

Two New Species of *Echiuricopus* n. gen. (Copepoda, Poecilostomatoida) Associated with Echiurans from the Yellow Sea

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ABSTRACT

Two new species of poecilostomatoid copepods associated with echiurans are described from an intertidal mud flat in the Yellow Sea. A new genus *Echiuricopus* is created to accommodate two new species, *E. aprilis* and *E. tenuipes*. Major differences between the two new species are displayed in body length, length of caudal ramus seta I, length/width ratio of leg 5 exopod, and armature of the first antennular segment. *Echiuricopus* n. gen. is closely related to the genus *Goidelia* Embleton, 1901, but is distinguished from the latter chiefly by having seven caudal setae, a claw-like process on the first antennular segment, one claw-like process on the maxillary syncoxa, the absence of an inner coxal seta on legs 1-4, different armatures on legs 1-4, and an elongate leg 5 exopod.

Keywords: *Echiuricopus* n. gen., Copepoda, external association, Echiura, new species, Korea

INTRODUCTION

Echiuran worms (phylum Annelida: class Polychaeta: subclass Echiura) comprise about 165 described species, most of which live in burrows in soft sediments (Goto et al., 2013). This animal group is poorly known in terms of their copepod associates. Currently, only four species of copepods have been found in association with echiurans (Anker et al., 2005). *Goidelia japonica* Embleton, 1901 was found in the rectum and on the body surface of *Urechis unicinctus* (von Drasche) in Japan and Korea (Embleton, 1901; Kim, 1998). *Echiurophilus fizei* Delamare Deboutteville and Nunes-Ruivo, 1955 has been recorded from the digestive tract of *Thalassema inansense* Ikeda in Vietnam (Delamare Deboutteville and Nunes-Ruivo, 1955). *Hemicyclops mortoni* Boxshall and Humes, 1987 was recovered from the burrows of *Ochetostoma erythrogrammon* Leuckart and Rüppell in Hong Kong (Boxshall and Humes, 1987), while *Goidelia pelliviva* Kim, 2000 is known as an external associate living on the surface of *Thalassema* sp. in the Yellow Sea (Kim, 2000). During field work on the intertidal zone of the Korean coast of the Yellow Sea, two species of unidentified echiurans were collected. Examination of

washings of these hosts yielded two species of previously unknown copepods belonging to a new genus. Both species are described and illustrated below.

MATERIALS AND METHODS

Echiuran hosts were dug out with a shovel on the tidal flat during low tide. The collected echiuran samples were placed in plastic bags and fixed with ethanol. In the laboratory, echiurans were agitated in water and copepods were sorted out from the resulting residues. Prior to microscopic observation and dissection, copepod specimens were immersed in lactic acid for more than 10 min. Mounting was done following the reversed slide method (Humes and Gooding, 1964). All illustrations were drawn with the aid of a drawing tube mounted on an Olympus BH microscope. The terminology for the caudal ramus setae follows that of Huys and Boxshall (1991). The intact type specimens have been deposited in the National Institute of Biological Resources (NIBR), Incheon, Korea. Descriptions of species were made on the basis of the dissected and figured paratypes. In the species descriptions body length was measured from the

anterior apex of the cephalothorax to the posterior margin of the caudal rami, excluding caudal setae. In the formula for the armature of antenna and legs 1–4, Roman numerals indicate spines and Arabic numerals represent setae.

SYSTEMATIC ACCOUNTS

Subclass Copepoda Milne-Edwards, 1840
 Order Poecilostomatoida Burmeister, 1835
 Family Catiniidae Bocquet and Stock, 1957

***Echiuricopus* n. gen.**

Diagnosis. Body cyclopiform. Prosome flattened, consisting of cephalothorax and 3 metasomites. Urosome 5-segmented in female and 6-segmented in male. Fifth pedigerous somite of female with distinct epimera. Female genital area located ventrally. Dorsal suture between last 2 abdominal somites obscure. Caudal ramus elongate, with 7 setae, including well developed outer proximal seta (seta I). Rostrum lamelliform or not well defined. Antennule 6-segmented; in female, first segment with claw-like anterior process, with identical armature in both sexes. Antenna consisting of coxo-basis and 3-segmented endopod; basis and first endopodal segment each with 1 seta; second endopodal segment with 1 seta and 1 pectinate claw in female, or 1 pectinate claw and 1 large setiform element bearing 1 large and several smaller sucking discs in male; terminal endopodal segment with 2 setae and 4 distally pectinate claws. Labrum with concave posterior margin bearing a pair of linguiform processes. Mandible with 1 thick, spiniform element distally. Maxillule with 3 setae. Female maxilla 2-segmented; syncoxa extended posterodistally forming strong horse-head shaped process; allobasis tipped with 3 small setae. Male maxilla 1-segmented, lamelliform. Female maxilliped represented by sclerotized rudiment. Male maxilliped 4-segmented; terminal segment represented by claw. Legs 1–4 with 3-segmented rami; coxae without inner seta; second endopodal segment with

inner seta. Number of setae and spines on third exopodal and endopodal segments of legs 1–4: 7, 8, 6, 6, and 4, 4, 3, 2, respectively. No sexual dimorphism in legs 1–4. Leg 5 consisting of well defined protopod and elongate exopod; exopod with total of 4 setae.

Type species. *Echiuricopus aprilis* n. sp.

Etymology. The generic name *Echiuricopus* is derived from the host taxon Echiura, and the Greek *kope*, meaning oar and forming part of the higher taxon name Copepoda. Gender is masculine.

Remarks. The new genus is closely related to *Goidelia* Embleton, 1901 which is also known to be associated with echiurans in Japan and Korea. While describing *Goidelia pelliviva*, Kim (2000) could differentiate it from its sole congener *G. japonica* only by slight differences. The two new species of *Echiuricopus* n. gen. described below are likewise very similar to each other, whereas, the two genera reveal significant differences between them, which lead to the creation of the new genus *Echiuricopus* to accommodate the two new species. Unlike *Goidelia*, *Echiuricopus* has a prominent outer proximal seta (seta I) on the caudal ramus, a claw-like process on the first antennular segment, a single claw-like process (rather than 2 hooks in *Goidelia*) on the maxillary syncoxa, a 4-segmented (rather than 3-segmented) male maxilliped, no inner coxal seta on all swimming legs, and an elongate exopod on leg 5. Armature formulae of leg rami are consistent within each genus but differ between genera, the setation of exopods of legs 1–4 being more reduced in *Goidelia* than in *Echiuricopus*. On the contrary, the setation of the endopods is more reduced in *Echiuricopus* than in *Goidelia*. The morphological differences between the two genera are summarized in Table 1.

The familial assignment of the genus *Goidelia* has been contentious since its proposal. It was originally placed in the Clausidiidae by Embleton (1901), but later, in the “synaptiphilid series” by Gooding (1963) along with the genera *Presynaptiphilus* Bocquet & Stock, 1960, *Synaptiphilus* Canu & Cuénot, 1892, *Myzomolgus* Bocquet & Stock, 1957, and *Catinia* Bocquet & Stock, 1957 (according to Boxshall and Halsey, 2004, the former two belong in

Table 1. Differences between the genera *Goidelia* Embleton and *Echiuricopus* n. gen.

Characteristic	<i>Goidelia</i>	<i>Echiuricopus</i> n. gen.
Seta I of caudal ramus	Absent	Prominent
Claw-like process of antennular 1st segment	Absent	Present
Syncoxa of ♀ maxilla	With 2 hooks	With 1 claw-like process
♂ maxilliped	3-segmented	4-segmented
Inner coxal seta of legs 1–4	Present	Absent
Numbers of elements on 3rd exopodal segments of legs 1–4	6, 6, 6, 6	7, 8, 6, 6
Numbers of elements on 3rd endopodal segments of legs 1–4	5, 5, 4, 3	4, 4, 3, 2
Leg 5 exopod	Lamelliform	Elongate

the Synaptophilidae, and the latter two in the Catiniidae), in the Catiniidae by Ho (1984) and Kim (2000), and in the Echiurophilidae by Boxshall and Halsey (2004). Boxshall and Halsey's (2004) cause of action to place *Goidelia* in the Echiurophilidae requires reassessment, since the latter and the type genus of the family, *Echiurophilus* Delamare Deboutteville and Nunes-Ruivo, 1955, radically different. Perhaps the establishment of a new family may be needed to accommodate *Goidelia* and *Echiuricopus* n. gen. Tentatively, I have elected to place both genera in the Catiniidae, pending future morphology/or molecularly based analysis of the Catiniidae and its related families.

Echiuricopus aprilis n. sp. (Figs. 1-4)

Material examined. Three ♀♀ and 3♂♂ from an unidentified echiuran, collected from an intertidal mudflat (37°28'40"N, 126°22'46"E) on Yeongjong Island off Incheon, Korean coast of the Yellow Sea, on 20 Apr 2015, by Kim IH. Holotype (♀, NIBRIV0000330540), allotype (♂, NIBRIV0000325915), and paratypes (1♀, 1♂, NIBRIV0000330541) have been deposited in the NIBR, Incheon, Korea. Dissected paratypes (1♀, 1♂) are retained in the collection of the author.

Female. Body (Fig. 1A) with flattened prosome and cylindrical urosome. Body length of dissected and figured specimen 990 µm. Other 2 examined specimens 1,018 and 1,061 µm, respectively. Prosome consisting of cephalothorax and 3 metasomites, 589 µm long. Cephalothorax nearly hemi-circular and 287 × 393 µm, with longitudinal rows of setules and spinules on each side of ventral surface, as in next species. First to third metasomites (second to fourth pedigerous somites) 113 × 407, 98 × 389, and 95 × 324 µm, respectively. Second and third metasomites with posterolaterally projected, tapering epimera. Third metasomite with blunt lateral margins and rimmed with membrane along posterodorsal margin. Urosome (Fig. 1B, C) 5-segmented. First urosomite (fifth pedigerous somite) broad, 78 × 209 µm, with posterolaterally expanded, tapering epimera, and rimmed with membrane along posterodorsal margin and distal part of lateral margins. Genital double-somite sub-rectangular, 109 × 148 µm, wider than long, with rounded corners and membrane along posterodorsal margin; genital area located ventrally on somite (Fig. 3C). Three abdominal somites markedly narrower than genital double-somite, 70 × 75, 34 × 57, and 16 × 48 µm, respectively. Dorsal boundary obscure between last 2 abdominal somites (Fig. 1D). Second abdominal somite with membrane along posteroventral margin. Last abdominal somite with row of several spinules near base of caudal ramus. Caudal ramus slender, 91 × 18 µm (ratio of length to width 5.06 : 1), gradually tapering distally, with 4 spinules on

outer distal corner, and armed with 7 naked setae; outer proximal seta (seta I) prominent but not longer than half length of caudal ramus; other 6 setae located distally or subdistally; seta V longest among setae, 436 µm long; seta IV second longest, 105 µm long.

Rostrum absent. Antennule (Fig. 1E) 6-segmented and 169 µm long; armature formula 4 + I, 13, 9, 4 + aesthetasc, 2 + aesthetasc, and 7 + aesthetasc; first segment with 1 plumose seta, 3 simple setae, 1 spine bearing spinules all around its shaft, and 1 backwardly recurved spinous process arising from the anterior margin; spine on first segment inserted on posterior proximal region of anterior process (Fig. 1F); second segment with small dentiform process proximally on anterior margin (Fig. 1F). Antenna (Fig. 2A) consisting of coxo-basis and 3-segmented endopod; coxo-basis longer than endopod, with 1 inner distal seta; first endopodal segment with 1 seta and 1 dentiform process on outer margin; second endopodal segment with 1 claw bearing row of 8 spinous processes and 1 small seta; terminal endopodal segment with 2 setae and 4 claws; these claws unequal in length and armed each with 7, 9, 9, and 8 spinous processes from inner to outer, respectively.

Labrum (Fig. 2B) tapering abruptly, with roundly concave posterior margin bearing row of spinules and 1 pair of transparent linguiform processes. Mandible (Fig. 2C) with 1 thick, spinulose spine distally. Paragnaths weakly developed, represented by transparent, smooth lobes (Fig. 2B). Maxillule (Fig. 2D) represented by a small lobe bearing 2 smaller inner and 1 longer outer setae, all of which being sparsely plumose. Maxilla (Fig. 2E) 2-segmented; syncoxa sclerotized, with pronounced, horse-head-shaped posterodistal outgrowth bearing 2 large dentiform processes and about 20 spinules; allobasis gradually tapering distally, with rounded distal end, and tipped with 3 small setae. Maxilliped represented by sclerotized vestige.

Legs 1-4 (Figs. 2F, G, 3A, B) with 3-segmented slender rami; outer margin of rami spinulose; coxae spinulose along outer margin and lacking inner seta. Inner distal spine on basis 19 µm long. Armature formula of legs 1-4 as follows:

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

Leg 5 (Fig. 2H) consisting of protopod and exopod. Protopod nearly rectangular, about 83 × 76 µm, clearly defined at base, with fine spinules on outer distal surface and 1 long, slender outer distal seta. Exopod 115 × 27 µm (ratio 4.26 : 1), broadest in middle, with 3 obliquely longitudinal rows of spinules and 4 spinulose setae (proximal, middle,

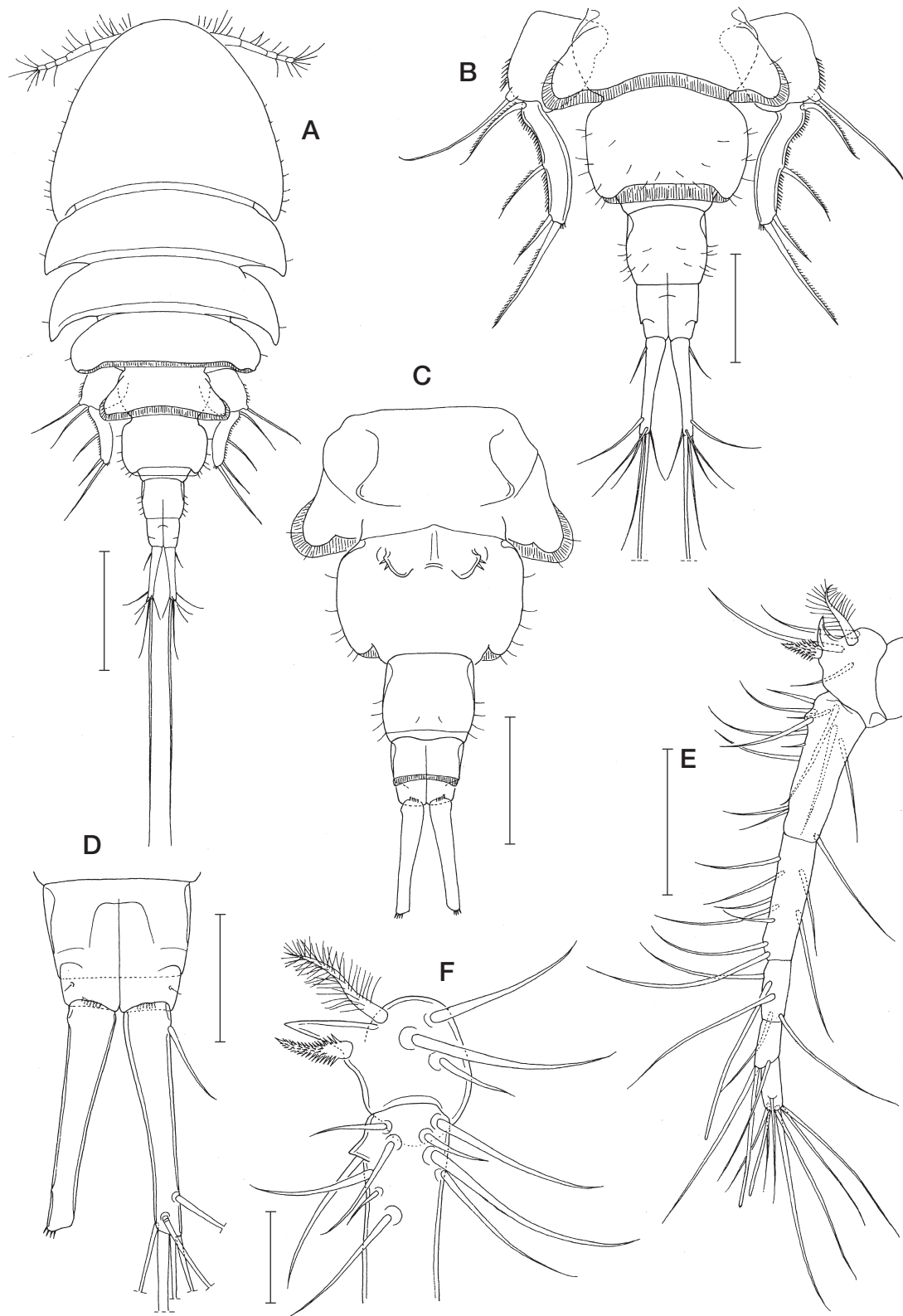


Fig. 1. *Echiuricopus aprilis* n. sp., female. A, Habitus, dorsal; B, Urosome, dorsal; C, Urosome (excluding fifth pedigerous somite), ventral; D, Distal part of urosome, dorsal; E, Antennule; F, Proximal part of antennule. Scale bars: A=0.2 mm, B, C=0.1 mm, D, E=0.05 mm, F=0.02 mm.

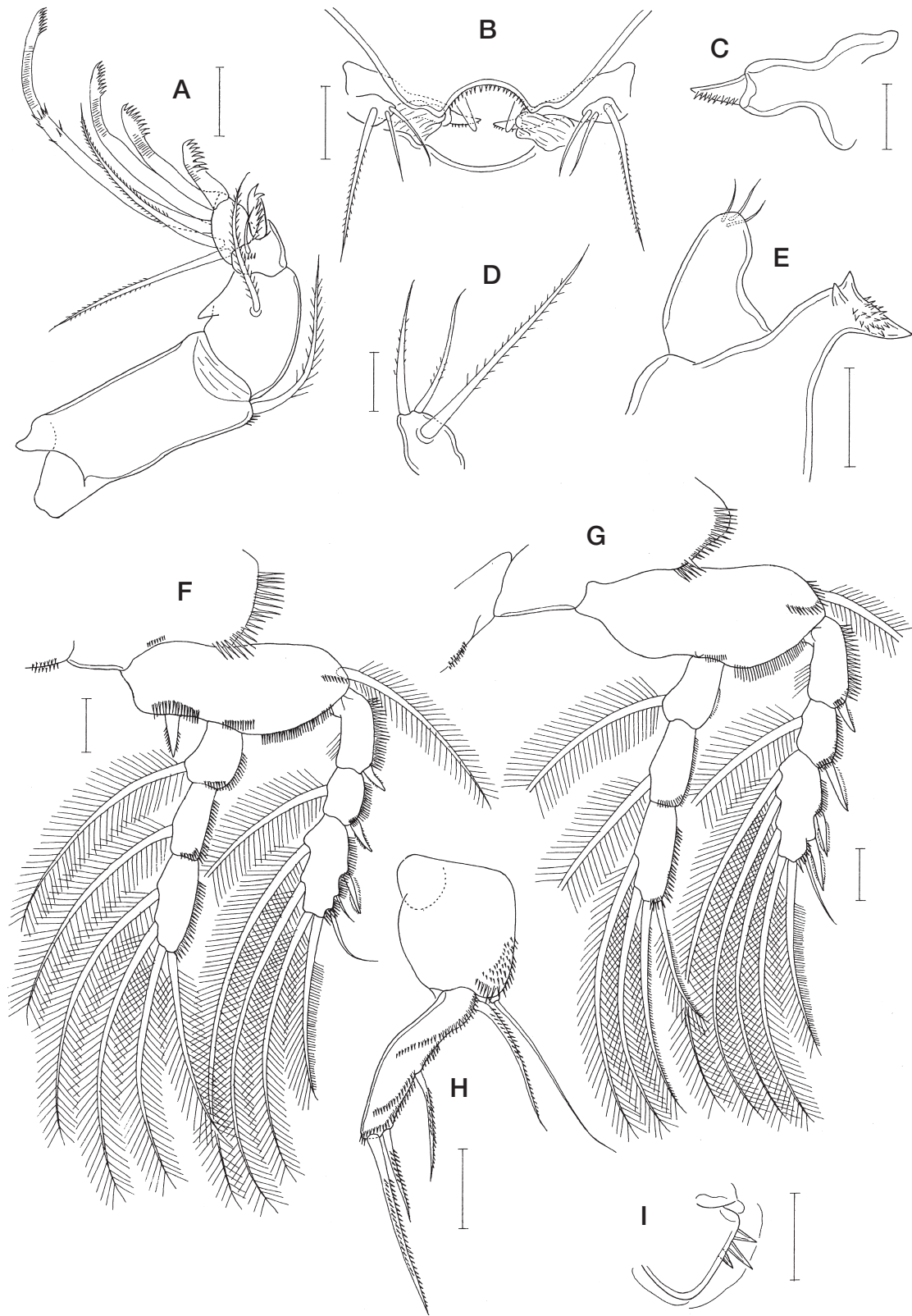


Fig. 2. *Echiuricopus aprilis* n. sp., female. A, Antenna; B, Oral region; C, Mandible; D, Maxillule; E, Maxilla; F, Leg 1; G, Leg 2; H, Leg 5; I, Genital area. Scale bars: A, B, E-G, I=0.02 mm, C, D=0.01 mm, H=0.05 mm.

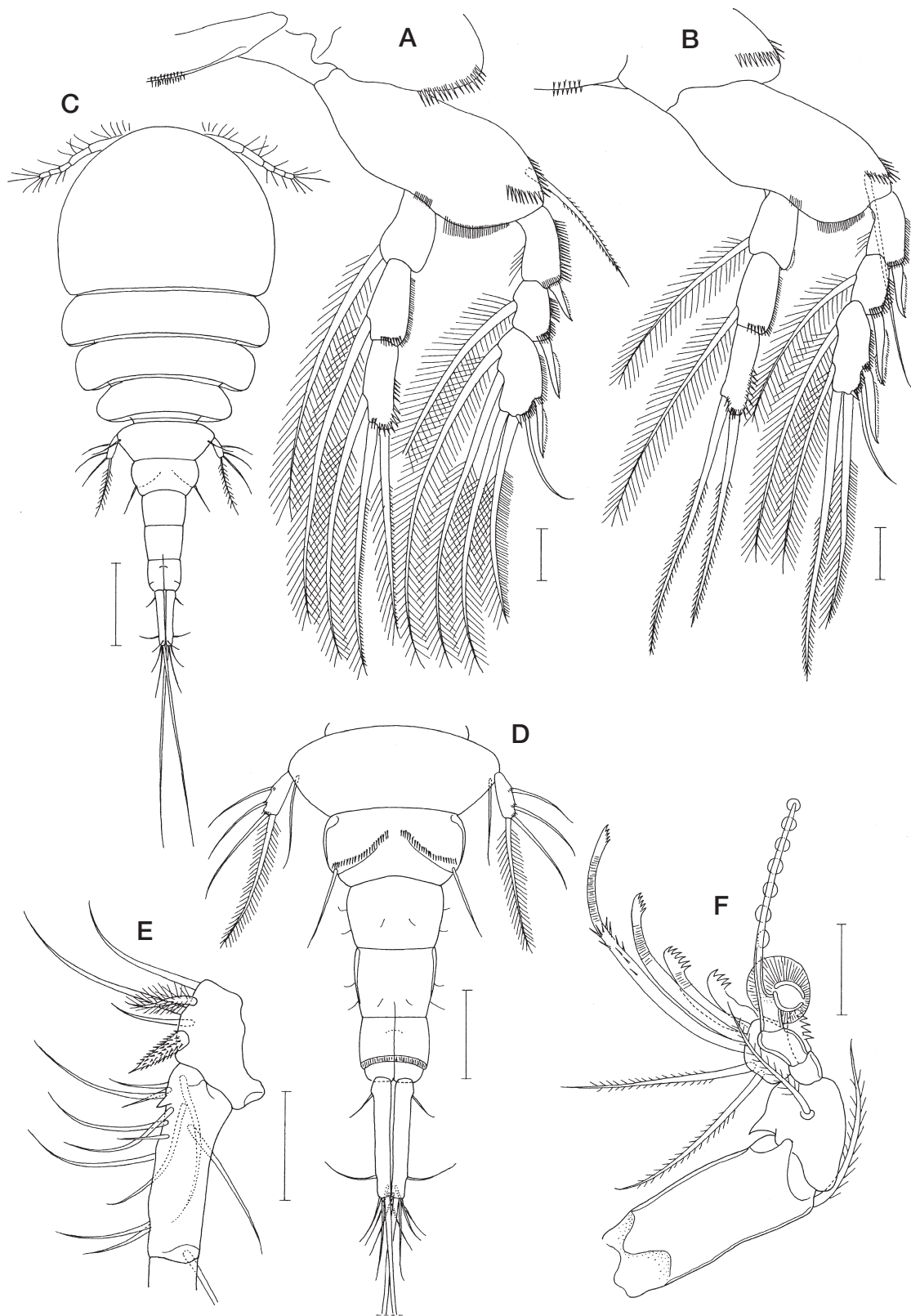


Fig. 3. *Echiuricopus aprilis* n. sp. Female: A, Leg 3; B, Leg 4. Male: C, Habitus, dorsal; D, Urosome, ventral; E, Proximal part of antennule; F, Antenna. Scale bars: A, B, E, F=0.02 mm, C=0.1 mm, D=0.05 mm.

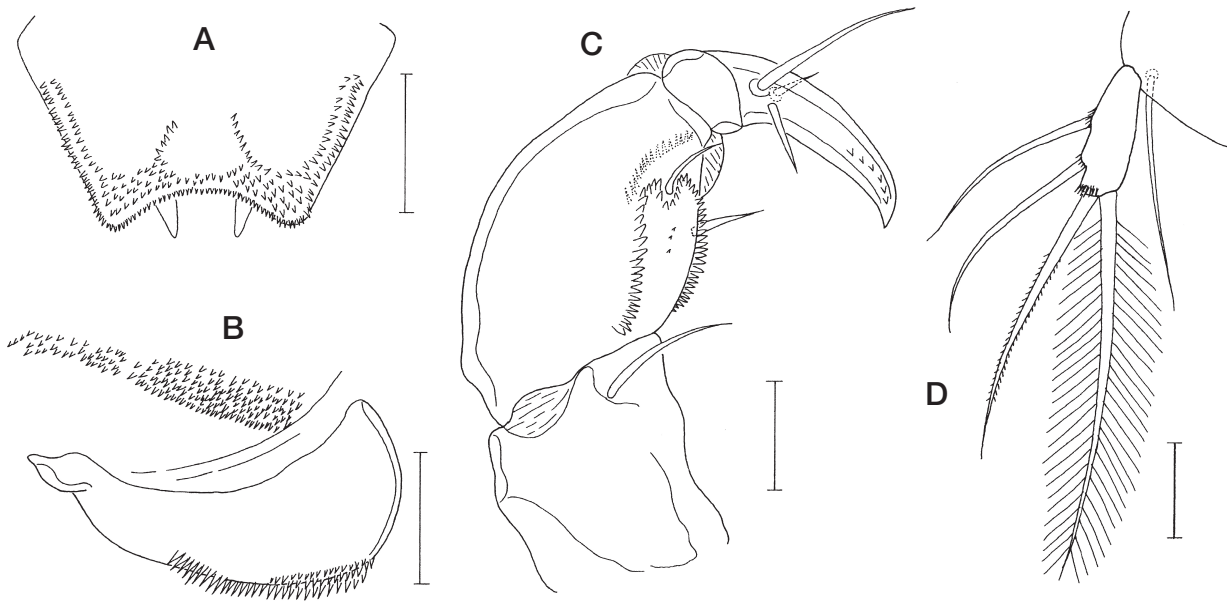


Fig. 4. *Echiuricopus aprilis* n. sp., male. A, Labrum; B, Maxilla; C, Maxilliped; D, Leg 5. Scale bars: A-D=0.02 mm.

subdistal, and distal ones); lengths of these setae 98, 73, 62, and 124 μm , from proximal to distal, respectively. Leg 6 (Fig. 2I) represented by 3 small spiniform elements on genital operculum.

Male. Body (Fig. 3C) tapering posteriorly and 630 μm long. Prosome 354 μm long. Cephalothorax 197 \times 255 μm . Three metasomites similar in length. First metasomite as wide as cephalothorax. Urosome (Fig. 3D) 6-segmented. First urosomite (fifth pedigerous somite) 48 \times 121 μm , much wider than other urosomites. Genital somite 40 \times 82 μm , with row of fine spinules along genital operculum and 1 naked seta posterolaterally. First to last abdominal somites 36 \times 56, 39 \times 46, 27 \times 40, and 9 \times 34 μm , respectively. Caudal ramus 69 \times 11 μm (ratio 6.27 : 1).

Rostrum absent as in female. Antennule with same number of armature elements, but first segment lacking anterior process (Fig. 3E). Antenna (Fig. 3F) different from that of female; second endopodal segment with 1 claw bearing 5 spinous processes and 1 long, spiniform element bearing proximal articulation, 1 large sucking disc and row of 7 or 8 small sucking discs; claws on terminal endopodal segment each with 4, 6, 5, and 5 distal spinous processes, from inner to outer, respectively.

Labrum (Fig. 4A) spiniferous on ventral surface. Mandible, paragnath and maxillule as in female. Maxilla (Fig. 4B) broad, lamella-like, with spinulose posterior margin and accompanied by transversely elongate anterolateral patch of spinules. Maxilliped (Fig. 4C) 4-segmented; first segment with 1 seta subdistally; second segment nearly fusiform,

with 2 similar setae and 3 longitudinal rows of spinules on inner surface; third segment small and unarmed; terminal segment as strong claw bearing 3 unequal setae proximally and row of several denticles in distal region.

Leg 1 with weakly sigmoid inner distal spine on basis, otherwise as in female. Legs 2-4 as in female. Leg 5 (Fig. 4D) represented by 1 naked dorsolateral (basal) seta on fifth pedigerous somite and free exopod; exopod 28 \times 10 μm and armed with 4 setae; these setae 42, 46, 59, and 81 μm long, respectively, from proximal to distal; largest distalmost seta plumose, adjacent seta sparsely plumose, and other 2 proximal setae naked. Leg 6 represented by 1 posterolateral seta on genital operculum (Fig. 3D).

Etymology. The specific name is derived from the Latin *aprilis* (meaning “belonging to April”), alluding to the finding of the new species in April.

Echiuricopus tenuipes n. sp. (Figs. 5-7)

Material examined. Four ♀♀ from an unidentified echiuran (host species different from that of *Echiuricopus aprilis* n. sp.), collected from an intertidal mudflat (37°28'42"N, 126°22'49"E) on Yeongjong Island off Incheon, Korean coast of the Yellow Sea, on 17 Jun 2015, by Kim IH. Holotype (♀, NIBRIV0000330542) and paratypes (2 ♀♀, NIBRIV0000325916) have been deposited in the NIBR, Incheon, Korea. Dissected paratype (1 ♀) is retained in the collection of the author.

Female. Body (Fig. 5A) similar in form to *E. aprilis* n. sp.,

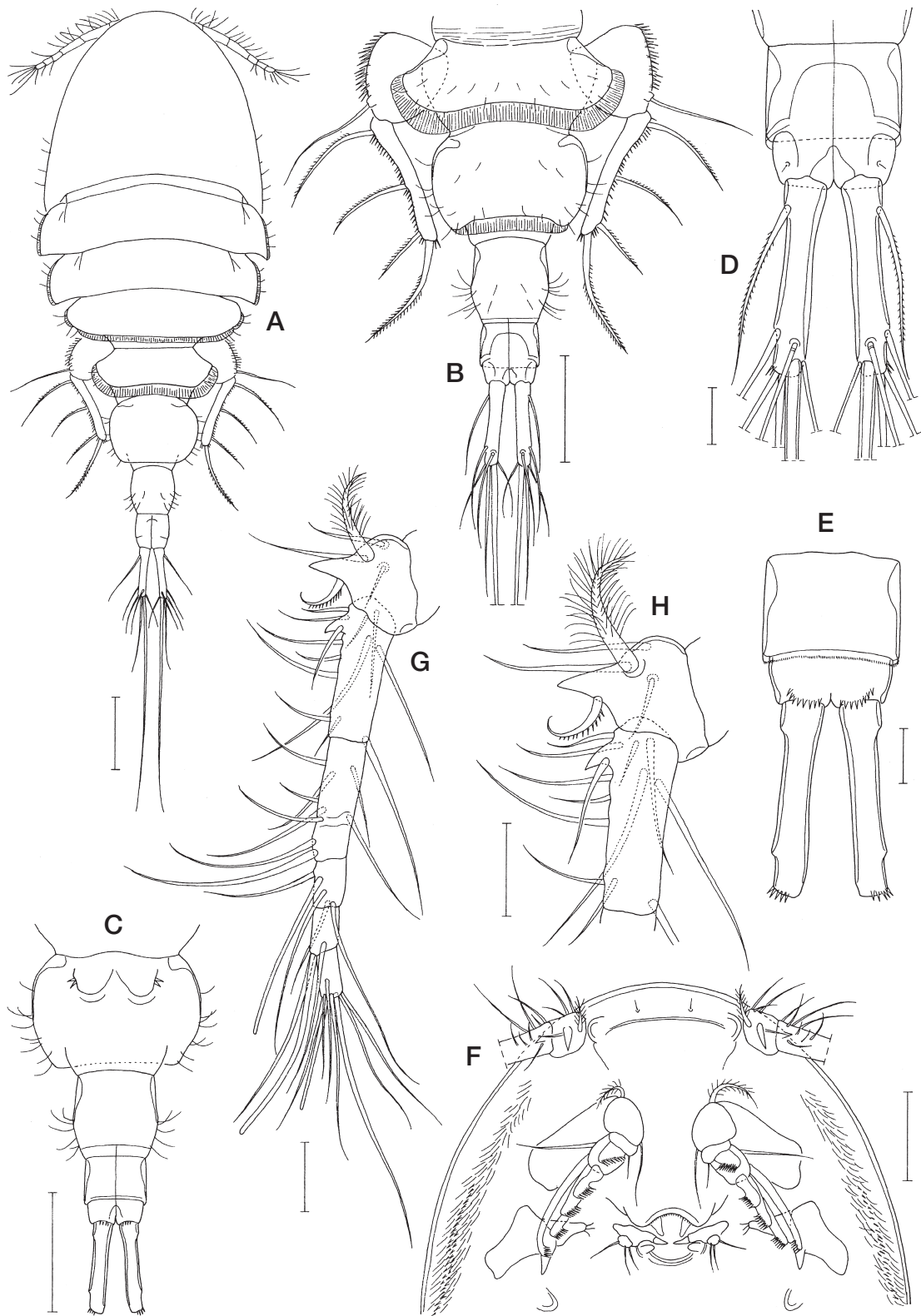


Fig. 5. *Echiuricopus tenuipes* n. sp., female. A, Habitus, dorsal; B, Urosome, dorsal; C, Urosome (excluding fifth pedigerous somite), ventral; D, Distal part of urosome, dorsal; E, Distal part of urosome, ventral (caudal ramus setae omitted); F, Cephalic region, ventral; G, Antennule; H, Proximal part of antennule. Scale bars: A-C=0.1 mm, D, E, G, H=0.02 mm, F=0.05 mm.

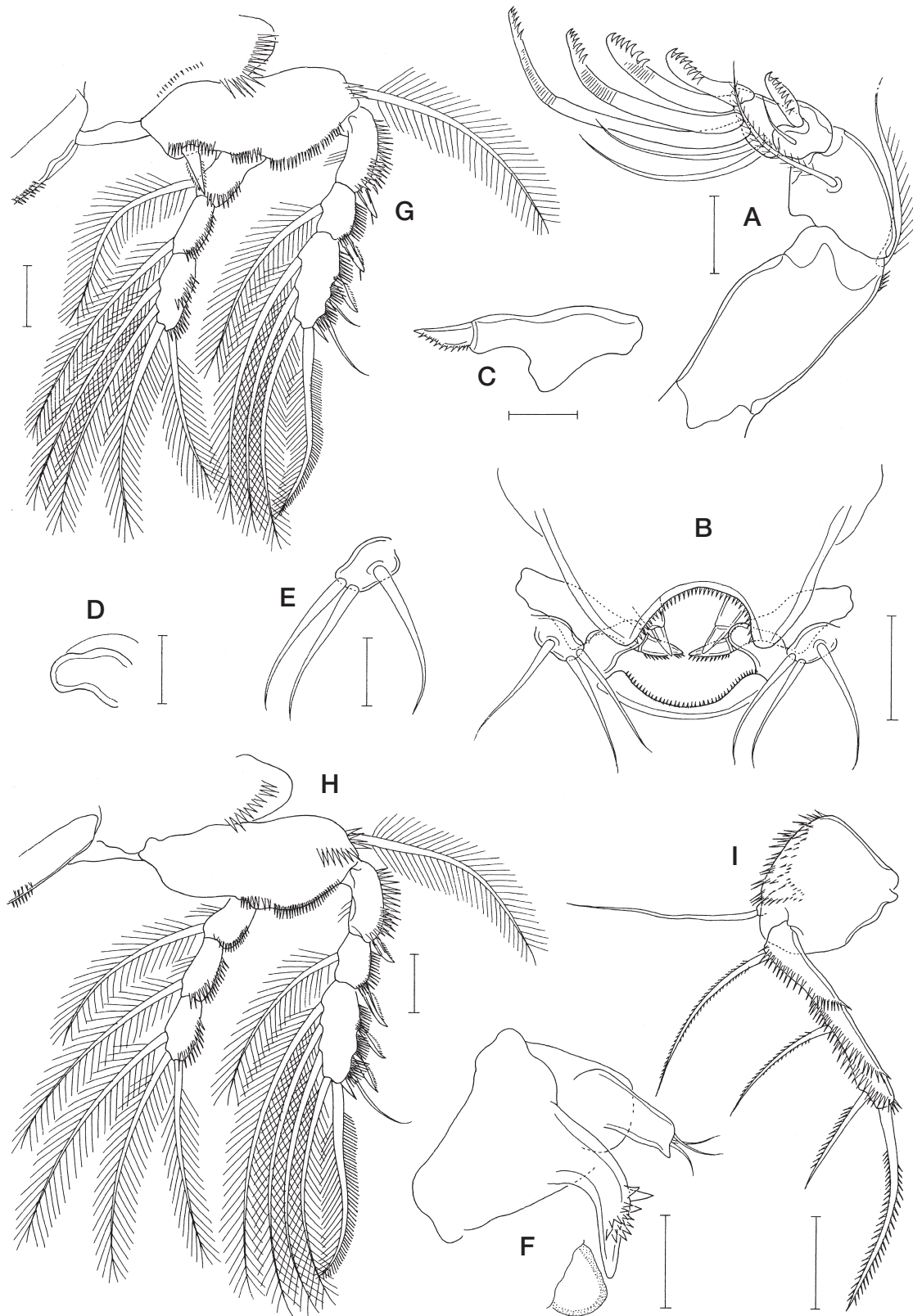


Fig. 6. *Echiuricopus tenuipes* n. sp., female. A, Antenna; B, Oral region; C, Mandible; D, Paragnath; E, Maxillule; F, Maxilla and vestigial maxilliped; G, Leg 1; H, Leg 2; I, Leg 5. Scale bars: A, B, F-H=0.02 mm, C-E=0.01 mm, I=0.05 mm.

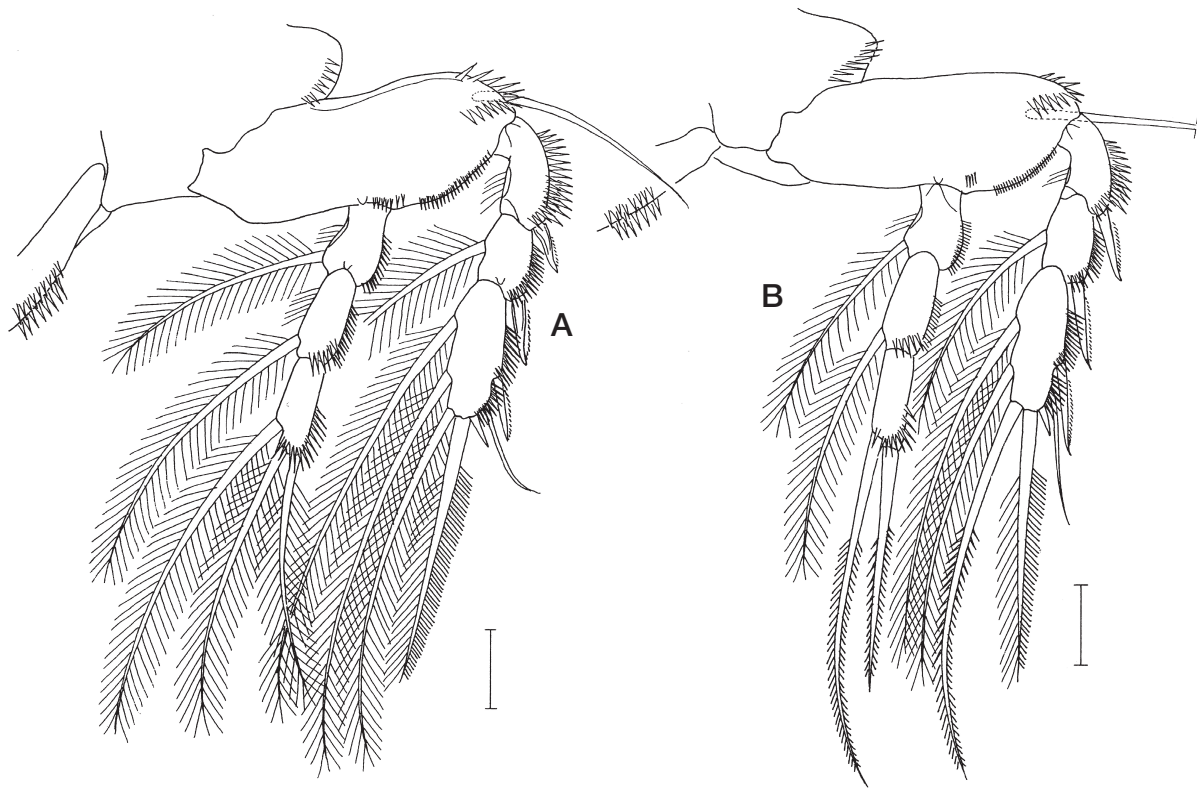


Fig. 7. *Echiuricopus tenuipes* n. sp., female. A, Leg 3; B, Leg 4. Scale bars: A, B=0.02 mm.

but metasomites with less extended epimera and narrow membranous rim along lateral margins. Length of figured and described largest specimen 864 μm ; smallest one 820 μm . Prosome 470 μm long. Cephalothorax 239 \times 303 μm , with longitudinal rows of setules and spinules on each side of ventral surface (Fig. 5F). First to third metasomites (second to fourth pedigerous somites) 76 \times 318, 70 \times 291, and 85 \times 242 μm , respectively. Second and third metasomites with angular posterolateral corners. Urosome (Fig. 5B) 5-segmented. First urosomite (fifth pedigerous somite), 67 \times 175 μm , with epimera broader than those of *E. aprilis* n. sp. and rimmed with membrane along posterodorsal and lateral margins. Genital double-somite sub-rectangular, 93 \times 131 μm , wider than long, with rounded corners and membrane along posterodorsal margin; genital area located ventrally on somite (Fig. 5C). Three abdominal somites distinctly narrower than genital double-somite, 76 \times 65, 35 \times 49, and 16 \times 44 μm , respectively. Dorsal boundary obscure between last 2 abdominal somites (Fig. 5D). Last abdominal somite with row of several spinules (more prominent than those of *E. aprilis* n. sp.) near base of caudal ramus (Fig. 5E). Caudal ramus 72 \times 15 μm (ratio of length to width 4.80 : 1), with 5 spinules on outer distal corner, and armed with 7 setae; outer proximal seta (seta I) large, sparsely plumose, as long as caudal ramus,

and extended slightly beyond distal end of ramus (Fig. 5D); other 6 setae naked and located distally or subdistally; seta V longest among setae, 303 μm long; seta IV second longest, 106 μm long.

Rostrum obscure (Fig. 5F). Antennule (Fig. 5G) 6-segmented; armature formula 4 + I, 13, 9, 4 + aesthetasc, 2 + aesthetasc, and 7 + aesthetasc; first segment with 1 broad plumose seta, 4 setae, and 1 pointed anterior process (Fig. 5H); one of setae inserted on posterior proximal region of anterior process and spinulose along posterior margin; second segment with beak-like process proximally on anterior margin. Antenna (Fig. 6A) similar to that of *E. aprilis* n. sp., but outer process on first endopodal segment blunt; 4 claws on terminal endopodal segment each with 7, 7-8, 7-8, and 6 spinous processes, respectively, from inner to outer, respectively.

Labrum (Fig. 6B) similar to that of *E. aprilis* n. sp., but posterior linguiform processes with articulation (or annulation) near middle. Mandible (Fig. 6C) and paragnath (Fig. 6D) not different from that of *E. aprilis* n. sp. Maxillule (Fig. 6E) with 3 naked setae; all of these setae nearly equal in length. Maxilla (Fig. 6F) slightly different from that of *E. aprilis* n. sp. in having pointed posterodistal corner of distal segment. Maxilliped as sclerotized rudiment posterior to

Table 2. Differences between females of *Echiuricopus aprilis* n. sp. and *E. tenuipes* n. sp.

Characteristic	<i>E. aprilis</i>	<i>E. tenuipes</i>
Body length (μm)	990–1,061	820–864
Caudal ramus (μm)	91×18 (ratio 5.06 : 1)	72×15 (ratio 4.80 : 1)
Seta I of caudal ramus	Less than half as long as caudal ramus	As long as caudal ramus
Leg 5 exopod (μm)	115×27 (ratio 4.26 : 1)	114×19 (ratio 7.58 : 1)
Element inserted on process of 1st antennular segment	Spiniform, with spinules all around its shaft	Setiform, unilaterally spinulose

maxilla (Fig. 6F).

Legs 1–4 (Figs. 6G, H, 7A, B) with 3-segmented slender rami; outer margin of rami and posterior margin basis densely spinulose; coxa of these legs spinulose along outer margin and lacking inner seta. Inner distal spine on basis $16 \mu\text{m}$ long. Third exopodal segment of legs 1–4 with large spinule at outer distal corner. Third endopodal segment of leg 2 with 3 or 4 setae (4 being typical condition). Armature formula of legs 1–4 as follows:

	Coxa	Basis	Exopod	Endopod
Leg 1:	0-0	1-I	I-0; I-1; I, 6	0-1; 0-1; 4
Leg 2:	0-0	1-0	I-0; I-1; II, 6	0-1; 0-1; 4 (or 3)
Leg 3:	0-0	1-0	I-0; I-1; I, 5	0-1; 0-1; 3
Leg 4:	0-0	1-0	I-0; I-1; I, 5	0-1; 0-1; 2

Leg 5 (Fig. 6I) consisting of protopod and exopod. Protopod nearly rectangular, about $75 \times 64 \mu\text{m}$, clearly defined at base, with spinules on outer surface and 1 long, slender, naked outer distal seta. Exopod $114 \times 19 \mu\text{m}$ (ratio 7.58 : 1), narrowest about halfway its length, with 3 obliquely longitudinal rows of spinules and 4 spinulose setae; lengths of these setae 101, 75, 60, and $116 \mu\text{m}$, from proximal to distal, respectively. Leg 6 (Fig. 5C) represented by 3 small spiniform elements on genital operculum.

Male. Unknown.

Etymology. The specific epithet is derived from a combination of the Latin words *tenuis* (= slender) and *pes* (= foot), alluding to the slender exopod of leg 5.

Remarks. *Echiuricopus tenuipes* n. sp. is very similar to *E. aprilis* n. sp., displaying only very few morphological differences. Major differences are exhibited in the body length, the length of the outer proximal seta (seta I) on the caudal ramus, the shape of one element on the first antennular segment, and the width of the exopod of leg 5. These differences are summarized in Table 2.

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