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Two Groundwater Copepods of the Genus *Parastenocaris* (Harpacticoida, Parastenocarididae) from South Korea

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Abstract: Two subterranean harpacticoid species are recorded from cavern and interstitial waters in South Korea: *Parastenocaris ondali* n. sp. and *P. brevipes* Kessler, 1913. *Parastenocaris ondali* n. sp. resembles *P. nipponensis* Chappuis, 1955 from Japan, but differs from it by shorter caudal rami, armature of leg 5, and short endopodal processes of leg 4 in both sexes. Herein, the new species is described, and systematic accounts of both species are provided with detailed illustrations.

Key words: Copepoda, Harpacticoida, Korea, *Parastenocaris*, subterranean, taxonomy

Taxonomic studies of subterranean copepods are still very scanty in Korea. Miura (1969) first recorded seven harpacticoid species including a new genus, *Gulcamptus*, as well as three new species, *G. uenoi*, *Canthocamptus morimotoi* and *Attheyella coreana*. Since Kim and Chang (1991) described *Acanthocyclops tokchokensis* from wells at Deogjeeogdo Island in the Yellow Sea, the second author (CYC) and his colleagues have recorded several subterranean cyclopid species: two semi-subterranean cyclopid species *Ochridacyclops coreensis* Chang and *Itocyclops yezoensis* (Ito) from several springs and wells (Lee et al., 2004); *Acanthocyclops fonticulus* Lee and Chang, 2007 from mountain springs (Lee and Chang, 2007); four cave-dwelling cyclopid species, *Megacyclops magnus* (Marsh, 1920), *Acanthocyclops orientalis* Borutzky, 1966, *A. robustus* (Sars, 1863) and *Diacyclops suoensis* Ito, 1956 from 10 limestone caves (Lee et al., 2007).

Parastenocaridids are characteristic inhabitants of fresh ground waters. Almost all species live in the interstitial but a few tropical species can be found in damp mosses (Boxshall and Halsey, 2004). More than 240 species of 5 genera are currently recognized in the family Parastenocarididae. However, in Korea, only *Parastenocaris nipponensis* Chappuis, 1955 was reported from a driven well near Seongryu-gul Cave at Uljin by Miura (1969), which is supposed to be identical with the new species herein.

The authors have examined parastenocaridid specimens from cavern and interstitial waters in South Korea, and confirmed two species including a new species. This paper deals with description of the new species with the taxonomic accounts and illustrations of both species.

MATERIALS AND METHODS

Materials examined in the present study were collected from various subterranean waters such as a cavern lake, a foothill spring and interstitial waters of riversides and a costal marsh, at eight localities (Fig. 1) in South Korea during the period from August, 1987 to September, 2007. Samplings were made by sieving sandy sediments with a plankton net or a hand net of 64 μm mesh. Copepod specimens were then 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 0.5 mm diameter tungsten wire, sharpened by electrolysis (Huys and Boxshall, 1991; Huys et al., 1996). Mounted specimens were observed using a differential interference contrast microscope (Olympus BX-51) equipped with Nomarski optics. All drawings were made with the aid of a camera lucida.

Measurements were made using a digital camera for microscope (Cool SNAP 5.0M, Roper Scientific Co., USA) and a calibration software QCapture Pro (ver. 5.0, Media Cybernetics Inc., USA).

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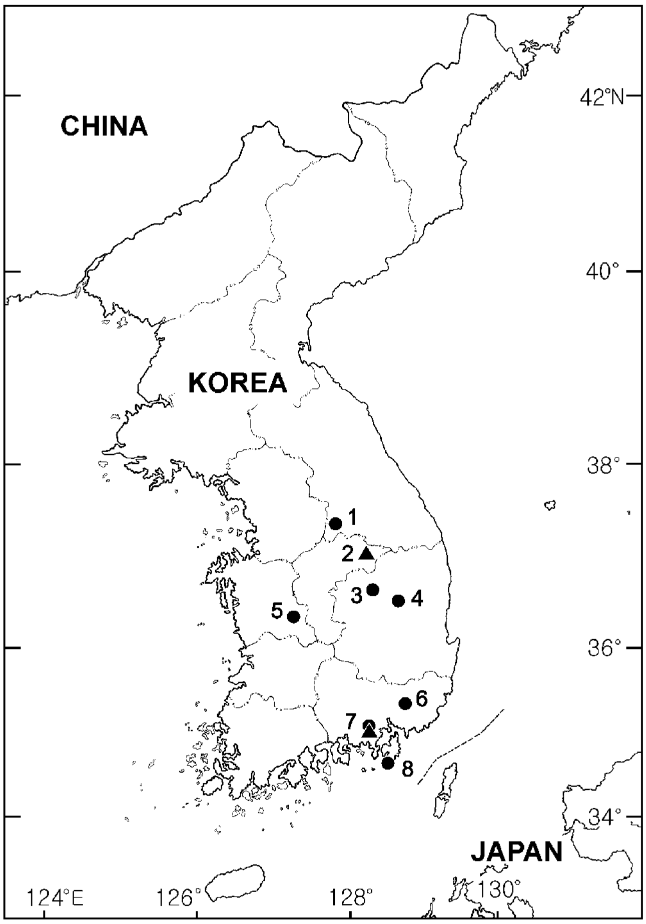

Fig. 1. A map showing localities in South Korea. 1, Cheonunsa Temple, Wonju; 2, Ondal-gul Cave, Danyang; 3, Yecheon; 4, Nakdonggang River, Andong; 5, Daejeon National Cemetery; 6, Pyochungsa Temple, Miryang; 7, Namgang River, Haman; 8, Jeogu-ri, Geoje Island. ▲, *Parastenocaris ondal* n. sp.; ●, *P. brevipes.*

Materials for scanning electron microscopy were prefixed overnight at 4°C in 2.5% glutaraldehyde, followed by rinsing with 0.1 M phosphate buffer (pH 7.2-7.4) three times, each for 10 minutes. Specimens were postfixed for 2 hours in 2% cold osmium tetroxide in 0.1 M phosphate buffer, and left in phosphate buffer overnight. After dehydration through a graded series of ethanol (50-100% at 10% interval) for 30 minutes each, the material was critical point dried, coated with gold-palladium in a high evaporator, and then examined with a scanning electron microscope (Hitachi S-4800) operated at 15 KV.

Type specimens have been deposited in the National Institute of Biological Resources (NIBR), Incheon, Korea, and in the specimen room of the Department of Biological Science, Daegu University (DB), Korea.

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 pereiopods (swimming legs).

SYSTEMATIC ACCOUNTS

Family Parastenocarididae Chappuis, 1933
Genus *Parastenocaris* Kessler, 1913
***Parastenocaris ondali* sp. nov.**
(Figs. 2-4)

Parastenocaris nipponensis Chappuis, 1955 *sensu* Miura, 1969, p. 253, Figs. 47-51.

Type: Holotype ♀(DB20026), allotype ♂(DB20027), dissected in lactophenol, Ondal-gul Cave (37°3'43"N, 128°28'59"E), Danyang, 13 August 2007 (*leg*. J. M. Lee). Paratypes: ♀(NIBRIV0000137623), ♂(NIBRIV0000137624), undissected in 80% ethyl alcohol, collection details same as in holotype.

Additional material examined: 1♀, 1♂, Namgang R., Haman, 17 October 1995 (C.Y. Chang and H.S. Rho).

Description: *Female*. Body (Fig. 2A) vermiform, elongate, very slender, subcylindrical, about 450-510 μm in length; tinged with snowy white; podoplean boundary between prosome and urosome inconspicuous. Cephalosome and first pedigerous somite fused to cephalothorax, nearly as long as sum of next 2 prosomites combined, with round integumental window dorsally. Rostrum not developed, small, narrow, not defined from cephalic shield at base. Nauplius eye absent. Outer distal margin of each prosomite not protruded. Urosomites consisting of fifth pedigerous somite, genital double-somite and 3 free urosomites, with narrow, smooth hyaline membrane along posterior margin both dorsally and ventrally; first 3 urosomites ornamented with 1-2 pairs of sensillae dorsally or dorsolaterally; second to fourth urosomites with ellipsoidal integumental windows dorsally. Fifth pedigerous somite, genital double-somite and anal somite enlarged, comparing with other urosomites. Genital apertures located midventrally on genital somite, with genital operculum, representing unarmed leg 6; copulatory pore located on ventral midline immediately posterior to genital apertures. Posterior and lateral margins of anal somite smooth; paired rows of 3-4 spinules present on ventral surface. Anal operculum (Fig. 2B) gently convex with smooth, truncated posterior edge, not extending beyond posterior margin of anal somite, even in lateral view (Fig. 2C).

Caudal rami (Fig. 2B-D) cylindrical, extremely elongated, 5.0-5.6 times longer than wide, slightly narrowing posteriorly. Both inner and outer margins smooth without spinule or setule rows; a few minute spinules present on

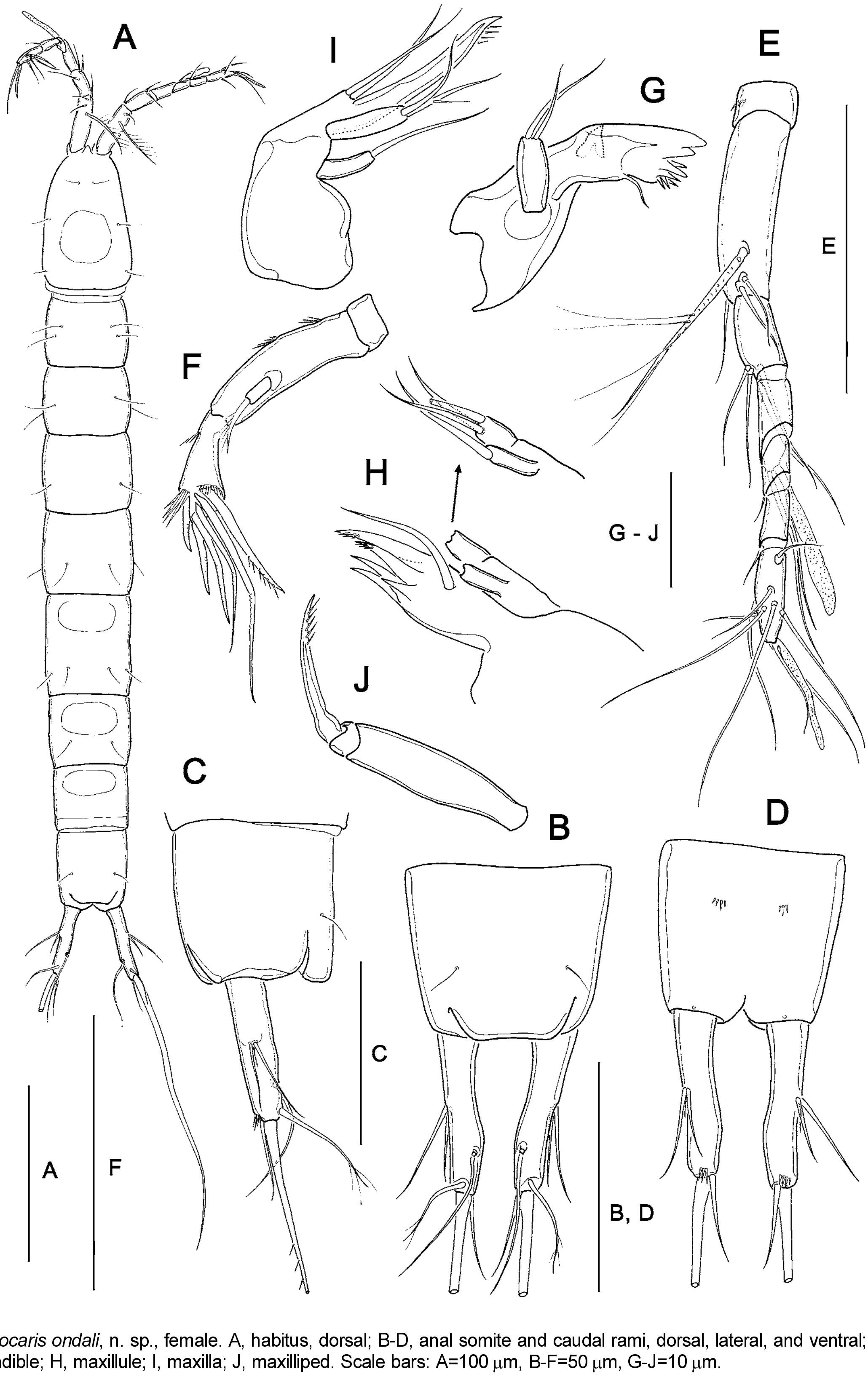

Fig. 2. *Parastenocaris ondali*, n. sp., female. A, habitus, dorsal; B-D, anal somite and caudal rami, dorsal, lateral, and ventral; E, antennule; F, antenna; G, mandible; H, maxillule; I, maxilla; J, maxilliped. Scale bars: A=100 μm, B-F=50 μm, G-J=10 μm.

posterior margin ventrally; dorsal keel not apparent. Lateral caudal setae consisting of 3 naked setae, including 1 minute seta between 2 long setae, located at proximal 2/5 (slightly anterior to middle) of lateral margin of caudal ramus. Outer

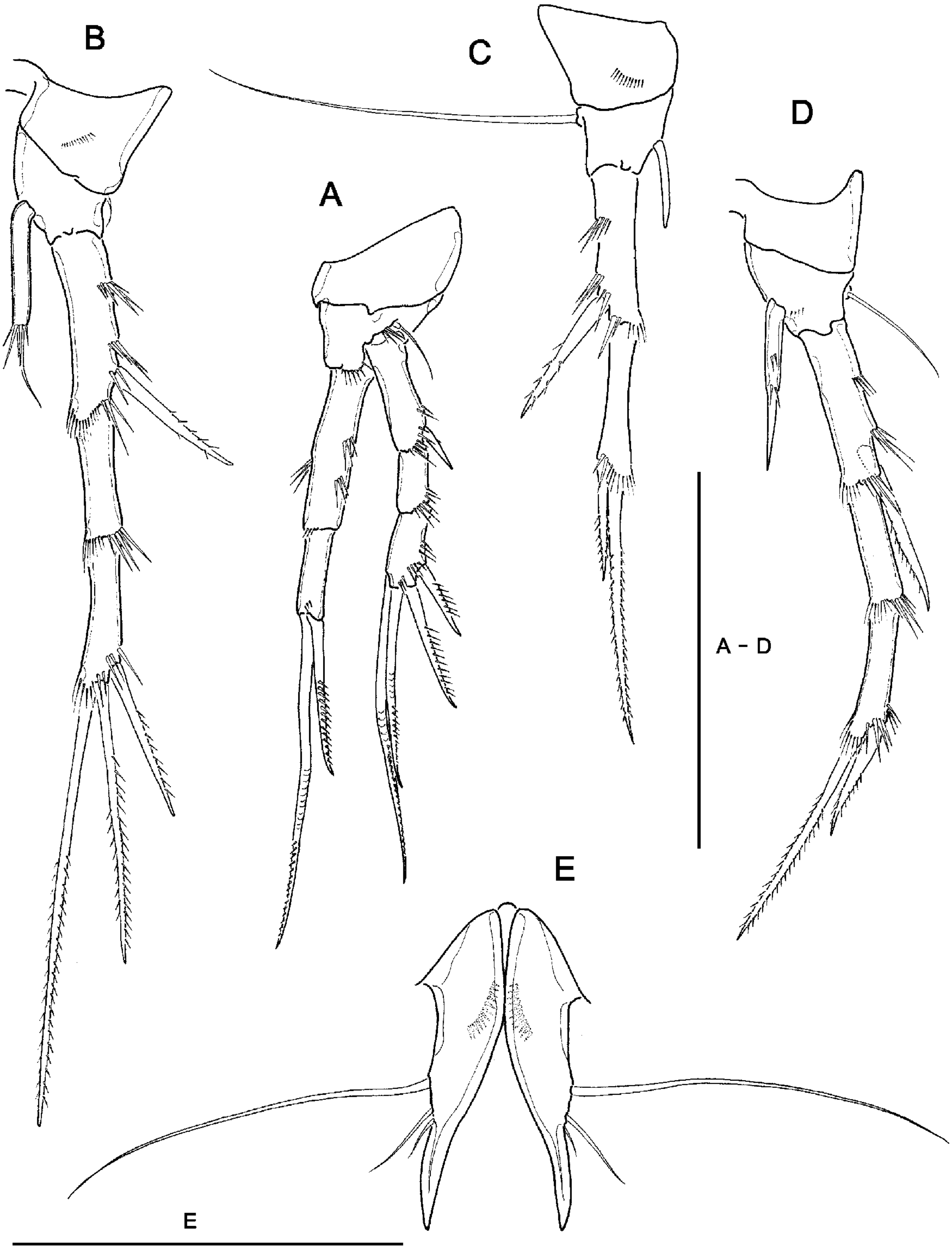

Fig. 3. *Parastenocaris ondali*, n. sp., female. A-E, legs 1-5. Scale bars: A-E=50 μm.

caudal seta situated rather dorsally, about 1.2 times as long as inner caudal seta. Terminal caudal seta single, well developed, weakly pinnate, without fracture plane at its basal part. Dorsal caudal seta located near distal quarter of inner margin of caudal ramus, on basal socket, nearly as long as caudal ramus.

Antennule (Fig. 2E) elongate, longer than cephalothorax, 7-segmented; segment 2 elongate, longer than next 3 segments combined, bearing 1 stout seta with long secondary hairs; segment 4 with 1 long aesthetasc distally, its tip not reaching to distal end of antennule; segments 5 and 6 small; segment 7 elongate, with 1 aesthetasc apically. Setal formula: 1-[0], 2-[4], 3-[4], 4-[2+aesthetasc], 5-[1], 6-[1], 7-[7+trithek (2 naked setae+1 aesthetasc)]. Antenna (Fig. 2F) with separate coxa; allobasis much elongated, with 2 groups of spinules on medial margin; endopod 1-segmented, armed with 7 elements in total laterally and distally; exopod 1-segmented, peduncular, bearing 1 plumose seta apically (Fig. 5A, arrowhead). Mandible (Figs. 2G) with well developed coxal gnathobase bearing 8 teeth along distal margin and 1 dorsal seta; palp 1-segmented, peduncular, bearing 2 setae apically (Fig. 5A, arrow). Maxillule (Fig. 2H) with praecoxal arthrite bearing 5 elements with 1 setae on frontal surface; coxal endite cylindrical, bearing 1 naked seta apically; allobasis bearing total 3 setae distally; exopod lacking. Maxilla (Fig. 2I) armed with 2 syncoxal endites, proximal endite bearing 1 setal element, distal endite with 2 setae; basis forming 1 strong pectinate claw; endopod represented by small protuberance bearing 2 naked setae distally. Maxilliped (Fig. 2J) subchelate; syncoxa and basis much elongated, both lateral margins smooth; endopod armed with 1 strong claw, serrated distally.

Legs 1-4 biramous; exopods 3-segmented in legs 1, 2 and 4, while 2-segmented in leg 3; endopods 2-segmented in leg 1, 1-segmented, forming a spinous process in legs 2-4. Leg 1 (Fig. 3A), inner distal seta on basis lacking; enp 1 elongate, slightly shorter than exp 1 and exp 2 combined, inner seta lacking; enp 2 with 2 geniculate setae; exp 1 elongate, about 2 times longer than exp 2; exp 2 without outer spine; exp 3 with 2 spines and 2 geniculate setae distally. Leg 2 (Fig. 3B), basal seta vestigial; endopod 1-segmented, elongate, its tip not reaching distal end of exp 1, bearing 1 seta on apex flanked by several setules. Leg 3 (Fig. C), lateral seta on outer proximal margin of basis very long; exp 1 bearing 1 stout spine outer distally with 2 groups of spinules; exp 2 with 2 spinous elements apically, inner one about 2.5 times longer than outer one; endopod representing 1 slender, elongate, naked projection. Leg 4 (Fig. 3D), exp 1 with stout, long spine, its tip a little exceeding over exp 2; endopod 1-segmented, forming pointed, spinous projection with 2 rows each of 2-3 spinules, its tip not reaching distal end of exp 1. Seta/spine armature of legs 1-4 as follows (Arabic numerals representing setae, while Roman numerals indicating spines):

Leg 1	basis 1-0	exopod I-0; 0-0; II,2	endopod 0-0; 2
Leg 2	basis 1-0	exopod I-0; 0-0; II,1	endopod 1
Leg 3	basis 1-0	exopod I-0; I,1	endopod 0
Leg 4	basis 1-0	exopod I-0; 0-0; I,1	endopod 0

Leg 5 (Fig. 3E) acute-triangular, forming a strong, gently curved inward, spinous projection distally, with 3 bare setae in total along lateral margin, 1 long seta nearly in the middle, 2 small setae at base of spinous projection. Medial margin gently curved, smooth without seta or spinule. Oblique row of 12-14 spinules near medial margin on ventral surface.

Male. Body (Fig. 4A) approximately 430 μm in length. General appearance similar to that of female. Sexual dimorphism shown in antennule, genital somite, leg 3, endopod of leg 4, and leg 5.

Caudal rami (Fig. 4B, C) a little shorter than in female, about 4.6-4.8 times longer than wide; dorsal caudal seta much longer than caudal ramus.

Antennule (Fig. 4D) 7-segmented; geniculate between segments 3 and 4; setal formula: 1-[0], 2-[6], 3-[4], 4-[1], 5-[3+aesthetasc], 6-[0], 7-[8+aesthetasc].

Leg 2 (Fig. 4F) similar to female's, except for weak spine of exp 1.

Leg 3 (Fig. 4G) highly modified; basis produced to triangular protrusion distally in frontal view, bearing 1 small, slender spinous process showing endopodal rudiment on inner proximal margin; exopod 2-segmented, distal segment elongated, tapering distally, forming a projection, with 1 stout spine outer distally; 1 spinule row present outer proximally.

Leg 4 (Fig. 4H), basis bearing 2 spinous processes representing endopod; outer one gently curved inward, a little longer than inner one; inner one armed with 4-5 secondary spinules distally. Exp 1 bearing outer distal spine, weaker than in female, with setule row along distal part of inner margin; exp 3 with 1 outer distal spine and 1 apical spiniform seta.

Leg 5 (Fig. 4I) similar to female's, except for spinule row on distal part of inner margin.

Etymology: The proposed specific name, *ondali*, is taken from the type locality of Ondal Cave. Ondal is the name of a famous general of Goguryeo Dynasty, one of the oldest kingdoms of Korea.

Remarks: Five genera are currently recognized in the family Parastenocarididae Chappuis, 1933 (Dussart and Defaye, 1990; Boxshall and Halsey, 2004). Among them, genera *Forficatocaris, Paraforficatocaris, Potamocaris* and *Murunducaris* contain only a few species and are exclusively Neotropical (Reid, 1994, cited from Karanovic, 2004).

Genus *Parastenocaris* Kessler currently comprises about 220 species and subspecies. According to the system of species groups proposed by Lang (1948), *P. ondali* n. sp. is obviously allied with the *prosperina*-group in that it has the characteristic endopodal structure of male leg 4, that is, a hook-like spine flanking a complex process medially.

Parastenocaris ondali n. sp. is apparently closely related to *P. nipponensis* Chappuis, 1955 from Japan, with which it

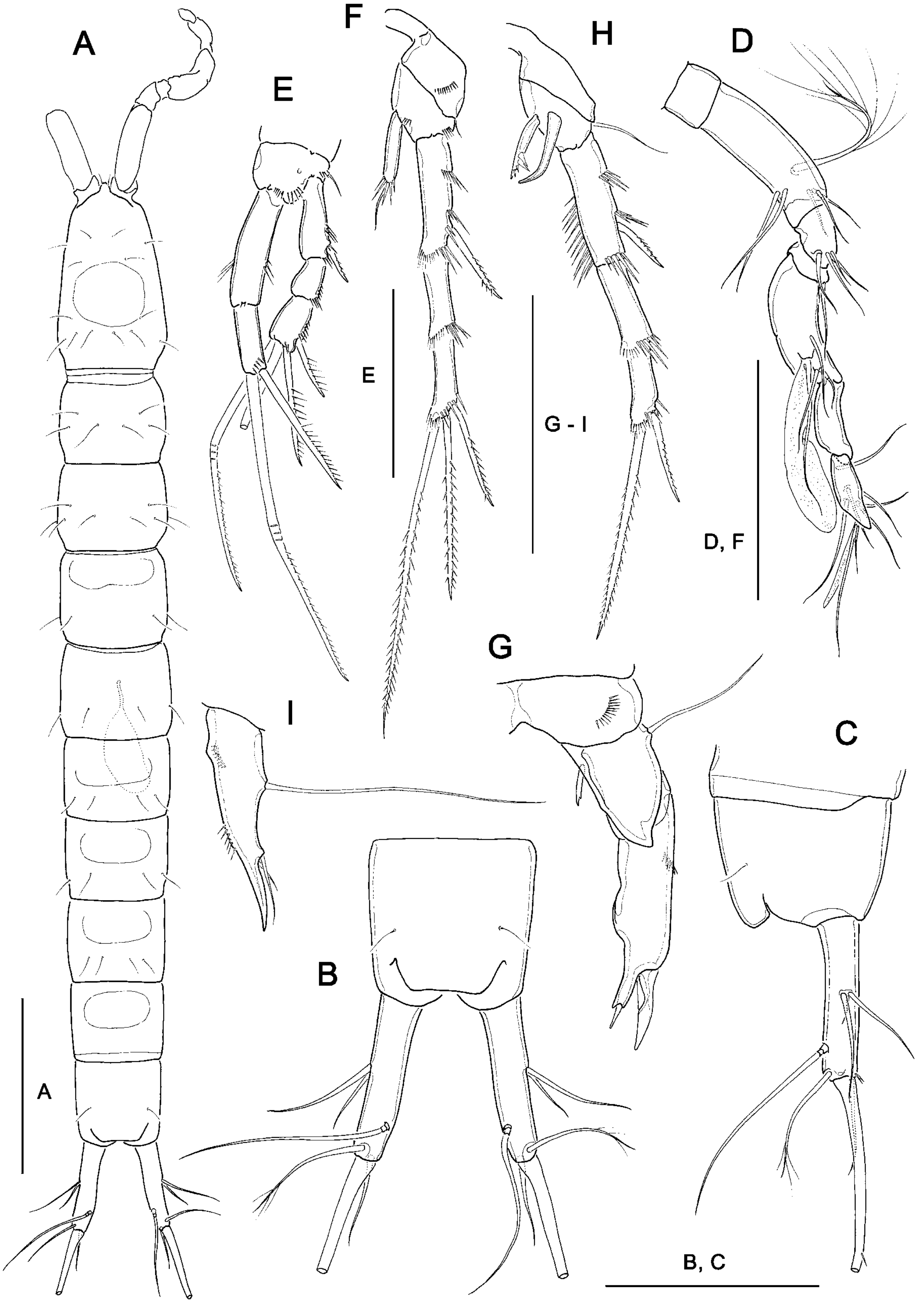

Fig. 4. *Parastenocaris ondali*, n. sp., male. A, habitus, dorsal; B-C, anal somite and caudal rami, dorsal and lateral; D, antennule; E-I, legs 1-5. Scale bars: A=100 μm, B-D, F-I=50 μm, E=30 μm.

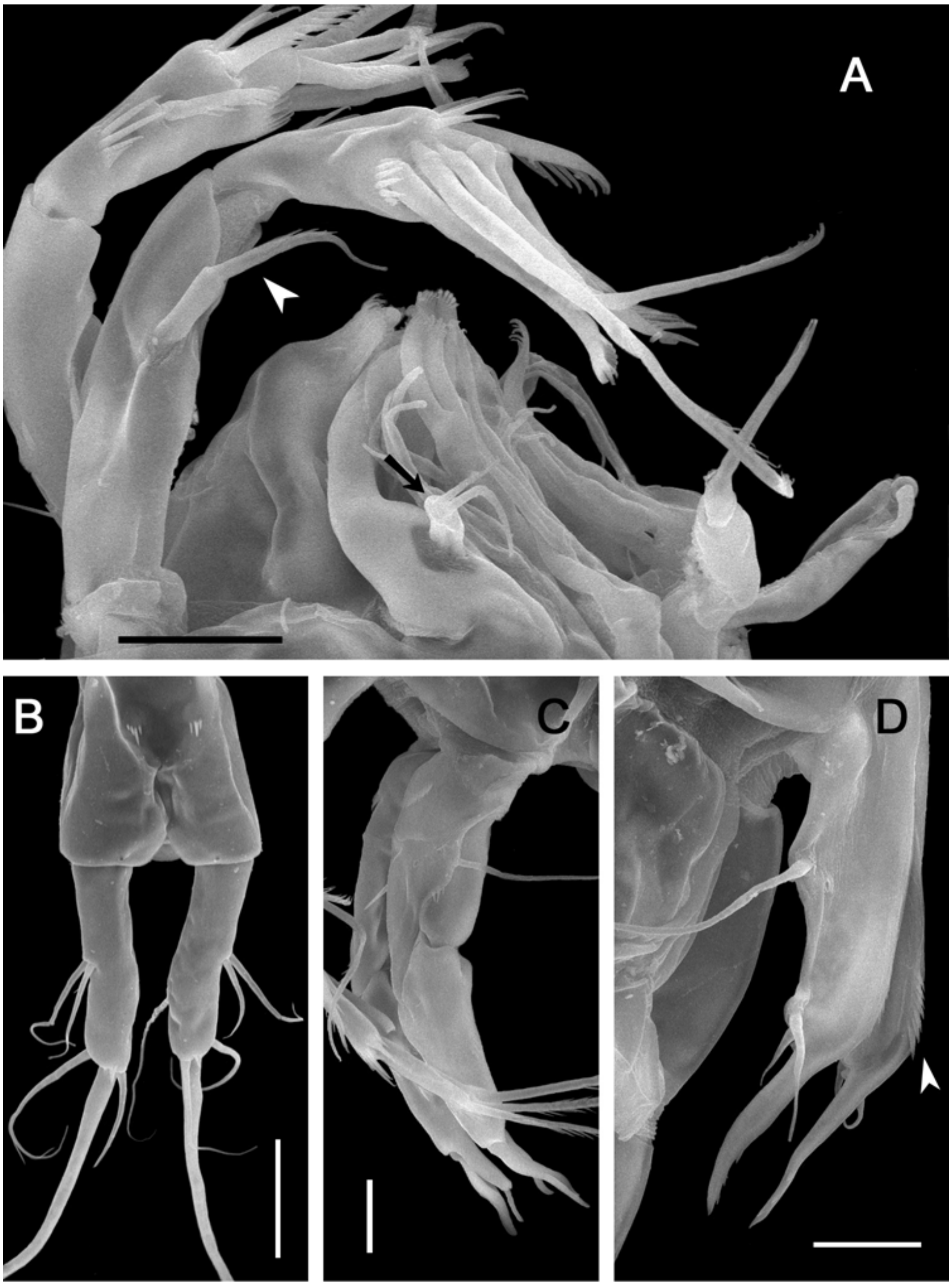

Fig. 5. *Parastenocaris ondali*, n. sp., SEM photomicrographs. A, mouthparts, lateral (arrowhead indicating antennary exopod bearing an apical seta; arrow indicating maxillular palp bearing 2 setae); B, female anal somite and caudal rami, ventral; C, male leg 3, lateral; D, male leg 5, lateral (arrowhead indicating a spinule row on the distal part of medial edge). Scale bars: A=10 μm, B=20 μm, C=15 μm, D=5 μm.

shares the elongate caudal rami, 2 spinous processes as the endopodal structure of male leg 3, and acute triangular leg 5 in both sexes, although both figures of the male in the original description (Chappuis, 1955) and of the topotypical female in Miura (1964) were inadequate and misinterpreted.

The dorsal integumental windows, male antennule, mouthparts and male leg 2 were neither depicted nor mentioned in the original description. Moreover, Dr. Miura's description of the female, outer spine of leg 3 exopod and dorsal caudal seta were overlooked. Nevertheless, based on other important characterstics in their figures, *P. ondali* n. sp. clearly differs from *P. nipponensis* by the followings: (1) caudal rami are shorter (about 5-5.5 times as long as wide in female, while they are about 6 times in the female of *P. nipponensis*); (2) female leg 5 has 2 outer distal setae and a smooth inner margin (against a minute projection outer distally and one seta on inner margin in *P. nipponensis*); (3) male leg 5 has a spinule row along distal part of the inner margin (while smooth in *P. nipponensis*); (4) in male leg 3, the curved endopodal spinous process is relatively shorter (while it far exceeds the medial process in *P. nipponensis*); (5) outer distal spines of leg 3 exopod in female are relatively much longer than in *P. nipponensis*; (6) endopodal process of leg 4 in female is relatively shorter than in *P. nipponensis* (not reaching the distal margin of exp 1, while much extending over exp 1 in *P. nipponensis*), and (7) dorsal caudal seta is well developed, nearly as long as, or even a little longer than caudal ramus in both sexes (while the dorsal caudal seta is only approximately half as long as the caudal ramus in Chappuis' figure).

Miura (1969) reported *P. nipponensis* Chappuis, 1955 from a driven well near Seongryu-gul Cave at Uljin, South Korea. Although he omitted the figures of leg 5 of both sexes, the decisive discriminative characters of the East Asian species, his figures of relatively shorter caudal rami and short endopodal spinous process of male leg 4 suggest that his identification might be incorrect and the specimens he examined be identical with the new species herein (in his report, he also commented on these discrepancies between the Korean specimens and the Japanese topotypes of *P. nipponensis*). Furthermore, his figure of the short endopodal process in female leg 4 (misspelled as 'leg 2' in his figure legend) also provides another strong indication that the Korean specimens he examined agree with the present new species.

Parastenocaris brevipes **Kessler, 1913 Fig. 6**

Parastenocaris brevipes Kessler, 1913, p. 514, figs. 1-9; Lang, 1948, p. 1223, fig. 491(1); Dussart, 1967, p. 409, fig. 178; Tai and Song, 1979, p. 295, fig. 165; Miura, 1984, p. 548, figs. 303-304; Janetzky et al., 1996, p. 180, fig. 89.

SPECIMENS EXAMINED: 2♀♀, 1♂, Cheonunsa Temple (spring), Wonju, 26 July 1999 (J.M. Lee and Y.H. Song); 1♂, Daejeon National Cemetery (interstitial waters of hillside brook), 30 July 1990 (C.Y. Chang); 1♀, Yecheon filtration plant (interstitial waters of streamlet), 22 June 2007 (J.M. Lee); 1♀, same locality, 14 September 2007 (J.M. Lee); 6♀♀, 2♂♂, Nakdonggang R. (interstitial waters), Andong, 29 July 1999 (J.M. Lee and Y.H. Song); 1♀, Pyochungsa Temple (interstitial waters of mountain stream), Miryang, 10 July 1999 (C.Y. Chang); 1♂, Namgang R. (interstitial waters), Haman, 17 Oct. 1995 (C.Y. Chang and H.S. Rho); 6♀♀, 2♂♂, coastal marsh (interstitial waters), Jeogu-ri, Geojedo Is., 18 Aug. 1987 (C.Y. Chang).

Diagnosis: *Female*. body (Fig. 6A) about 450-600 μm long; cephalothorax and second to fourth urosomites each with large integumental window; anal operculum convex with smooth, truncated posterior edge, not extending beyond posterior margin of anal somite; caudal rami (Fig. 6B) 3-4 times longer than wide, narrowing posteriorly after level of lateral caudal seta; lateral caudal seta located near middle of lateral margin of caudal ramus; outer caudal seta bare, situated subdistally, about 1.5 times as long as inner caudal seta; dorsal caudal seta located middle of inner margin of caudal ramus, nearly as long as caudal ramus; antennule (Fig. 6C) 7-segmented, showing setal formula: 1-[0], 2-[4], 3-[3], 4-[2+aesthetasc], 5-[1], 6-[1], 7-[8+ aesthetasc]; antennary exopod 1-segmented, bearing 1 seta apically (Fig. 6D); mandibular palp 1-segmented, bearing 2 setae apically; leg 2 (Fig. 6F) with 1-segmented endopod, its tip not reaching to distal end of exp 1, bearing 1 seta flanked with a few setules on apex; leg 3 (Fig. 6G) with 1 endopodal spinous process slightly not reaching to distal end of exp 1; leg 4 (Fig. 6H) armed with 1 strong endopodal spinous process, its tip much beyond distal end of exp 2; leg 5 (Fig. 6I), medial margin produced to strong spinous projection distally, with 3 bare setae in total along lateral margin. *Male*: leg 3 (Fig. 6J), basis with 1 small spinous projection on inner distal margin; exopod curved inward, bearing 1 stout spine outer distally, with hyaline membranes along inner margin and on distal end; leg 4 (Fig. 6K) with complex endopodal structure, comprising curved endopod with 1 spinule row and 1 membranous lobe distally, flanked by 3 protrusions on inner distal part of basis; leg 5 (Fig. 6L) shaped as oblong plate in overall appearance, but slightly bilobate on posterior margin, separated by a weak notch; inner lobe with 2 bare setae distally; outer lobe bearing 1 long lateral seta outer distally, flanked by 1 minute spinule near notch.

DISTRIBUTION: Europe (Sweden, Norway, Finland, Germany, Poland, Russia), China, Korea, USA.

ECOLOGY: Typically inhabiting interstitial waters of various freshwater habitats, mostly at the streamside.

REMARKS: This species is the representative one of the genus *Parastenocaris*, and is distributed throughout the Holarctic region. Korean specimens coincide well with Kessler's (1913) original description, except for a minor discrepancy of a relatively long dorsal caudal seta (nearly as long as caudal ramus, while it is much shorter in the original description). The "double" integumental window on cephalothorax was obvious in three Korean specimens from two localities (*see* Fig. 6A). The integumental window on cephalothorax (or nuchal organ) has not been properly figured or even described in many recorded species, and tended to be regarded as "without particular phylogenetic importance" (Karanovic, 2004). Recently, the "double" integumental window on cephalothorax was reported in *P. palmerae* Reid, 1991 from USA and *P. solitaria* Karanovic,

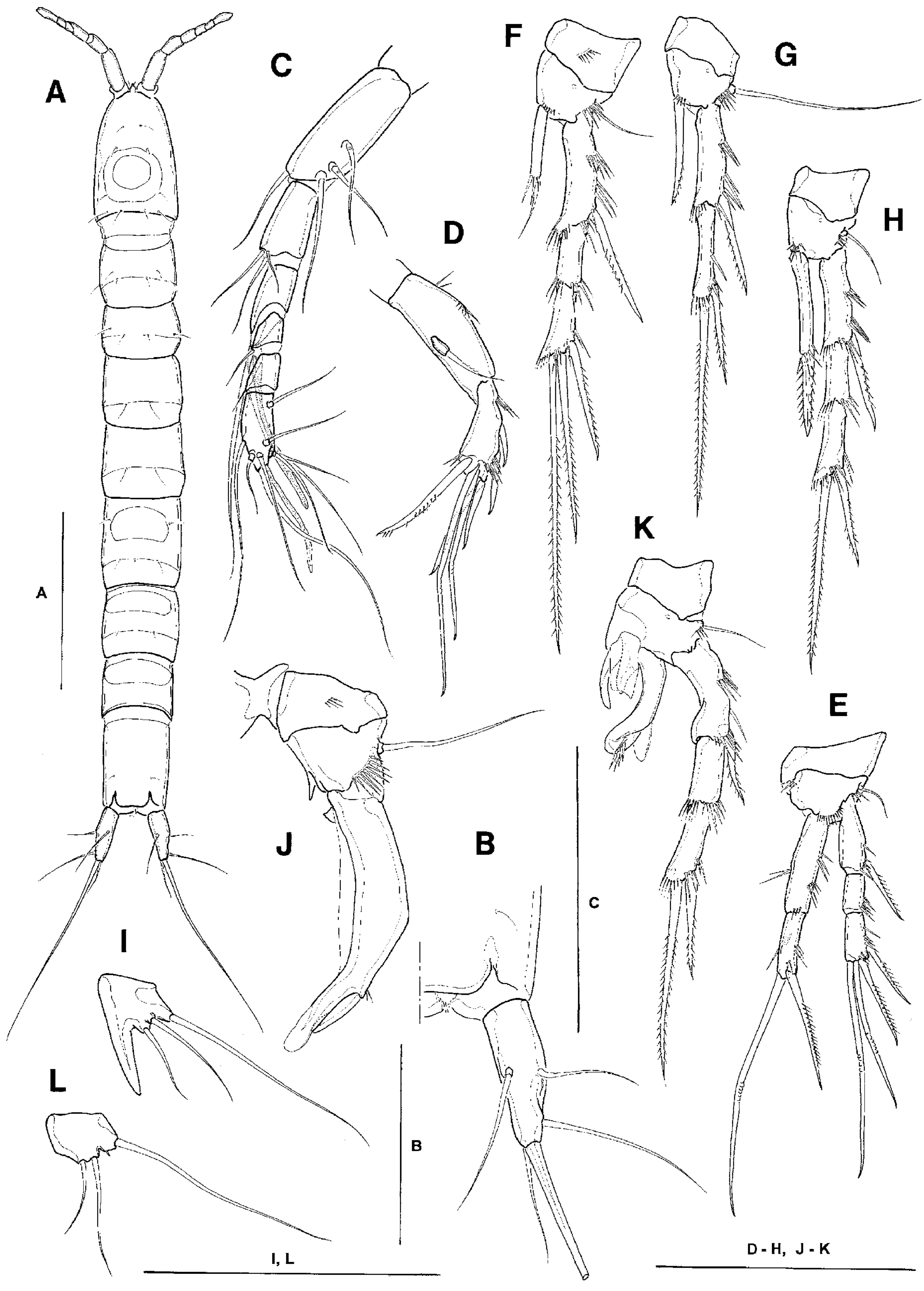

Fig. 6. *Parastenocaris brevipes*. A-I, female: A, habitus, dorsal; B, anal somite and caudal rami, dorsal; C, antennule; D, antenna; E-I, legs 1-5. J-L, male legs 3-5. Scale bars: A=100 μm, B-L=50 μm.

2004 from Australia. Whether the "double" integumental window on cephalothorax be a taxonomic character or not is still uncertain, and should be evaluated in the future studies.

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REFERENCES

Boxshall GO and Halsey SH (2004) An Introduction to Copepod Diversity, vols. I, II. The Ray society, London, pp 1-966.

Chappuis PA (1955) Harpacticoides troglobies du Japon. *Notes biospéol* 10: 183-190.

Dussart B (1967) Les copépodes des eaux continentales d'Europe occidentale. Tome I. Calanoïdes et Harpacticoïdes. Ed. Boubée, Paris, pp 1-500.

Dussart BH and Defaye D (1990) Répertoire Mondial des Crustacés Copépodes des Eaux Intérieures III. Harpacticoïdes. Crustaceana, suppl. 16, E.J. Brill, pp 1-384.

Huys R and Boxshall GA (1991) Copepod evolution. The Ray Society, London, pp 1-468.

Huys R, Gee JM, Moore CG, and Hamond R (1996) Marine and brackish water harpacticoid copepods. Part I. Synopses of the British fauna (New Series), vol. 51, pp 1-352.

Janetzky W, Enderle R, and Noodt W (1996) Crustacea: Copepoda: Gelyelloida und Harpacticoida. In: Schwoerbel J and Zwick P (eds), Süsswasserfauna von Mitteleuropa, Gustav Fischer Verlag, Stuttgart 8(4/2): 1-228.

Karanovic T (2004) Subterranean Copepods from Arid Western Australia. Crustaceana monographs, 3. Brill, Leiden, pp 1-366.

Kessler E (1913) *Parastenocaris brevipes* nov. gen. et nov. Spec., ein neuer Süsswasserharpacticiden. *Zool Anz* 42(11): 514-520.

Kim HS and Chang CY (1991) *Acanthocyclops tokchokensis*, a new cyclopoid copepod species from wells in Tokchok Island of Korea. *Korean J Zool* 34: 300-306.

Lang K (1948) Monographie der Harpacticiden. Nordiska-Bokhandeln, Stockholm, 2 vols., pp 1-1682.

Lee JM and Chang CY (2007) *Acanthocyclops fonticulus* (Cyclopoida, Cyclopidae), a new species of cyclopoid copepods from mountain springs in Korea. *Integr Biosc* 11(1): 61-68.

Lee JM, Jeon JM, and Chang CY (2004) Two semi-subterranean Copepods from Korea. *Korean J Biol Sci* 8: 145-154.

Lee JM, Kim W-R, Choi Y-G, and Chang CY (2007) Four cyclopoid copepods from limestone caves and lava tube in South Korea. *Korean J Syst Zool* 23(2): 155-167.

Miura Y (1964) Subterranean harpacticoid copepods from a driven well in Japan. *Jour Zool* 14(2): 133-141.

Miura Y (1969) Results of the speleological survey in South Korea 1966 XIV. Subterranean harpacticoid copepods of South Korea. *Bull Nat Sci Mus Tokyo* 12: 241-254.

Miura Y (1984) Nihon no rikusuisan Harpacticoida (Sokomijinko-rui) in Nippon/Chyugoku Tansuisan Kaiashi-rui. *Yonago printosha Yonago* 500-562 (in Japanese).

Shirayama Y, Kaku T, and Higgins RP (1993) Double-sided microscopic observation of meiofauna using an HS-slide. *Benthos Res* 44: 41-44.

Tai A-Y and Song Y-Z (1979) Harpacticoida Sars, 1903. In: Shen CJ (ed), Fauna Sinica, Crustacea, Freshwater Copepoda. Science Press, Peking, pp 164-300.

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