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# Two new species of *Halicyclops* (Copepoda, Cyclopoida) from the estuarine interstitial waters in South Korea*

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## Abstract

Two new cyclopoid species belonging to the genus *Halicyclops* Norman, 1903 are described from brackish waters in South Korea: *H. lanceolatus* **sp. nov.** and *H. pumilus* **sp. nov.** *Halicyclops lanceolatus* was collected from two river mouths, both connected to caves. It belongs to the *thermophilus* group in showing 3,4,4,3 spine formula on legs 1-4 and lateral process on the genital double-somite. Among the members of the species group, it is closely allied with *H. thermophilus* Kiefer, 1929 and *H. uncus* Ueda and Nagai, 2009. However, it differs from them by a stout, lanceolate inner apical spine on leg 5 exopod, very short lateral process of the genital double-somite, short caudal rami, and shorter inner apical spine on the third endopodal segment of leg 4. *Halicyclops pumilus* was collected from interstitial waters of estuarine sandy beaches, and it is characteristic in having a single inner seta on the second endopodal segments of legs 2-3, and quadrate shape of leg 5 exopod with stumpy spines.

**Key words:** Brackish, copepods, Halicyclopinae, psammobiontic, taxonomy

## Introduction

Taxonomic studies on genuine brackish cyclopids in Korea are still scanty. Yoo & Lim (1989) first reported a brackish cyclopoid species, *Halicyclops ryukyuensis* Ito, 1962 from the Yeongsan estuary dam, situated at the southwestern corner of the Korean Peninsula. Chang & Min (2005) recorded *Mesocyclops marinus* Guo, 2000 from Ganghwado Island, Incheon, and *Thermocyclops uenoi* Ito, 1952 from a coastal well, Yeosu, in the middle of the southern coast of Korea. Yoon & Chang (2008) reported two species from the southern coast, *Limnoithona sinensis* Burckhardt, 1913 and *Apocyclops borneoensis* Lindberg, 1953. Recently, Chang (2009) recorded nine brackish species of six genera in his monographic study, including four *Halicyclops* species.

Since May 2008 we have participated in the project of 'Discovery of the Korean Indigenous Species', sponsored by the National Institution of Biological Resources, Korea, and have carried out a comprehensive reexamination of the previous records as well as of new material obtained from various brackish waters in Korea during the research period, especially of the genus *Halicyclops*. As a result, we found two interstitial species from estuaries in Korea, both of which turn out to be new to science and are described below.

## Material and methods

Material examined in the present study was collected from estuaries and a coastal well at five localities in Korea during the period from May 1988 to July 2010. Samplings were made by stirring up the top centimeters of littoral sediments and then scooping them using a dipnet of 64 μm aperture, or by decanting and sieving the sandy sediments after digging a sampling hole down to the groundwater level beside the water fringe in the river mouths. Copepods were fixed and stored in 4% buffered formalin.

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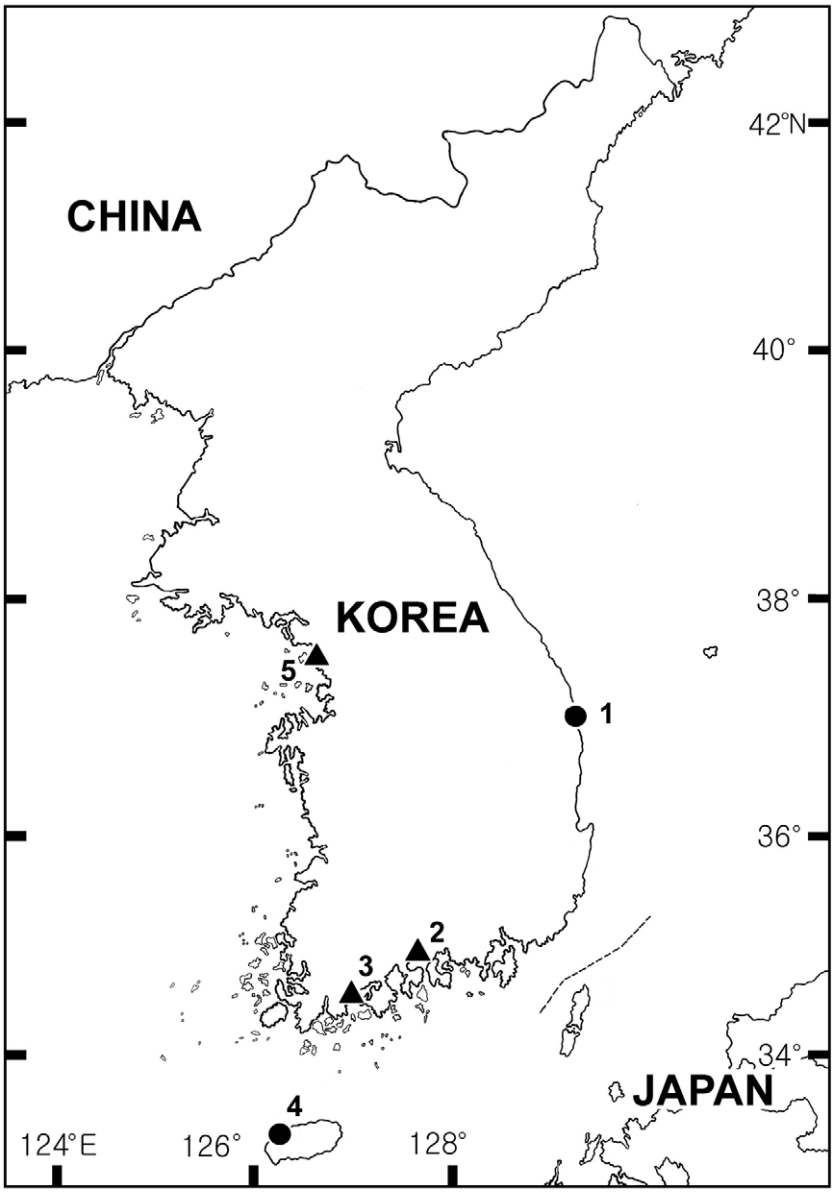


**FIGURE 1.** Sampling localities in South Korea: 1, estuary of Wangpicheon River, Uljin; 2, estuary of Seomjin River, Gwangyang; 3, Sumunpo Beach, Boseong; 4, Jaeamcheon-gul Cave, Jeju Island; 5, Jakyakdo Island, Incheon. (● *Halicyclops lanceolatus*; ▲ *Halicyclops pumilus*)

After treatment in a solution of 5% glycerin–95% ethyl alcohol for 1–2 days, specimens were dissected and mounted in lactophenol between two coverslips (18X18 mm and 22X24 mm) on an H-S slide (Shirayama et al. 1993), which was designed for the observation of both sides of the specimens. Dissection was performed using two needles made from a 0.5 mm diameter tungsten wire by electrolysis (Huys & Boxshall 1991). Mounted specimens were observed using a differential interference contrast microscope Olympus BX-51 equipped with Nomarski optics. Measurements were done with 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).

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

Abbreviations used in text and figure legends: A1, antennule; A2, antenna; P1–P5, legs (pereiopods) 1–5; enp1–3 or exp1–3, first to third endopodal or exopodal segments of each leg; Fu, furca or caudal rami; L/W, length to width ratio.

## Systematics

### Family Cyclopidae Dana, 1846

### Subfamily Halicyclopinae Kiefer, 1927

### Genus *Halicyclops* Norman, 1903

### *Halicyclops lanceolatus* sp. nov.

(Figs 2–4)

**Type locality.** Springs (0.5–1 m deep, sandy bottom on basalt rocks) in Jaeamcheon-gul Cave and a small ditch originating from the cavern springs and discharging into Hyeopjae Beach, Jeju Island, South Korea, 33°23′28.73″N 126°14′19.28″E.

Type material. Holotype, intact female in alcohol (NIBRINV0000245091). Allotype, intact male in alcohol (NIBRINV0000245092). Paratypes: two dissected females (DB20036, 20037), one dissected male (DB20038); nine females in alcohol. All collected at the type locality, 2 March 2010, *leg*. J.M. Lee.

**Additional material examined.** Three females from a sandy dune at the estuary of Wangpicheon River, Uljin, South Korea, 36°58′10″N 129°24′40″E, 26 July 2010, *legs*. C.Y. Chang & J.M. Lee.

**Etymology.** The specific name is a Latin adjective *lanceolatus*, meaning lanceolate, spear-like, which refers to the stout, lanceolate spines with broad blades of P1–P5, especially the inner apical on P5 exopod.

**Description.** Female. Body (Fig. 2A) relatively small, about 580 μm long, measured from anterior margin of cephalothorax to posterior margin of Fu, excluding caudal setae; maximum width at posterior end of cephalothorax, about 210 μm; L/W 2.8. Body slightly flattened dorsoventrally. Prosome comprising cephalothorax incorporating first pedigerous somite and 3 free pedigerous somites; posterior margins of prosomites nearly smooth, except for serrated outer posterior margins of second and third prosomites. Cephalothorax not strongly protruded anteriorly; nearly as long as wide; ovoid integumental window (or median depression) present mid-dorsally; about 40 or more sensilla scattered on dorsal and lateral surfaces. Rostrum completely fused to cephalothorax; rostral expansion rarely visible from dorsal view. Fifth pedigerous somite incorporating basis and endopod of P5, bearing an outer basal seta on posterior corner of dorsal surface. Genital double-somite (Fig. 2B) slightly wider than long (L/W 0.96, at level of lateral expansion); lateral sides weakly expanded laterally, with its tip only pointed posteriorly; in dorsal view, sclerotized wrinkles ahead lateral expansion, armed with 3 appendages representing P6; genital area simple, with a big median copulatory pore; paired spermatophores attached on copulatory pore small, ovoid; with paired cuticular recesses ventrolaterally at posterior half of genital double-somite. Pseudoperculum of preanal somite (Fig. 2B) protruding posteriorly, with 11–12 strong teeth along posterior margin, extending slightly over anal operculum (Fig. 2B).

Fu (Fig. 2B) about 1.1 times longer than wide; nearly parallel to each other; armed with spinules at outer distal margin of ramus and near base of outer caudal seta; with 6 caudal setae, lacking seta I. Lateral caudal seta arising from proximal quarter a little dorsally. Inner caudal seta minute, 0.5 times as long as ramus. Outer caudal seta about 1.6 times longer than ramus. Dorsal caudal seta arising from shallow protuberance, 2.6 times longer than ramus. Small cuticular tube with a minute pore present outside the protuberance. Both inner and outer terminal caudal setae with breaking planes; outer terminal caudal seta ornamented heterogeneously on its outer margin: distal half of outer margin setulose, distal half of inner margin plumose.

A1 (Fig. 3A) slightly not reaching to halfway of cephalothorax; 6-segmented. Fourth segment twice longer than wide; last segment about 2.9 times longer than wide. Aesthetasc each arising from fourth and last segment distally. Setal formula: 8, 12, 5 (+ 1 spine), 6 (+ 1 aesthetasc), 2, 10 (+ 1 aesthetasc).

A2 (Fig. 3B) 3-segmented, comprising coxobasis and 2-segmented endopod. Coxobasis armed with 2 inner distal setae, and 1 outer distal seta representing exopod. First endopodal segment bearing 1 pinnate inner seta, with smooth margins lacking spinules. Second endopodal segment elongate, 2.9 times as long as wide, about 1.6 times longer than first endopodal segment; ornamented with 1 setule row along outer edge; armed with 5 lateral and 7 apical setae.

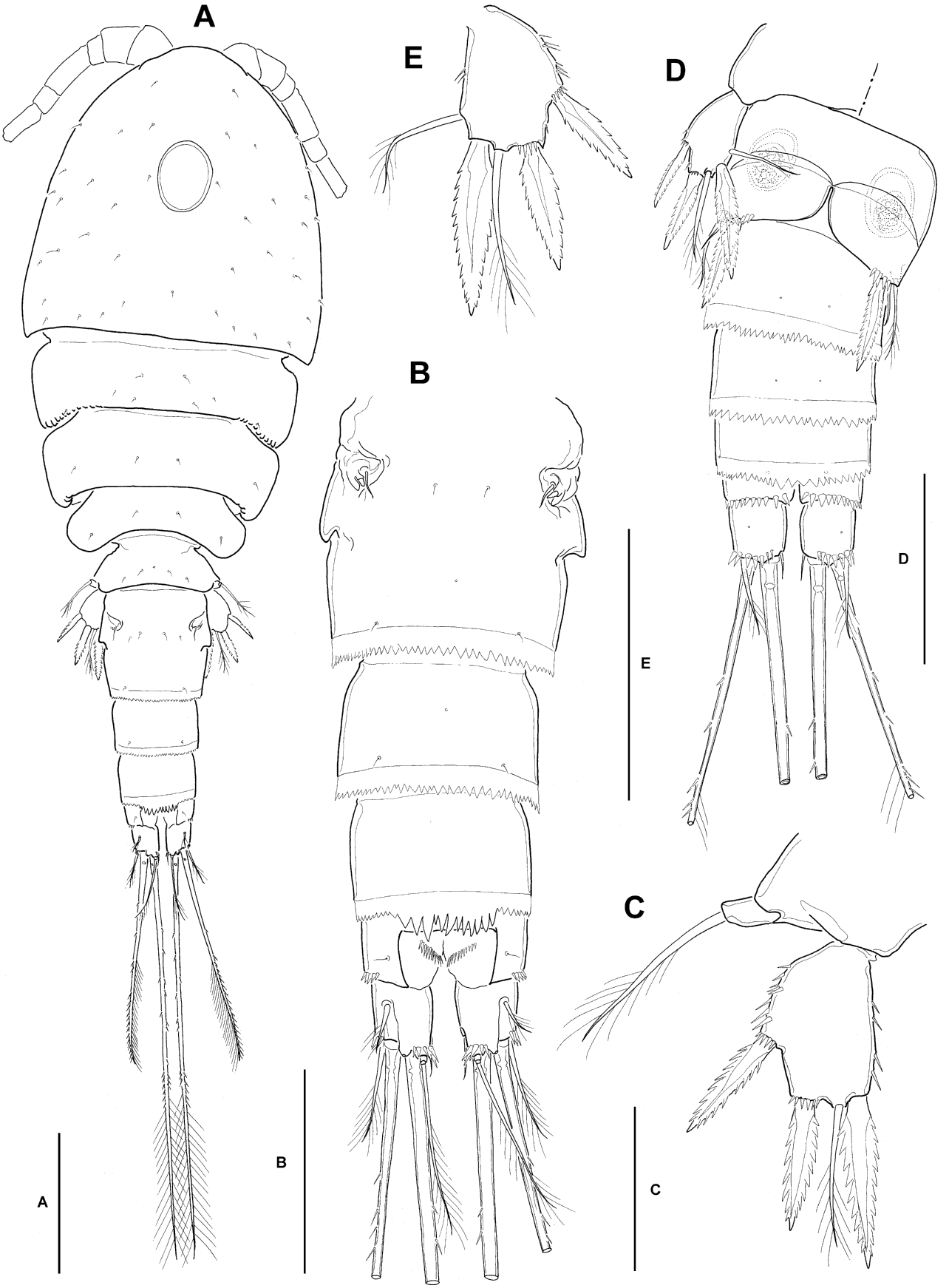


**FIGURE 2.** *Halicyclops lanceolatus* **sp. nov.** A–C, female: A, habitus, dorsal; B, urosome, dorsal; C, P5. D–E, male: D, urosome, dorsal; E, P5. Scales: 50 µm.

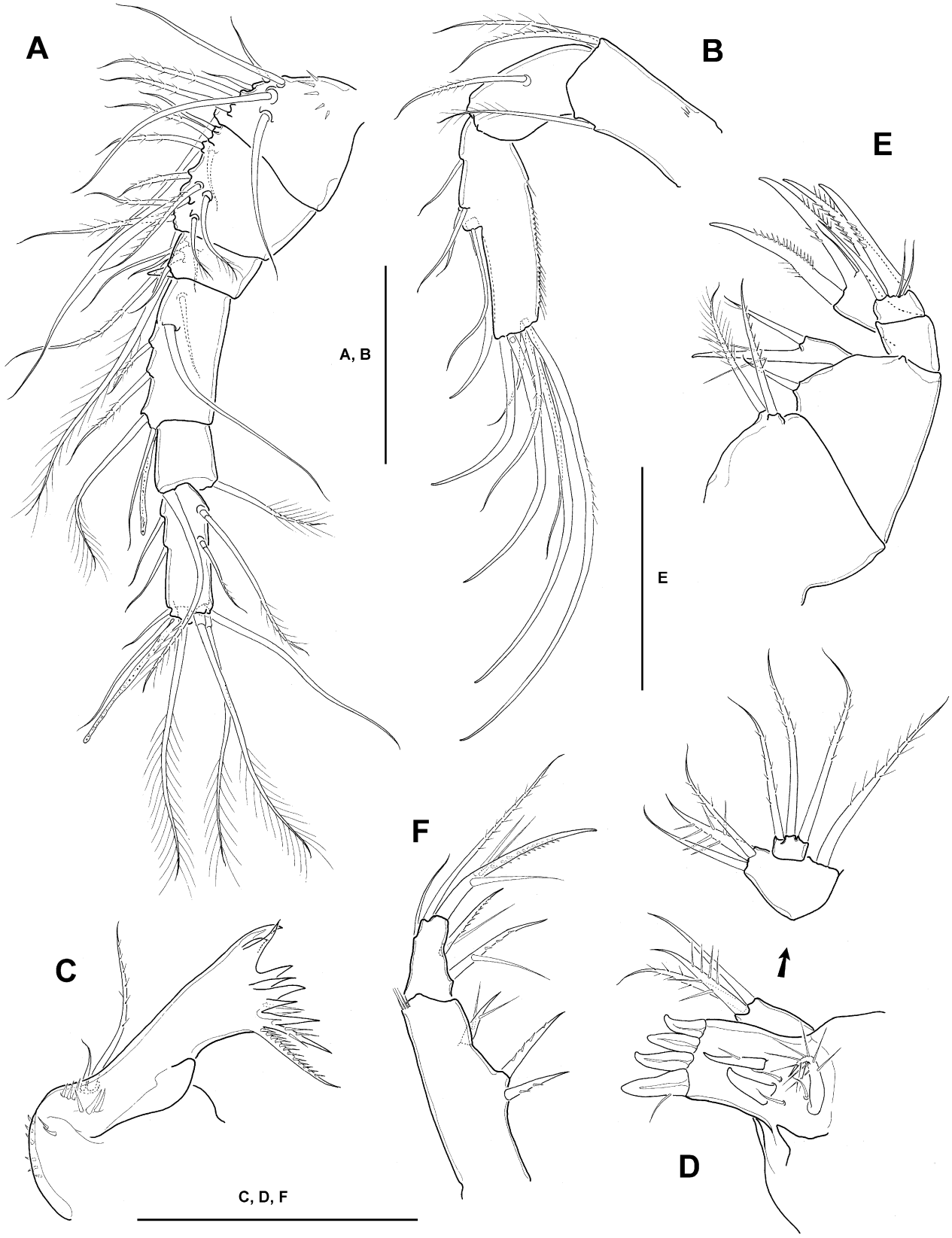


**FIGURE 3.** *Halicyclops lanceolatus* **sp. nov.**, female. A, A1; B, A2; C, mandible; D, maxillule; E, maxilla; F, maxilliped. Scales: 50 µm.

Mandible (Fig. 3C) with well-developed coxal gnathobase, armed with 10–11 teeth including outermost pinnate spine, flanking 1 outer distal pinnate seta. Palp very reduced, represented by 2 naked setae on small protuberance, of which shorter one small, about 1/3 times as long as longer one.

Maxillule (Fig. 3D), praecoxal arthrite bearing 4 strong tooth-like spines distally; 7 elements with various shapes present along inner margin, including 1 proximalmost fanglike projection. Palp 2-segmented; coxobasis bearing 1 pinnate, 1 spiniform and 1 naked setae inner distally, plus 1 outer pinnate seta representing exopod; distal segment, representing endopod, armed with 3 stout setae.

Maxilla (Fig. 3E) 4-segmented, comprising praecoxa, coxa, basis and 1-segmented endopod. Praecoxal endite with 1 pinnate and 1 plumose setae. Coxa with 1 naked seta representing proximal endite; distal endite movable, forming 1 bisetose lobe completely fused with naked seta proximally. Basis forming 2 strong claw-like spines with 1 naked seta between them basally. Endopod carrying 5 elements of 2 claw-like spines, 1 naked spiniform setae and 2 minute slender setae.

Maxilliped (Fig. 3F) 2-segmented, comprising protopod and completely defined endopod; protopod about 2.3 times longer than endopod. Protopod with 2 spiniform setae proximally and 1 bisetose seta distally, representing endites; 1 setule row present on outer distal corner of protopod. Endopod bearing 5 setae in total, comprising 2 inner setae, 1 apical, 2 outer subapical pinnate setae.

P1–P4 (Figs. 4A–D) biramous, both rami 3-segmented. Coxal setae pinnate. Spine formula of 3,4,4,3. Seta/spine armature of P1–P4 as follows:

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| P1 | coxa | 0-1 | basis | 1-1 | exp | I-1; I-1; III,1,4 | enp | 0-1; 0-2; II,1,3 |
| P2 | coxa | 0-1 | basis | 1-0 | exp | I-1; I-1; IV,1,4 | enp | 0-1; 0-2; II,I,3 |
| P3 | coxa | 0-1 | basis | 1-0 | exp | I-1; I-1; IV,1,4 | enp | 0-1; 0-2; II,I,3 |
| P4 | coxa | 0-1 | basis | 1-0 | exp | I-1; I-1; III,1,4 | enp | 0-1; 0-2; II,I,2 |

P1 (Fig. 4A), intercoxal sclerite with 1 row of long hairs and 1 setule row along distal margin of both lateral lobes; medial seta on P1 basis stout, ornamented with long setules proximally and secondary spinules distally, not reaching to poseterior end of enp2; two distal spines on exp3 not strikingly elongate, about 1.4 times longer than proximal one. P2–P4, intercoxal sclerites of P2–P3 with setules along distal margin of both lateral lobes, while lateral lobes of P4 lacking hairs or setules; enp2 with 2 inner setae; proximalmost seta on P2–P3 enp3 modified to spiniform; spines on enp3 and exp3 lanceolate with broad blades. P4 (Fig. 4D), enp3 about 1.4–1.5 times longer than wide; both inner setae spiniform; apical spine nearly same in length with enp3, and about 1.2 times longer than outer apical spine.

P5 (Fig. 2C), basis and endopod completely incorporated to fifth pedigerous somite; basal seta inserted on small protuberance arising from dorsolateral corner of somite. Exopod not elongate, about 1.3 times longer than wide; inner margin nearly straight, ornamented with spinule rows; inner apical spine apparently long, its tip generally extending to posterior one-fifth of genital double-somite, 1.15 times longer than exopod, and 1.2 times longer than apical plumose seta; apical seta slightly shorter than exopod. P6 indistinct, represented by small genital operculum armed with 3 elements of 2 toothlike spines and 1 long seta.

Male. Body (Fig. 2D) small, about 450 μm long. Fu (Fig. 2D) nearly as long as wide, armed with spinules on outer distal corner and ahead of base of dorsal caudal seta. Small cuticular tube present outside the longitudinal protuberance, with a pore on its tip. Mid-dorsal hyaline fringe of preanal somite not heavily protruding posteriorly, with about 10 strong teeth along posterior margin, extending slightly over anal operculum. A1 13-segmented, strongly geniculate, with geniculation between segment 11 and segment 12. Setal formula: 8, 4, 4, 4, 4, 1, 1, 2, 2, 3, 1, 1, 11. Aesthetasc formula: 3, 0, 1, 0, 0, 1, 0, 1, 0, 1, 0, 1, 2. Segment 6 with 1 short, spiniform seta; segments 9–11 each bearing 1 short, strong, pinnate seta anterodistally.

Shape and armature of P1–P4 nearly same as in female, except for inner distal seta on P1 basis far exceeding over posterior end of enp2. P5 exopod (Fig. 2E) not elongate, about 1.3 times longer than wide; medial margin straight and smooth, with 1 slender seta subdistally; inner apical spine strongly lanceolate, about 1.3 times longer than exopod, its tip reaching to middle of third urosomite (first abdominal somite). P6 (Fig. 2D), innermost spine stout and long, its tip reaching to middle of fourth urosomite.

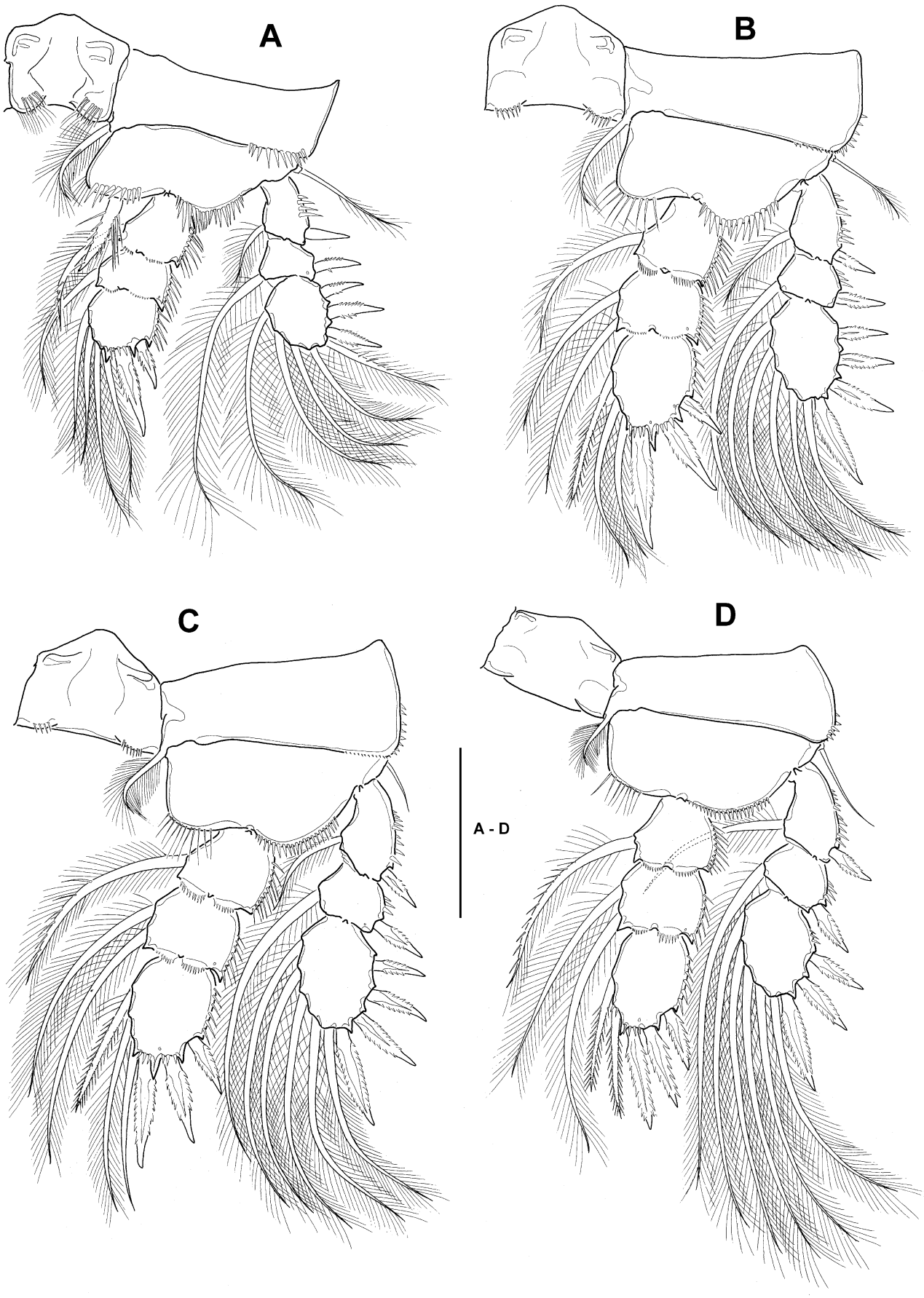


**FIGURE 4.** *Halicyclops lanceolatus* **sp. nov.**, female. A, P1; B, P2; C, P3; D, P4. Scale: 50 µm.

**Ecology.** Type specimens were collected from two cavern springs near the exit of Jaeamcheon-gul Cave, a small cave belonging to the Hyeopjae lava tube system in Jeju Island, and from a small canal connecting the cave with Hyeopjae Beach. Both the springs and canal showed low salinity of 0.2–7.3 ‰, varying depending on tide and distance from the coast. This species was also collected from the estuary of Wangpicheon River, Uljin, about 3.5 km away from Seongryu Cave. Considering the environments of both collection sites, the minute body size, and small number (usually only four) of eggs in an egg sac, this species is supposedly related with cavern environment and/or genuine interstitial species.

**Remarks.** The genus *Halicyclops* is classified into seven morphological groups according to the spine formula of P1–P4 exp3 (see Pesce 2011). Among them, group B showing the spine formula of 3,4,4,3 is the most predominant, which currently comprises 68 species or subspecies (Boxshall 2011). The *thermophilus* group is a subgroup of group B, which is characterized by the presence of a well developed chitinous spiniform process on each side of the genital double-somite (Herbst 1983). In Korea, only one species is recorded as a member of the *thermophilus* group: *H. japonicus* Ito, 1965 (see Chang 2012).

As well summarized in Ueda & Nagai (2009), Karanovic (2008) considered *H. spinifer* Kiefer, 1935 from India as a junior synonym of *H. thermophilus* Kiefer, 1929 from Java, Indonesia, both of which had been insufficiently and inadequately described. Karanovic regarded the main morphological discrepancies between the two species, that is, the relative lengths of the lateral process on the genital double-somite and of the inner apical spine on the female P5, as an intraspecific variation among different geographical populations. His proposition extended to other species belonging to the *thermophilus* group, "which were generally created only by a difference in a single character, that is, the shape (spiniform or plumose) of the setae on the P4 enp3 in *H. japonicus* and *H. dedeckeri* Brownell, 1983, and the length of the inner apical spine on the P5 in *H. latus* Shen & Tai, 1964" (Ueda & Nagai 2009). However, Ueda & Nagai (2009) refuted Karanovic's synonymization by arguing that the characters above as well as pseudoperculum (mid-dorsal hyaline membrane on the posterior margin of preanal somite) should be regarded as interspecific. Accordingly, the East Asian species should be recognized as valid species in the *thermophilus* group.

In comparison with the detailed redescription of *H. thermophilus*, the nominotypical species of the species group, by Karanovic (2008), *H. lanceolatus* **sp. nov.** resembles it with regards to a remarkably large inner apical spine on P5. Besides the shape and size of the lateral process on the genital double-somite (very short and laterally produced with strongly chitinized, tooth-like tip in *H. lanceolatus*, while very long and claw-like expansion produced posteriorly in *H. thermophilus*), *H. lanceolatus* differs from *H. thermophilus* in the following: (1) cephalic window (or integumental depression) is present; (2) pseudoperculum comprises about 12 thick, serrate protrusions (versus 14–15 thin and sharp, spiniform protrusions in *H. thermophilus*); (3) P4 enp3 is about 1.2 times longer than wide, with thick, lanceolate apical spines, of which the inner one is shorter than enp3 (versus more than 1.5 times as long as wide, with normal apical spines, of which the inner one is much longer than enp3 in *H. thermophilus*); (4) inner apical spine of P5 is apparently lanceolate, and longer than apical seta (versus the inner apical spine shorter than apical seta in *H. thermophilus*); (5) A1 is armed with an aesthetasc on fifth segment (versus lacking in *H. thermophilus*). Considering that the characters above are very important in meeting the species criteria in the cyclopoid classification, the discrepancies are significant enough for the two species to be regarded as distinct and valid ones. Thus, this new species reinforces Ueda & Nagai's argument (2009) that the morphological differences (especially, in the lateral process on genital double-somite and inner apical spine of P5 exopod) between *H. thermophilus* and the species from East Asia are not resulted from intraspecific variations but from interspecific characters, and therefore, the East Asian species are distinct species. To summarize, the two species *H. thermophilus* Kiefer, 1929 and *H. spinifer* Kiefer, 1935 should be regarded as *species inquirendae*, and other subsequent records under the name of '*H. thermophilus*' might be other distinct species.

*Halicyclops lanceolatus* is characteristic in having a stout, lanceolate inner apical spine on P5 exopod, as the specific name suggests. Besides this, *H. lanceolatus* differs from two Japanese species belonging to the *thermophilus* group, that is, *H. japonicus* Ito, 1956 and *H. uncus* Ueda & Nagai, 2009, by the very short lateral process of genital double-somite, which produces laterally with strongly chitinized, tooth-like tip (versus short process with spiny tip in *H. japonicus*, and long and claw-like expansion produced posteriorly in *H. uncus*), short caudal rami (about 1.2 times as long as wide, versus 1.8–2.0 in *H. japonicus*, and 1.5–1.7 in *H. uncus*), short inner apical spine on P4 enp3 (shorter than enp3, versus much longer than enp3 in *H. japonicus* and *H. uncus*), and large inner apical spine of P5 (apparently lanceolate, and longer than P5 exopod as well as apical seta, versus much shorter than P5 exopod and apical seta in *H. japonicus* and *H. uncus*) (Ito 1956; Ueda & Nagai 2009).

*Halicyclops lanceolatus* resembles *H. latus* Shen & Tai, 1964 from China in possessing short lateral processes on genital double-somite (Shen & Tai 1964). However, *H. lanceolatus* clearly differs from it by short Fu (about 1.2 times as long as wide, versus 1.7 in *H. latus*), long and stout inner apical spine of P5 (apparently lanceolate, and much longer than P5 exopod, versus much shorter, less than half the length of P5 exopod in *H. latus*), short inner apical spine on P4 enp3 (shorter than enp3, versus much longer than enp3 in *H. latus*), and well developed pseudoperculum (while lacking in *H. latus*).

*Halicyclops soqotranus* Baribwegure & Dumont, 2000 from the Indian Ocean is similar to *H. lanceolatus* in having short lateral processes on genital double-somite and short Fu (Baribwegure & Dumont 2000). However, it is distinguished from this new species by the seta/spine armature of P1–P4, that is, absence of inner seta on P1 basis, only 3 inner setae on P1 enp3, unmodified proximalmost inner seta on P2–P3, and unmodified inner setae on P4 enp3.

### *Halicyclops pumilus* sp. nov.

(Figs 5–7)

**Type locality.** Estuary of Seomjin River, Gwangyang, South Korea, 34°59′03.85″N 127°46′17.62″E.

Type material. Holotype, intact female in alcohol (NIBRINV0000245093). Paratypes: two dissected females (DB20038, 20039). All collected at the type locality, 17 October 1995, leg. C.Y. Chang & J.M. Lee.

**Additional material examined.** Three females from Jakyakdo Island, Incheon, South Korea, 37°29′15.35″N 126°37′18.82″E, 30 May 1988, *leg* C.Y. Chang. Four females from Sumunpo Beach, Boseong, South Korea, 34°37′52.20″N 127°01′40.56″E, 21 October 1995, *leg*. C.Y. Chang & J.M. Lee.

**Etymology.** The specific name comes from the Latin *pumilus*, meaning dwarf, which refers to the diminutive habitus of the species.

**Description.** Female. Body (Fig. 5A) very small, 387.7 μm long (m = 383.6, N = 8), excluding caudal setae; maximum width at posterior end of cephalothorax, 136.9 μm; L/W about 2.83. Body a little flattened dorsoventrally. Prosome comprising cephalothorax incorporating first pedigerous somite and 3 free pedigerous somites; posterior margins of prosomites serrated; outer distal corners of prosomites weakly expanded. Cephalothorax bell-shaped, L/W about 1.06; ovoid integumental window (or depression) present; 20–24 sensilla scattered on dorsal and lateral surfaces. Rostral expansion rarely visible from dorsal view. Genital double-somite (Fig. 5B) a little longer than wide; lateral sides not expanded or swollen, lacking spinous processes. Mid-dorsal hyaline fringe of preanal somite strongly protruded, with 6 acute teeth along posterior margin, far extending over anal operculum.

Fu (Fig. 5B) elongate, about 1.7–1.9 times (m = 1.78, N = 8) longer than wide; divergent posteriorly. Lateral caudal seta lying about halfway and a little dorsally. Inner caudal seta minute. Outer caudal seta 1.76 times longer than ramus. Dorsal caudal seta arising from distal end of longitudinal protuberance, 3.15 times longer than ramus, and 1.78 times longer than outer caudal seta. Small cuticular tube present outside the longitudinal protuberance, with a pore on its tip. Both inner and outer terminal caudal setae with breaking planes; proximal third bare, second third pinnate, distal third plumose.

A1 (Fig. 6A) not reaching to halfway of cephalothorax; 6-segmented. Fourth segment 1.74 times as long as wide; last segment 2.60 times longer than wide. Second segment bearing 12 setae, including 1 plumose and 1 bipinnate setae. Third segment shortest, bearing 5 setae including 1 short spiniform seta distally. Aesthetasc each arising from fourth and last segment distally. Seta formula: 8, 12, 5, 6 (+ 1 aesthetasc), 2, 10 (+ 1 aesthetasc).

A2 (Fig. 6B) 3-segmented, comprising coxobasis and 2-segmented endopod. Coxobasis unornamented, armed with 2 inner distal setae, lacking outer distal seta representing exopod. First endopodal segment bearing 1 inner seta, with smooth margins lacking spinules. Second endopodal segment 3.1 times as long as wide, about 1.5 times longer than first endopodal segment; ornamented with a few spinules on caudal face proximally; armed with 5 lateral and 7 apical setae.

Mandible (Fig. 6C), with well-developed coxal gnathobase, armed with 5 smooth teeth, 4 slender spiniform setae and 1 strong pinnate seta along cutting edge, flanking 1 outer distal pinnate seta. Palp very reduced, represented by 2 naked setae on small protuberance, of which shorter one minute.

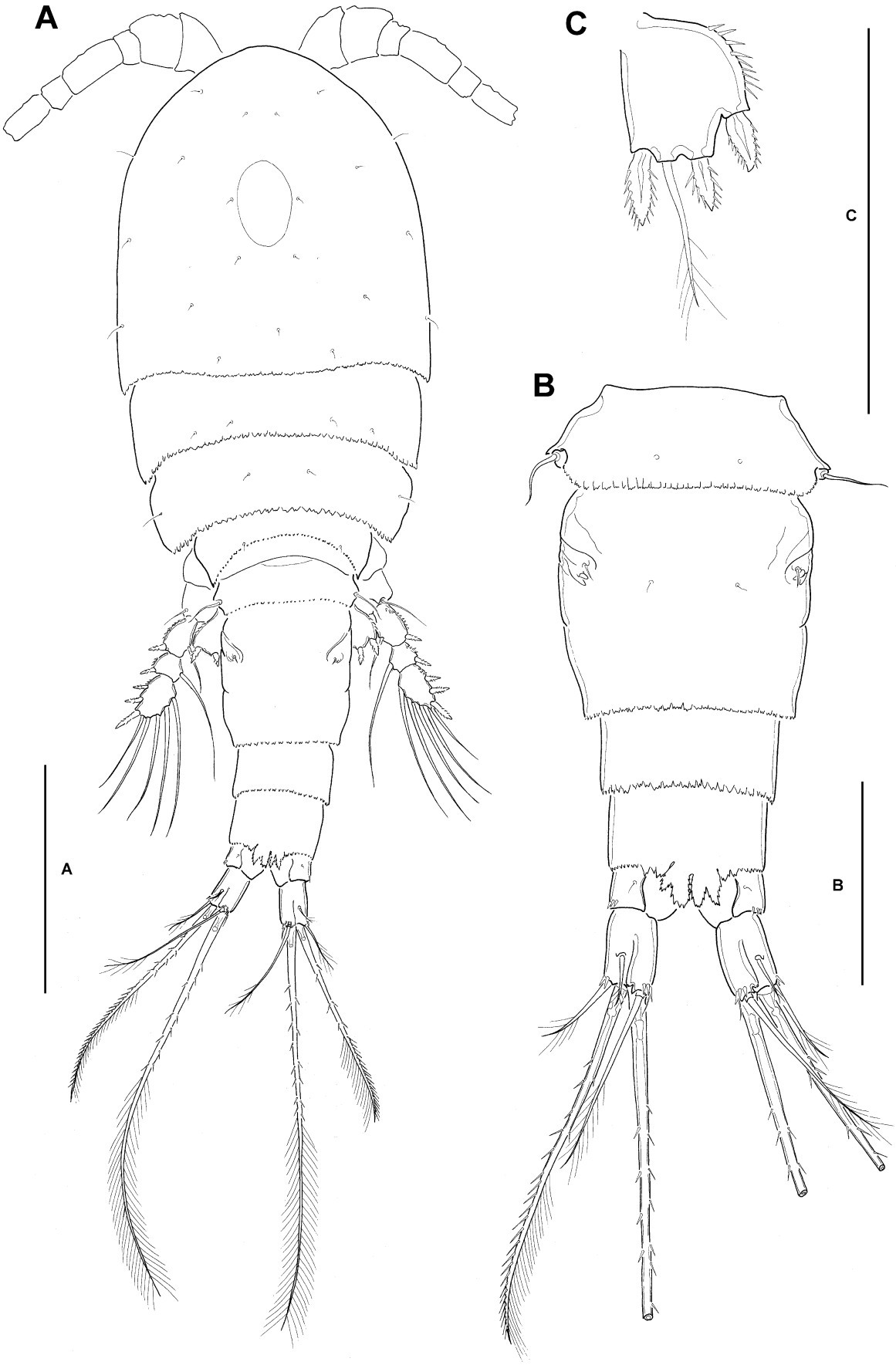


**FIGURE 5.** *Halicyclops pumilus* **sp. nov.**, female. A, habitus, dorsal; B, urosome, dorsal; C, P5 exopod. Scales: A, B = 100 µm; C = 20 µm.

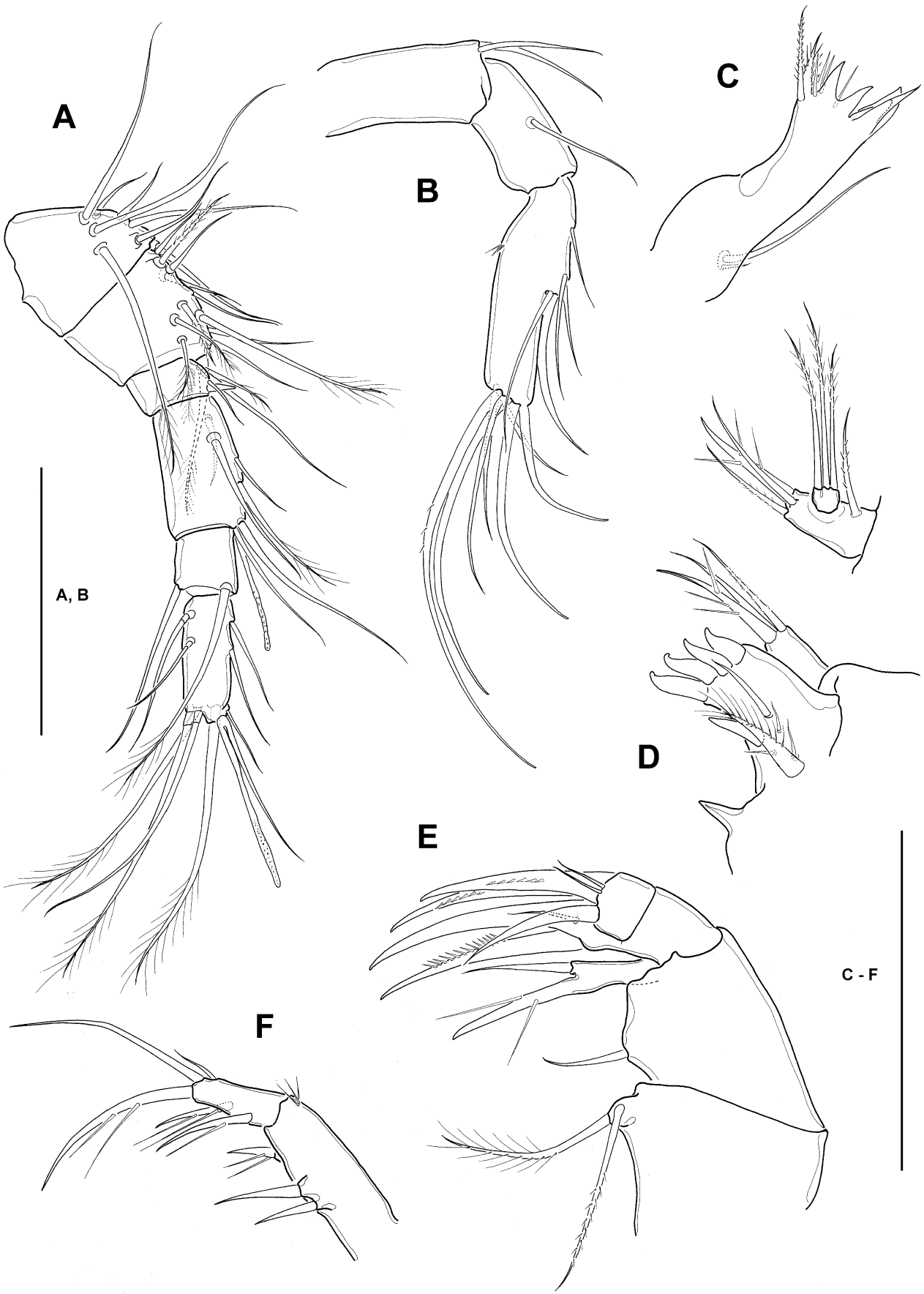


**FIGURE 6.** *Halicyclops pumilus* **sp. nov.**, female. A, A1; B, A2; C, mandible; D, maxillule; E, maxilla; F, maxilliped. Scales: 50 µm.

Maxillule (Fig. 6D), praecoxal arthrite bearing 4 strong spines of which innermost one ornamented with 1–2 accessory setae proximally; 7 elements with various shapes present along inner margin, including 1 strong proximalmost projection. Palp 2-segmented; coxobasis bearing 1 strong spinulose and 2 slender naked setae distally, plus 1 outer pinnate seta representing exopod; distal segment, representing endopod, with 3 long plumose setae.

Maxilla (Fig. 6E) 4-segmented, comprising praecoxa, coxa, basis and 1-segmented endopod. Praecoxal endite with 2 setae, one of which pinnate. Coxa with 1 naked seta representing proximal endite; distal endite movable, forming 1 bisetose lobe completely fused with naked seta proximally. Basis forming 2 strong claw-like spines with 1 naked seta between them basally. Endopod carrying 5 elements of 1 naked, 2 spiniform and 2 spinulose setae.

Maxilliped (Fig. 6F) 2-segmented, comprising protopod and completely defined endopod; protopod about 2 times longer than endopod. Protopod with 2 naked proximal setae and 1 distal seta ornamented with 2 setules basally each on protuberance, representing endites; 3–4 setules present on outer distal corner of protopod. Endopod bearing 5 setae in total, comprising 2 inner setae, 1 apical, 2 subapical setae, of which inner and apical setae ornamented with 1 or 2 long setules.

P1–P4 (Fig. 7A–D) biramous, both rami 3-segmented. Spine formula of 3,4,4,3. Seta/spine armature of P1–P4 as follows:

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| P1 | coxa | 0-1 | basis | 1-1 | exp | I-1; | I-1; | III,2,3 | enp | 0-1; | 0-1; | I,I+1,3 |
| P2 | coxa | 0-1 | basis | 1-0 | exp | I-1; | I-1; | IV,1,4 | enp | 0-1; | 0-1; | I,II,3 |
| P3 | coxa | 0-1 | basis | 1-0 | exp | I-1; | I-1; | IV,1,4 | enp | 0-1; | 0-1; | I,II,3 |
| P4 | coxa | 0-1 | basis | 1-0 | exp | I-1; | I-1; | III,1,4 | enp | 0-1; | 0-1; | I,II,2 |

P1 (Fig. 7A), intercoxal sclerite with hairs along distal margin of both lateral lobes; medial seta on P1 basis short but stout, not reaching to poseterior end of enp1; outer spines on exp3 become a bit (10–30%) longer distally. P2–P4, intercoxal sclerite bare along distal margin of both lateral lobes; enp2 with single inner seta. P4 (Fig. 7D), enp3 1.50 times longer than wide; both inner setae spiniform, short, nearly as long as enp3, and 23% shorter than inner apical spine; inner apical spine 1.23 times longer than enp3, and about 2 times longer than outer apical spine. P5 (Fig. 5C) basis and endopod completely incorporated to fifth pedigerous somite; basal seta inserted on small protuberance arising from dorsolateral corner of somite. Exopod nearly rectangular, 1.18 times longer than wide, with straight inner margin and angular inner distal corner; outer margin round, ornamented with spinule row; spines stumpy, inner apical spine longest, only 52% of exopod in length; apical seta 1.1 times longer than exopod, and 2.0 times longer than inner apical spine. P6 indistinct, represented by small genital operculum armed with 3 elements of 2 minute spinous projections and 1 long naked seta.

Male. Unknown.

**Ecology.** Specimens were collected by rinsing sandy sediments at two river mouths discharging into the southern coast of Korea, and at a small seaside ditch on the western coast of Korea, where brackish shells such as Asian clams, *Corbicula fluminea* (Müller, 1774), and purple olive clams, *Nuttallia japonica* (Deshayes, 1857), were abundant.

**Remarks.** This species belongs to the species group with the character combination of 3,4,4,3 spine formula, absence of lateral processes on genital somite, and well developed hyaline fringe of preanal somite. However, this species is characterized and easily distinguishable from its congeners by single inner seta on P2–P4 enp2 and very short spines on oval-shaped P5 exopod.

The new species is strikingly similar to two interstitial species, *H. gauldi* Pleşa, 1961 from the Atlantic coast of Ghana, West Africa and *H. ytororoma* Lotufo & Rocha, 1993 from the Atlantic coast of Brazil in sharing a very small body armed with single inner seta on P2–P4 enp2, elongate Fu (about 2 times longer than wide), multipronged pseudoperculum, short medial spine on basis of P1, and very stumpy spines on nearly quadrate P5 exopod.

Considering zoogeographical distribution and the high endemism rate of the interstitial copepods, the morphological similarities between the two marine species from the South Atlantic and the present new species from estuaries in the Northwest Pacific can be easily presumed to be the result of convergent evolution. However, in particular detail, they have a few morphological discrepancies: (1) *H. gauldi* and *H. ytororoma* show a spiniform inner proximalmost seta, deformed as a spatulate spine, each on P2–P3 enp3 (see Lotufo & Rocha 1993 for the character state of *H. gauldi*), while both of the setae are normally plumose in *H. pumilus*; (2) fourth segment of A1

is much shorter in *H. pumilus* (L/W is about 1.7–1.8, against more than 2 in *H. gauldi* and *H. ytororoma*); and (3) *H. gauldi* has only 3 setae on P1 enp3, while *H. ytororoma* and *H. pumilus* have 4 setae are normal in *H. pumilus*. Moreover, it is noteworthy to mention that the middorsal integumental depression of cephalothorax is apparently shown in *H. pumilus*, while any information on it was not given nor figured in the descriptions of *H. gauldi* and *H. ytororoma* (Pleşa 1961; Lotufo & Rocha 1993).

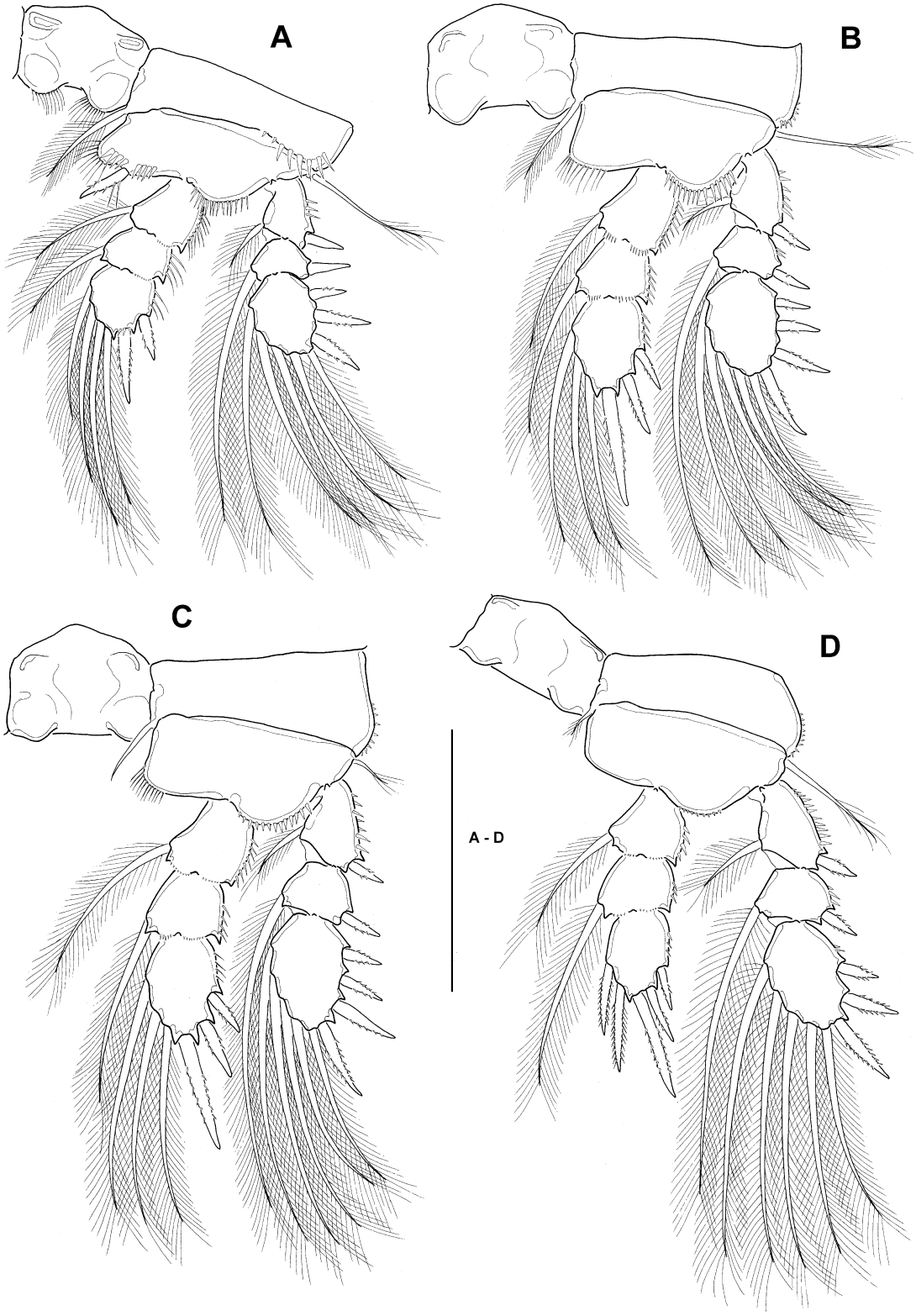


**FIGURE 7.** *Halicyclops pumilus* **sp. nov.**, female. A, P1; B, P2; C, P3; D, P4. Scale: 50 µm.

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