Korean J. Syst. Zool. Vol. 24, No. 3: 241-250, November 2008

Two Brackish Cyclopoid Copepods from Southern Coast of Korea

Hong Ju Yoon and Cheon Young Chang*

Department of Biological Science, Daegu University, Gyeongsan 712-714, Korea

ABSTRACT

Two brackish cyclopoid species are reported mostly from the estuaries and salt marshes in the southern coast of Korea: *Limnoithona sinensis* (Burckhardt, 1913) and *Apocyclops borneoensis* Lindberg, 1954. The two species as well as the genera are newly added to Korean fauna. Herein, the redescription is provided with the systematic accounts and detailed illustrations of them.

Key words: *Apocyclops borneoensis*, brackish waters, Copepoda, Cyclopoida, Korea, *Limnoithona sinensis*, Taxonomy

INTRODUCTION

The faunistic studies on the harpacticoid copepods from Korean brackish waters have been accomplished continually, since Chang and Kim (1991) described *Harpacticella itoi* from Tamjin River, Gangjin: two *Mesochra* species (Lee and Chang, 2003), two *Onychocamptus* species (Lee and Chang, 2005), two new *Neotachidius* (Huys et al., 2005), three Cletodidae species (Lee and Chang, 2007), two Ameiridae species (Chang, 2007), Two *Leptocaris* species (Lee and Chang, 2008a), five *Nitokra* species (Chang and Yoon, 2008), four Tachidiidae species (Chang, 2008) and two new species (*Itunella arenaria* and *Mesochra bisetosa*) (Lee and Chang, 2008b). As for the calanoid copepods, Soh et al. (2001) classified four neritic *Peudodiaptomus* in Korean waters, among which two brackish species (*P. inopinus* and *P. poplesia*) were included. Lee et al. (2007) reported eight species belonging to four genera from brackish waters in Korea.

The taxonomic studies on the genuine brackish cyclopids are relatively very poor in Korea. Yoo and Lim (1989) reported *Halicyclops ryukyuensis* Ito, 1962 from Yeongsanho Lake, Mokpo. Recently, Chang and Min (2005) recorded two brackish cyclopids, *Mesocyclops marinus* Guo, 2000 from Ganghwado Is., Incheon, and *Thermocyclops uenoi* Ito, 1952 from a coastal well, Yeosu, middle of southern coast of Korea.

In the present study, we provide the redescription of two cyclopoid species, *Limnoithona sinensis* (Burckhardt, 1913) and *Apocyclops borneoensis* Lindberg, 1954, based on the specimens from the various brackish waters such as estuaries, coastal marshes, and brackish lakes in southern coast of Korea. The two species as well as the genera are newly reported from Korea.

*To whom correspondence should be addressed
Tel: 82-53-850-6454, Fax: 82-53-850-6459
E-mail: cychang@daegu.ac.kr

MATERIALS AND METHODS

Materials examined in the present study were collected from estuaries, coastal salt marshes and brackish lake at five localities (Fig. 1) in South Korea during the period from July, 1987 to February, 2007. Collections were made with a dip-net of 64 μm mesh. Copepods were fixed and stored in 4% buffered formalin.

Specimens were dissected and mounted in lactophenol on H-S slide, 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.

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 legs (pereiopods).

SYSTEMATIC ACCOUNTS

Order Cyclopoida Burmeister, 1854
Family Oithonidae Dana, 1853

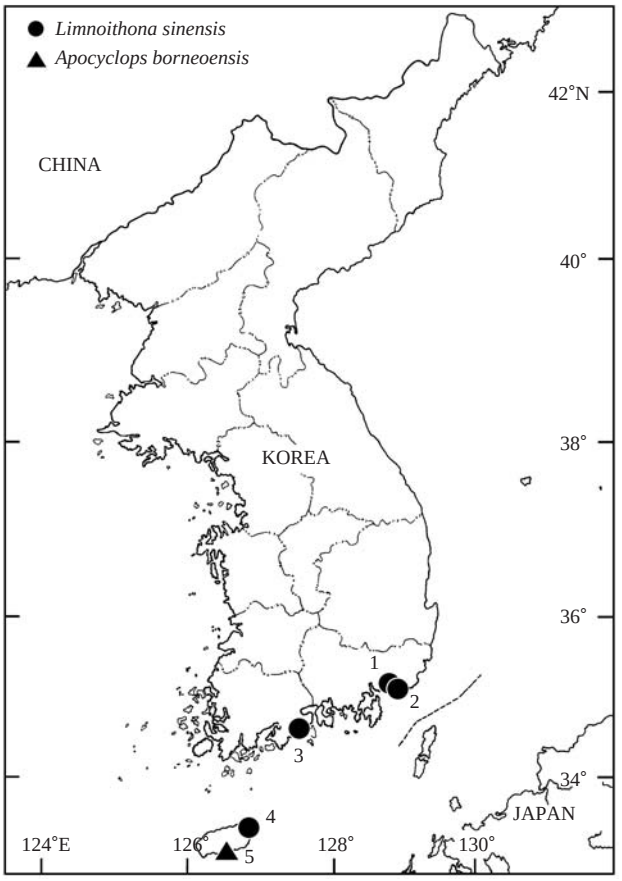

Fig. 1. A map showing localities in South Korea. 1, Jomancheon Stream, Gimhae; 2, estuary of West-Nakdonggang River, Gimhae; 3, Dolsando Island, Yeosu; 4, Seongsanpo, Jeju Island; 5, Saeseom Islet, Seogwipo, Jeju Island.

Genus [1]**Limnoithona* Burckhardt, 1913

[2]***Limnoithona sinensis* (Burckhardt, 1913) (Figs. 2-4)**

Oithona (*Limnoithona*) *sinensis* Burckhardt, 1913, p. 421, pl. 15P, figs. 1-4, pl. 15Q, figs. 1, 7-9, pl. 16R, figs. 1, 5, 6, 10, 13, pl. 16S, figs. 2, 9-16.

Limnoithona sinensis: Kiefer, 1929, p. 11, fig. 4; Tai and Chen, 1979, p. 303, fig. 169.

Material examined. 13♀♀, 5♂♂, West-Nakdonggang R., Garak, Gimhae, 28 Nov. 1995 (K.J. Cho); 2♀♀, 1♂, Jomancheon Str. (lower reaches), Gimhae, 28 Nov. 1995 (K.J. Cho); 8♀♀ (3 ovi.), Dolsando Is. (salt marsh), Yeosu, 3 Feb. 2005 (C.Y. Chang and J.M. Lee); 3♀♀, Seongsanpo (reed marsh), Jeju Is., 13 Jan. 2007 (J.M. Lee and C.Y. Chang).

Description. Female. Body (Fig. 2A) slender, about 580 μm (ranging 576-584 μm, N=6) in length, tapering behind from border of cephalothorax. Rostrum not protruding anteriorly in dorsal view, not defined from cephalic shield at base. Cephalosome divided with first pedigerous somite, a little longer than sum of next 4 prosomites. Outer distal margin of each prosomite not protruded posterolaterally.

First urosomite (fifth pedigerous somite) broadened posteriorly; as basal segment of P5 fully fused into the somite, lateral seta shown as issuing from the somite in dorsal view (Fig. 2A). Genital double-somite with faint line marking fusion in dorsolateral sides; about 1.7 times as long as broad; proximal part swollen; genital field with separate copulatory pores on both sides, each connected to oval seminal receptacle. Genital double-somite and next two urosomites with narrow hyaline fringe along posterior margin. Posterior margin of dorsal surface of anal somite armed with 8-10 spinules. Anal operculum gently rounded with smooth posterior edge (Fig. 3A).

Fu elongate, 4-5 times longer than wide, a little narrowing in distal portion, a little divergent to each other posteriorly (Fig. 3A). Both lateral margins and dorsal surface rather smooth. Lateral caudal setae (caudal seta II) locating near proximal third of lateral margin of Fu, flanked with 3-4 spinules. Outer caudal seta (caudal seta III) plumose terminally, shorter (about 0.7 times) than inner caudal seta (caudal seta VI). Terminal caudal setae (caudal seta IV and V) well developed, plumose; inner one about 1.7 times longer than outer one. Dorsal caudal seta (caudal seta VII) locating just anterior to bases of terminal caudal setae, a little longer than Fu, a little more than 2 times as long as inner caudal seta.

A1 (Fig. 2B) slightly not reaching posterior margin of third prosomite, 13-segmented (7th and 8th segments usually indistinctly divided); segment 3 stout, segment 10 relatively elongate. Setal formula: 1-[3], 2-[5], 3-[7], 4-[6], 5-[4], 6-[2], 7-[1], 8-[1], 9-[1], 10-[1], 11-[1], 12-[3], 13-[7+1 aesthetasc]. A2 (Fig. 2C) 4-segmented, consisting of coxobasis and 3 free endopodal segments; coxobasis with 1 seta; enp 1 distinctly divided with coxobasis, with 1 seta, enp 2 with 5 setae, and enp 3 with 7 setae, respectively; exopod or exopodal seta absent.

Mandible (Fig. 2D) armed with well developed coxal gnathobase; palp composed of allobasis, 1 free endopodal segment and 4-segmented exopod; allobasis elongated bearing 1 basal seta and 3 distal setae; endopod with 5 setae; exopod showing 1, 1, 1, 2 setal arrangement. Maxillule (Fig. 2E) with syncoxal arthrite bearing 9 distal elements in total; 2 setae on outer surface representing epipodite; a small protrusion with 1 seta apically representing coxal endite; basal endite subdivided into 2 parts, each with 2 pinnate setae distally; endopod bearing 4 setae; exopod with 4 setae.

[1]*민물긴배검물벼룩속 (신칭), [2]*민물긴배검물벼룩 (신칭)

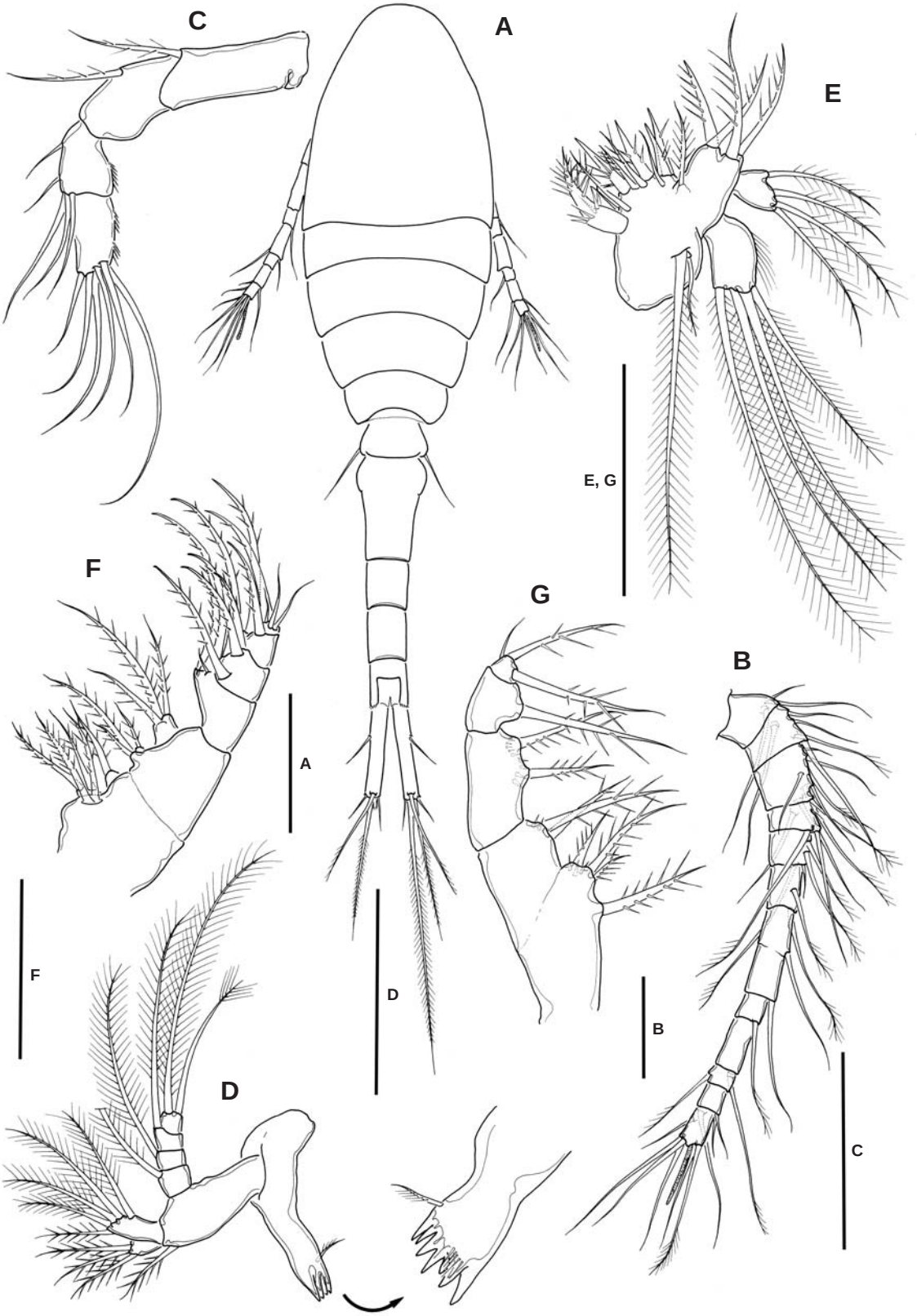

Fig. 2. *Limnoithona sinensis*, female. A, habitus, dorsal; B, A1; C, A2; D, mandible; E, maxillule; F, maxilla; G, maxilliped. Scale bars=100 μm (A) and 50 μm (B-G).

Maxilla (Fig. 2F) 6-segmented; praecoxa and coxa each forming 2 endites, bearing 4, 1, 3, 3 setae, respectively; basis with 3 setae; endopod 3-segmented, with 4, 2, 4 setae, respectively. Maxilliped (Fig. 2G) 4-segmented; syncoxa (praecoxa plus coxa) subdivided with oblique fold, bearing groups of 1, 3, 2 setae distally; basis with 2 setae; endopod 2-segmented, with 1 and 3 setae, respectively.

P1-P4 (Fig. 3B-E), biramous, both exopods and endopods 3-segmented. Spine formula (number of outer spines on exp 3 of P1-P4) 3, 3, 3, 3 (excluding distal spine). Seta formula (number of setae on exp 3 of P1-P4) 4, 5, 5, 5. Spine/seta armature of P1-P4 as follows (Arabic numerals representing setae, while Roman numerals indicating spines):

P1 basis 1-1 exp I-1; I-1; III,I,4 enp 0-1; 0-1; 1,2,3
P2 basis 1-0 exp I-1; I-1; III,I,5 enp 0-1; 0-2; 1,2,3
P3 basis 1-0 exp I-1; I-1; III,I,5 enp 0-1; 0-1; 1,2,3
P4 basis 1-0 exp I-1; I-1; III,I,5 enp 0-1; 0-1; 1,2,2

P1, basis with 1 inner spiniform seta posteromedially, exceeding enp 2 (Fig. 3B); coupler (intercoxal sclerite) with 2 naked lateral lobes, caudal face with 8-9 spinules near posterior margin. P2 enp 2 bearing 2 inner setae; coupler ornamented with 1 row of 8-10 spinules near middle of caudal face; posterior margin naked (Fig. 3C). P3 coupler similar as in P2 coupler except with 1 row of 15-16 spinules near middle of caudal face (Fig. 3D). P4 enp 3 1.6 times as long as wide, armed with 2 apical setae, their lengths similar to each other (Fig. 3E, arrow); coupler with 8-10 spinules along gently rounded posterior margin, with 11-12 minute spinules near middle of caudal face.

P5 composed of protopod and 1 free exopodal segment; protopod incorporated into somite bearing 1 outer protopodal plumose seta subdorsally; exopod a little elongate, about 2.2 times longer than wide, with 1 inner spiniform seta 1 (Fig. 3F, arrow), 1 terminal and 1 outer distal plumose setae. P6 (Fig. 4A) vestigial, represented by 2 spiniform projections and 1 naked seta with peduncle, locating at dorsolateral surface of genital double-somite.

Male. Body slender, about 560 μm long (ranging 545-580 μm, N=3). General appearance and seta/spine arrangement similar to those of females. Fu about 6 times as long as wide; location of lateral caudal seta and the relative length ratio of caudal setae similar as in female. Sexual dimorphism shown in A1, urosomites including genital somite, and P6.

A1 (Fig. 4B) 15-segmented; digeniculate, articulation apparent between antepenultimate (ancestral segments XIX to XX fused) and penultimate (XXI to XXIII fused) segments; sheath present on segment XV; last segment subchirocerate.

Urosome consisting of 5th pedigerous somite, genital somite and 4 free abdominal somites (Fig. 4C). Genital somite covered with paired genital plates ventrally (Fig. 4D), bearing P6 represented by small protuberance on distolateral corner of genital plate with 1 minute innermost spine, 1 median pinnate seta and 1 outer plumose seta; with paired genital apertures.

Ecology. This species was reported from estuaries and freshwater lakes near seashore in China (Tai and Chen, 1979); in Korea, it occurred from the lower reaches of West-Nakdong River, Gimhae, a coastal bog at Dolsando Is., Yeosu, and a reed marsh (brackish lake) near Seongsanpo Port, Jeju Is. in the winter season. Recently, this species has been reported as introduced into the west coast of North America (Ferrari and Orsi, 1984).

Distribution. China, Korea and west coast of North America.

Remarks. Genus *Limnoithona* was established by Burckhardt (1913) originally as a new subgenus for an oithonid cyclopid species, '*Oithona* (*Limnoithona*) *sinensis*', from brackish waters in southern China, which bears 3 setal elements on exopod of P5 (against at most 2 setae in other genera of the family Oithonidae, *Oithona* and *Dioithona*). Later, another species, *L. tetraspinosa*, with 4 setal elements on exopod of P5 was found also in China, and currently only these two species are recorded in this genus. Recently, *Limnoithona* lineage is regarded as arising basally, and the similarities between this genus and members of the Cyclopinidae are suggested (cited from Boxshall and Halsey, 2004)

Korean specimens well coincide with the original description (Burckhardt, 1913) and Tai and Chen (1979)'s redescription from China, except for two minor discrepancies. The coxobasis of oithonid cyclopids is known as sometimes fused with the first endopodal segment of A2 (Boxshall and Halsey, 2004) as shown in the original description of the present species (cf. Burckhardt, 1913, Pl. 16R, fig. 1), while they are distinctly divided in all the Korean specimens. As the other report on the Chinese specimens (Tai and Chen, 1979) did neither mention nor draw the A2, so the genuine difference between two populations cannot be settled down.

Furthermore, in the Tai and Chen (1979), the segments 7 and 8 of A1 in female is drawn as completely divided to each other (cf. Tai and Chen, 1979, fig. 169b), while they are indistinctly divided (or partly fused) in our specimens from Korea as well as in the original description (cf. Burckhardt, 1913, Pl. 15Q, fig. 1).

Family Cyclopidae Sars, 1913
Subfamily Cyclopinae Kiefer, 1927
Genus [1]******Apocyclops* Lindberg, 1942
[2]******Apocyclops borneoensis* Lindberg, 1954 (Fig. 5)**

[1]*야릇검물벼룩속(신칭), [2]*야릇검물벼룩(신칭)

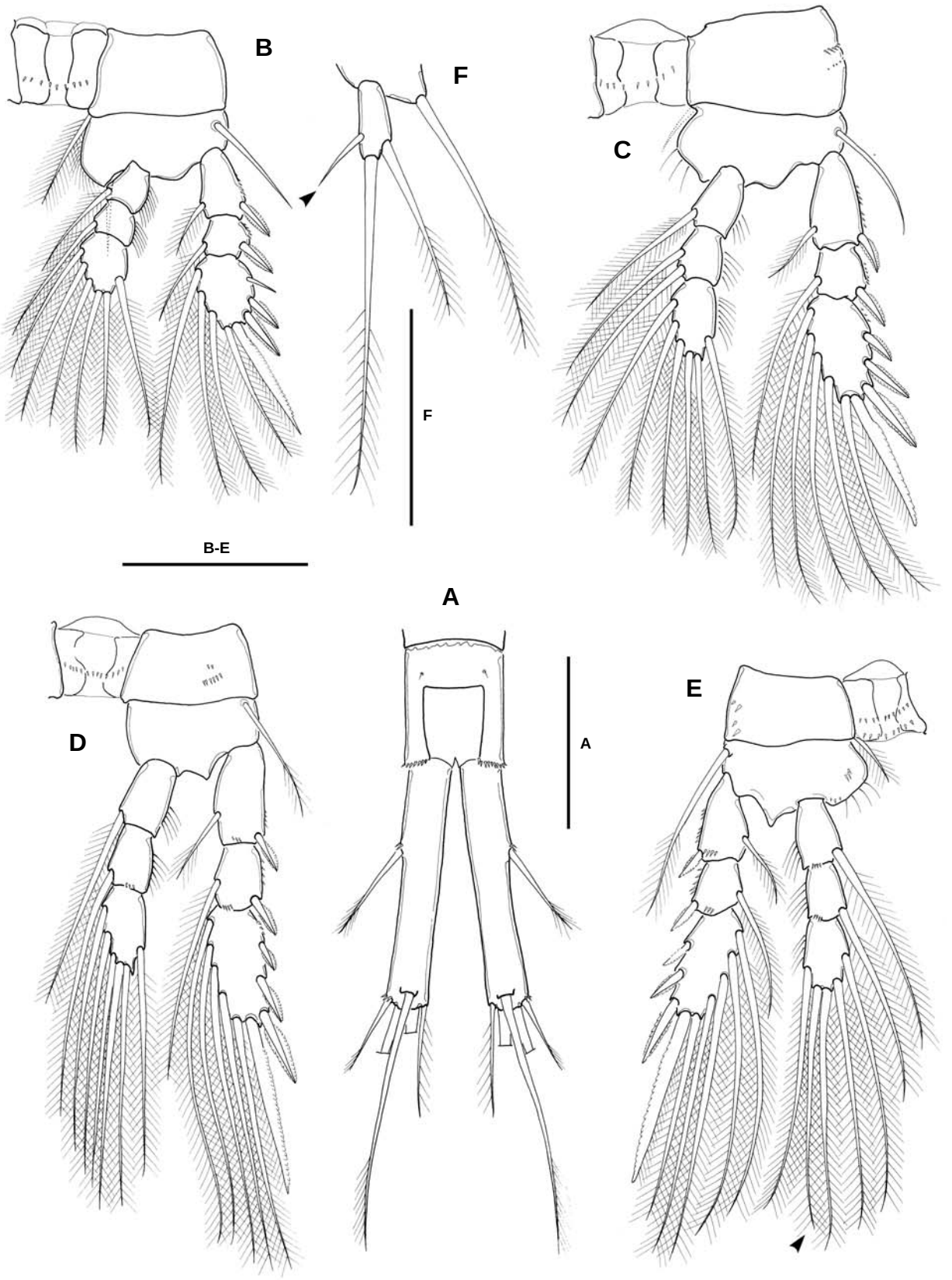

Fig. 3. *Limnoithona sinensis*, female. A, anal somite and Fu, dorsal; B-F, P1-P5. Scale bars=50 μm (A-F).

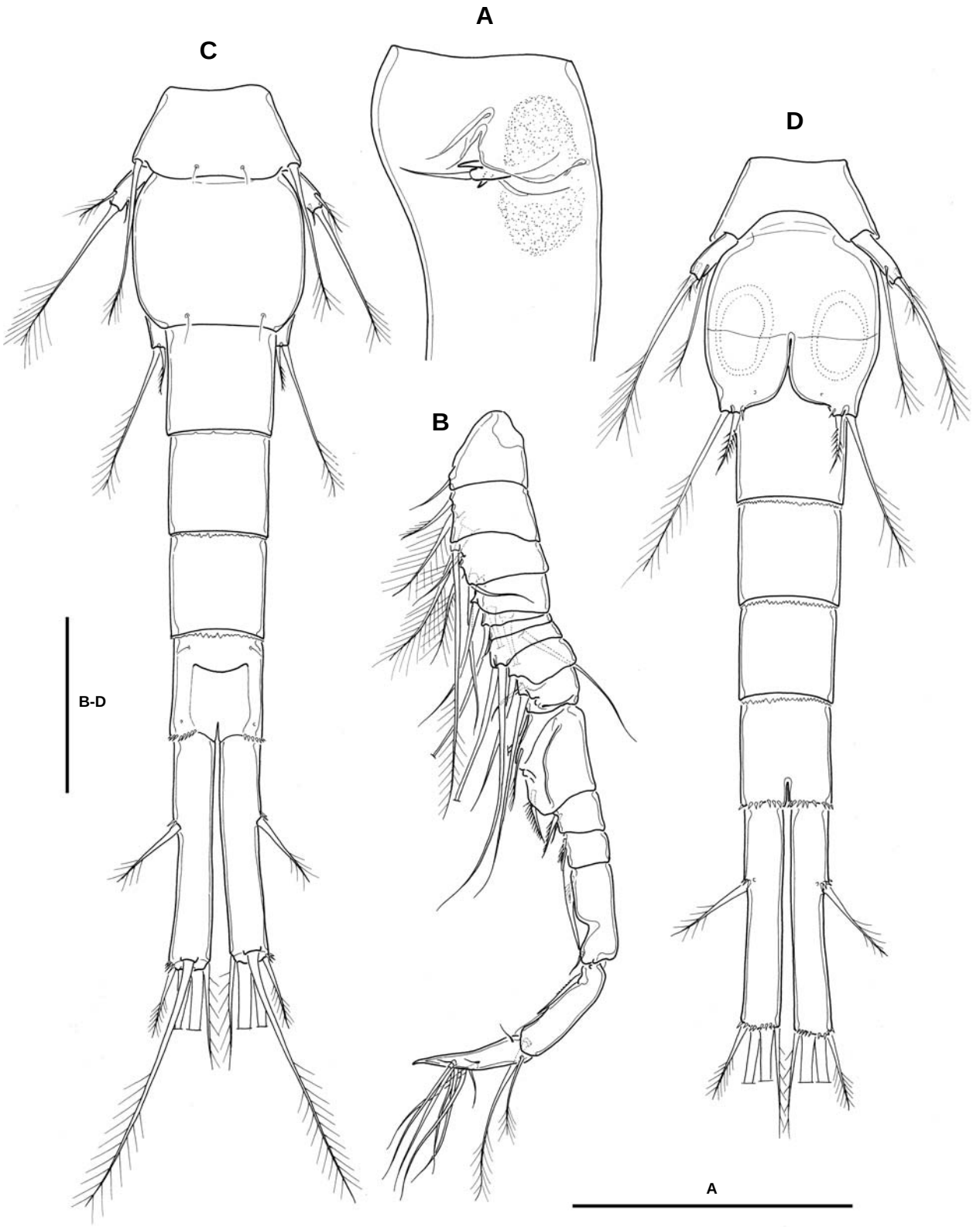

Fig. 4. *Limnoithona sinensis*. A, female P6 and genital somite, lateral. B-D, male: B, A1; C, urosome, dorsal; D, urosome, ventral. Scale bars=50 μm (A-D).

Apocyclops borneoensis Lindberg, 1954, p. 168, fig. 3; Tai and Chen, 1979, p. 396, fig. 237; Ishida, 2002, p. 59, fig. 31.

Material examined. 5♀♀, Saeseom islet (salt marsh), Seogwipo, Jeju Is, 11 Feb. 1987 (C.Y. Chang).

Description. Female. Body (Fig. 5A) about 970 μm long (ranging 962-983 μm, N=5), excluding caudal seta; somewhat slender, greatest width about 31% of body length at posterior margin of cephalothorax; tinged with pale brown. Prosome ellipsoidal, a little longer than urosome; widest at posterior margin of cephalothorax, and gradually tapering behind. Rostrum reduced. Cephalothorax somewhat protruding anteriorly, about 2 times longer than next three thoracic somites combined. Fourth pedigerous somite producing posterolaterally. First urosomite (fifth pedigerous somite) broadened posteriorly; basal segment of P5 fully fused into the somite, lateral basal seta issuing from dorsal side of the somite; exopodal segment with 1 inner spine and 1 distal seta shown in dorsal view (Fig. 5A, B). Fifth pedigerous somite without patch of hairs dorsolaterally.

Genital somite 1.1 times longer than wide, anterior part a little swollen laterally, nearly as long as next three urosomites combined, and gradually tapering behind. Seminal receptacle 'T'-shaped in general appearance (Fig. 5B); anterior part forming side wings, their lateral tip not bent posteriorly; posterior part ellipsoidal, much narrower than anterior part. Posterolateral margin of anal somite with 7-8 spinules dorsally. Anal operculum gently convex, smooth on its posterior margin.

Fu strikingly elongate, about 8 times (ranging 7.6-8.9, N=5) as long as wide, nearly parallel to each other; with 1 oblique row of minute spinules ahead of dorsal seta, without hairs along inner (medial) margin. Lateral caudal seta inserted at about distal third of lateral margin of ramus; lateral margin not interrupted by minute spinules. Outer caudal seta (caudal seta III) 1.2-1.3 times longer than inner caudal seta (caudal seta IV). Inner terminal caudal seta (caudal seta V) about 1.5 time longer than outer terminal caudal seta (caudal seta IV), 1.8-1.9 times as long as Fu. Dorsal caudal seta (caudal seta VII) long, plumose, 2.3-2.5 times longer than outer caudal seta, and about half the length of Fu.

A1 (Fig. 5C) a little exceeding posterior margin of third prosomite, consisting of 11 segments, without hyaline membrane on distal 3 segments; segments 7 and 8 elongate, segment 7 slightly (1.04 times) longer than segment 8. Setal formula: 1-[9], 2-[4], 3-[6], 4-[1], 5-[1 (spiniform)], 6-[2], 7-[3], 8-[2+1 aesthetasc], 9-[2], 10-[2], 11-[7+1 aesthetasc]. A2 (Fig. 5D) 3-segmented, consisting of basis (fused with first endopodal segment) and 2 free endopodal segments; exopod represented by 1 long seta at outer distal corner of basis; basis with 3 setae along medial margin; first free endopodal segment with 9 setae, distal endopodal segment with 7 setae. Mandlble, maxilla and maxilliped shown as typical shape of genus *Apocyclops*.

P1-P4, biramous, both exopods and endopods 2-segmented. Spine formula (number of spines on exp 2 of P1-P4) 3,4,4,3. Seta formula (number of setae on exp 3 of P1-P4) 5,5,5,5. Spine/seta armature of P1-P4 as follows (Arabic numerals representing setae, while Roman numerals indicating spines):

P1	basis 1-1	exp I-1; III,1,4	enp 0-1; 1,I+1,3
P2	basis 1-0	exp I-1; III,I+1,4	enp 0-1; 1,I+1,4
P3	basis 1-0	exp I-1; III,I+1,4	enp 0-1; 1,I+1,4
P4	basis 1-0	exp I-0; II,I+1,4	enp 0-1; 1,I,4

P1 (Fig. 5E), basis with 1 inner seta exceeding middle of enp 2; coupler (intercoxal sclerite) with 2 lateral lobes, bearing 2-3 spinules on posterior margin; frontal face with 5-6 spinules laterally; caudal face with 1 row of 18-21 spinules near posterior margin. P2 coupler with 1 transverse row of minute spinules on posterior part of caudal face; lateral lobe ornamented with 2-3 spinules on posterior margin. P3 (Fig. 5F) showing same setae/spine armature as in P2; lateral lobes of coupler each with 4 spinules on posterior margin; caudal face with 2 spinule rows. P4 (Fig. 5G), coupler armed with 1 transverse rows of about 20 spinules in the middle of caudal face and 4 spinules at each lateral side; lateral lobes naked on posterior margin; coxa armed with 1 transverse row of 18-21 spinules, without interruption or gap, along posterior margin of caudal face; exp 1 lacking inner seta; enp 2 about 2.1-2.2 times as long as wide, about 1.7 times longer than apical spine.

P5 (Fig. 5H), basal segment fully fused into 5th pedigerous somite, lateral seta issuing from dorsal side of the somite; exopodal (distal) segment trapezoidal, about 1.4 times wider than long, narrowing distally, with 1 inner spine and 1 lateral seta; inner surface hirsute, furnished with minute spinules densely; bearing 1 innermost spine and 2 setae, inner seta about 1.7 times longer than P5 segment (ranging 1.54-1.80), and nearly as long as outermost seta.

Male. Not collected.

Ecology. This species was described from the coastal salt marsh in Borneo Is., Indonesia, and reported from saline waters at Kwangtung, southern China, and a seashore rice paddy in Iriomote Is., Okinawa, Japan. In Korea, it was found in the salt marsh in Saeseom islet, adjacent to the breakwater of Seogwipo Port, Jeju Is., southernmost part of Korea.

This species has been rarely occurred, however, considering the collection records, it must be a tropical species, and apparently favors the shallow coastal salt marshes with high

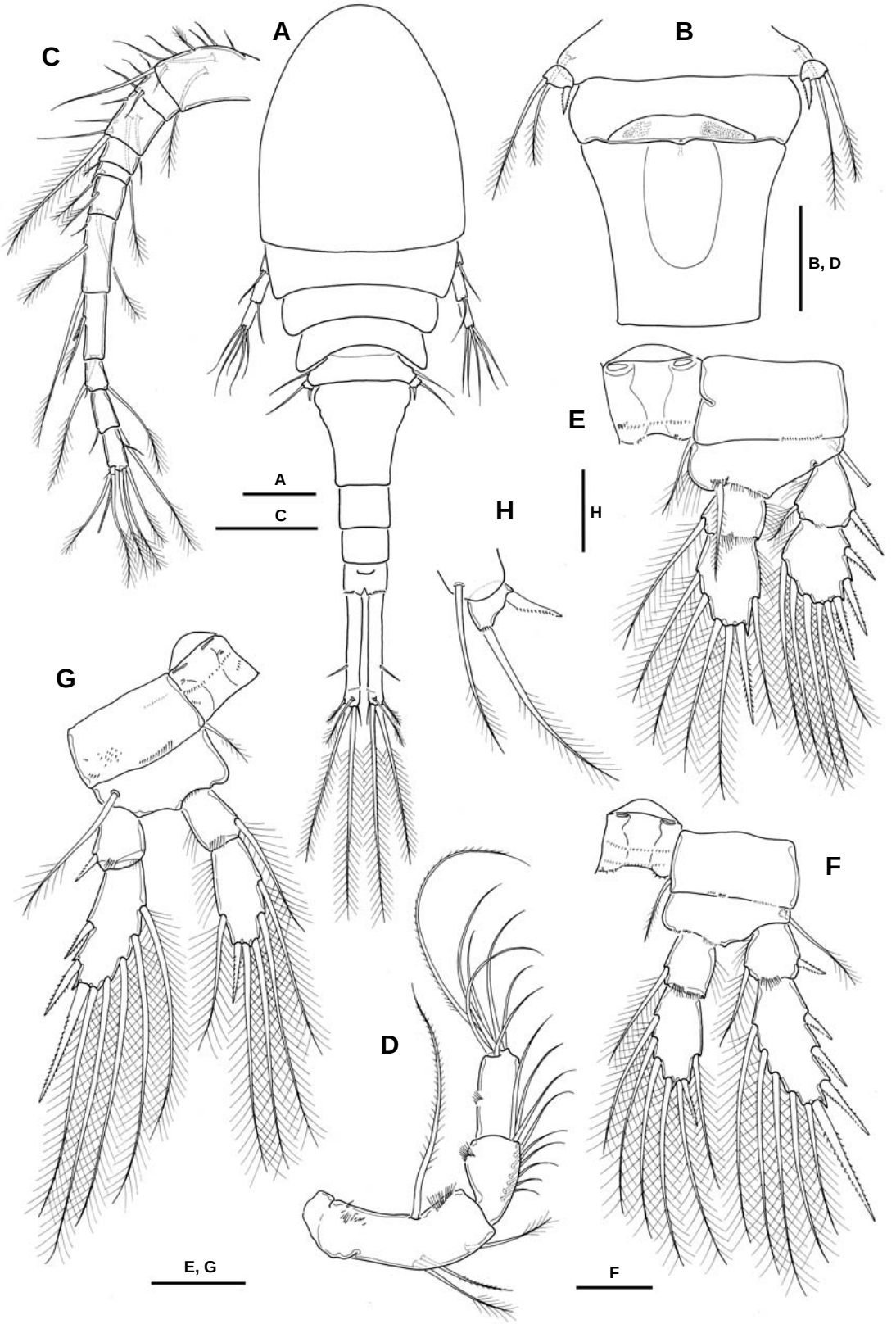

Fig. 5. *Apocyclops borneoensis*, female. A, habitus, dorsal; B, 5th pedigerous somite and genital somite, ventral; C, A1; D, A2; E, P1; F, P3; G, P4; H, P5. Scale bars=100 μm (A, C), 50 μm (B, D-H).

organic content especially in summer season. In Korea, this species co-occurred with *Sinodiaptomus tenellus*, *Pseudodiaptomus inopinus* (Calanoida), *Leptocaris brevicornis*, *Tigriopus japonicus*, *Tisbe* sp., *Nitokra koreanus*, *N. affinis californica*, *Schizopera neglecta*, *Onychocamptus mohammed* (Harpacticoida), *Paracyclopina nana*, *Halicyclops japonicus* (Cyclopoida).

Distribution. Indonesia (Borneo), China (Kwangtung), Japan (Iriomote Is., Okinawa) and Korea (Jeju Is.).

Remarks. Ito (1957) described *A. japonensis* from eel-culture ponds near seashore of Mie prefecture, southern Honshu, Japan, and differentiating it from *A. borneoensis* Lindberg by more elongated Fu (a little more than 10 times longer than wide, while 7-9 time in *A. borneoensis*), and a little bigger body (slightly more than 1 mm long, ranging 1,004-1,079 μm long, while less than 1 mm in *A. borneoensis*, 864-988 μm in Borneo specimens, about 990 μm in Chinese specimens, and 962-983 μm in Korean specimens). Ishida (2002) identified the specimens found in the rice paddy at Iriomote Is., Okinawa as *A. borneoensis*, and he regarded *A. japonensis* as a junior synonym of *A. borneoensis*. Considering our specimens of *A. borneoensis*, we think the relatively longer dorsal caudal seta of *A. japonensis* (2.6-3.0 times as long as outer caudal seta in *A. japonensis*, against 2.2-2.4 times in Borneo specimens, and 2.3-2.5 times in Korean specimens of *A. borneoensis*) should be treated as the more significant taxonomic character than the above characters. Other differences mentioned by Ito (1957) seem to be the minor or insignificant discrepancies between local populations or resulted by the measurement deviations. As *Apocyclops* is very rare taxon, and *A. japonensis* has not been reported thereafter, the genuine identity of *A. japonensis* would be confirmed pending further future studies.

ACKNOWLEDGEMENTS

Authors appreciate Dr. Ji Min Lee for her help in preparing figure plates, and thank Messrs. Hyung Wook Lim and Jin Mo Jeon for their assistance in collecting samples. Second author (CYC) is grateful to Dr. Janet Reid for providing him with references. Authors also appreciate three anonymous reviewers for their critical comments that greatly improved the manuscript.

REFERENCES

Boxshall, G.O. and S.H. Halsey, 2004. An Introduction to Copepod Diversity, vols. I, II. The Ray Society, London, pp. 1-966.

Burckhardt, G., 1913. Zooplankton aus ost-und südasiatischen Binnengewässern. Zool. Jahrb., Syst., 34: 341-472.

Chang, C.Y., 2007. Two harpacticoid species of genera *Nitokra* and *Ameira* (Harpacticoida: Ameiridae) from brackish waters in Korea. Integr. Biosc., 11(2): 247-253.

Chang, C.Y., 2008. Brackish-water copepods of the family Tachidiidae (Copepoda: Harpacticoida) from Korea. Korean J. Syst. Zool., 21(2): 229-240.

Chang, C.Y. and H.S. Kim, 1991. *Harpacticella itoi*, a new harpacticoid species (Copepoda: Harpacticoida: Harpacticidae) from Korea. Korean J. Syst. Zool., 7(1): 73-80.

Chang, C.Y. and G.-S. Min, 2005. Key to the Korean freshwater cyclopoid copepods and their DNA taxonomy. Junghaeng-Sa Publ. Co., Seoul, pp. 1-153 (in Korean).

Chang, C.Y. and H.J. Yoon, 2008. *Nitokra* Copepods (Harpacticoida: Ameiridae) from Korea. Korean J. Syst. Zool., 24(1): 115-127.

Ferrari, F.D. and J. Orsi, 1984. *Oithona davisae*, new species and *Limnoithona sinensis* (Burckhardt, 1912) (Copepoda: Oithonidae) from the Sacramento San-Joaquin Estuary, California. J. Crustacean Biol., 4: 106-126.

Huys, R. and G.A. Boxshall, 1991. Copepod Evolution. The Ray Society, London, pp 1-468.

Huys, R., S. Ohtsuka, S. Conroy-Dalton and Y. Kikuchi, 2005. Description of two new species of *Neotachidius* Shen and Tai (Copepoda, Harpacticoida, Tachidiidae) from Korean brackish waters and proposal of a new genus for *Tachidius* (*Tachidius*) *vicinospinalis* Shen and Tai, 1964. Zool. Jour. Linn. Soc., 143(1): 133-159.

Ishida, T., 2002. Illustrated fauna of the freshwater cyclopoid copepods of Japan. Bull. Biogeogr. Soc. Japan, 575: 37-106 (in Japanese).

Ito, T., 1957. Groundwater copepods from South-Western Japan. Hydrobiologia, 11: 1-28.

Kiefer, F., 1929. Crustacea Copepoda. II. Cyclopoida Gnathostoma. Das Tierreich, Berlin and Leipzig, 53: 1-102.

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 Korea. Korean J. Syst. Zool., 21(1): 31-34.

Lee, J.M. and C.Y. Chang, 2007. Three cletodid copepods of the genera *Limnocletodes* and *Kollerua* (Harpacticoida, Cletodidae) from coastal marshes and estuaries in South Korea. Ocean Sci. Jour., 42: 255-267.

Lee, J.M. and C.Y. Chang, 2008a. Copepods of the genus *Leptocaris* (Harpacticoida, Darcythompsoniidae) from salt marshes in South Korea. Korean J. Syst. Zool., 24(1): 89-98.

Lee, J.M. and C.Y. Chang, 2008b. Two canthocamptid copepods of the genera *Itunella* and *Mesochra* (Harpacticoida, Canthocamptidae) from brackish waters in South Korea. J.

Nat. Hist., 42(25-28): 1729-1747.
Lee, J.M., H.J. Yoon and C.Y. Chang, 2007. A faunistic study on the brackish-water calanoid copepods from South Korea. Korean J. Syst. Zool., 23(2): 135-154.
Lindberg, K., 1954. Cyclopides (Crustaces Copepodes) d'iles du Pacifique Sud (Melanesie et Micronesie) et de Borneo. Kungl. Fysiogr. Sal. Lund Forhandl., 24(18): 1-14.
Soh. H.Y., H.-L. Suh, O.H. Yu and S. Ohtsuka, 2001. The first record of two demersal calanoid copepods, *Pseudodiaptomus poplesia* and *P. nihonkaiensis* in Korea, with remarks on morphology of the genital area. Hydrobiologia, 448: 203-215.
Tai, A.Y. and G.X. Chen, 1979. Cyclopoida Sars, 1886. *In* Shen, C.J., ed., Fauna Sinica, Crustacea, Freshwater Copepoda. Science Press, Peking, pp. 301-420.
Yoo, K.-I. and B.J. Lim, 1989. Systematic studies on the freshwater Copepoda (Crustacea) in Lake Yongsan, Korea. Korean J. Lim., 22: 127-146.

Received October 9, 2008
Accepted November 4, 2008