

A New Species of *Pennatulicola* Humes and Stock (Copepoda: Cyclopoida: Rhynchomolgidae) Associated with a Pennatulacean from Tokyo Bay, Japan

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A new species of poecilostome cyclopoid copepod, *Pennatulicola piscatorius* n. sp., is described as an associate of the pennatulacean genus *Pteroeides* from Tokyo Bay, Japan. The new species is distinguishable from its congeners by the following combination of features: exopod of leg 5 with conical inner process arising 38% of way distally, maxillule with three apical setae, and basis of legs 1–4 with a simple outer seta. This is the first record of the genus *Pennatulicola* in East Asia.

Key Words: *Pennatulicola piscatorius* n. sp., associated fauna, *Pteroeides*, sea pen.

Introduction

Sea pens (pennatulaceans) belong to the order Pennatulacea in the phylum Cnidaria and are known to host associated copepods of the families Lamippidae and Rhynchomolgidae. Humes (1985) counted 15 species in six genera of poecilostome cyclopoid copepods associated with 14 species in eight genera of pennatulaceans. Those copepods include eight species from the Lamippidae: *Enalcyonium albidum* (Zulueta, 1908), *E. concinnum* (Humes, 1957), *Lamippe bouligandi* Laubier, 1972, *L. pteroidis* Zulueta 1910, *L. rubra* Bruzelius, 1858, *Lamippella delamarei* Bouligand, 1965, *Lamippula chattoni* (Zulueta, 1908), and *L. pallida* (Zulueta, 1908); and seven species from the Rhynchomolgidae: *Pennatulicola pteroidis* (Della Valle, 1880), *P. pterophilus* (Stock, 1962), *P. serratipes* (Ummerkutty, 1961), *Critomolgus pteropadus* (Humes, 1978), *C. ptilosarci* (Humes and Stock, 1973), *C. trispinosus* (Stock, 1959), and *C. virgulariae* (Humes, 1978).

Since then, two additional species of copepod have been described from pennatulaceans: *Critomolgus nudus* Kim, 2000 from *Virgularia gustaviana* (Herklots, 1863) and *Zamoligus cavernularius* Kim, 2000 from *Cavernularia obesa* Valenciennes in Milne Edwards and Haime, 1850. Both of these belong to the family Rhynchomolgidae and were discovered in the Yellow Sea (Kim 2000a, b). Therefore, in total, 17 species in seven genera of cyclopoid copepods have been recorded as associates of pennatulaceans.

The genus *Pennatulicola* consists of four known species, viz., *P. corallophilus* Nair and Pillai, 1986 from a scleractinian coral and *P. pteroidis* (Della Valle, 1880), *P. pterophilus* (Stock, 1962), and *P. serratipes* (Ummerkutty, 1962) from pennatulaceans. In the present paper a new species of *Pen-*

natulicola associated with the pennatulacean genus *Pteroeides* is described from Tokyo Bay, Japan.

Materials and Methods

The copepods were collected from external washings of one pennatulacean of the genus *Pteroeides* taken accidentally with a fishhook in Tokyo Bay. The copepods were preserved in 80% ethanol. For microscopic observation, some of specimens were dissected and observed using the reverse slide method (Humes and Gooding 1964). The description was done mainly on the basis of dissected paratypes. In the description, the body length does not include the setae on the caudal rami. In the armature formula for the antennule and legs 1–4, Roman and Arabic numerals represent spines and setae, respectively. All figures were drawn with the aid of a drawing tube attached to the microscope. Type specimens have been deposited in the National Museum of Nature and Science, Tsukuba. Terminology follows Huys and Boxshall (1991) and Humes and Boxshall (1996).

Order **Cyclopoida** Burmeister, 1835

Family **Rhynchomolgidae** Humes and Stock, 1972

Genus ***Pennatulicola*** Humes and Stock, 1972

Pennatulicola piscatorius n. sp.

(Figs 1–3; Table 1)

Material examined. 25♀♀, 4♂♂ from external washings of one pennatulacean of the genus *Pteroeides* (cf. *Pteroeides sparmanni* Kölliker, 1869) taken with a fishhook in Tokyo Bay, Japan (35°16'00"N, 139°43'40"E), depth about

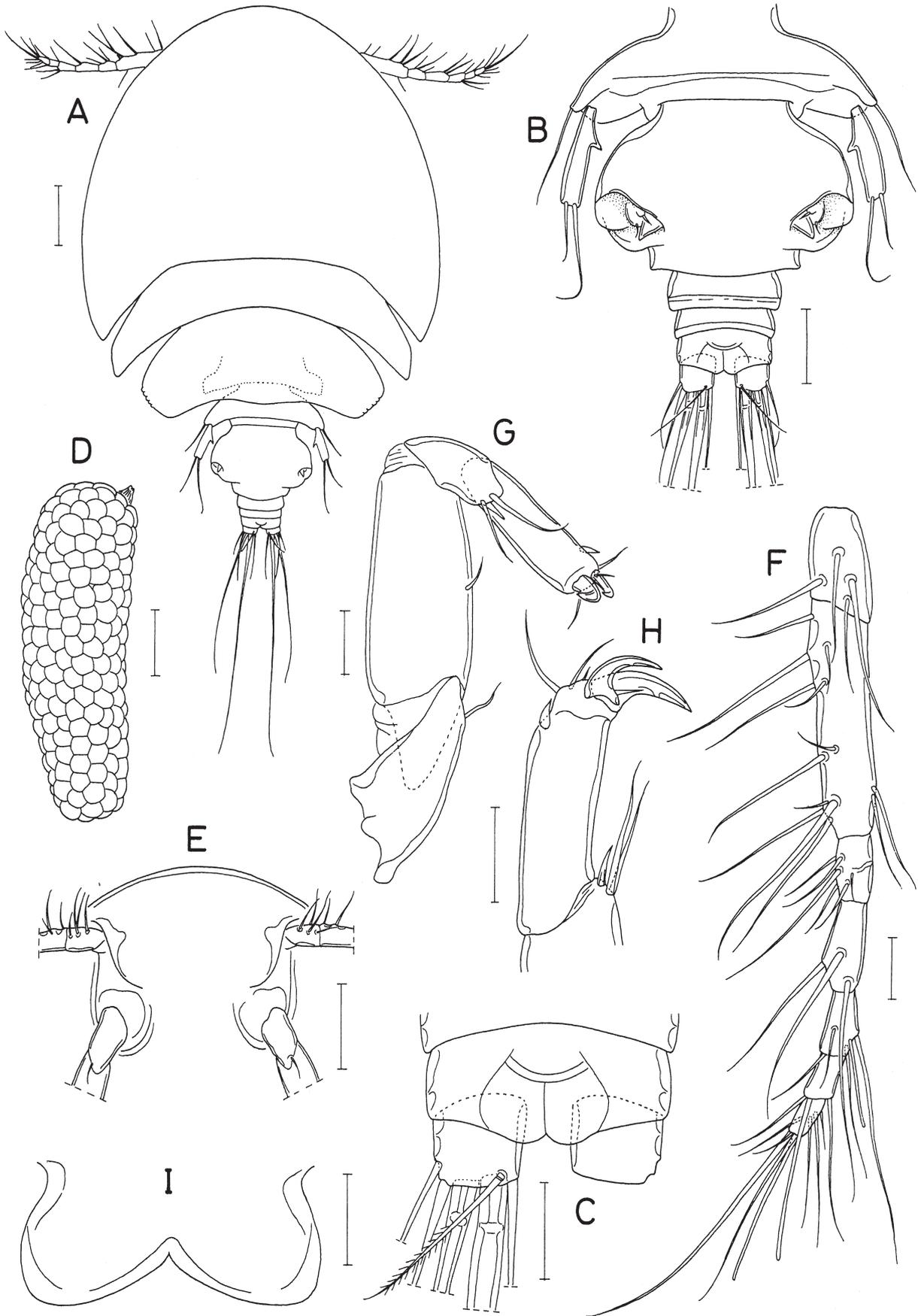


Fig. 1. *Pennatulicola piscatorius* n. sp., female, paratype. A, habitus, dorsal; B, urosome, dorsal; C, anal somite and caudal rami, dorsal; D, egg sac; E, rostral area, ventral; F, antennule; G, antenna; H, distal part of antenna; I, labrum. Scale bars: A, D, E, 0.2 mm; B, 0.1 mm; C, F–I, 0.05 mm.

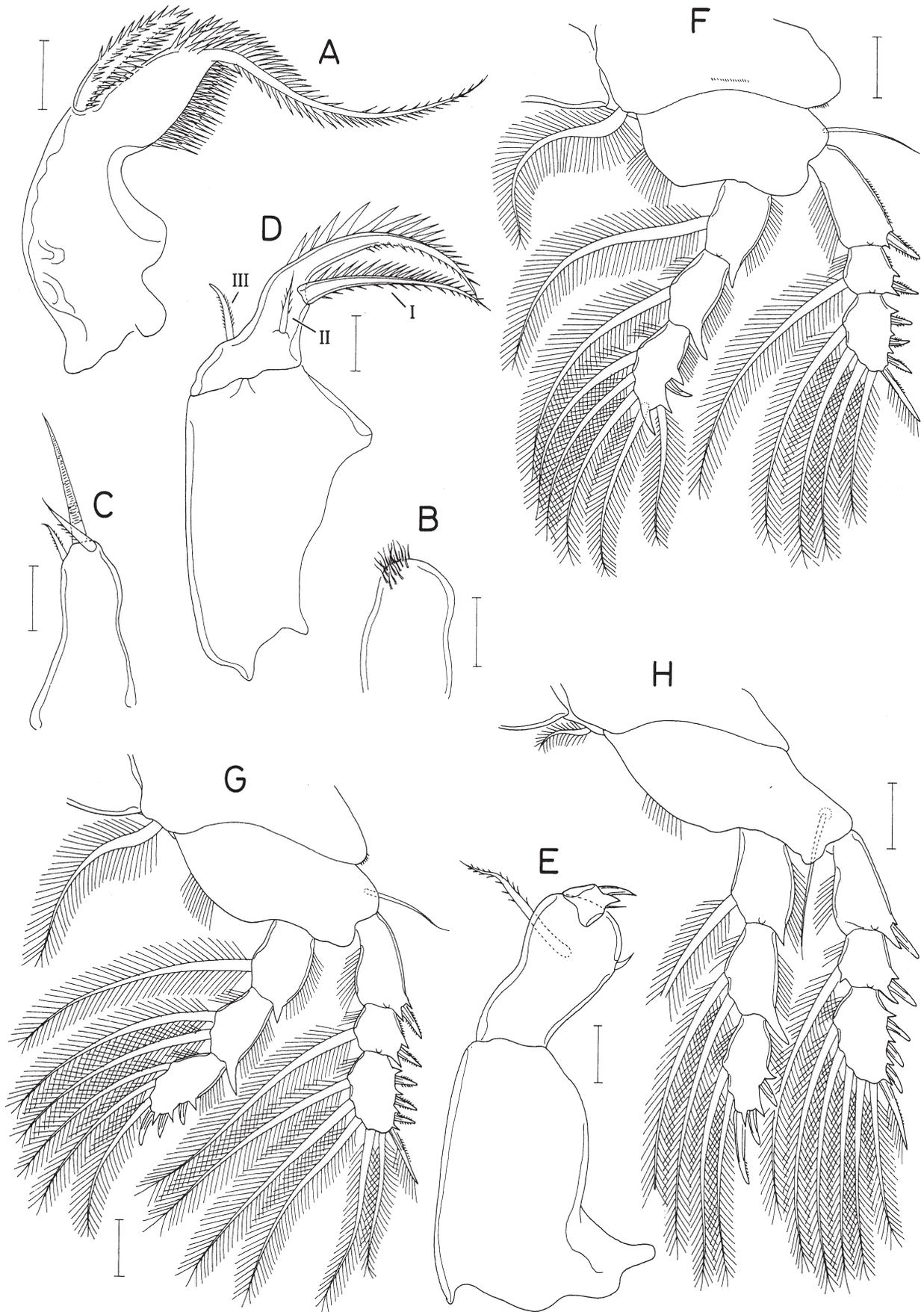


Fig. 2. *Pennatulicola piscatorius* n. sp., female, paratype. A, mandible; B, paragnath; C, maxillule; D, maxilla (Roman numerals I–III indicate setae I–III); E, maxilliped; F, leg 1; G, leg 2; H, leg 3. Scale bars: A–E, 0.02 mm; F–H, 0.05 mm.

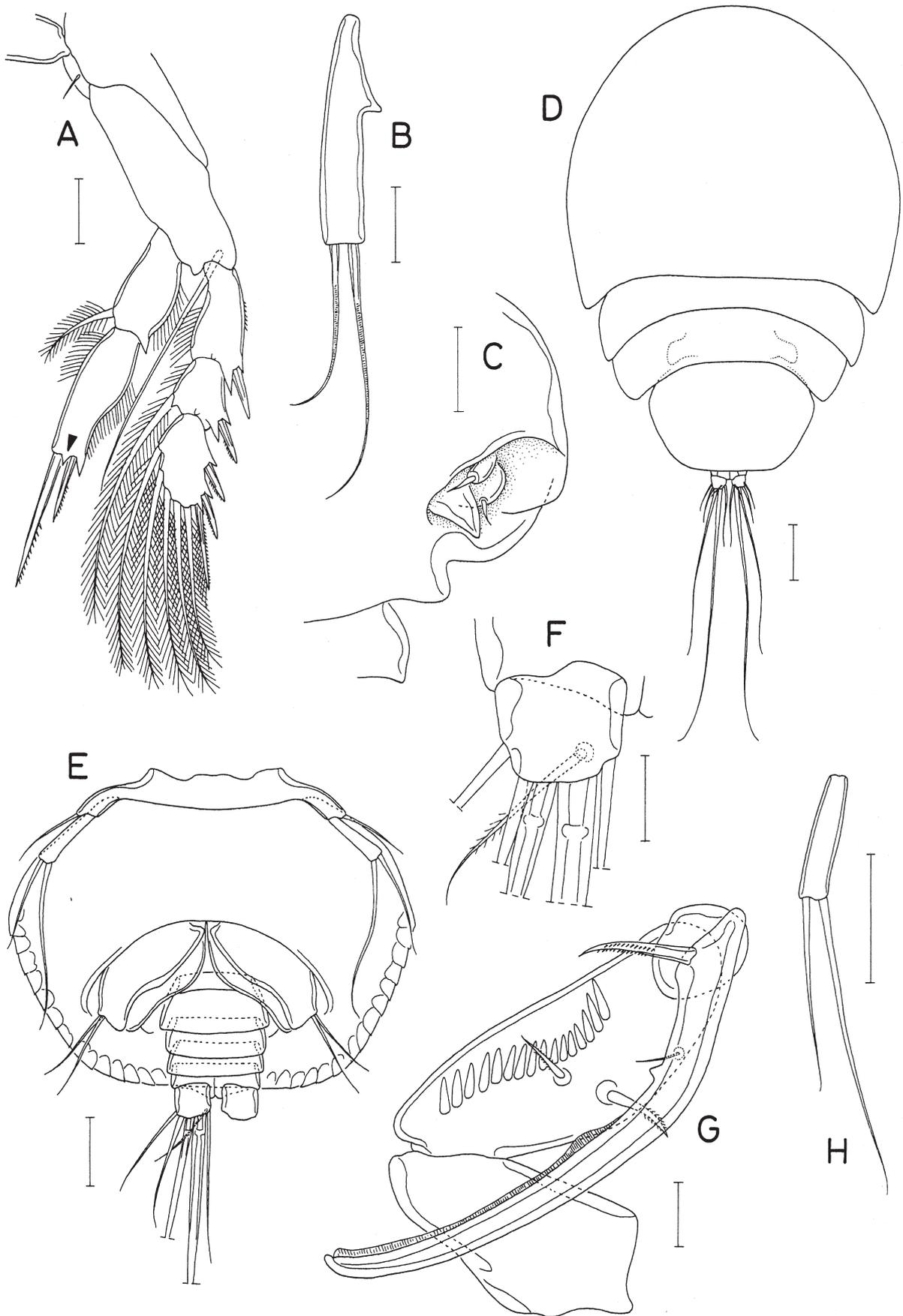


Fig. 3. *Pennatulicola piscatorius* n. sp. Female, paratype: A, leg 4 (arrowhead indicates inner terminal process that is usually absent); B, exopod of leg 5; C, genital aperture. Male, paratype: D, habitus, dorsal; E, urosome, ventral; F, right caudal ramus, ventral; G, maxilliped; H, exopod of leg 5. Scale bars: A–C, E, H, 0.05 mm; D, 0.1 mm; F, G, 0.02 mm.

Table 1. Armature formula of legs 1–4. Roman and Arabic numerals representing spine and setae respectively.

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

15 m, coll. H. Itoh, 18 August 2007. Holotype (intact ♀, NSMT-Cr 23836), allotype (intact ♂, NSMT-Cr 23837), and paratypes (22♀♀, 2♂♂, all intact, NSMT-Cr 23838) have been deposited in the National Museum of Nature and Science, Tsukuba. Dissected paratypes (2♀♀, 1♂) are kept in the second author's collection.

Female. Body (Fig. 1A) broad, with large prosome and small urosome. Mean body length 1.66 mm (1.47–1.74 mm), based on 7 specimens (holotype 1.70 mm long). Length of dissected and described paratype 1.74 mm. Greatest width 1.18 mm. Prosome flattened, nearly circular, 1.32 mm long, consisting of cephalothorax and second to fourth pedigerous somites. Cephalothorax 0.85 mm long, corresponding to more than 60% of prosomal length, and consisting of completely fused cephalosome and first pedigerous somite, without any trace of dorsal suture line; its posterolateral corners extending posteriorly, with angular tips. Second pedigerous somite broader but shorter than third pedigerous somite, with its epimeral parts tapering and directed posterolaterally. Third pedigerous somite about twice as long as second one, with truncate and weakly crenate lateral margins. Fourth pedigerous somite strongly reduced, 392 µm wide, and concealed by preceding somite in dorsal view. Urosome (Fig. 1B) 5-segmented, 514 µm long and less than half as long as prosome. First urosomal somite (fifth pedigerous somite) extending laterally, wider than genital double-somite. Genital double-somite expanded laterally, 228×338 µm in length and width, thus much wider than long, and consisting of expanded anterior part and short, narrower posterior part; short posterior region 198 µm wide; genital aperture large, located dorsolaterally in posterior area of expanded anterior part; genital operculum with 2 small setae and 1 large, conical process. Three free abdominal somites short, unornamented dorsally and ventrally, respectively 49×150, 37×132, and 52×126 µm in size. Anal somite (Fig. 1C) with large anal area. Caudal ramus (Fig. 1C) short, 46×46 µm, as long as wide, with 6 setae; dorsal seta (seta VII) weakly pinnate and articulated at base; other 5 setae simple; outer lateral seta (seta II) located at 70% of length of outer margin; longest inner median terminal seta (seta V) about 770 µm long; second longest nearby seta (seta IV) about 500 µm long. Egg sac (Fig. 1D) 1.05×0.34 µm, containing numerous eggs; each egg about 70 µm in diameter.

Rostrum (Fig. 1E) very broad but almost fused with cephalosome, without posterior margin and discernible only by lateral margins. Antennule (Fig. 1F) slender, 498 µm long, 7-segmented; armature formula 4, 13, 6, 3, 4+aesthetasc, 2+aesthetasc, and 7+aesthetasc; all setae simple; aesthetascs on 3 distal segments thin. Antenna (Fig. 1G) 4-segmented; first segment (coxobasis) with 1 subdistal seta on inner

margin; second segment (first endopodal segment) longest among segments, with 1 seta near middle of inner margin; third segment shortest, with 1 short spiniform seta and 2 longer setae at inner distal corner; fourth segment (Fig. 1H) 128×40 µm, 3.2 times as long as wide, armed with 2 claws and 5 setae; one claw massive, 53 µm long, other one narrower, 45 µm long; outer subdistal seta short, broad, and foliaceous; one of remaining 4 setae inserted on proximal region of inner margin of narrower claw.

Labrum (Fig. 1I) much broader than long, with smooth lateral and distal margins and shallow posteromedian incision. Mandible (Fig. 2A) with broad inner proximal notch; blade relatively narrow, with 2 rows of spinules (one row consisting of shorter spinules than other row) on inner margin, large, spinulose outer scale (lappet) bearing 5 rows of spinules (1 row on outer margin and 2 rows each on ventral and dorsal surfaces; 2 ventral rows not visible in Fig. 2A); distal lash elongate, spinulose, nearly as long as rest of mandible. Paragnath (Fig. 2B) lamelliform, with apical tuft of setules. Maxillule (Fig. 2C) tapering and armed distally with 3 unequal setae, longest one simple and wrinkled, other 2 smaller and weakly spinulose. Maxilla (Fig. 2D) 2-segmented; proximal segment unarmed and unornamented; distal segment with 3 (or 2) setae and terminating in long distal lash with spinules on both margins (proximal spinules on outer margin large, more distal ones gradually decreasing in size, about 16 in total); inner seta (seta I) large, as long as distal lash, with spinules along both margins (spinules on outer margin larger than those of inner margin); anterior seta (seta II) weakly spinulose; outer proximal seta (seta III) absent or present (present only in 1 of 4 observed mandibles; prominent and finely spinulose if present). Maxilliped (Fig. 2E) 3-segmented; first segment largest but unarmed; second segment increasingly broadened distally, with 2 unequal spinulose setae (larger one about 7 times as long as smaller one); third segment small, broader than long, and terminating in claw-like, pointed process, with 1 spine and 1 thin seta.

Legs 1–4 biramous. Legs 1–3 (Fig. 2F–H) with 3-segmented rami, Leg 4 (Fig. 3A) with 3-segmented exopod and 2-segmented endopod. Inner seta on coxa of legs 1 and 2 large, but reduced in leg 3 and rudimentary and simple in leg 4. Outer seta on basis of legs 1–4 simple, that of leg 4 very long, extending to distal end of its exopod. Legs 1–3 with prominent, beak-like process on outer distal corner of first and second endopodal segments and 3 similar processes on third endopodal segment (1 outer and 2 distal). Leg 4 also with process on outer distal corner of proximal endopodal segment and 1 or 2 distal processes on distal segment; inner one (indicated by arrowhead in Fig. 3A) of these pro-

cesses occasionally present, but usually absent; two terminal spines 107 μm (inner) and 52 μm (outer) long. Armature formula of legs 1–4 shown in Table 1.

Leg 5 consisting of 1 simple dorsolateral seta on fifth pedigerous somite and free exopod (Fig. 1B); exopod (Fig. 3B) narrowing proximally, 154 μm long, 28 μm wide (measured across distal region), with truncate distal margin, with conical process on inner margin at 38% of segment length, and 2 distal simple setae (longer, inner one 177 μm long, and shorter, outer one 114 μm long). Leg 6 represented by 2 small setae and massive conical process on genital operculum (Fig. 3C).

Male. Body (Fig. 3D) dorsoventrally depressed as in female but narrower and much smaller. Length of dissected specimen 865 μm , half as long as that of female. Greatest width 592 μm . Cephalothorax 488 μm long, more than half as long as entire body. Fourth pedigerous somite concealed by preceding somite, not visible in dorsal view. Urosome (Fig. 3E) 6-segmented. First urosomal somite (=fifth pedigerous somite) very short and 192 μm wide. Genital somite large, plate-like, 210 \times 292 μm , roughly hexagonal, and covering most of abdomen in dorsal view, with finely serrulate lateral and posterior margins and thick sclerotization along these margins. Abdomen short and inserting into ventral surface of genital somite. Four abdominal somites much wider than long. Caudal ramus (Fig. 3F) short, slightly wider than long, 27 \times 30 μm (ratio 0.90:1), and armed as in female.

Rostrum, antennule, and antenna as in female, without sexual dimorphism. Mouthparts, except for maxilliped, also as in female. Maxilliped (Fig. 3G) consisting of 3 segments and terminal claw; first segment unarmed; second segment with 2 inner setae (one of them slightly larger and finely spinulose in distal half) and longitudinal row of spinules (16 spinules in dissected specimen) on inner side; third segment short and unarmed; terminal claw large, weakly curved, fringed with narrow membrane along distal two-thirds of inner margin, and armed with 1 spiniform, spinulose proximal seta as well as small setule and conical tubercle near proximal fifth of claw.

Legs 1–4 as in female. Leg 5 segmented as in female, but its exopod (Fig. 3H) rectangular, without inner process, and 49 \times 12 μm in size (ratio 4.08:1), with 2 simple setae on distal margin (outer seta 73 μm long, inner one 120 μm long). Leg 6 represented by 2 similar simple setae on genital operculum (Fig. 3E).

Etymology. The specific name *piscatorius* is a Latin adjective meaning “of fishing”, alluding to the accidental catch of the host with a fishhook while fishing.

Remarks. One morphologically diagnostic feature of the genus *Pennatulicola*, distinguishing it from its related genera, is the presence of a large lappet on the outer margin of the mandible. At present, four species are placed in this genus, but one of these, *P. corallophilus* differs from its congeners. It was recorded as an associate of a scleractinian coral of the genus *Porites* in the Arabian Sea (Nair and Pillai 1986) and has four spines and five setae (armature III, I, 5) on the third exopodal segment of leg 4, a unique setation

in the genus. In addition, *P. corallophilus* displays several other features that are unusual in *Pennatulicola*: (1) the body is small, 1.07 mm long in the female; (2) the fourth pedigerous somite is visible in dorsal view; (3) the mandible is broad, with an expanded inner margin that is perpendicular to the distal lash; (4) the maxillule is armed with only two distal setae; and (5) the exopod of leg 5 is finely spinulose and lacks any process on the inner margin. It does have a “lappet” on the convex margin of the mandible, which is the main diagnostic feature of *Pennatulicola* (Humes and Stock 1973); otherwise, it might most readily be assigned to *Critomolgus* Humes and Stock, 1972.

The other three congeners can be differentiated from *P. piscatorius* n. sp. as follows. In *Pennatulicola pteroidis*, which was redescribed by Stock (1959), the exopod of female leg 5 is broadened distally, with a pointed process situated subdistally (not subproximally as in the new species) on the inner margin; the caudal ramus of the male, as illustrated by Stock (1959), is distinctly wider than long; and leg 1 is sexually dimorphic, with the third endopodal segment of the male bearing a large medio-distal process. In *P. pterophilus*, which was redescribed by Humes (1978), the second endopodal segments of legs 1–3 each have a bifurcate process at the inner distal corner (Stock 1962; Humes 1978); the exopod of female leg 5 is more elongate, with a subdistal conical process on the inner margin (Humes 1978); the maxillule has only two distal setae (Stock 1962; Humes 1978); leg 1 is sexually dimorphic (Humes 1978), as in *P. pteroidis*; and the posterodorsal margin of the genital double-somite is expanded posteriorly (Humes 1978). *P. serratipes* was described as an associate of the pennatulacean *Pteroeides esperi* Herklots from India. The original description of this copepod is quite ambiguous, without presentation of sufficient species-specific features. However, based on the original illustrations given by Ummerkutty (1962), *P. serratipes* may be differentiated from the new species based on the following features: (1) the first antennular segment has three setae (*vs* four setae in *P. piscatorius* n. sp.); (2) the posterolateral corners of the genital double-somite are sharply pointed (*vs* angular in *P. piscatorius*); (3) the outer seta on the basis of legs 1 and 4 (and possibly legs 2 and 3, as well) is pinnate (*vs* simple in *P. piscatorius*); (4) the outer distal process on the first and second endopodal segments of leg 3 is weak (*vs* prominent in *P. piscatorius*); (5) the first endopodal segment of leg 4 lacks an outer distal process (*vs* present in *P. piscatorius*); (6) the exopod of leg 5 extends to the posterior margin of the genital double-somite (*vs* only to 60% of the length of the genital double-somite in *P. piscatorius*); (7) the second segment of the male maxilliped bears an elevated ridge distal to a row of spinules, as Ummerkutty (1962) pointed out (*vs* no ridge present in *P. piscatorius*). At least some of the above features of *P. serratipes*, especially (2) and (3), may be real and useful for distinguishing it from *P. piscatorius*.

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References

- Burmeister, H. 1835. Beschreibung einiger neuen oder weniger bekannten Schmarotzerkrebse, nebst allgemeinen Betrachtungen über die Gruppe, welcher sie angehören. *Nova Acta physico-medica Academiae Caesareae Leopoldino-Carolinae Naturae Curiosorum (Acta der Kaiserlichen Leopoldinisch-Carolinischen Deutschen Akademie der Naturforscher)* 17: 269–336.
- Humes, A. G. 1978. Lichomolgoid copepods (Cyclopoida), with two new species of *Doridicola*, from sea pens (Pennatulacea) in Madagascar. *Transactions of the American Microscopical Society* 97: 524–539.
- Humes, A. G. 1985. Cnidarians and copepods: a success story. *Transactions of the American Microscopical Society* 104: 313–320.
- Humes, A. G. and Boxshall, G. A. 1996. A revision of the lichomolgoid complex (Copepoda: Poecilostomatoida), with the recognition of six new families. *Journal of Natural History* 30: 175–227.
- Humes, A. G. and Gooding, R. U. 1964. A method for studying the external anatomy of copepods. *Crustaceana* 6: 238–240.
- Humes, A. G. and Stock, J. H. 1972. Preliminary notes on a revision of the Lichomolgidae, cyclopoid copepods mainly associated with marine invertebrates. *Bulletin Zoologisch Museum, Universiteit van Amsterdam* 2: 121–133.
- Humes, A. G. and Stock, J. H. 1973. A revision of the family Lichomolgidae Kossmann, 1877, cyclopoid copepods mainly associated with marine invertebrates. *Smithsonian Contributions to Zoology* 127: 1–368.
- Huys, R. and Boxshall, G. A. 1991. *Copepod Evolution*. The Ray Society, London, 468 pp.
- Kim, I.-H. 2000a. Poecilostomatoid copepods from an intertidal mud flat in the Yellow Sea. *Journal of Natural History* 34: 367–432.
- Kim, I.-H. 2000b. *Zamoligus cavernularius* n. sp. (Copepoda, Poecilostomatoida, Rhynchomolgidae) associated with a pennatulacean in the Yellow Sea. *Korean Journal of Biological Sciences* 4: 251–255.
- Nair, B. U. and Pillai, N. K. 1986. Three new species of copepods associated with South Indian invertebrates. *Crustaceana* 50: 27–38.
- Stock, J. H. 1959. Copepod associated with Neapolitan invertebrates. *Pubblicazioni della Stazione Zoologica di Napoli* 31: 59–75.
- Stock, J. H. 1962. *Lichomolgus pterophilus* n. sp., a cyclopoid copepod associated with the East Indian sea-pen *Pteroides*. *Beaufortia* 9: 155–163.
- Ummerkutty, A. N. P. 1962. Studies on Indian copepods 5. On eleven new species of marine cyclopoid copepods from the south-east coast of India. *Journal of the Marine Biological Association of India* 3: 19–69.