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Three Cletodid Copepods of the Genera *Limnocletodes* and *Kollerua* (Harpacticoida, Cletodidae) from Coastal Marshes and Estuaries in South Korea

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Abstract – Three brackish-water harpacticoid species belonging to the family Cletodidae are reported from the salt marshes in South Korea: *Limnocletodes behningi* Borutzky, 1926, *L. angustodes* Shen and Tai, 1963 and *Kollerua longum* (Shen and Tai 1979). Two genera, *Limnocletodes* and *Kollerua*, and the three species are newly added to Korean fauna. This paper deals with the redescription and systematic accounts of them, with detailed illustrations.

Key words – taxonomy, Cletodidae, *Limnocletodes*, *Kollerua*, Korea

1. Introduction

The taxonomic study on the brackish-water harpacticoid copepods is scanty in Korea. Chang and Kim (1991) described a new species *Harpacticella itoi* at the lower reaches of Tamjin River, flowing into southwestern coast of Korea. Song and Chang (1995) reported 9 harpacticoid species of 6 families around coasts of Jindo Island, including two *Tachidius* species occurring in the coastal marshes and estuaries. Recently the authors reported two species, *Mesochra alaskana* and *M. suifunensis* at the estuaries of southeastern coast of Korea (Lee and Chang 2003), and two *Onychocamptus* species (*O. vitiospinulosa* and *O. mohammed*) from brackish waters at the southern coast (Lee and Chang 2005). Huys *et al.* (2005) described two new species of the genus *Neotachidius* from the brackish waters of Kwangyang Bay.

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To make a comprehensive study on the brackish-water copepod fauna, the authors have examined the copepod specimens deposited in the specimen room of the Department of Biological Science, Daegu University, which have been collected from the various brackish-waters such as coastal marshes, estuaries, and brackish-water lakes in South Korea since 1988. As a provisional result of the researches, we make a redescription of three harpacticoid species belonging to the family Cletodidae, which constitute new records from Korea.

2. Materials and Methods

Materials examined in the present study were collected from coastal salt marshes and estuaries at nine localities (Fig. 1) in South Korea during the period from July, 1994 to May, 2007. Collections were made with a dipnet of 64 μ m mesh. Copepods were fixed and stored in 4% buffered formalin.

Specimens were dissected and mounted in lactophenol on H-S slide (Shirayama *et al.* 1993), a recent variation of Cobb slide, after treatment in a solution of 5% glycerin-95% ethyl alcohol for 1-2 days. Dissection was performed using two needles made from 0.25 mm diameter tungsten wire by electrolysis (Huys and Boxshall 1991). Mounted specimens were observed using a differential interference contrast microscope (Olympus BX-51) equipped with Nomarski optics. All drawings and measurements were made with the aid of a camera lucida.

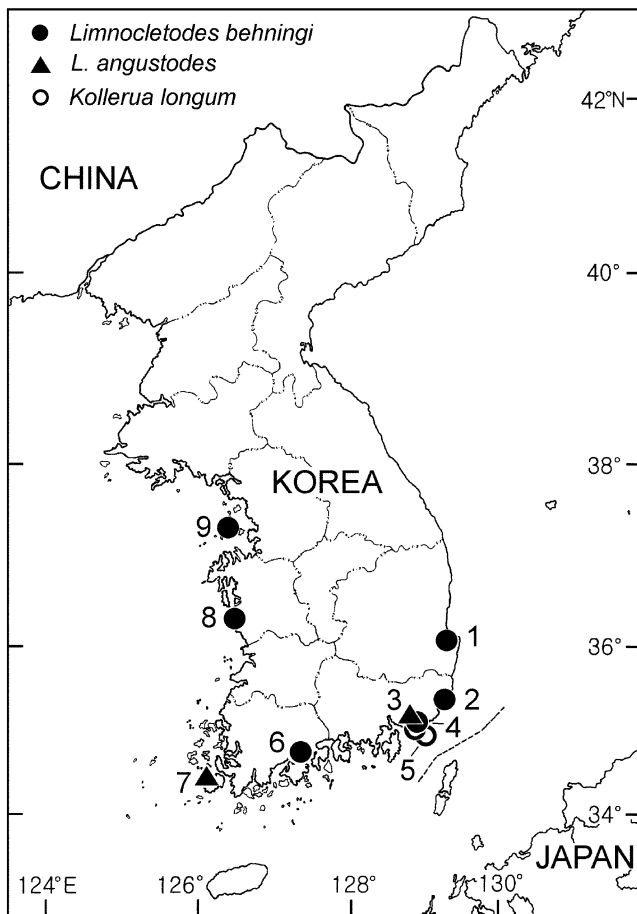


Fig. 1. A map showing localities in South Korea. 1, estuary of Hyeongsan R., Pohang; 2, estuary of Hoiyacheon R., Ulsan; 3, estuary of West-Nakdong R., Gimhae; 4, Ulsukdo Is., Busan; 5, Dadaepo, Busan; 6, Beolgyo, Boseong; 7, Jindo Is.; 8, Muchangpo, Boryeong; 9, Yeongheungdo Is., Incheon.

Abbreviations used in the text and figure legend follow the conventional ones frequently used in the taxonomy of copepods: A1, antennule; A2, antenna; enp 1-3 or exp 1-3, the first to third endopodal or exopodal segment of each leg; Fu, caudal rami; P1-P6, first to sixth pereopods (thoracic legs).

3. Systematic Accounts

Family Cletodidae T. Scott, 1905

Genus *Limnocletodes* Borutzky, 1926

***Limnocletodes behningi* Borutzky, 1926** (Figs. 2-4)

Limnocletodes behningi Borutzky, 1926, p. 213, figs. 1-6; Lang, 1948, p. 1321; Borutzky, 1952, p. 378, fig. 103 (16-32); Shen and Tai, 1962, p. 399, figs. 33-45; Shen and Sung,

1965, p. 176; Damian-Georgescu, 1970, p. 215, fig. 100; Wells, 1971, p. 516, fig. 27-34; Tai and Song, 1979, p. 289, fig. 162; Apostolov and Marinov, 1988, p. 315, fig. 123 (2a-k); Ishida, 1993, p. 166; Ishida and Kikuchi, 2000, p. 34, fig. 55.

Material examined

3 ♀♀, 1 ♂, estuary of Bulgeunnori Str., Yeongheungdo Is., Incheon, 11 Nov. 2005 (H.W. Lim); 2 ♀♀, 2 ♂♂, Muchangpo (salt marsh), Boryeong, 1 May 2007 (C.Y. Chang and H.J. Yoon); 3 ♀♀, 2 ♂♂, estuary of Hyeongsan R., Pohang, 24 Sep. 2005 (H.W. Lim); 4 ♂♂, estuary of Hoiyacheon Str., Ulsan, 21 Jun. 2006 (C.Y. Chang and J.M. Lee); 1 ♀, Ulsukdo Is., estuary of Nakdong R., Busan, 28 Oct. 2006 (H.J. Ji, J.S. park and S.Y. Yang); 1 ♀, 1 ♂, estuary of Beolgyocheon Str., Boseong, 26 Feb. 2004 (C.Y. Chang).

Description

Female: Body (Fig. 2A) about 450 µm long (ranging 429-475 µm, standard deviation 24, N=10); spindle-shaped, tapering posteriorly from border of cephalothorax, without clear distinction between prosome and urosome. Rostrum small and blunt, not defined at its base. Cephalothorax longer than sum of next 3 prosomites. Distolateral margin of each prosomites not protruded. Genital double-somite distinctly divided with subcuticular ridge marking line of fusion, in dorsal view, with spinule row along posterior margin. Anal operculum semicircular with spinule row along posterior edge (Fig. 2B).

Fu columnar, 1.1-1.3 times longer than wide, a little divergent posteriorly (Fig. 2B). Lateral caudal seta (caudal seta II) locating near middle of lateral margin of Fu. Outer caudal seta (caudal seta III) slightly longer than inner caudal seta (caudal seta VI).

A1 (Fig. 2C) short and blunt, 4-segmented; third segment bearing 1 long aesthetasc; fourth segment tapering distally, forming a conical shape, with pinnate setae on distal end and anterior margin. A2 (Fig. 2D) exopod 1-segmented, about 2.5-3 times longer than broad, with 3 pinnate setae. Mandible (Fig. 3A) with well developed coxal gnathobase bearing several bicuspidate teeth along distal margin and 1 seta at dorsal corner; palp 1-segmented with both rami fused to basis, tapering distally, armed with 6 setae in total; medialmost seta a little swollen and stout. Maxillula (Fig. 3B) with praecoxal arthrite bearing 5 elements with 4 spinules on both frontal and caudal surfaces; coxal arthrite with cylindrical endite bearing 2 setae; exopod and endopod

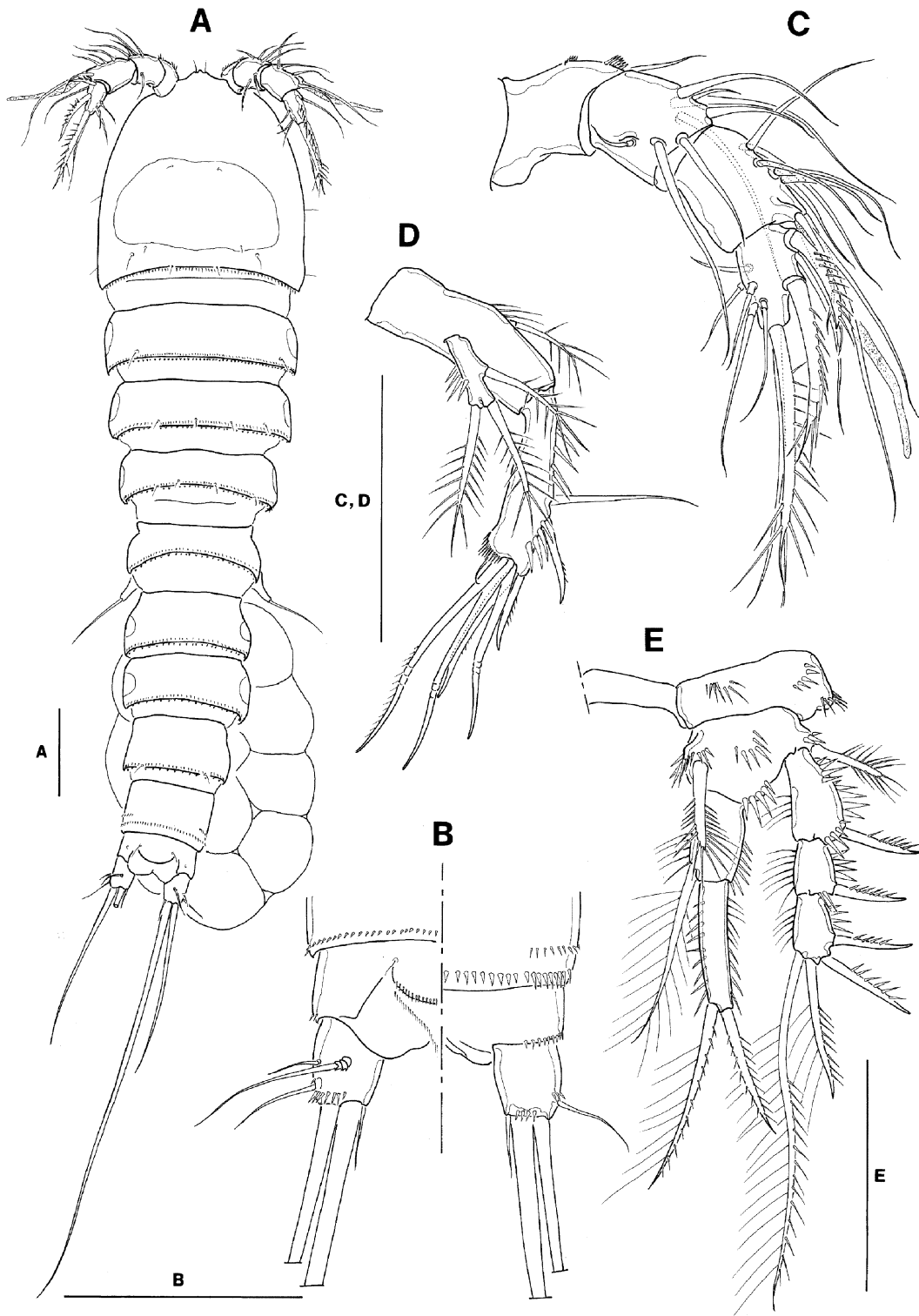


Fig. 2. *Limnocletodes behningi* Borutzky, female. A, habitus (dorsal); B, anal somite and Fu, showing both dorsal (left) and ventral (right) sides; C, A1; D, A2; E, P1. Scale bars = 50 μ m.

fused to basis, bearing total 6 setae and 1 spine ornamented with 3 accessory setae at its distal third. Maxilla (Fig. 3C) armed with 2 syncoxal endites and 1 proximal seta, each

syncoxal endite bearing 3 setal elements; allobasis forming 1 strong pectinate claw, flanked by 2 setae; endopod represented by small protuberance bearing 2 long setae.

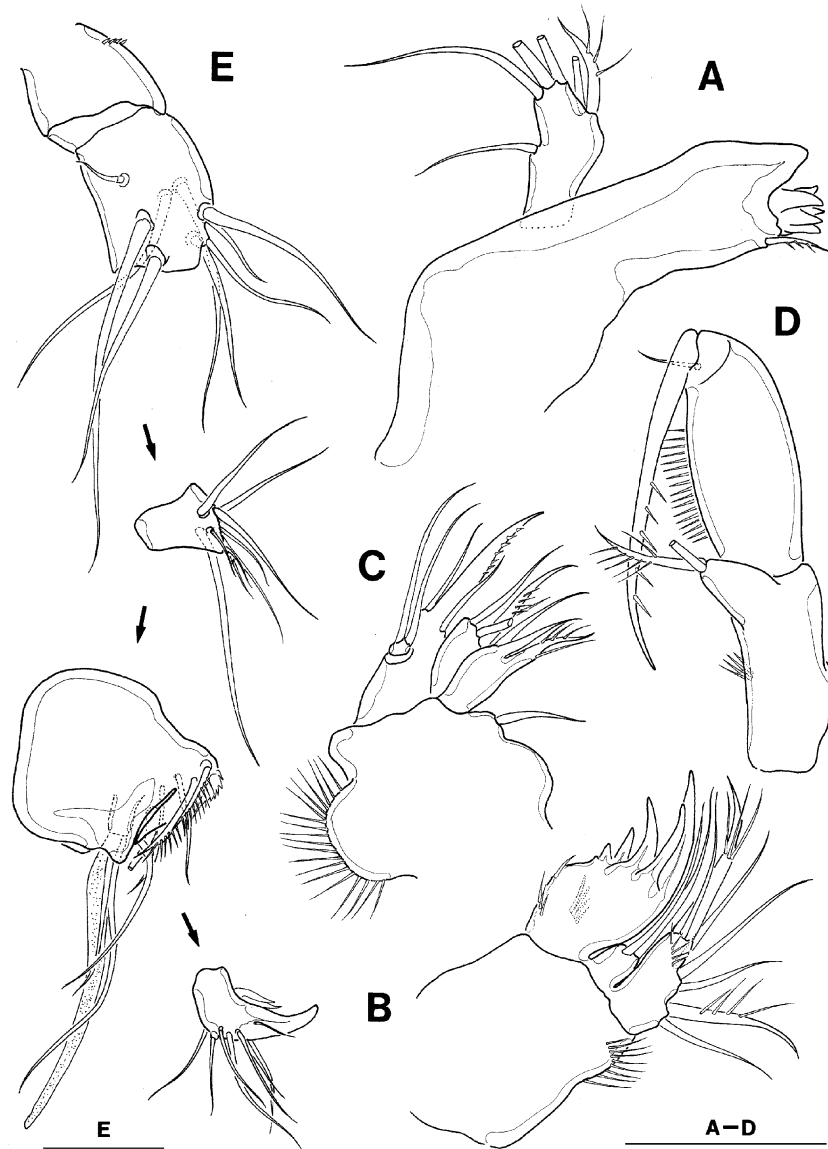


Fig. 3. *Limnocoletodes behningi* Borutzky. A-D, female: A, mandible; B, maxillule; C, maxilla; D, maxilliped. E, male A1. Scale bars = 20 μm .

Maxilliped (Fig. 3D) subchelate; syncoxa protruded distomedially with 2 pinnate setae; basis pectinate along inner margin and 1 seta on distomedial edge; endopod represented by 1 strong and curved claw, bearing 5 spinules as accessory armature.

P1-P4, endopods 2-segmented, exopods 3-segmented. P1 (Fig. 2E), endopod a little longer than exopod; enp 1 not elongated, with 1 seta distomedially; enp 2 with 1 spine and 1 seta apically; exp 2 without inner seta; exp 3 with 2 outer spines and 2 apical setae. P2-P4 (Fig. 4A-C), enp 1 small, without inner seta; enp 2 elongate, with 2 or 3 setae. Seta and spine arrangements of P1-P4 as follows (Arabic numerals

representing setae, while Roman numerals indicating spines):

P1 basis 1-1 exp I-0; I-0; II,2,0 enp 0-1; 0,I,1

P2 basis 1-0 exp I-0; I-1; II,2,0 enp 0-0; 1,1,0

P3 basis 1-0 exp I-0; I-1; II,2,0 enp 0-0; 1,1,0

P4 basis 1-0 exp I-0; I-1; II,2,0 enp 0-0; 1,1,1

P5 (Fig. 4D) baseoendopod nearly triangular; distomedial corner strikingly elongated, bearing total 3 setae (2 inner and 1 apical setae), with 1 short spine and 1 setule on distomedial margin; exopod forming 1 small plate, about 2.5 times longer than wide, with 2 apical setae.

Ovigerous female carrying 1 egg sac under genital somite,

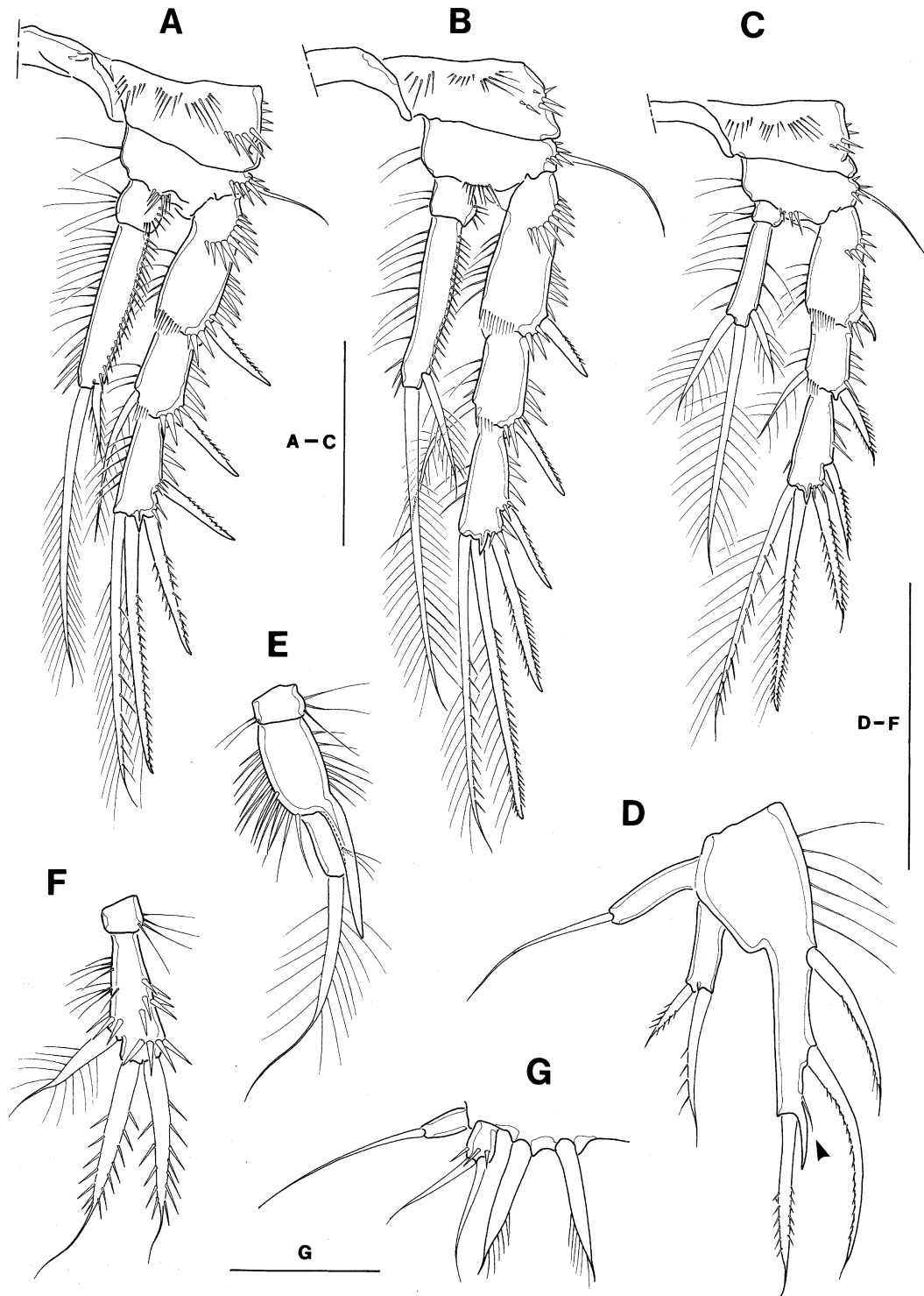


Fig. 4. *Limnocoletodes behningi* Borutzky. A-D, female P2-P5. E-G, male: E, endopod of P3; F, endopod of P4; G, P5. Scale bars = 50 μm (A-F) and 20 μm (G).

containing about 10-16 eggs.

Male: Body about 380 μm long (ranging 366-401 μm , mean 384 μm , standard deviation 18, N=3); Sexual dimorphism

shown in A1, endopods of P3 and P4, and P5. A1 (Fig. 3E) subchirocerate, 5-segmented; geniculate between segments 4 and 5; segment 2 with 9 setae; segment 3 short with 8 setae;

segment 4 swollen, bearing 1 long aesthetasc; last segment forming claw-like projection apically, with 8 bare setae and 2 spiniform setae medially. P3 endopod (Fig. 4E) 3-segmented; enp 1 lacking inner seta; enp 2 with 1 distomedial spine; enp 3 with 1 apical seta. P4 endopod (Fig. 4F) 2-segmented; enp 1 without inner seta; enp 2 with 3 stout pinnate setae.

P5 (Fig. 4G) baseoendopod vestigial, with 2 swollen setae; exopod reduced to small oblong plate, bearing 2 apical setae.

Remarks

In the genus *Limnocletodes* Borutzky, 1926, six species have been known so far: *L. behningi* Borutzky, 1926, *L. secundus* Sewell, 1934, *L. angustodes* Shen and Tai, 1963, and *L. oblongatus* Shen and Tai, 1964, *L. wellsii* Gee, 1998, and *L. mucronatus* Gee, 1998. These species are differentiated basically by the shape of P5. Among them, *L. behningi* shares the same style of triangular endopodal lobe of baseoendopod bearing 2 spiniform setae on inner margin with two Indian species, *L. secundus* and *L. wellsii*. *Limnocletodes wellsii* is clearly discernible from *L. behningi* and *L. secundus* by P4 exp 2 without inner seta (Gee 1988). Lang (1948) and Shen and Tai (1963) distinguished *L. behningi* from *L. secundus* by the length of endopod in relation to exp 1 in the female P3 and P4. However, Wells (1971) regarded *L. secundus* as a junior synonym of *L. behningi* for the reason that the character is variable and invalid. Later, in his revision of the genus, Gee (1988) maintained *L. secundus* as *species inquirenda*, and proposed the diagnostic character for the two species: P2 and P3 enp 2 are equal in length to each exp 1 in *L. behningi*, while 1.5 times longer in *L. secundus*.

Korean specimens come close to the opinion of Wells (1971). Considering the criteria of Lang (1948) and Shen and Tai (1963), P3 endopod in Korean specimens is much longer than exp 1 as in *L. secundus*, while P4 endopod is nearly as long as exp 1 as in *L. behningi*. Furthermore, considering Gee (1998)'s criteria, the length ratio of enp 2 to exp 1 in P2 is 1.23, and in P3 1.12, respectively. So, the character of relative length ratio between endopod (or enp 2) and exp 1 in P2-P4 is not consistent and rather variable.

Korean specimens add another new variant type to the varieties of female P5 of *L. behningi* (cf. Wells 1971, figs. 38-43), that is, on the distomedial margin of baseoendopod, a short spine is flanked by an additional setule (Fig. 4D, arrow).

This species is known usually from the brackish-waters

(esp. estuaries) or occasionally from freshwaters, and widely distributed in the eastern part of Eurasian continent. Borutzky (1952) mentioned that this species was encountered in large numbers in the intestines of river fishes such as *Gobio gobio* and *Abramis brama*.

Distribution

Korea, China, Japan, Russia (Caspian Sea), India, Bulgaria, Rumania.

Limnocletodes angustodes Shen and Tai, 1963 (Fig. 5)

Limnocletodes angustodes Shen and Tai, 1963, p. 425, figs. 47-54; Tai and Song, 1979, p. 291, fig. 163; Kikuchi *et al.*, 1993, p. 21, fig. 4.

Material examined

1 ♀, lower reaches of Nakdong R., Gimhae, 19 Dec. 1995 (C.Y. Chang); 1 ♀, estuary of Geonyangnaeseom, Jindo Is., 23 Jul. 1994 (C.Y. Chang and S.J. Song).

Description

Female: Body (Fig. 5A) 510-530 µm in length, spindle-shaped, tapering posteriorly from border of cephalothorax. Rostrum small and blunt, fused to cephalic shield at base, triangular in general shape in frontal view, with 2 sensillae anteriorly. Body somites excluding anal somite ornamented with spinules along posterior margins. Sensillae distributed sparsely on dorsal surface of prosomites. Cephalothorax with large depression, longer than sum of next 3 prosomites. Distolateral margin of each prosomites not strongly protruded. Genital double-somite with subcuticular ridge marking line of fusion (suture), in dorsal view. Anal operculum semicircular with fine spinules along posterior edge (Fig. 5B).

Fu columnar, 1.1-1.3 times longer than wide; a little narrowing posteriorly (Fig. 5B). Inner margin smooth without spinules or setule row. Lateral caudal setae (caudal seta I, II) locating at proximal third of lateral margin of Fu. Three stout spines present at posterolateral side of Fu dorsally, and 4-5 spinules along posterior margin ventrally. Outer caudal seta (caudal seta III) about 1.2-1.3 times longer than inner caudal seta (caudal seta VI). Dorsal caudal seta (caudal seta VII) locating nearly in the middle of Fu.

A1 short and blunt, 4-segmented (Fig. 5C); third segment bearing 1 long aesthetasc; fourth segment tapering distally, with stout pinnate setae apically and anteroproximally. A2

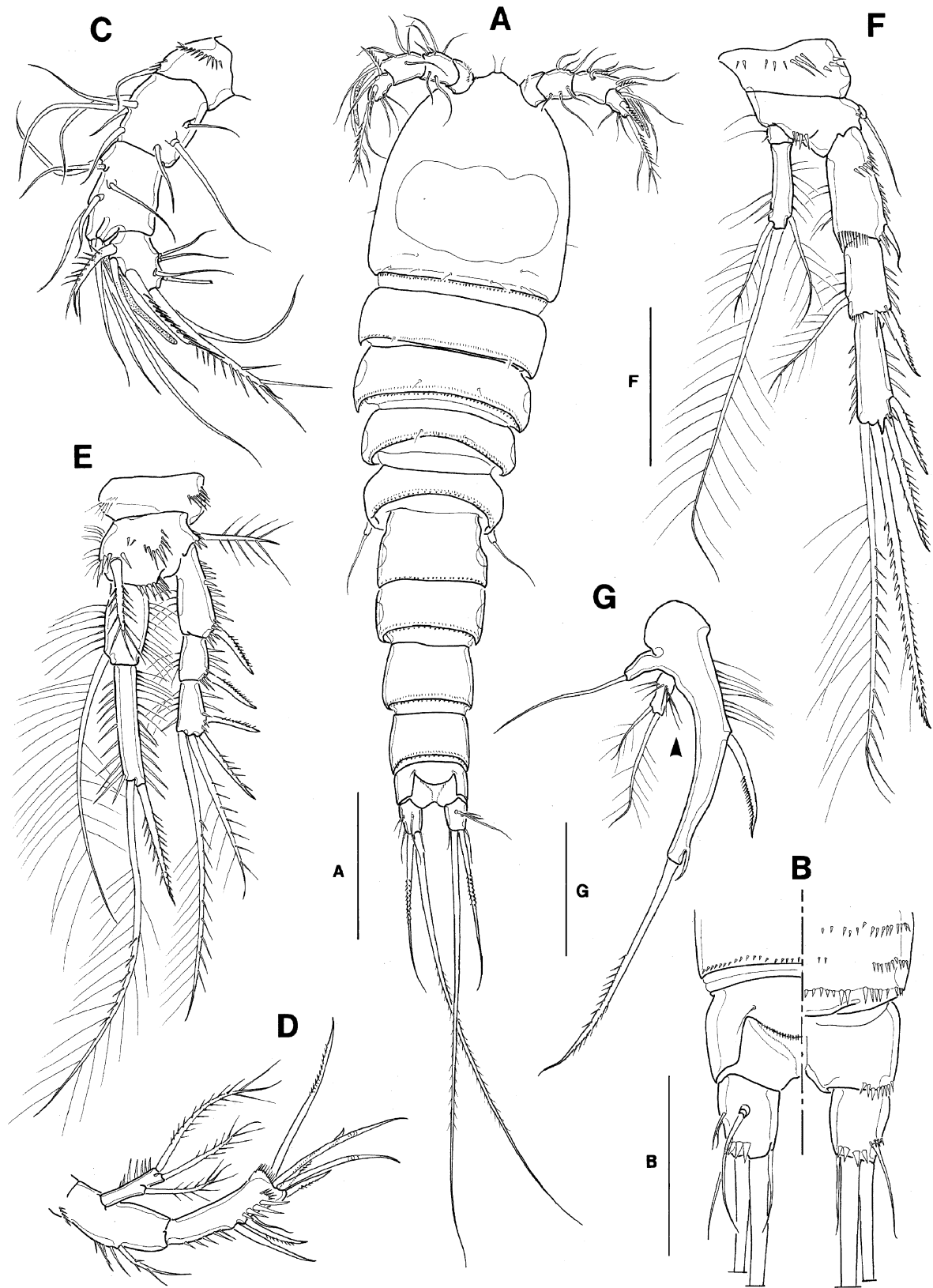


Fig. 5. *Limnocletodes angustdes* Shen and Tai, female. A, habitus (dorsal); B, anal somite and Fu, showing both dorsal (left) and ventral (right) sides; C, A1; D, A2; E, P1; F, P4; G, P5. Scale bars = 100 µm (A) and 50 µm (B-G).

(Fig. 5D) 3-segmented; exopod 1-segmented, elongated, with 3 setae in total. Shape and seta/spine ornamentation of mandible, maxillule, maxilla, and maxilliped nearly same as in preceding species.

P1-P4, endopods 2-segmented, exopods 3-segmented. Seta and spine arrangements of P1-P4 as in *L. behningi*. P1 (Fig. 5E), exopod a little shorter than endopod; seta on distomedial corner of basis pinnate, its tip not reaching distal end of enp 1; enp 1 not elongated, with 1 long seta distomedially; enp 2 much longer than enp 1, with 1 spine and 1 seta apically; exp 2 without inner seta; exp 3 with 2 outer spines and 2 apical setae. P2-P4, enp 1 small, without inner seta; enp 2 elongate. P4 exp 3 with spinules along inner margin (Fig. 5F).

P5 (Fig. 5G) baseoendopod narrow, exceedingly protruded medially, with 1 medial spiniform seta on middle of inner margin, 1 small seta near end of inner margin and 1 long apical seta; exopod forming 1 small plate, about 1.5-2 times longer than wide, with 2 apical setae and 1 setule row around middle of segment.

Male: Not observed.

Remarks

This species was reported from estuaries and freshwater lakes in China (Tai and Song 1979); in Korea, it occurred from the lower reaches of West-Nakdong River, Gimhae, and a salt marsh at Jindo Is., southwestern coast of Korea.

Korean specimens well coincided with the original description from a delta of Pearl River, Kwangtung (Shen and Tai 1963), and Kikuchi *et al.* (1993)'s redescription from a freshwater lake at west Shanghai, China, except for a minor discrepancy of the presence of setule row around middle of P5 exopod (Fig. 5G, arrow).

Distribution

Korea, China.

Genus *Kollerua* Gee, 1994

Kollerua longum (Shen and Tai, 1979) (Figs. 6-8)

Enhydrosoma longum Shen and Tai, 1979, p. 234, fig. 2; Tai and Song, 1979, p. 270, fig. 151.

Kollerua longum: Gee, 1994, p. 106; Bodin, 1997, p. 180.

Material examined

1 ♂, Ulsukdo Is., mouth of Nakdong R., Busan, 28 Oct.

2006 (H.J. Ji, J.S. Park and S.Y. Yang); 3 ♀♀ (2 ovi.), 2 ♂♂, Dadaepo (reed marsh), Busan, 28 Sep. 2005 (C.Y. Chang, J.M. Lee and H.W. Lim)

Description

Female: Body (Fig. 6A) small, cylindrical, 445 µm long (ranging 444-447 µm, mean 446 µm, N=3); tapering posteriorly from border of cephalothorax, without clear distinction between prosome and urosome. Tinged with dark brown. Integument thick. In preserving medium, body usually rolling up in ventral direction. All prosomites and first three urosomites with 2 or 3 pairs of papillary projections (each bearing 1 sensilla apically) along posterior margin (Fig. 6A); 4th urosomite and anal somite with 1 pair of papillary projections (Fig. 6B). Genital double-somite and next urosomite with 1 pair of papillary projections ventrally (Fig. 6C). Rostrum narrow, protruding anteroventrally; not defined at its base; frontal margin nearly straight, both anterolateral corners projected, and slightly pointing upward (Fig. 6D, arrow). Cephalothorax nearly as long as next three prosomites combined. Genital double-somite dorsally with subcuticular ridge marking line of fusion (suture), but fully confluent ventrally. Urosomites protruding posterolaterally; abdominal somites with bristle row along posterior margins of both dorsal and ventral sides. Anal operculum convex with spinule row along posterior edge.

Fu cylindrical, 1.6-1.8 times longer than wide (Fig. 6B); proximal part of inner margin swollen; longitudinal keel extending along inner margin to dorsal caudal seta. Caudal setae I and II a little prior to middle of outer margin. Posterolateral corner of Fu expanding posteriorly, bearing outer caudal seta (caudal seta III) at its tip. Outer terminal caudal seta (caudal seta IV) and inner caudal seta (caudal seta VI) slender and short; inner terminal caudal seta (caudal seta V) and outer terminal caudal seta confluent proximally.

A1 blunt, 5-segmented (Fig. 6D); aesthetasc present on 3rd segment; 4th segment very short, while last segment elongate. A2 (Fig. 6E) exopod 1-segmented, with 2 setae laterally and apically. Mandible (Fig. 7A) armed with well developed coxal gnathobase bearing several bicuspidate teeth along distal margin and 1 seta at dorsal corner; palp 1-segmented, with 3 setae in total. Maxillula (Fig. 7B) with praecoxal arthrite bearing 5 spinous processes with 3 setae; coxal arthrite with cylindrical endite bearing 2 setae; exopod and endopod fused to basis, bearing total 4 setae. Maxilla (Fig. 7C) armed with 2 syncoxal endites, each

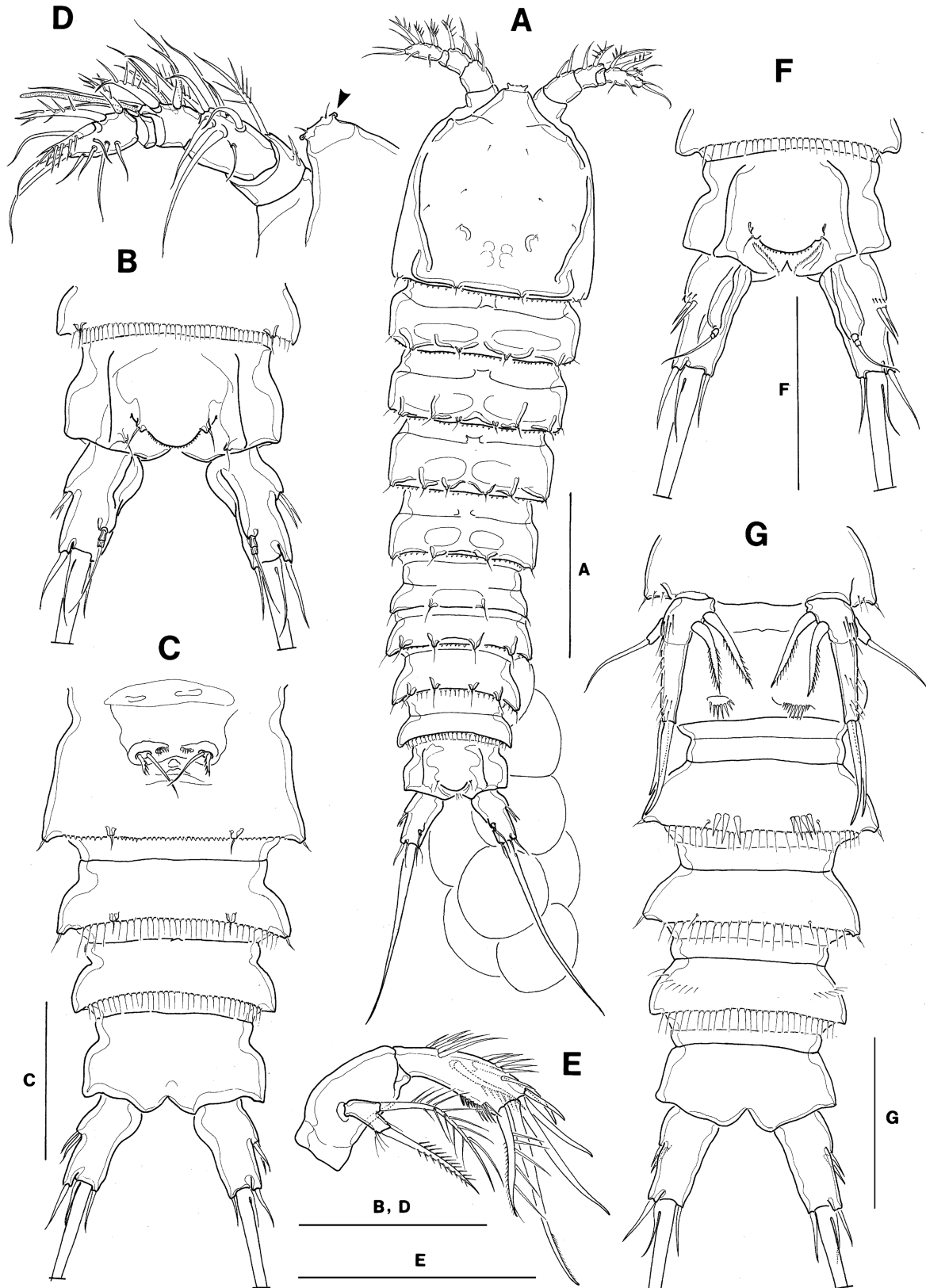


Fig. 6. *Kollerua longum* (Shen and Tai). A-E, female: A, habitus, dorsal; B, anal somite and Fu, dorsal; C, urosome, ventral; D, A1; E, A2. F-G, male: F, anal somite and Fu, dorsal; G, P5 and urosome, ventral. Scale bars = 100 μ m (A) and 50 μ m (B-G).

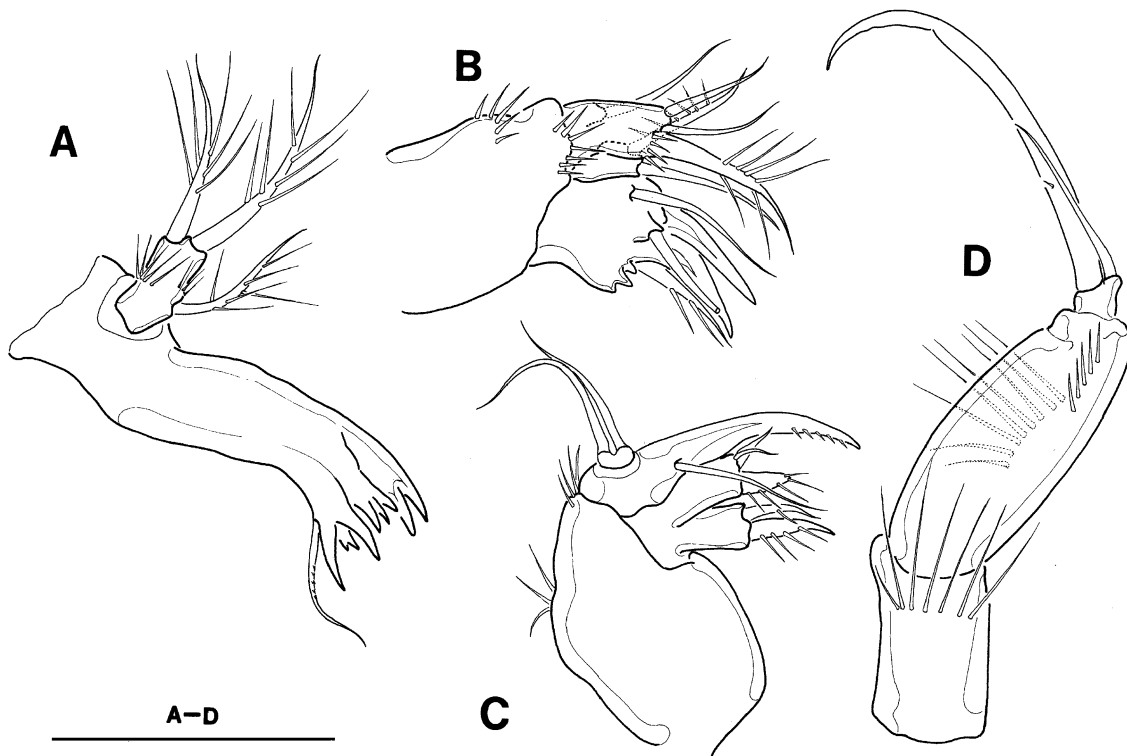


Fig. 7. *Kollerua longum* (Shen and Tai). A-D, female: A, mandible; B, maxillule; C, maxilla; D, maxilliped. Scale bar = 20 μ m.

bearing 2 or 3 setal elements; allobasis forming 1 strong pectinate claw, flanked by 2 proximal setae; endopod represented by small protuberance bearing 2 long bare setae. Maxilliped (Fig. 7D) subchelate; syncoxa ornamented with 7 setules distally; basis armed with about 8 long setules along inner margin and 5 spinules on distolateral edge; endopod represented by 1 strong and curved claw, bearing 1 long seta as accessory armature.

P1-P4, all exopods 3-segmented, endopods of P1-P3 2-segmented, P4 endopod 1-segmented. P1 enp 1 lacking inner seta. Seta and spine arrangements of P1-P4 as follows (Arabic numerals representing setae, while Roman numerals indicating spines):

- P1 basis 1-1 exp I-0; I-0; II,2,0 enp 0-0; 0,I,1
 P2 basis 1-0 exp I-0; I-0; II,2,0 enp 0-0; 0,1,1
 P3 basis 1-0 exp I-0; I-0; II,2,1 enp 0-0; 0,1,1
 P4 basis 1-0 exp I-0; I-0; II,2,1 enp 0,1,1

P5 (Fig. 8E) baseopod elongate, protruding distomedially, its tip not reaching end of exopod, with 2 inner setae and 1 apical seta; exopod exceedingly elongate, about 4.3 times longer than wide, bearing 3 setae in total (1 apical and 2 lateral setae). P6 represented by 2 setae in middle of genital

somite; inner seta much longer than outer one (Fig. 6C).

Ovigerous female carrying 1 egg sac under urosomites, containing about 8-10 eggs.

Male: Body about 420 μ m long (ranging 418-428 μ m, mean 423 μ m, N=3). Similar to female in general appearance, except a little more slender. Genital somite and first abdominal somite completely divided (Fig. 6G). Inner margin of Fu nearly straight compared with that of females. P3 endopod (Fig. 8F) 2-segmented; enp 2 bearing 1 strong distolateral projection with 2 apical plumose setae. P5, lacking endopodal lobe, bearing 2 setae on proximal part of medial margin and 2 setae apically (Fig. 6G).

Variability

Korean specimens were variable in the length to width ratio of Fu (in 5 females, ranging from 1.68 to 1.84, $m = 1.75 \pm 0.06$; in 6 males, from 1.55 to 1.82, $m = 1.71 \pm 0.10$), and in the length to width ratio of exopod of female P5 (ranging from 4.2 to 4.8, $m = 4.5 \pm 0.2$ in 5 females examined).

Remarks

Gee (1994) made a revision of the genus *Enhydrosoma*, and established a new genus *Kollerua* for five fresh- or

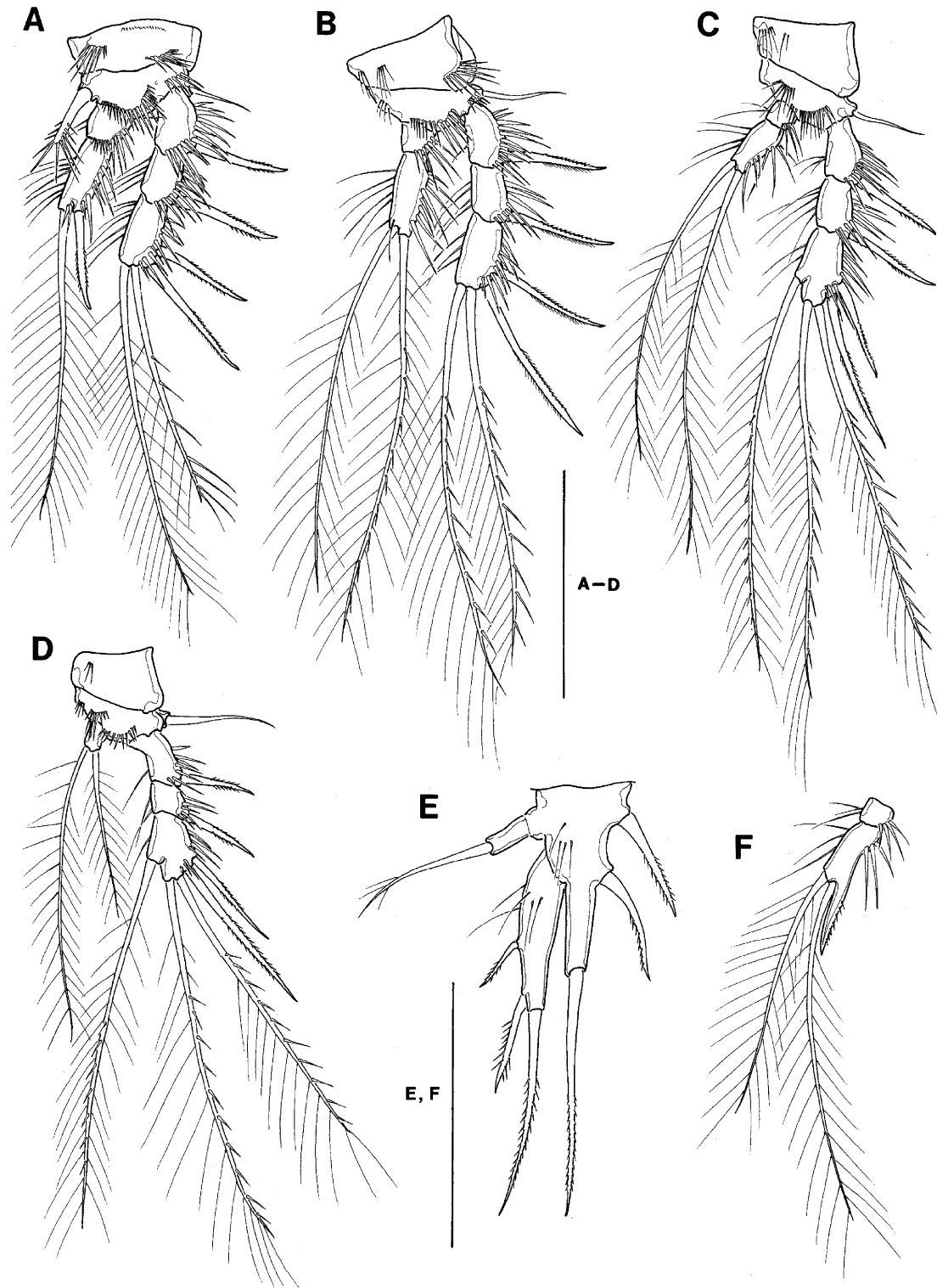


Fig. 8. *Kollerua longum* (Shen and Tai). A-E, female P1-P5. F, male P3 endopod. Scale bars = 50 μ m.

brackish-water species from Asia, which share 1-segmented P4 endopod: *K. uniarticularum* (Borutzky, 1928), *K. breviarticularum* (Shen and Tai, 1964), *K. biarsteini* (Borutzky,

1971), *K. radhakrishnai* (Reddy, 1979), and *K. longum* (Shen and Tai, 1979). Among the other four congeneric species, *K. longum* most resembles *K. uniarticularum* from

the mouth of Suifun River in the Maritime Territory, Russia and *K. breviarticularum* from southern China in having the scissors-like appearance of female P5, but it differs from *K. uniarticularum* by the number of setae on P2 exp 3 (2 setae in *K. longum*, while 3 in *K. uniarticularum*), and from *K. breviarticularum* by the number of setae on P5 exopod (3 setae in *K. longum*, while 2 in *K. breviarticularum*), respectively.

In South Korea, this species was collected from a salt marsh (a reed marsh situated at the supratidal zone of Dadaepo Beach, southwest Busan) and from Ulsukdo Is. (delta) locating at the mouth of Nakdong River, Busan, where co-occurred with various brackish-water copepods: *Sinodiaptomus tenellus*, *Pseudodiaptomus inopinatus*, *Acartia pacifica* (Calanoida), *Leptocaris brevicornis*, *Nitokra lacustris*, *Neotachidius parvus*, *Shizopera neglecta*, *Mesochra sufunensis*, *Onychocamptus mohammed*, *Limnocletodes behningi* (Harpacticoida), *Paracyclopina nana*, *Halicyclops japonicus*, *H. sinensis*, *Oithona davisae*, and *O. similis* (Cyclopoida).

Distribution

Korea, China (Kwangtung).

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