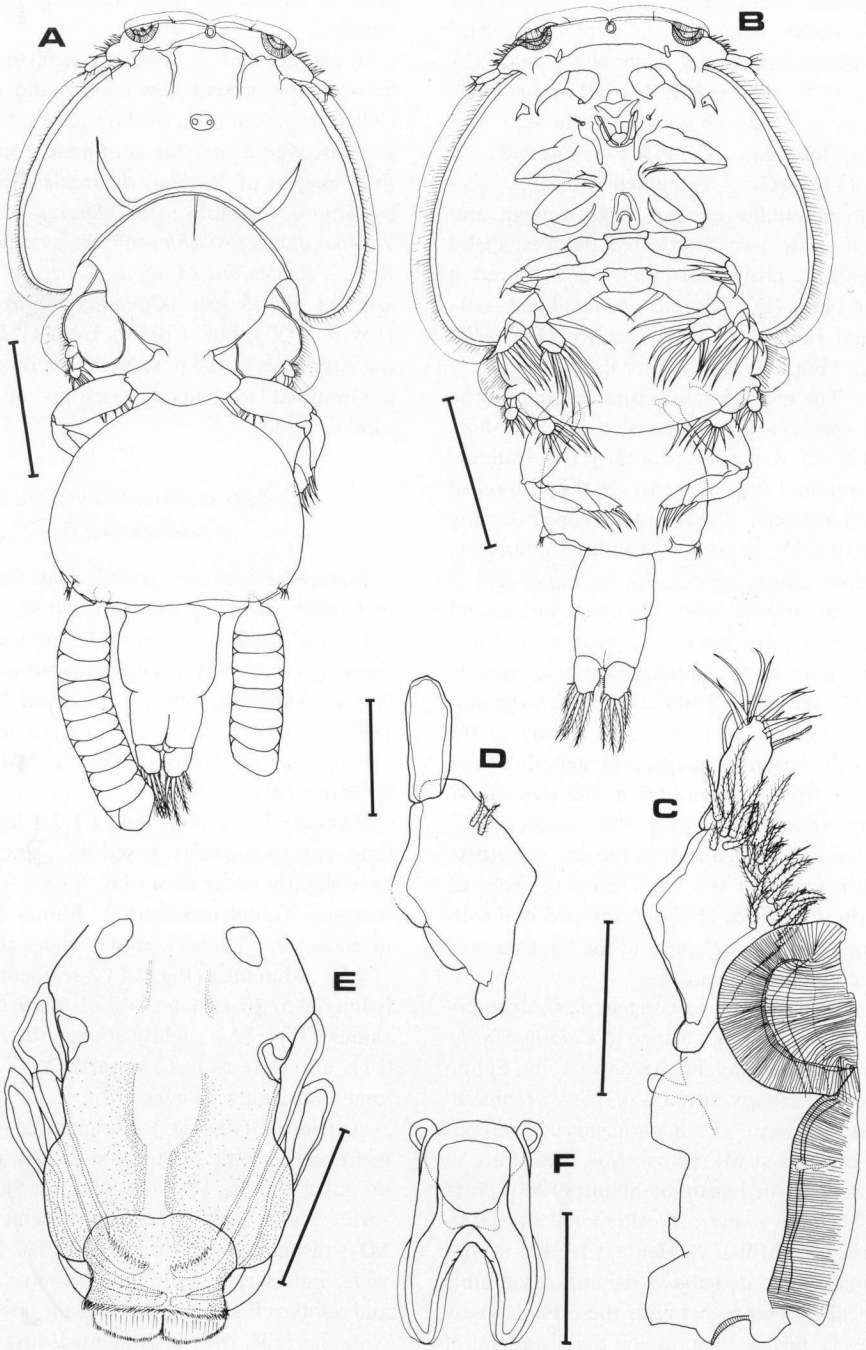

Fig. 5. *Caligus multispinosus* Shen, female: A. habitus, dorsal; B. same, ventral; C. frontal plate, lunule, and antennule; D. antennule, showing only armature on dorsal surface; E. mouth tube with mandibles; F. sternal furca. Scale bars: 0.6 mm in A, B; 0.15 mm in C; 0.1 mm in D, E, F.

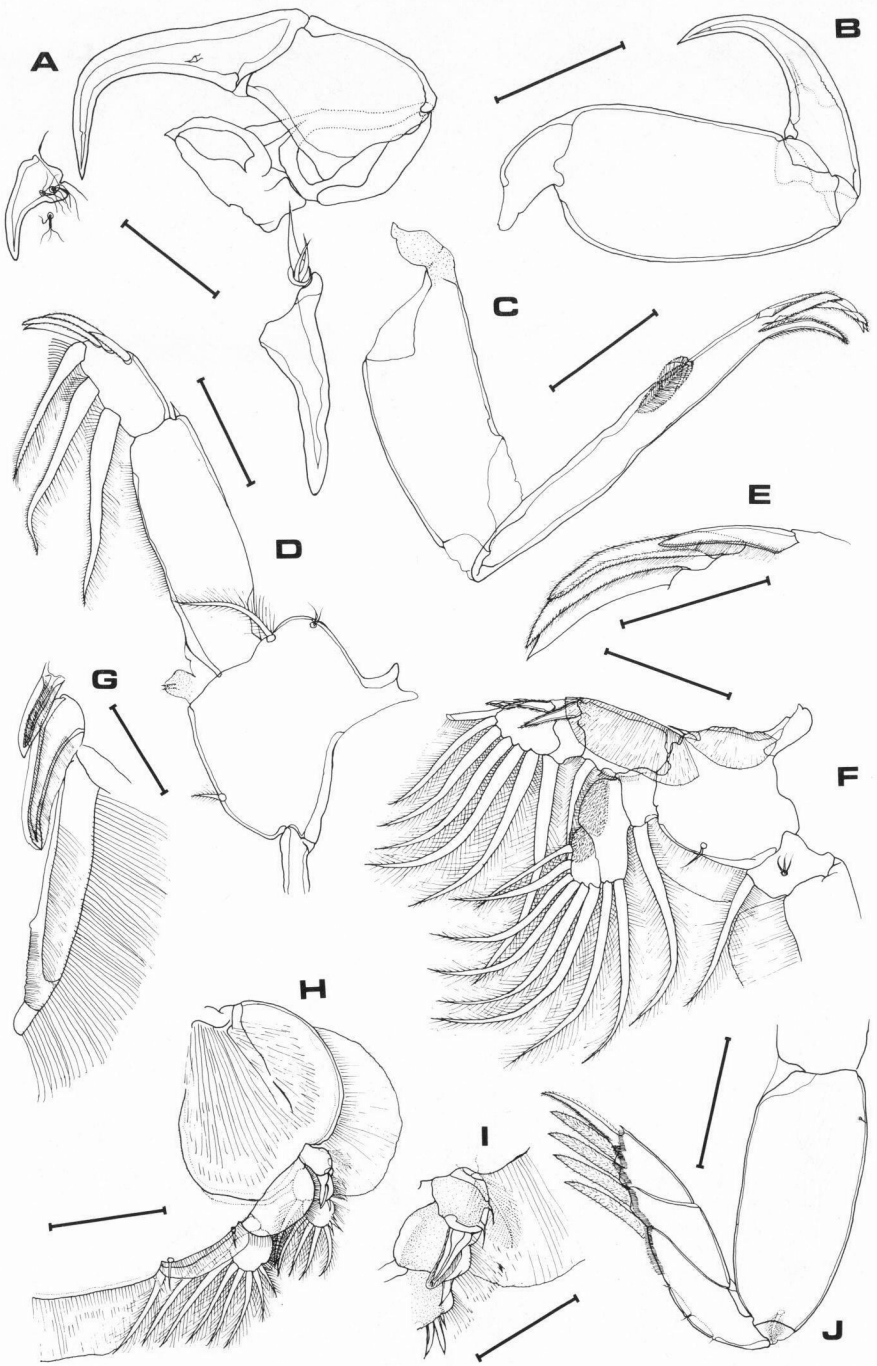

Fig. 6. *Caligus multispinosus* Shen, female: A. antenna, postantennary process, and maxillule; B. maxilliped; C. maxilla; D. leg 1; E. tip of leg 1 exopod; F. leg 2, ventral; G. outer armature on terminal segment of leg 2 exopod; H. leg 3, ventral; I. outer armature on leg 3 exopod; J. leg 4. Scale bars: 0.1 mm in A, C, D, I; 0.15 mm in B; 0.05 mm in E; 0.2 mm in F, H, J; 0.03 mm in G.

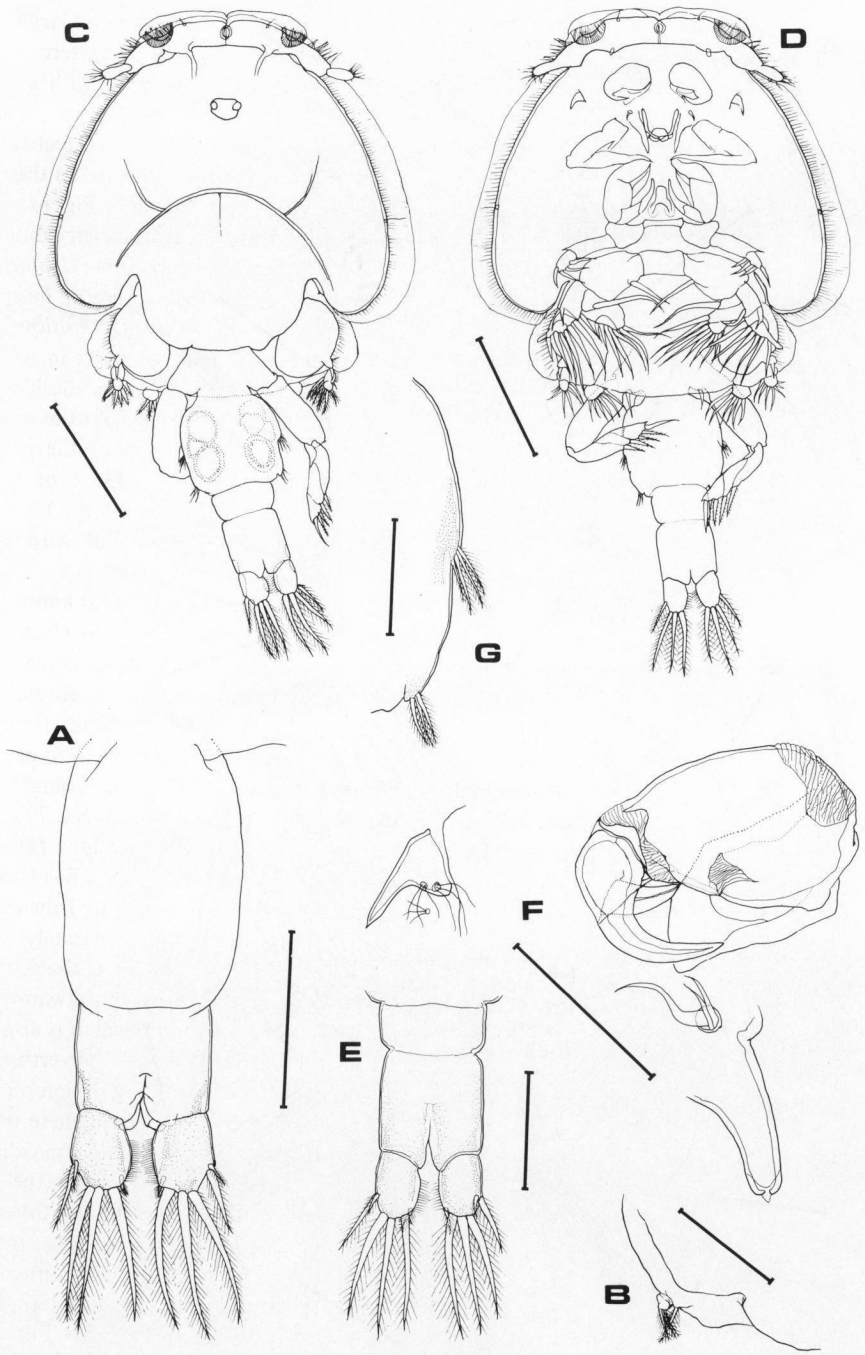

Fig. 7. *Caligus multispinosus* Shen, female: A. abdomen and caudal rami, ventral; B. posterolateral corner of genital segment, showing leg 5. Male: C. habitus, dorsal; D. same, ventral; E. abdomen and caudal rami, ventral view; F. antenna, postantennary process, and maxillule; G. lateral margin of genital double somite. Scale bars: 0.3 mm in A; 0.2 mm in B, E; 0.4 mm in C, D; 0.1 mm in F, G.

nearby on sternum.

Mouth tube (Fig. 5E) longer than wide. Distal margins of labium and labrum fringed with a hyaline membrane. Labrum with a submarginal row of denticles. Mandible (Fig. 5E) with 12 teeth on mediodistal margin. Maxillule (Fig. 6A) comprising of a sharply pointed process and a basal papilla bearing 3 setae. Maxilla (Fig. 6C) 2-segmented and brachiform; proximal segment (lacertus) unarmed; slender distal segment (brachium) carrying on medial margin a lamella with 4 leaflets and terminally 2 unequal elements (calamus and canna). Maxilliped (Fig. 6B) 3-segmented; proximal segment stout but unarmed, middle and distal segment fused to form a strong claw and carrying a seta in basal region. Tines of sternal furca (Fig. 5F) pointed and slightly curved medially.

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

Leg 1	Exp 1–0: IV, 3	Enp (rudimentary)
Leg 2	Exp I-1; I-1; II, I, 5	Enp 0–1; 0–2; 6
Leg 3	Exp I-0; 1–1; 3.4	Enp 0–1; 6
Leg 4	Exp I-0; I-0; III	Enp (missing)

Fine ornamentations on legs 1–4 as in typical *Caligus*. Protopod of leg 1 (Fig. 6D) carrying 1 outer and 1 inner short, plumose seta. Outer 3 terminal elements on leg 1 exopod (Fig. 6E) ciliated bilaterally. Proximal 2 outer spines on 3rd segment of Leg 2 (Fig. 6F) fringed with hyaline membrane. Leg 3 (Fig. 6H) bearing a large hyaline membrane on ventral surface of protopod in addition to a marginal membrane. Outer spine on 1st segment (Fig. 6I) long, reaching beyond base of outer spine on 2nd segment. Outer spines on leg 4 exopod (Fig. 6J) covered with cilia except for distal most one. Leg 5 (Fig. 7B) represented by 3 short, plumose setae on posterolateral corner of genital double somite.

Male—Body (Fig. 7C, D) 1.79 (1.78–1.20) long, based on 2 specimens. Carapace about as long as wide, 1.00×1.02, excluding hyaline lateral membranes. Genital double somite slightly wider than long, 0.30×0.31, carrying rudimentary leg 5 (represented by 4 setae) at about midway on lateral margin and rudimentary leg 6 (represented by 3 setae) on posterolateral corner (Fig. 7G). Abdomen (Fig. 7E) 2-segmented; proximal segment wider than long, 0.18×0.08, but anal segment longer than wide, 0.20 ×0.18. Caudal ramus (Fig. 7E) slightly longer than wide, 0.10×0.08, and armed as in female.

Antenna (Fig. 7F) 3-segmented; proximal segment unarmed; middle segment large, robust, and armed with 3 corrugated pads; terminal segment a strong, curved claw equipped with a large, subterminal hook.

Remarks—The most unusual feature of the present species is the ornamentation of the spines on the exopod of leg 4. As shown in Fig. 6J, the exopod is 3-segmented and carries four hairy outer spines. Of over 200 species of *Caligus*, only *C. platytarsis* Bassett-Smith shares the same structure on leg 4 with the present species. However, *C. multispinosus* is easily distinguished from *C. platytarsis* in the structure of the maxillule and sternal furca. Besides, in *C. platytarsis*, the hairy outer spines on the exopod of leg 4 are short and obtuse. Unlike the present species, *Caligus platytarsis* is a parasite of mullet (*Mugil* spp.) from India (Bassett-Smith, 1898: Rangnekar, 1955; Pillai, 1961, 1985) and Australia (Kabata, 1965).

Caligus multispinosus is so far known as a parasite of butterfish [*Pampus argenteus* (Euphrasen)] from China (Shen, 1957) and India (Pillai, 1961, 1985). The specimens examined in this study, being parasitic on different hosts, differs slightly from those occurring on the butterfish in the length of the abdomen. While the ratio of the abdominal length/width for the specimens from the butterfish is 2.79 : 1 and 2.97 : 1, respectively, for those from China (Shen, 1957) and India (Pillai, 1985), it is only 1.84 : 1 for those parasitic on the black sea bream in Taiwan.

Aside from bearing a moderately long abdomen and hairy outer spines on leg 4, the general morphology of *C. multispinosus* from Taiwan is very close to *Caligus laticaudus* Shiino, which is also a parasite of the sparid fish from Japan. Nevertheless, based on Shiino's (1960) original description of *C. laticaudus*, additional differences between these two species are found in the structure of the maxilliped (with a prominent medial protrusion on the corpus in *C. laticaudus*) and sternal furca (with a pair of blunt tines in *C. laticaudus*).

Kirtisinghe (1964: 56) made a mistake in placing Pillai's (1961) *C. multispinosus* into a synonym of *Caligus diaphanus* Nordmann. Pillai (1985: 282–285) duly corrected that mistake and supported his correction by providing a redescription of *C. diaphanus* based on the specimens deposited in the British Museum. Pillai (1985) was skeptical about the occurrence of *C. diaphanus* in Sri Lanka (=Ceylon).

Thus, it is very likely that *C. diaphanus* in Thompson and Scott's (1903) report and Kirtisinghe's review (1964) was a misidentification for *C. multispinosus.*

Acknowledgements

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