

Freshwater Harpacticoids of Genera *Phyllognathopus* and *Harpacticella* from South Korea

Cheon Young Chang* and Hong Ju Yoon

Department of Biology, College of Natural Sciences, Daegu University, Gyeongsan 712-714, Korea

ABSTRACT

A taxonomic study on the genera *Phyllognathopus* and *Harpacticella* has been accomplished as one of the serial researches on the freshwater harpacticoids in South Korea. As a result, four species belonging to the genera are clarified, three of which are new to Korean fauna: *P. viguieri* (Maupas), *P. paludosus* Mrázek, and *H. paradoxa* (Brehm).

Key words: Taxonomy, *Phyllognathopus*, *Harpacticella*, Harpacticoida, freshwater Copepoda, Korea

INTRODUCTION

Following the serial taxonomic studies (Chang, 2001, 2002; Chang and Ishida, 2001; Chang and Lee, 2003a, b; Lee and Chang, 2003, 2005, 2006) on the freshwater harpacticoids in South Korea, this paper deals with the genera *Phyllognathopus* and *Harpacticella* from Korea.

Phyllognathopus harpacticoids are widely distributed in both temperate and tropical latitudes, and occur in a great variety of freshwater habitats (Boxshall and Halsey, 2004). Most species are known as typically semi-terrestrial, occurring frequently from the so-called cryptic microhabitats such as arboreal mosses, temporary bogs, leaf litter, dead wood, man-made temporary containers, and so on (Reid, 1986, 2001). Eleven species are recorded in the genus *Phyllognathopus*. However, no member of this genus has not been reported from Korea so far.

Harpacticella harpacticoids are mostly freshwater or brackish-water, and six species have been currently known in this genus. In Korea, two species are recorded: *Harpacticella itoi* Chang and Kim, 1991 and *H. oceanica* Ito, 1977. *H. itoi* was described from the lower reaches of Tamjin River, Gangjin (Chang and Kim, 1991), and thereafter reported from the estuaries at eastern coast (Yeongokcheon Stream, Gangreung; Wangpicheon Stream, Uljin) and southern coast (Bangjukpo, Dolsando Is., Yeosu), and from a coastal spring at Aewol, Jejudo Is. (Song and Chang, 1993). *H. oceanica* is known as marine, and reported from intertidal zone of Homigot, Pohang and Samyang, Jejudo Is. (Song and Chang, 1993), and from

coastal marshes of Jindo Is. (Song and Chang, 1995). Distributions of both species are still restricted to the Far East.

MATERIALS AND METHODS

Samplings were made with a 63 µm mesh net, and sampled copepods were fixed and stored in 4% buffered formalin. All the specimens were dissected, drawn, and measured in lactophenol on H-S slide (Shirayama et al., 1993), a recent variation of Cobb slide. Dissection is performed using two needles made from 0.35 mm diameter tungsten wire by electrolysis (Huys and Boxshall, 1991; Huys et al., 1996). Mounted specimens were observed under a differential interference contrast microscope (Olympus BX51) with Nomarski optics. Figures were prepared with the aid of a camera lucida.

Abbreviations used in the text and figure legend follow the conventional ones frequently used in the taxonomy of freshwater copepods: *enp* 1-3 or *exp* 1-3, the first to third endopodal or exopodal segments of each leg; L/W, length to width ratio.

TAXONOMIC ACCOUNTS

Family ¹*Phyllognathopodidae* Gurney, 1932

Genus ²*Phyllognathopus* Mrázek, 1893

³*Phyllognathopus viguieri* (Maupas, 1892) (Figs. 1, 2)

Belisarius viguieri Maupas, 1892, p. 135.

Phyllognathopus viguieri: Gurney, 1932, p. 8, figs. 345-372; Lang, 1948, p. 268, fig. 137; Dussart, 1967, p. 160, fig. 55; Tai and Song, 1979, p. 166, fig. 86; Janetzky et al., 1996, p. 35, fig. 9; Ishida and Kikuchi, 2000, p. 11,

*To whom correspondence should be addressed

Tel: 82-53-850-6454, Fax: 82-53-850-6459
E-mail: cychang@daegu.ac.kr

¹*주걱턱장수노벌레과 (신칭), ²*주걱턱장수노벌레속 (신칭), ³*주걱턱장수노벌레 (신칭)

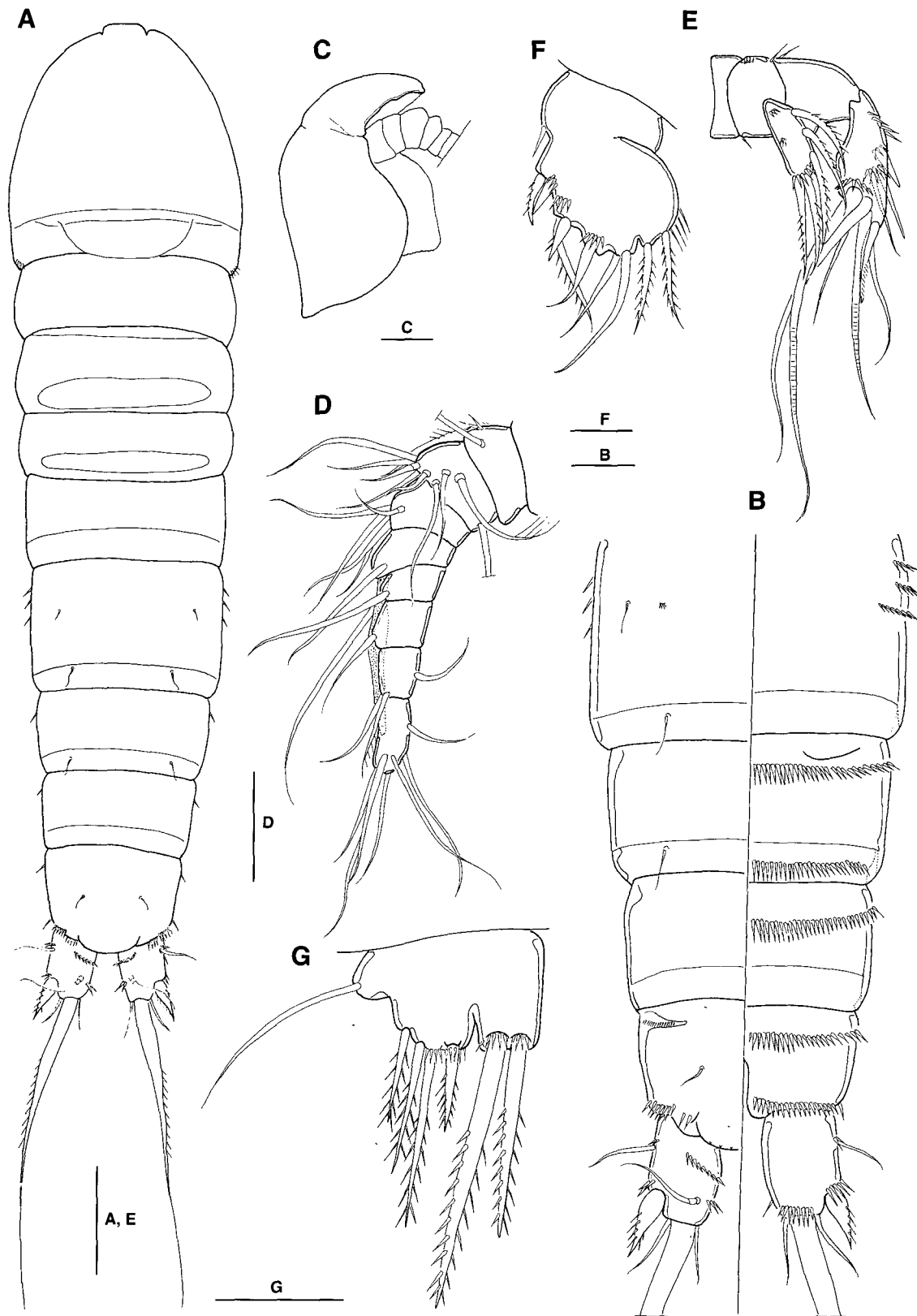


Fig. 1. *Phyllognathopus viguieri* (Maupas), female. A, habitus, dorsal; B, urosome, dorsal (left) and ventral (right); C, cephalosome (lateral); D, antennule; E, antenna; F, maxilliped; G, leg 5. Scale bars=0.05 mm (A-G).

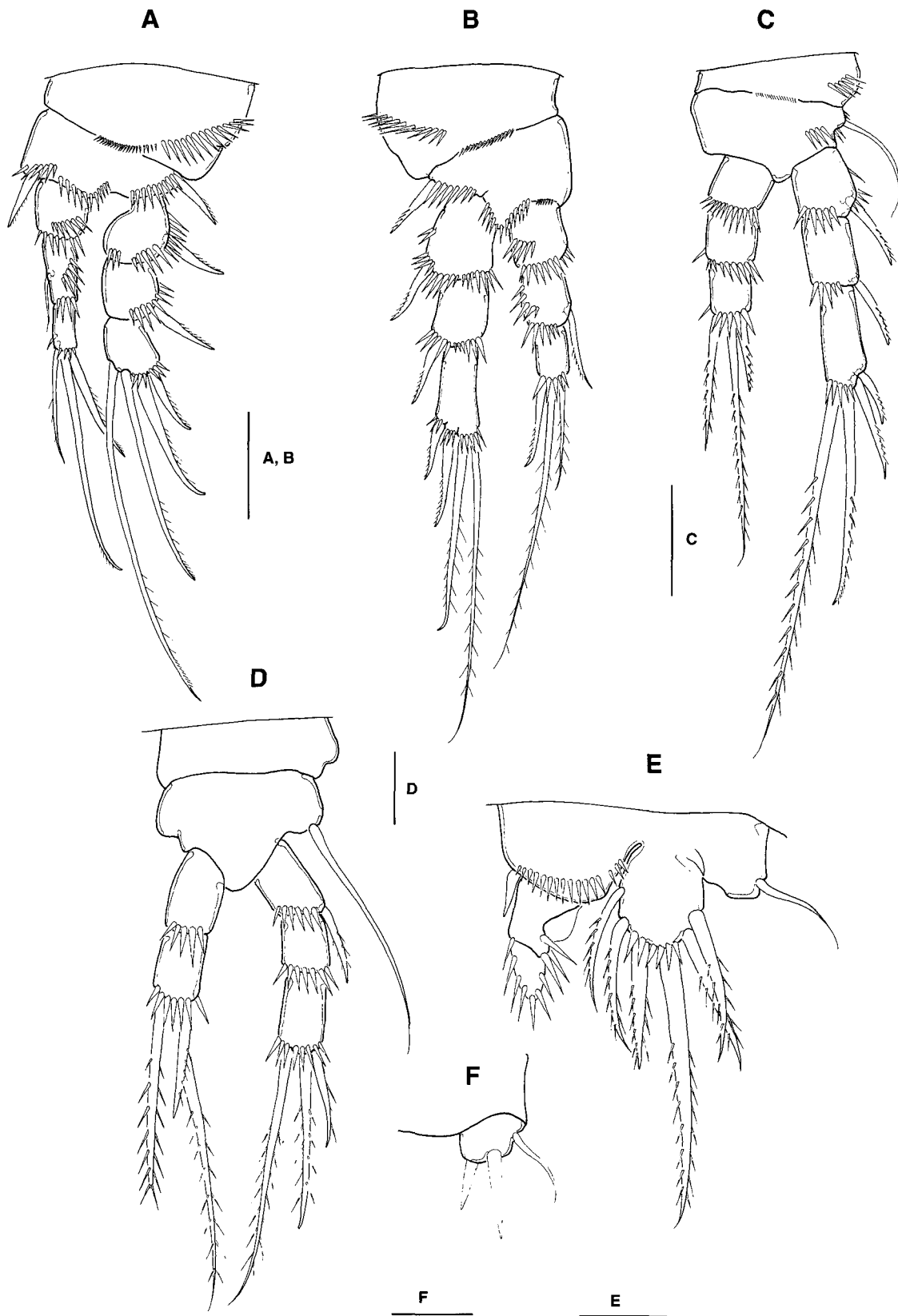


Fig. 2. *Phyllognathopus viguieri* (Maupas). A-D, female legs 1-4; E-F, male legs 5-6. Scale bars=0.05 mm (A-F).

fig. 1.

Material examined. 1 ♀, 1 ♂, Gangnung Univ. (spring at foothill), Gangreung, 28 Dec. 2006 (C.Y. Chang and J.M. Lee); 1 ♀, 1 ♂, Songgye Valley (moss, fallen leaves), Wolaksan Mt., Chungju, 26 Jul. 1999 (C.Y. Chang and J.M. Lee); 1 ♀, Simpi-gul Cave, 1 Aug. 1996 (H.S. Rho); 1 ♀, Banyasa Temple (leaf litter), Baekhwasan Mt., Yeongdong, 13 Sep. 1999 (C.Y. Chang); 1 ♂, Hyeongsangang River, Pohang, 1 Oct. 1999 (C.Y. Chang and J.M. Lee); 1 ♀, Seoknamsa Temple (rotten leaves), Gajisan Mt., Eonnyang, 13 Aug. 1996 (C.Y. Chang); 1 ♀, Gaetaesa Temple (brook), Nonsan, 14 Sep. 1999 (C.Y. Chang); 1 ♂, Cheondungsan Mt. (foothill puddle), Unju, Jeollabuk-do, 14 Sep. 1999 (C.Y. Chang); 1 ♂, Geumsansa Temple (brook), Moaksan Mt., Jeonju, 29 Oct. 1999 (C.Y. Chang); 1 ♀, Yukmojeong Valley (fallen leaves), Jirisan Mt., Namwon, 4 Sep. 1999 (J.M. Lee and Y.H. Song); 1 ♀, Piagol Valley (moss, fallen leaves), Jirisan Mt., Gurye, 6 Aug. 1988 (C.Y. Chang); 1 ♀, Eorimok Hill (spring), Hallasan Mt., Jejudo Is., 16 Jun. 1999 (C.Y. Chang).

Female. Body minute and slender, 0.5-0.6 mm long. Rostrum conspicuous, extending downward in lateral view (Fig. 1A, C), its tip reaching posterior margin of third segment of antennule. Prosoma 5-segmented, comprising cephalosome and 4 free thoracic somites. Urosome (Fig. 1B) a little narrowing posteriorly. Posterodorsal margins of all abdominal somites smooth, while spinule rows present on ventral surface. Genital double-somite a little wider than long. Anal operculum convex; posterior margin smooth or with several minute projections.

Caudal rami cylindrical, a little divergent, slightly tapering distally; 1.2-1.4 times longer than broad (Fig. 1B). Oblique spinule row present on dorsomedial face. Lateral seta located on proximal one-third. Outer caudal seta (caudal seta III) outstandingly swollen. Terminal caudal seta (caudal seta V) much swollen proximally, less than half the body length.

Antennule (Fig. 2D) 8-segmented, short and blunt, not reaching one-third of cephalothorax; 4th segment with 1 long aesthetasc, not reaching tip of antennule. Exopod of antenna (Fig. 2E) 1-segmented, bearing total of 5 setae (2 apical and 3 lateral setae). Maxilliped (Fig. 1F) phyllopodial form; flattened, indistinctly 2-segmented; furnished with 9 setae along distal margin of distal segment.

Legs 1-4 (Fig. 2A-D) biramous, both exopods and endopods 3-segmented, except 2-segmented endopod of leg 4. Leg 1, endopod slightly beyond middle of exopod; enp 1 not elongate, without inner seta; enp 2 with 1 distomedial

seta; enp 3 with 1 spine and 2 setae; exp 3 with 2 apical setae and 2 lateral spines. Leg 4 relatively smaller than other legs; both exp 3 and enp 3 armed with 3 apical elements. Setal/spine armature of leg 2-4 as follows (Arabic numerals representing setae, while Roman numerals indicating spines):

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

Leg 3 basis I-0 exp I-0; I-0; II,1,1 enp 0-0; 0-0; I,1,1

Leg 4 basis I-0 exp I-0; 0-0; I,1,1 enp 0-0; I,1,1

Leg 5 (Fig. 1G), baseoendopod partly fused with exopod proximally. Inner expansion of baseoendopod protruding, reaching tip of exopod, with 2 thick spiniform setae, outer seta about 1.5 times longer than inner one. Exopod represented by small plate, with 4 setae in total.

Male. Body about 0.4-0.5 mm long. Ornamentation of legs 1-4 and caudal rami nearly same as in female. Baseoendopod of leg 5 (Fig. 2E) partly fused with exopod, a little swollen with 1 protuberance bearing about 10 spinules or setules around distal margin. Exopod oval with 6 setae, apical one longest. Leg 6 (Fig. 2F) represented by small protrusion with 1 slender outer seta and 2 short spines.

Ecology. *P. viguieri* occurred principally from various mountain waters like springs, leaf litter around temporary bogs, brooks, caves, and semi-terrestrial soils or mosses. Lehman and Reid (1993) reported *P. viguieri* preyed on at least seven phytoparasitic, two free-living and one entomopathogenic nematode species. This species frequently co-occurred with *Bryocamptus zschokkei caucasicus*, *B. nivalis*, *Attheyella coreana*, and *Canthocamptus mirabilis* group in South Korea.

Remarks. According to the references involved, this species is shown as somewhat variable in the length ratio of caudal rami, shape of anal operculum (posterior margin smooth or not), shape of caudal setae (inner terminal caudal seta and outer caudal seta usually swollen basally), shape of setae on the inner lobe of baseoendopod of female leg 5 (swollen or not), and shape of protuberance or seta on the inner lobe of baseoendopod of male leg 5. It is uncertain whether the variability is resulted from the wide-distribution and great adaptability of *P. viguieri s. lat.* or from the taxonomic confusion by the species complex. Lang (1948) synonymized all *Phyllognathopus* species and subspecies as *P. viguieri* (Maupas), but nowadays at least 11 species have been recognized (Boxshall and Halsey, 2004).

Distribution. Korea, Japan, China, Vietnam, Indonesia, Europe, Africa, America, New Zealand.

¹*Phyllognathopus paludosus* Mrázek, 1893 (Figs. 3, 4)
Phyllognathopus paludosus Mrázek, 1893, p. 97, pl. 4, figs.

¹*가시주걱턱장수노벌레 (신칭)

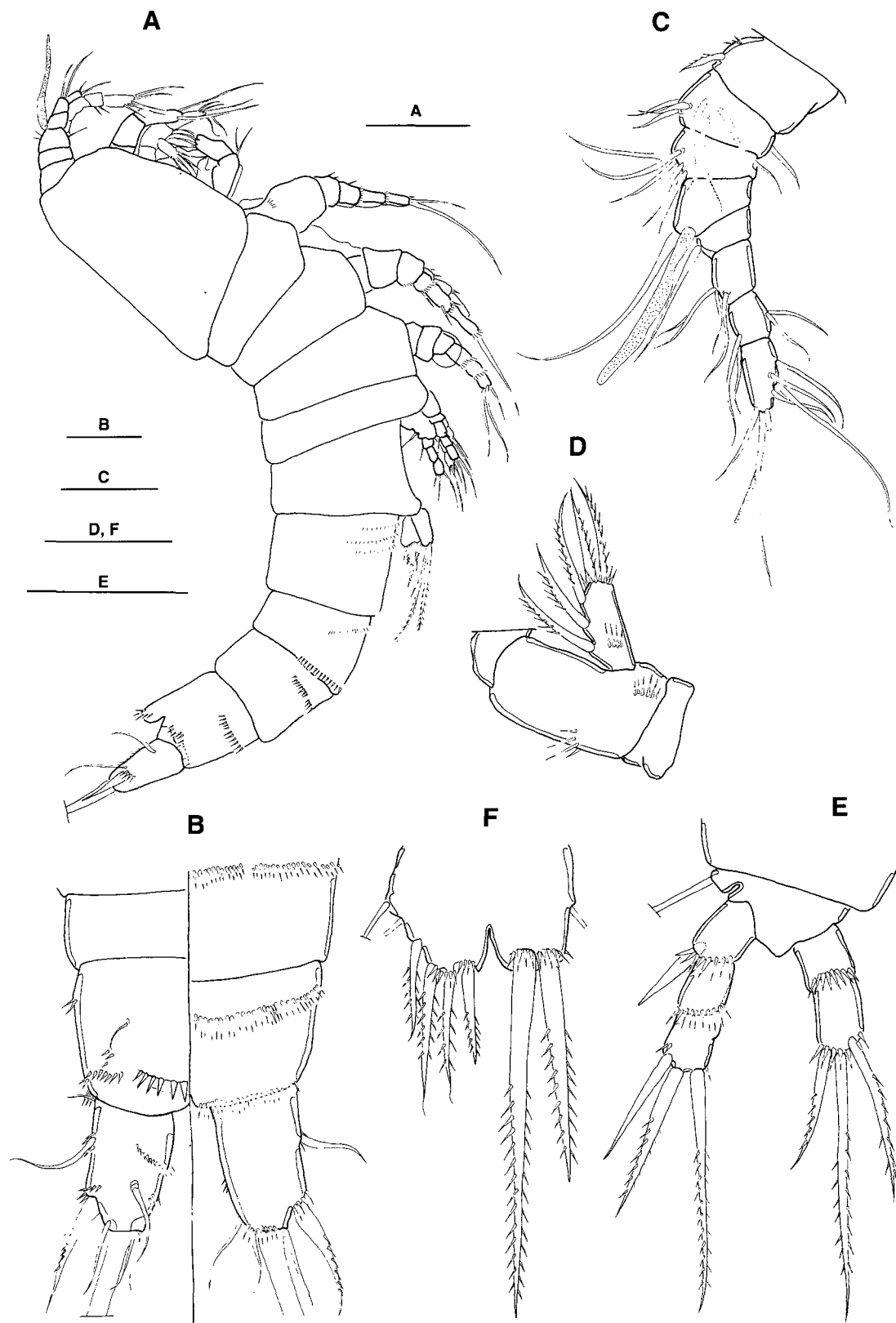


Fig. 3. *Phyllognathopus paludosus* Mrázek, female. A, habitus, lateral; B, anal somite and caudal rami, dorsal (left) and ventral (right); C, antennule; D, antenna (coxa, basis and exopod); E-F, legs 4-5. Scale bars=0.05 mm (A-F).

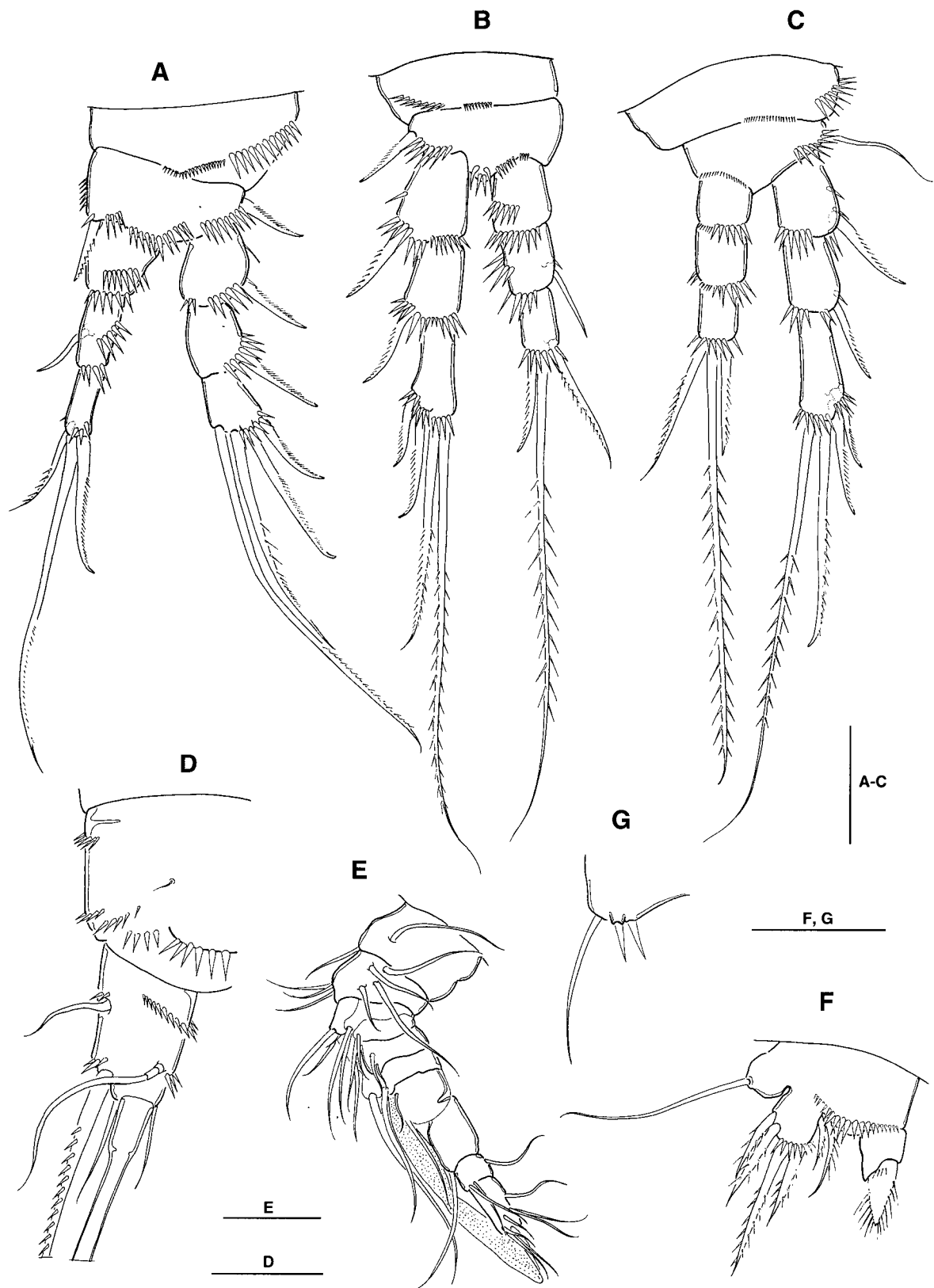


Fig. 4. *Phyllognathopus paludosus* Mrázek. A-C, female legs 1-3. D-G, male: D, anal somite and caudal ramus (dorsal, left); E, antennule; F, leg 5; G, leg 6. Scale bars=0.05 mm (A-G).

1-16; Damian-Georgescu, 1970, p. 61, figs. 19-20; Tai and Song, 1979, p. 168, fig. 87.

Viguiereella paludosa: Borutzky, 1925, p. 29, figs. 5-7; Gurney, 1932, p. 328.

Material examined. 5 ♀♀, Dorisa Temple (foothill bog), Taejosan Mt., Seonsan, 14 Nov. 1999 (C.Y. Chang and J.M. Lee); 1 ♂, 5 ♀♀, Pyochungsa Temple (mountain stream), Milyang, 23 Jun. 1999 (C.Y. Chang); 1 ♂, 1 ♀, Bijindo Is. (coastal bog), Tongyeong, 8 Jun. 2002 (J.M. Lee and Y.H. Song).

Female. Body (Fig. 3A) minute and slender, 0.5-0.6 mm long. General appearance similar to preceding species. Anal operculum convex with 10-16 spinules along posterior margin.

Caudal rami (Fig. 3B) cylindrical, divergent each other, a little tapering distally; somewhat elongate, 1.5-2.0 times longer than broad. A spinule row present along dorsomedial face. Lateral caudal seta located on proximal one-third. Terminal caudal seta (caudal seta V) not swollen proximally.

Antennule (Fig. 3C) 8-segmented, short and blunt, not reaching midway of cephalothorax; 4th segment with 1 long aesthetasc, not reaching tip of antennule. Exopod of antenna (Fig. 3D) 1-segmented, with total 5 setae (2 apical and 3 lateral setae).

Legs 1-3 (Fig. 4A-C) biramous, both endopods and exopods 3-segmented. Leg 4 (Fig. 3E), endopod 2-segmented, exopod 3-segmented. Leg 1, endopod slightly beyond middle of exopod; enp 1 not elongate, without inner seta; enp 2 with 1 distomedial seta; enp 3 with 1 outer spine and 2 setae; exp 2 not elongate, without inner seta; exp 3 with 2 lateral spines and 2 setae. Setal/spine armature of leg 2-4 as in the preceding species.

Leg 5 (Fig. 3F), baseoendopod partly fused with exopod proximally. Inner expansion of baseoendopod protruding, reaching tip of exopod, with 2 thick spiniform setae, outer seta about 1.5 times longer than inner one. Exopod with 4 short setae.

Male. Body about 0.4 mm long. Sexual dimorphism only in antennules, genital segmentation, and in legs 5-6. Antennule (Fig. 4E) 9-segmented; 4th segment bearing 1 long, swollen aesthetasc, its tip much exceeding last segment. Baseoendopod of leg 5 (Fig. 4F) partly fused with exopod proximally; inner lobe a little protruding, with 1 stout seta; outer part of inner lobe with row of setules along posterior margin. Exopod oval with 6 setae in total, comprising 2 short medial, 2 apical, 2 lateral setae; outer apical one longest. Leg 6 (Fig. 4G) represented by small protrusion with 1 slender outer setae and 2 short spines.

Ecology. This species has been reported from littoral zone

of various freshwaters, like bogs, ponds, lakes and rivers (Tai and Song, 1979). In Korea, specimens were collected by rinsing the fallen leaves submerged in a puddle at foothill, a mountain stream, and a coastal bog, co-occurring with *Onychocamptus mohammed*, *Canthocamptus incurvsetosus*, *Elaphoidella bidens*, *Macrocyclops albidus* and *Microcyclops varicans*.

Remarks. Korean specimens coincides well with Tai and Song (1979)'s redescription for the Chinese specimens, except for two minor discrepancies: (1) in the female leg 5, the length arrangement of exopodal setae (second seta on the inner margin longest in Tai and Song, 1979, while third one longest in our Korean specimens); (2) in the male leg 6, Tai and Song (1979) described it as bearing 3 short spines, however, Korean specimens obviously have 1 outer slender seta and 2 short inner spines. Other significant and decisive characteristics of this species, such as elongate caudal rami (more than 1.5 times longer than wide) with normal terminal caudal seta (not swollen basally), and 10-16 acute spinules along posterior margin of anal operculum are consistent throughout the specimens examined.

Distribution. Korea, China, Europe, Africa, North America.

Family Harpacticidae Dana, 1846

Genus *Harpacticella* Sars, 1908

***Harpacticella itoi* Chang and Kim, 1991**

Harpacticella itoi Chang and Kim, 1991, p. 73, figs. 1-3; Song and Chang, 1993, p. 211; Ishida and Kikuchi, 2000, p. 12, fig. 4.

Material examined. 3 ♀♀, 1 ♂, estuary of Bulgeunnori Stream, Yeongheungdo Is., Incheon, 11 Nov. 2005 (H.W. Lim); estuary of Wangpicheon, Uljin, 7 May 1993 (C.Y. Chang and J.M. Lee); 1 ♀, 1 ♂, estuary of Buheungcheon Stream, Jangsa, Yeongdeok, 27 Feb. 2003 (C.Y. Chang); 22 ♀♀, 4 ♂♂, estuary of Daehwagang R., Janggi, Pohang, 7 Oct. 2004 (J.M. Jeon and H.W. Lim); 1 ♀, Dadaepo (reed marsh), Busan, 28 Sep. 2005 (C.Y. Chang, J.M. Lee and H.W. Lim); 1 ♀, Beolgyocheon Stream (estuary), Suncheon, 25 Feb. 2004 (C.Y. Chang); 12 ♀♀, 3 ♂♂, Gwakji (coastal spring), Jeju Is., 20 Jul. 2001 (C.Y. Chang and J.M. Lee); 6 ♀♀, 2 ♂♂, Gangjeongcheon Stream, Seogwipo, Jeju Is., 13 Jan. 2007 (C.Y. Chang and J.M. Lee).

Ecology. *H. itoi* occurred from the lower reaches of streams near seashore in Korea. This species frequently co-occurred with both brackish-water and freshwater species, like *Pseudodiaptomus inopius*, *Mesochra alaskana*, *M. suifunensis*, *Halicyclops* spp., *Nitokra* spp. and *Eucyclops serrulatus* group.

Remarks. Genus *Harpacticella* comprises total of 6 species: *H. inopinata* Sars, 1908 (type species), *H. paradoxa* (Brehm,

1924), *H. lacustris* Sewell, 1924, *H. amurensis* Borutzky, 1952, *H. oceanica* Ito, 1977, and *H. itoi* Chang and Kim, 1991. Among these 6 recorded species, *H. oceanica* is known as marine, *H. lacustris* and *H. itoi* brackish-water, and the others freshwater species. *H. itoi* is reported from the lower reaches of streams influenced by tides in Korea and Japan. This species is similar to *H. paradoxa* and *H. oceanica*, but easily distinguished from them by the short female exopodal segment of leg 5 (less than 1.5 times as long as wide) with 7 setae. All *Harpacticella* species have 4 or 5 apical or subapical setae on exopod of female leg 5, except *H. itoi*, which has two more setae on medial margin of the exopod. Ishida and Kikuchi (2000) ignored the slender proximal one, however, considering their figure, the shape and location of it fit well with Korean specimens. All the specimens from Korea also showed the character state consistently, and the number of exopodal setae of female leg 5 should be counted as 'seven'.

Distribution. Korea (streams around all coasts of South Korea), Japan.

¹**Harpacticella paradoxa* (Brehm, 1924) (Figs. 5, 6)

Handiella paradoxa Brehm, 1924, p. 99.

Harpacticella paradoxa: Pesta, 1930, p. 132, fig. 1; Lang, 1948, p. 343, fig. 156(1); Ito and Kikuchi, 1977, p. 41, figs. 1-38; Tai and Song, 1979, p. 180, fig. 94; Ishida and Kikuchi, 2000, p. 12, fig. 3.

Material examined. 18 ♀♀ (4 ovi.), 5 ♂♂, Gangjeongcheon Stream, Seogwipo, Jeju Is., 13 Jan. 2007 (C.Y. Chang and J.M. Lee); 3 ♀♀, Cheonjeyeon Fall, Jeju Is., 20 Apr. 1995 (C.Y. Chang); 2 ♀♀, same locality, 16 Jun. 1999 (C.Y. Chang).

Female. Body (Fig. 5A) 0.7-0.8 mm long; depressed dorsoventrally. Cephalothorax widest at posterior margin, then narrowing posteriorly; a little longer than sum of next 3 thoracic somites. Rostrum not conspicuous in dorsal view, extending downward. Urosome markedly narrower than prosomal somites, and narrowing posteriorly; composed of genital double-somite and 3 free abdominal somites. All urosomites with row of spinules on posteroventral margin. Anal operculum convex with smooth margin.

Caudal rami divergent, a little longer than wide, slightly tapering distally. Lateral surface of ramus with 2 setae (caudal setae I and II) located at middle of lateral margin of caudal rami. Outer caudal seta (caudal seta III) slender, a little shorter than inner caudal seta (caudal seta VI). Terminal caudal setae (caudal setae IV and V) well developed and its proximal part not swollen. Dorsal caudal seta (caudal

seta VII) short, situated dorsomedially.

Antennule (Fig. 5C) 7-segmented, short and blunt; not reaching one third of cephalothorax; 4th segment much longer than sum of next three, with 1 long aesthetasc. Exopod of antennae (Fig. 5D) slender and elongate, 2-segmented; proximal segment with 1 distal seta; distal segment bearing 1 proximal and 2 apical setae with whorl of spinules distally. Mandible, maxillula, maxilla and maxilliped as shown in Ito and Kikuchi (1977).

Legs 1-4 (Figs. 5E, 6A-C), both exopod and endopod 3-segmented. Leg 1 prehensile with claw-like spines apically on both exopod and endopod. Exopod stout, clearly longer than endopod; exp 1 1.3 times longer than next segment, with 4 claw-like spines distally; enp 1 with 1 long seta near distal third of inner margin; distal segment with 1 long claw-like spine. Legs 2-4 (Fig. 6A-C), both exopod and endopod 3-segmented. Ornamentation of legs 2-4 as in the preceding species (Arabic numerals representing setae, while Roman numerals indicating spines):

Leg 2 basis 1-0 exp I-1; I-1; III,2,2 enp 0-1; 0-1; I,2,2

Leg 3 basis 1-0 exp I-1; I-1; III,2,3 enp 0-1; 0-1; I,2,3

Leg 4 basis 1-0 exp I-1; I-1; III,2,3 enp 0-1; 0-1; I,2,2

Leg 5 (Fig. 5F) with inner expansion of baseoendopod, bearing 5 apical setae of different lengths, of which 4th seta from inner margin longest. Exopod somewhat ellipsoidal, narrowing distally, about 3 times longer than wide; bearing total 5, with groups of fine spinules on both sides of exopod.

Male. Body about 0.65 mm long. Ornamentation of legs 1-4 and caudal rami nearly same as in female. Baseoendopod of leg 5 (Fig. 6F) fused to fifth pedigerous somite, with 1 outer seta; exopod a little longer than wide, with 3 setae in all, without seta on inner margin. Leg 6 (Fig. 6G) represented by small protrusion with 3 long, naked setae.

Ecology. This species was originally described from a lake in Yunnan Province, China (Brehm, 1924). Ito and Kikuchi (1977) reported it from the aquatic plants (*Ranunculus aquatilis* var. *pantothrix*) at the Yukawa River in the middle of Japan. In Korea, this species occurred from puddles around Cheonjeyeon Fall and the lower reaches of Gangjeongcheon Stream, Seogwipo City, in the southern part of Jeju Is.

Remarks. In the lower reaches of Gangjeongcheon Stream, this species co-occurred with *Bryocamptus nivalis*, *Paracyclops fimbriatus*, *Macrocylops albidus*, and *H. itoi*. The co-occurrence of *Harpacticella* congeners (that is, *H. paradoxa* and *H. itoi*) is reported for the first time in this genus. The frequency of occurrence of *H. paradoxa* in South Korea is rather rare in comparison with that of *H. itoi*. How-

¹*파라독스어리장수노벌레 (신칭)

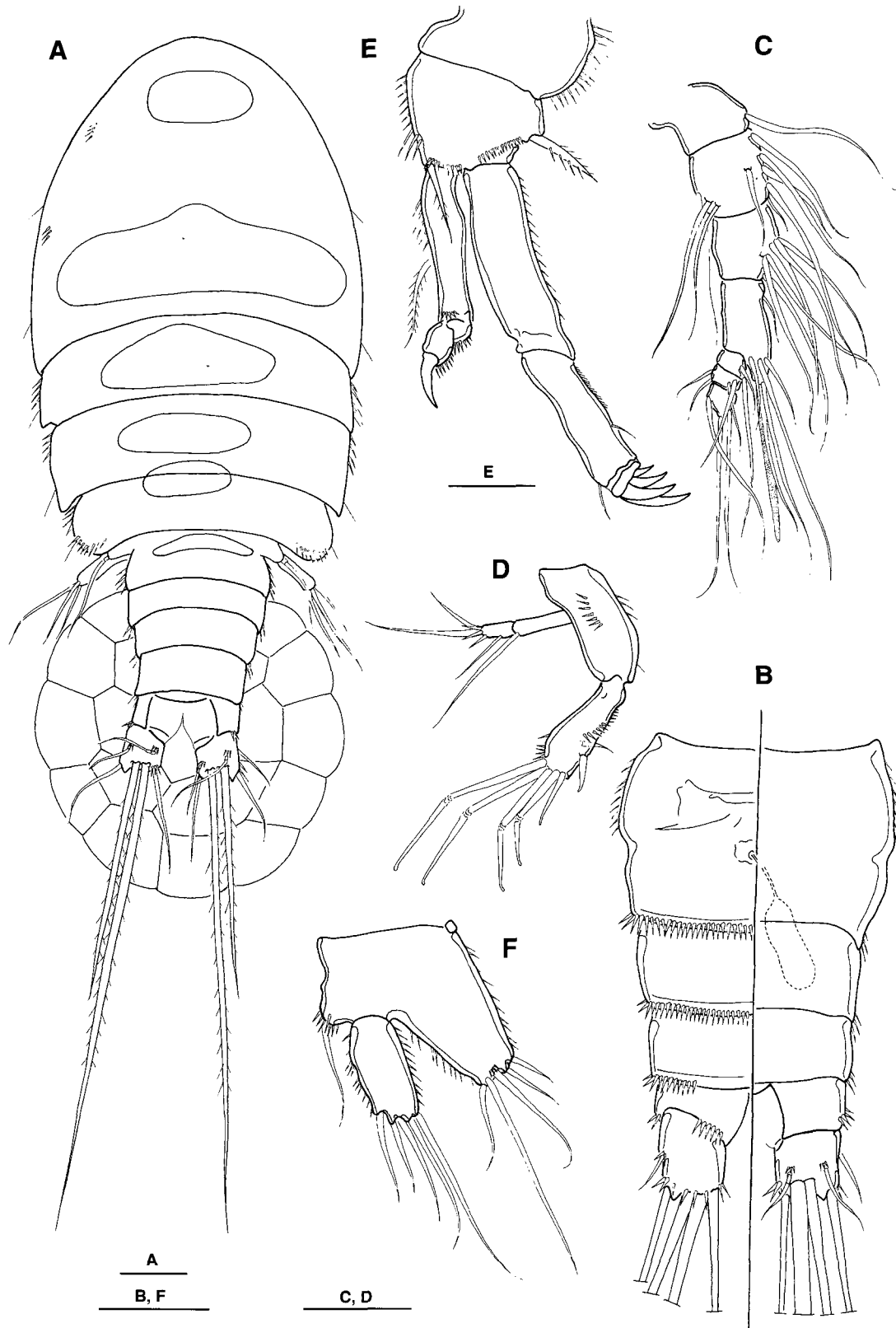


Fig. 5. *Harpacticella paradoxa* (Brehm), female. A, habitus, dorsal; B, urosome, ventral (left) and dorsal (right); C, antennule; D, antenna; E, leg 1; F, leg 5. Scale bars=0.05 mm (A-F).

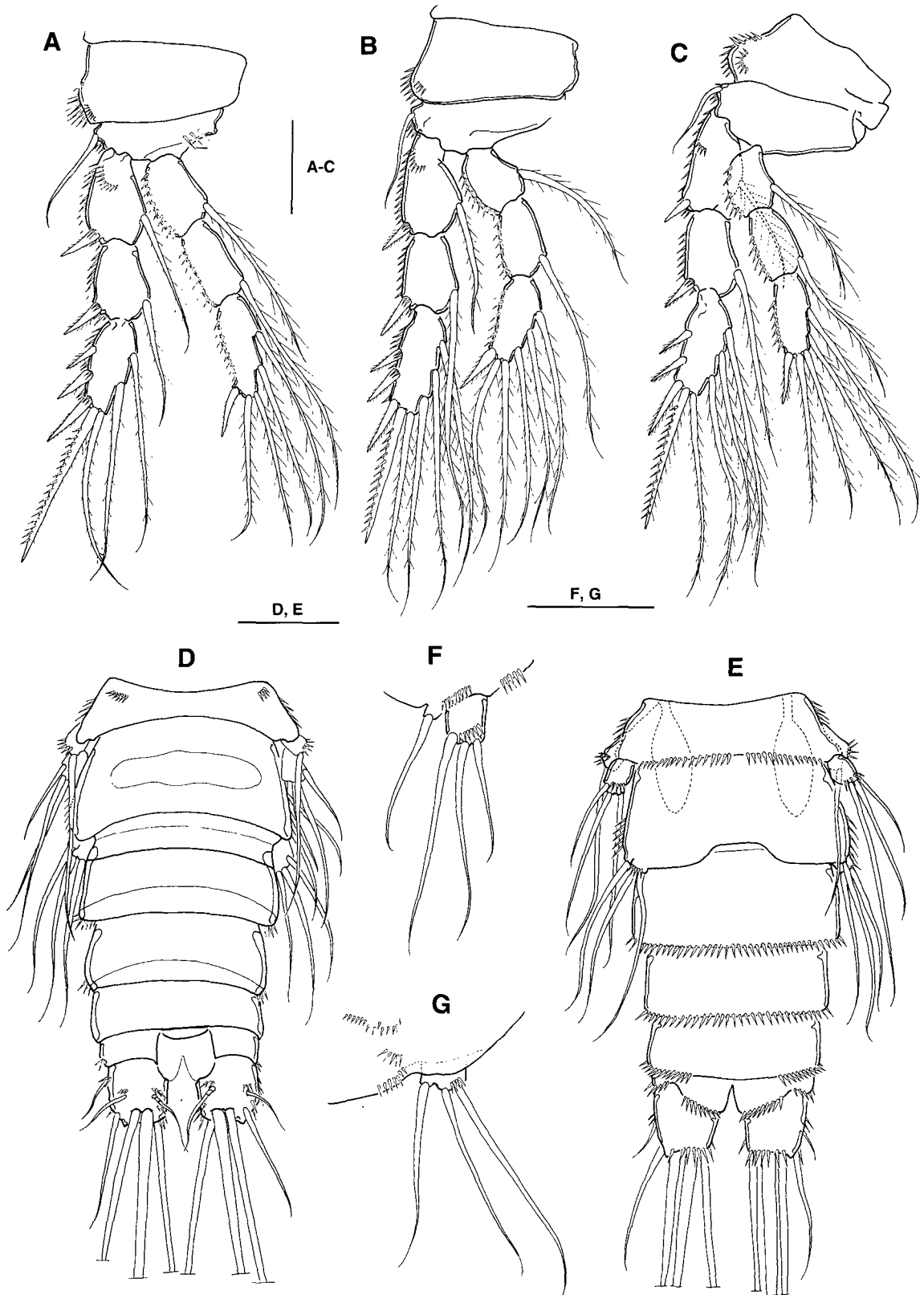


Fig. 6. *Harpacticella paradoxa* (Brehm). A-C, female legs 2-4. D-G, male: D, urosome, dorsal; E, urosome, ventral; F-G, legs 5-6. Scale bars=0.05 mm (A-G).

ever, in this place, *H. paradoxa* is relatively dominant. The ratio of individuals between them was 23 (*H. paradoxa*) : 8 (*H. itoi*). Special character displacement could not be detected in this co-occurrence case.

Distribution. Korea, China, Japan.

A key to the species of genus *Harpacticella* from Korea

1. Female leg 5 exopod rather quadrangular, about 1.3-1.4 times longer than wide, with 7 setae *H. itoi*
 Female leg 5 exopod ellipsoidal, more than 2 times longer than wide, with 5 setae 2
2. Caudal rami longer than wide; male leg 5 exopod with 3 setae; freshwater *H. paradoxa*
 Caudal rami wider than long; male leg 5 exopod with 4 setae; marine *H. oceanica*

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REFERENCES

- Borutsky, E.V., 1925. La faune des Harpacticides de tourbière près de Kossino. Trud. Kosinsk. Biol. Stn., 2: 25-42.
- Boxshall, G.O. and S.H. Halsey, 2004. An introduction to copepod diversity, vols. I, II. The Ray Society of London, pp. 1-966.
- Brehm, V., 1924. Diagnosen neuer Entomostraken. IV. Teil. Akad. Anz. Wien. 24(13): 99-100.
- Chang, C.Y., 2001. Redescription of *Canthocamptus mirabilis* Sterba (Copepoda, Harpacticoida), based on the topotypic material from China. Korean J. Syst. Zool., 17(1): 1-11.
- Chang, C.Y., 2002. Taxonomy on *Canthocamptus semicirculus* and *C. corensis* n. sp. (Harpacticoida, Canthocamptidae), with a key to the *C. mirabilis* species group from South Korea. Korean J. Syst. Zool., 18(2): 233-244.
- Chang, C.Y. and T. Ishida, 2001. Two new species of the *Canthocamptus mirabilis* group (Copepoda: Harpacticoida: Canthocamptidae) from South Korea. Proc. Biol. Soc. Wash., 114(3): 667-679.
- Chang, C.Y. and H.S. Kim, 1991. *Harpacticella itoi*, a new harpacticoid species (Copepoda: Harpacticoida: Harpacticoidae) from Korea. Korean J. Syst. Zool., 7(1): 73-80.

- Chang, C.Y. and J.M. Lee, 2003a. Taxonomy on freshwater canthocamptid harpacticoids (Copepoda) from South Korea I. Genus *Canthocamptus*. Korean J. Syst. Zool., 19 (1): 149-159.
- Chang, C.Y. and J.M. Lee, 2003b. Taxonomy on freshwater canthocamptid harpacticoids from Korea II. Genus *Attheyella*. Korean J. Syst. Zool., 19(2): 189-201.
- Damain-Georgescu, A., 1970. Crustacea, Copepoda, Harpacticoida (forme de apa dulce). Fauna Repub. social. Romania, Bucarest, 4 (11), pp. 1-250.
- Dussart, B., 1967. Les copépodes des eaux continentales d'Europe occidentale. Tome I. Calanoïdes et Harpacticoides. Ed. Boubée, Paris, pp. 1-500
- Gurney, R., 1932. The British fresh-water Copepoda. Vol. 2, Harpacticoida. Ray Society, London, pp. 1-336.
- Huys, R. and G.A. Boxshall, 1991. Copepod evolution. The Ray Society, London, pp. 1-468.
- Huys, R., J.M. Gee, C.G. Moore and R. Hamond, 1996. Marine and brackish water harpacticoid copepods. Part. 1. In Synopses of the British Fauna (New Series), No. 51. The Linnean Society of London and The Estuarine and Coastal Sciences Association, pp. i-vii, 1-352.
- Ishida, T. and Y. Kikuchi, 2000. Illustrated fauna of the fresh-water harpacticoid copepods of Japan. Bull. Biogeogr. Soc. Japan, 55: 7-94.
- Ito, T. and Y. Kikuchi, 1977. On the occurrence of *Harpacticella paradoxa* (Brehm) in Japan; a fresh-water harpacticoid copepod originally described from a Chinese Lake. Annot. Zool. Jpn., 50: 40-56.
- Janetzky, W., R. Enderle and W. Noodt, 1996. Crustacea: Copepoda: Gelyelloida und Harpacticoida. In Schwoerbel, J. and P. Zwick, eds., Süßwasserfauna von Mitteleuropa. Gustav Fischer Verlag, Stuttgart, 8(4/2), pp. 1-228.
- Lang, K., 1948. Monographie der Harpacticiden. Nordiska-Bokhandeln, Stockholm, 2 vols., pp. 1-1682.
- Lee, J.M. and C.Y. Chang, 2003. Taxonomy on freshwater canthocamptid harpacticoids from Korea III. Genera *Mesochra* and *Elaphoidella*. Korean J. Syst. Zool., 19(2): 203-216.
- Lee, J.M. and C.Y. Chang, 2005. Harpacticoid copepods of genus *Onychocamptus* (Laophontidae) from Korean J. Syst. Zool., 21(1): 31-34.
- Lee, J.M. and C.Y. Chang, 2006. Taxonomy on freshwater canthocamptid harpacticoids from Korea V. Genus *Bryocamptus*. Korean J. Syst. Zool., 22 (2): 195-208.
- Lehman, P.S. and J.W. Reid, 1993. *Phyllognathopus viguieri* (Crustacea: Harpacticoida), a predaceous copepod of phytoparasitic, entomopathogenic, and free-living nematodes. Soil Crop Sci. Soc. Florida Proc., 52: 78-82.
- Maupas, E., 1892. Sur le *Belisarius viguieri*, nouveau copépode d'eau douce. C. r. Séanc. Acad. Sci. Paris, 115: 135-137.
- Mrázek, A., 1893. Prispěvky k poznání sladkovodních Copepody. Vest. kral. ceske spol. nauk, 8: 1-74.
- Pesta, O., 1930. *Handiella* Brehm 1924 = *Harpacticella* G. O

- Sars, 1908. (Copepoda Harpacticoida). *Zool. Anz.*, 88: 132-138.
- Reid, J.W., 1986. Some usually overlooked cryptic copepod habitats. *Syllogeus*, 58: 594-598.
- Reid, J.W., 2001. A human challenge: discovering and understanding continental copepod habitats. *In* Lopes, R.M., J. W. Reid and C.E.F. Rocha, eds., *Copepoda: Developments in Ecology, Biology and Systematics*. Kluwer Academic Publishers, Dordrecht. *Hydrobiologia*, 453/454, pp. 201-226.
- Shirayama, Y., T. Kaku and R.P. Higgins, 1993. Double-sided microscopic observation of meiofauna using an HS-slide. *Benthos Research*, 44: 41-44.
- Song, S.J. and C.Y. Chang, 1993. Eight harpacticoid species of Harpacticidae (Copepoda, Harpacticoida) from Korea. *Korean J. Syst. Zool.*, 9(2): 203-220.
- Song, S.J. and C.Y. Chang, 1995. Marine harpacticoid copepods of Chindo Island, Korea. *Korean J. Syst. Zool.*, 11(1): 65-77.
- Tai, A.-Y. and Y.-Z. Song, 1979. Harpacticoida Sars, 1903. *In* C.J. Shen, ed., *Fauna Sinica, Crustacea, Freshwater Copepoda*. Science Press, Beijing, pp. 164-300.

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