Two species of the genus *Halicyclops* (Crustacea: Copepoda: Cyclopidae) from the Nansei Islands, Japan

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Running title: Two *Halicyclops* from Japan

Abstract

Two species of *Halicyclops* from the Nansei Islands of southern Japan are described: *Halicyclops* (*Halicyclops*) *japonicus* Ito, 1956 and *H.* (*H.*) *ishidai* sp. nov. *Halicyclops* (*H.*) *ishidai* most closely resembles *H.* (*H.*) *japonicus,* but is distinguished from the latter by the dorsal serration of urosomite 4 and the vestigial terminal accessory seta (VI) on the caudal ramus. A key to the species of *Halicyclops* in Japan is given.

Key words: Copepoda, Cyclopoida, Taxonomy, *Halicyclops* (*H.*) *japonicus, Halicyclops* (*H.*) *ishidai,* new species, Japan

Introduction

Halicyclops is a cosmopolitan genus of cyclopoid copepods of the subfamily Halicyclopinae Kiefer, 1927 including species and subspecies widely distributed in several kinds of surface brackish water bodies, tidal pools, lagoonal and estuarine coasts, anchialine caves, sinkholes, interstitial and sandy-beach habitats, as well as ponds and marshes (Pesce *et al.* 1996). To date, more than 70 species and subspecies are described in *Halicyclops* (Karanovic 2004). Recently, Karanovic (2006) divided *Halicyclops* into two subgenera and established a new subgenus, *Rochacyclops*. He hesitated to elevate the new subgenus *Rochacyclops* to generic rank because original descriptions of many species of *Halicyclops* are incomplete and males are known in only a few species.

At present, six species of *Halicyclops* have been recorded from Japan and all of them are included in the subgenus *Halicyclops* (Mizuno 1984; Ishida 2002): *H.* (*H.*) *sinensis* Kiefer, 1928; *H.* (*H.*) cf. *rotundipes* Kiefer, 1935; *H.* (*H.*) *japonicus* Ito, 1956; *H.* (*H.*) *higoensis* Ito, 1957; *H.* (*H.*) *fosteri* Wilson, 1958; and *H.* (*H.*) *ryukyuensis* Ito, 1962. I have found two species of *Halicyclops* from the Nansei Islands, southern Japan, one of which is *H.* (*H.*) *japonicus* and the other is an undescribed species. The present paper describes and illustrates these two species in detail, and presents a key to the species of *Halicyclops* in Japan.

Methods

Specimens were collected by scooping with a fine-mesh hand-net, and then fixed in 5% formalin at the site. Appendages were dissected and embedded in gum-chloral medium on glass slides. The specimens were examined using a phase-contrast and Nomarski differential interference contrast microscope, and illustrated with the aid of a camera lucida. The body length from the rostrum to the posterior margin of the caudal rami (excluding apical setae) was measured to the nearest 0.01 mm. The terminology proposed by Huys and Boxshall (1991) is adopted. The type material is deposited in the National Science Museum, Tokyo (NSMT).

Taxonomy

Halicyclops* (*Halicyclops*) *japonicus Ito, 1956
(Figs 1–2)

Halicyclops japonicus Ito, 1956: 472–473, fig. 3; Mizuno 1984: 572, fig. 322; Ishida 1993: 165, figs 4–7.
Halicyclops sp.: Ishida 1989: 25–26 (in part).

Material examined. Two females, length 0.48 mm, respectively (females “a” and “b”), Ogansaki (*ca* 24˚26'N, 124˚4'E), Ishigaki City, Okinawa Prefecture, Japan, 23 Apr 1993, collected by T. Ishida. Female, length 0.47 mm (female “c”), Ogansaki (*ca* 24˚26'N, 124˚4'E), Ishigaki City, Okinawa Prefecture, Japan, 10 May 1997, collected by T. Ishida.

Description. *Female* [based on female “a”]. Body cyclopiform (Fig. 1A); prosome with cephalothorax narrowing anteriorly and free pedigerous somites decreasing in width from anterior to posterior. Genital double-somite (Fig. 1B) length 0.9 × width, with well-developed chitinous spiniform process. Seminal receptacle with copulatory pore and pore-canal (an internal structure). Posterior margin of genital double-somite and subsequent somites serrate (Fig.1B, C). Dorsomedial serration of urosome 4 not reaching beyond half of anal operculum. Anal operculum weakly developed, barely convex, smooth, row of spinules present in anal cleft on either side of midline.

Caudal rami (Fig. 1C) length 1.6 × width. Caudal rami with six setae; seta (I) absent; posterolateral seta (III) length 0.7 × ramus; outer terminal seta (IV) plumose along outer margin and inner distal margin; inner terminal seta (V) with few spinules on inner side of middle part, plumose distally on both sides; terminal accessory seta (VI) distinct; dorsal seta (VII) length 1.9 × ramus.

Antennule six-segmented (Fig. 1D). First segment with spinule row ventrally. Setal formula 5, 8, 4, 5, 1 + aesthetasc, 9 + aesthetasc.

Antenna three-segmented (Fig. 1E), comprising coxobasis and 2-segmented endopod. Coxobasis armed with two inner setae; outer seta representing exopod. First endopodal segment with inner medial seta. Second endopodal segment with 13 setae, of which four on inner margin, one on outer margin and eight around apex; segment ornamented with spinule row along outer distal margin.

Labrum (Fig. 2A) posterior margin forming strong teeth and spinules.

Mandible (Fig. 2B) with coxal gnathobase blades mostly simple. Palp represented by two setae.

Maxillule (Fig. 2C) with praecoxal arthrite bearing three claws and four spines. Proximal segment of palp derived from coxa and basis, bearing one strong spinulose and two inner margin setae, plus outer spinulose seta representing exopod. Distal segment of palp, representing endopod, armed with three spinulose setae.

Maxilla four-segmented (Fig. 2D). Praecoxal endite with two setae. Coxa with proximal endite represented by single seta, distal endite with well-developed process carrying naked seta apically and weakly spinulose seta fused to endite. Basis drawn out into powerful spinulate claw and armed with strong accessory claw. Endopod one-segmented, with four setae, two of which strong.

Maxilliped two-segmented (Fig. 2E), syncoxa armed with three setae representing endite. Basis with three spinulose setae and two naked setae.

Legs 1–4 (Fig. 2F–I) with three-segmented rami. Intercoxal sclerites without surface ornamentation. Leg 4 (Fig. 2I), endopodal segment 3, inner terminal spine length 1.4 × outer terminal spine, inner and outer setae spiniform, outer seta length 1.1 × inner seta; exopodal segment 3, terminal spine length 0.8 × segment. Spine and seta formula of legs 1–4 as follows:

	Coxa	Basis	Exopod	Endopod
Leg 1	0–1	1–1	I–1; I–1; III–1–4	0–1; 0–1; I–I–3
Leg 2	0–1	1–0	I–1; I–1; III–I–5	0–1; 0–2; II–I–3
Leg 3	0–1	1–0	I–1; I–1; III–I–5	0–1; 0–2; II–I–3
Leg 4	0–1	1–0	I–1; I–1; II–I–5	0–1; 0–2; I–II–2

Leg 5 (Fig. 1B) exopod segment 2 length 1.3 × width, with one terminal seta and three serrated spines; terminal seta length 1.8 × innermost spine.

Leg 6 (Fig. 1B) represented by one naked seta and two protuberances.

Male. Unknown.

Variability. No males were collected, so the antennula morphology and sexual dimorphism could not be documented. In two specimens (females “b” and “c”), the distal segment of leg 1 has four inner setae, whereas there are three setae at this location in female “a”.

Remarks. The present materials well agree with the descriptions and figures of Ito (1956) in having the following features: the presence of a well-developed chitinous spiniform process on each side of the genital double-somite, the spine formula in exopodite 3 of legs 1–4 is 3.4.4.3, the dorsal serration of urosomite 4 does not reach beyond the half of the anal operculum, the outer margin of the outer terminal seta (IV) on the caudal ramus is setose, the terminal accessory seta (VI) on the caudal ramus is distinct, in legs 2 and 3 the innermost seta of endopod segment 3 is not modified, and in leg 4 the outer seta of the endopod segment 3 is spiniform. However, the specimens from Ishigaki Island are distinguished from the original description of *H.* (*H.*) *japonicus* by the following feature (the character state of the original description is shown in parentheses): the inner seta of leg 4 endopod segment 3 is spiniform (normal). This point is treated as an intraspecific variation widely observed in the genus *Halicyclops* (Ishida 1993). The Ishigaki materials are thus placed in *H.* (*H.*) *japonicus.*

Distribution. Hokkaido, Aomori, Toyama, Kagoshima (Yaku Island), Okinawa (Okinawa Is., Ishigaki Is., and Iriomote Is.) (Ishida 2002).

Halicyclops* (*Halicyclops*) *ishidai sp. nov.
(Figs 3–4)

Material examined. Holotype, female, length 0.47 mm, NSMT-Cr 17913, Akina River (28˚26'56"N, 129˚33'45"E), O Island, Kagoshima Prefecture, Japan, 7 Dec 2003, collected by T. Ishida. Paratypes, female, length 0.52 mm, NSMT-Cr 17914, data same as holotype; female, length 0.47 mm, NSMT-Cr 17915, Hiji River (26˚43'23"N, 128˚10'32"E), Kunigami Village, Okinawa Prefecture, 10 Mar 2003, collected by K. Tomikawa.

Description. Because *H. ishidai* is similar to the above-mentioned *H. japonicus,* overlapping features will be omitted in the following description. *Female* [holotype, NSMT-Cr 17913]. Genital double-somite (Fig. 3B) about as long as broad, with well developed chitinous spiniform process curved backward on each side. Dorsomedial serration of urosome 4 reaching beyond half of anal operculum.

Caudal rami (Fig. 3C) length 1.6 × width. Caudal rami with six setae; posterolateral seta (III) length 1.1 × ramus; outer terminal seta (IV) with spinules on outer margin of basal and middle part, plumose distally on both sides; inner terminal seta (V) with few spinules on both sides of middle part, plumose distally; terminal accessory seta (VI) vestigial, difficult to distinguish from row of spinules along distal margin of ramus; dorsal seta (VII) length 2.6 × ramus.

Antennule (Fig. 3D) setal formula 7, 8, 4, 5 + aesthetasc, 2, 10 + aesthetasc; one seta on segment 3 spiniform.

Antenna (Fig. 3E), second endopodal segment with 11 setae, of which four on inner margin, one on outer margin and six around apex.

Maxillule (Fig. 3H) with praecoxal arthrite bearing four claws and three spines, one of which spinulose. Proximal segment of palp with one strong spinulose and two inner margin setae.

Maxilla (Fig. 3I) endopod with three setae.

Maxilliped (Fig. 3J) basis with one strong terminal seta and four setae.

Leg 4 (Fig. 4D), endopodal segment 3, inner terminal spine length 1.2 × outer terminal spine, inner and outer setae spiniform, outer seta as long as inner seta;

exopodal segment 3, terminal spine as long as segment.

	Coxa	Basis	Exopod	Endopod
Leg 1	0–1	1–1	I–1; I–1; III–1–4	0–1; 0–1; I–I–4
Leg 2	0–1	1–0	I–1; I–1; III–I–5	0–1; 0–2; II–I–3
Leg 3	0–1	1–0	I–1; I–1; III–I–5	0–1; 0–2; II–I–3
Leg 4	0–1	1–0	I–1; I–1; II–I–5	0–1; 0–2; I–II–2

Leg 5 (Fig. 3B) exopod segment 2 length 1.4 × width, with one terminal seta and three serrated spines; terminal seta as long as innermost spine.

Male. Unknown.

Variability. No males were collected, so the antennula morphology and sexual dimorphism could not be documented.

Etymology. The new species is named in honour of the late Dr. Teruo Ishida in commemoration of his contributions to the taxonomy of freshwater copepods in Japan.

Remarks. *Halicyclops* (*H.*) *ishidai* most closely resembles *H.* (*H.*) *japonicus* in having the following features: the presence of a well-developed chitinous spiniform process on each side of the genital double-somite, the spine formula in exopodite 3 of legs 1–4 is 3.4.4.3, the outer margin of the outer terminal seta (IV) on the caudal ramus is setose, the coxa of maxilla lacks a spine row, in legs 1–4 the intercoxal sclerite lacks spine rows, in legs 2 and 3 the innermost seta of endopod segment 3 is normal, and in leg 4 the outer seta of the endopod segment 3 is spiniform. However, the new species is distinguished from the latter by the following features (the character states of *H.* (*H.*) *japonicus* are shown in parentheses): the dorsal serration of urosomite 4 reaches beyond half of the anal operculum (not reaching) and the terminal accessory seta (VI) on the caudal ramus is vestigial (distinct).

Halicyclops (*H.*) *ishidai* is also similar to *H.* (*H.*) *dedeckeri* Brownell, 1983 and *H.* (*H.*) *spinifer* Kiefer, 1935 as drawn by Pesce *et al.* (1996) in having the following features: the presence of a well-developed chitinous spiniform process on each side of the genital double-somite, the spine formula in exopodite 3 of legs 1–4 is 3.4.4.3, the terminal accessory seta (VI) of the caudal ramus is vestigial, and the coxa of the maxilla is without a spine row. However, the new species is distinguished from *H.* (*H.*) *dedeckeri* and *H.* (*H.*) *spinifer* by the following features: from *H.* (*H.*) *dedeckeri* (the character states of *H.* (*H.*) *dedeckeri* are shown in parentheses), the dorsal serration of urosomite 4 reaches beyond half of the anal operculum (not reaching), the caudal ramus is longer than wide (shorter), and in legs 2 and 3 the innermost seta of endopod segment 3 is normal (modified); from *H.* (*H.*) *spinifer* (the character states of *H.* (*H.*) *spinifer* are shown in parentheses), the outer margin of the outer terminal seta (IV) on the caudal ramus is setose (spinulose), in legs 2 and 3 the innermost seta of the endopod segment 3 is normal (modified), and in leg 4 the outer seta of endopod segment 3 is spiniform (normal).

Distribution. The new species has been found at O Island and Okinawa Island in the Nansei Islands of southern Japan.

Key to the species of *Halicyclops* in Japan

1 Spine formula on exopod 3 of legs 1–4 3.4.3.3…*H.* (*H.*) *sinensis* Kiefer, 1928
- Spine formula on exopod 3 of legs 1–4 3.4.4.2…*H.* (*H.*) *forsteri* Wilson, 1958
- Spine formula on exopod 3 of legs 1–4 3.4.4.3…2
2 Distal inner seta of leg 4 endopodite 3 plumose and much longer than inner distal spine...3
- Distal inner seta of leg 4 endopodite 3 spinulate and almost as long as inner distal spine…4
3 Each side of genital double-somite weakly produced…*H.* (*H.*) *higoensis* Ito, 1957
- Each side of genital double-somite straight…*H.* (*H.*) *ryukyuensis* Ito, 1962
4 Each side of genital double-somite straight…*H.* (*H.*) cf. *rotundipes* Kiefer, 1935
- Each side of genital double-somite with well-developed chitinous spiniform process... 5
5 Dorsal serration of urosomite 4 not reaching beyond half of anal operculum; terminal accessory seta (VI) on caudal ramus distinct…*H.* (*H.*) *japonicus* Ito, 1956
- Dorsal serration of urosomite 4 reaching beyond half of anal operculum; terminal accessory seta (VI) on caudal ramus vestigial…*H.* (*H.*) *ishidai* sp. nov.

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Figure legends

Fig. 1. *Halicyclops* (*Halicyclops*) *japonicus* Ito, 1956. Female "a". A, habitus, dorsal; B, urosome, ventral; C, anal somite and furcal rami, dorsal (II, anterolateral seta; III, posterolateral seta; IV, outer terminal seta; V, inner terminal seta; VI, terminal accessory seta; VII, dorsal seta); D, antennule; E, antenna.

Fig. 2. *Halicyclops* (*Halicyclops*) *japonicus* Ito, 1956. A: female "b". B–I: female "a". A, labrum; B, mandible; C, maxillule; D, maxilla; E, maxilliped; F, leg 1 and intercoxal sclerite, posterior; G, leg 2, posterior; H, leg 3 and intercoxal sclerite, posterior; I, leg 4, posterior.

Fig. 3. *Halicyclops* (*Halicyclops*) *ishidai* sp. nov. A–H: female, holotype (NSMT-Cr 17913). I and J: female, paratype (NSMT-Cr 17915**,** Hiji River 0.47 mm). A, habitus, dorsal; B, urosome, ventral; C, anal somite and furcal rami, dorsal (II, anterolateral seta; III, posterolateral seta; IV, outer terminal seta; V, inner terminal seta; VI, terminal accessory seta; VII, dorsal seta); D, antennule; E, antenna; F, labrum; G, mandible; H, maxillule; I, maxilla; J, maxilliped.

Fig. 4. *Halicyclops* (*Halicyclops*) *ishidai* sp. nov. Female, holotype (NSMT-Cr 17913). A, leg 1 and intercoxal sclerite, posterior; B, leg 2 and intercoxal sclerite, posterior; C, leg 3, posterior; D, leg 4 and intercoxal sclerite, posterior.

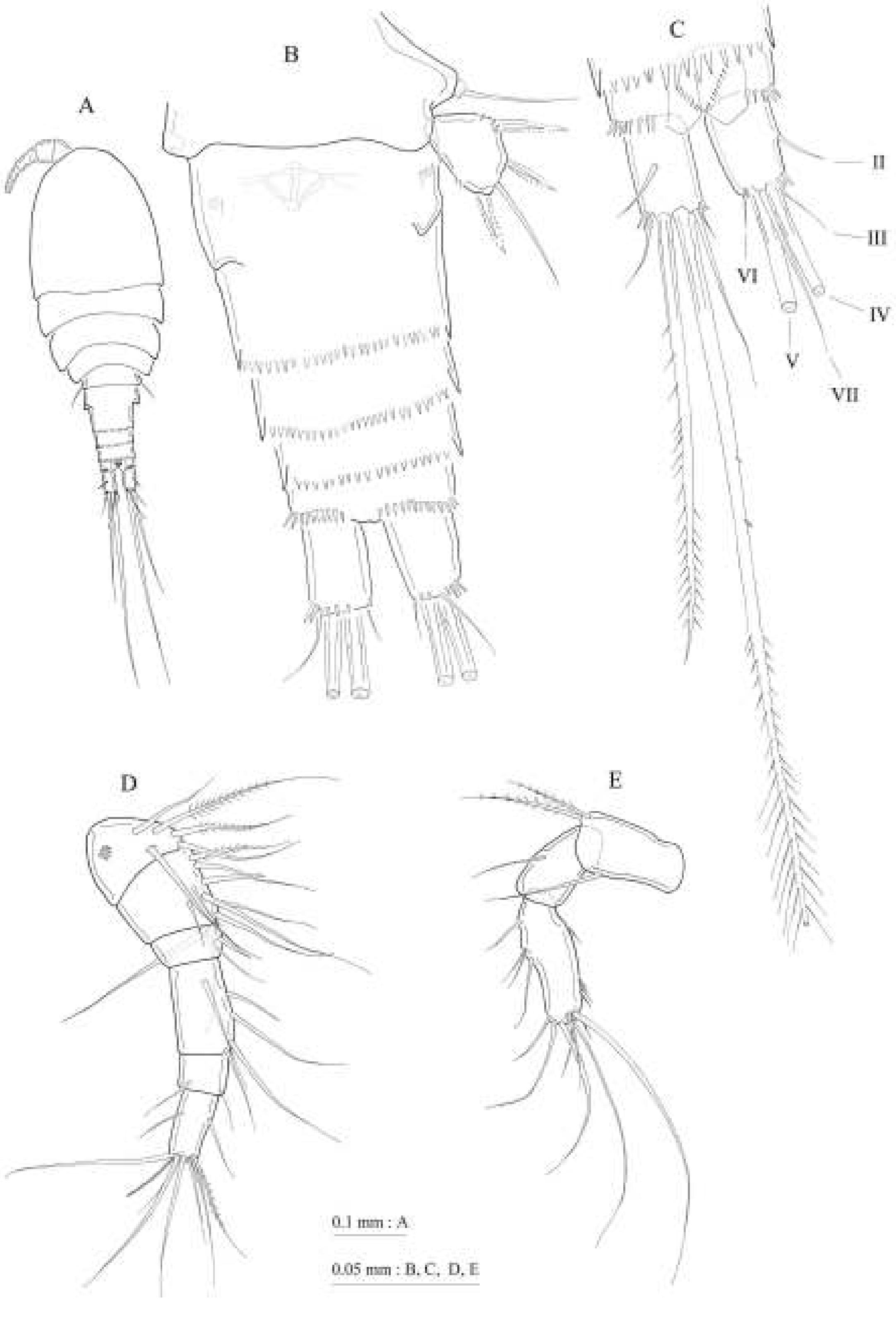

Fig. 1

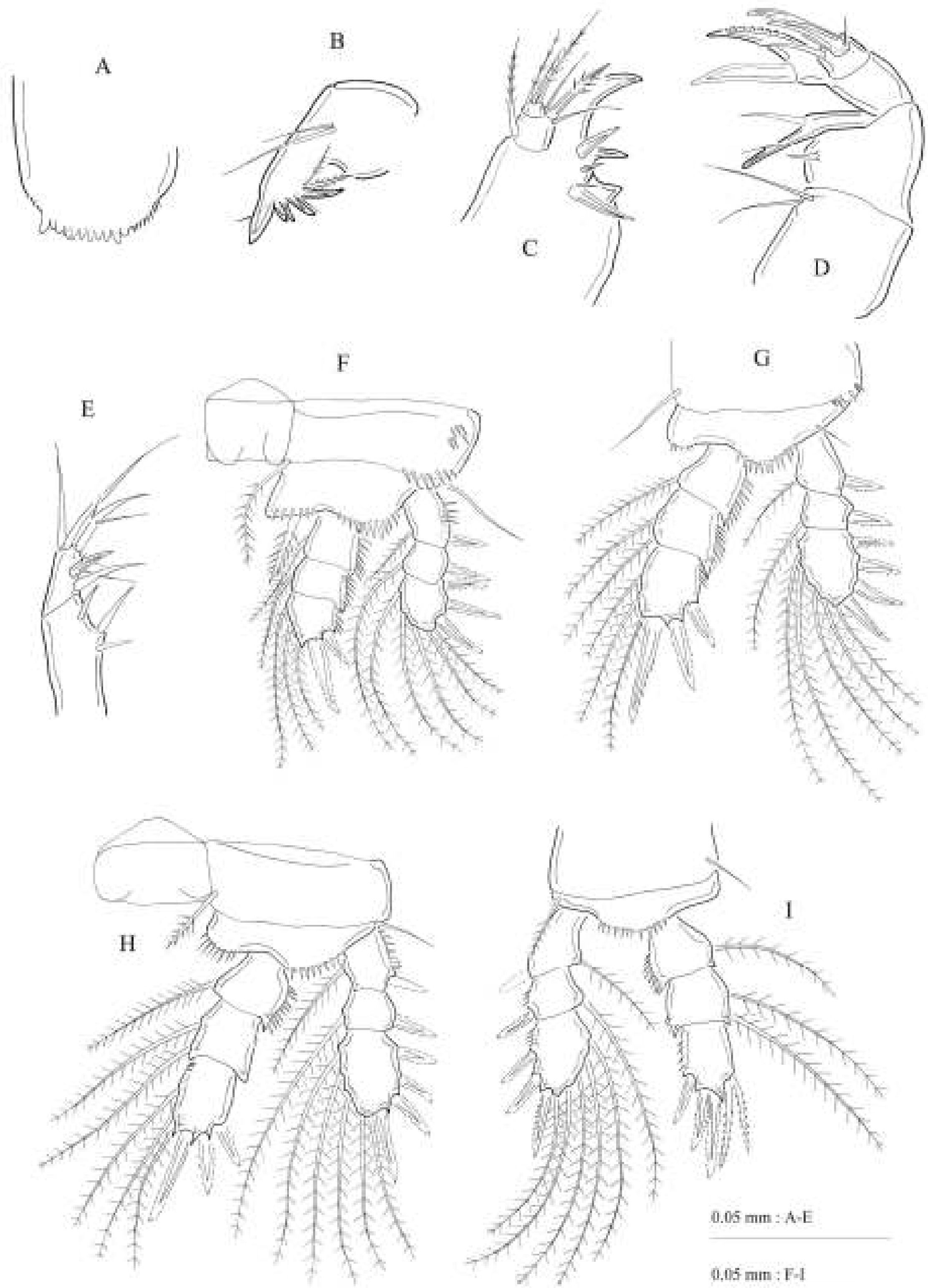

Fig. 2

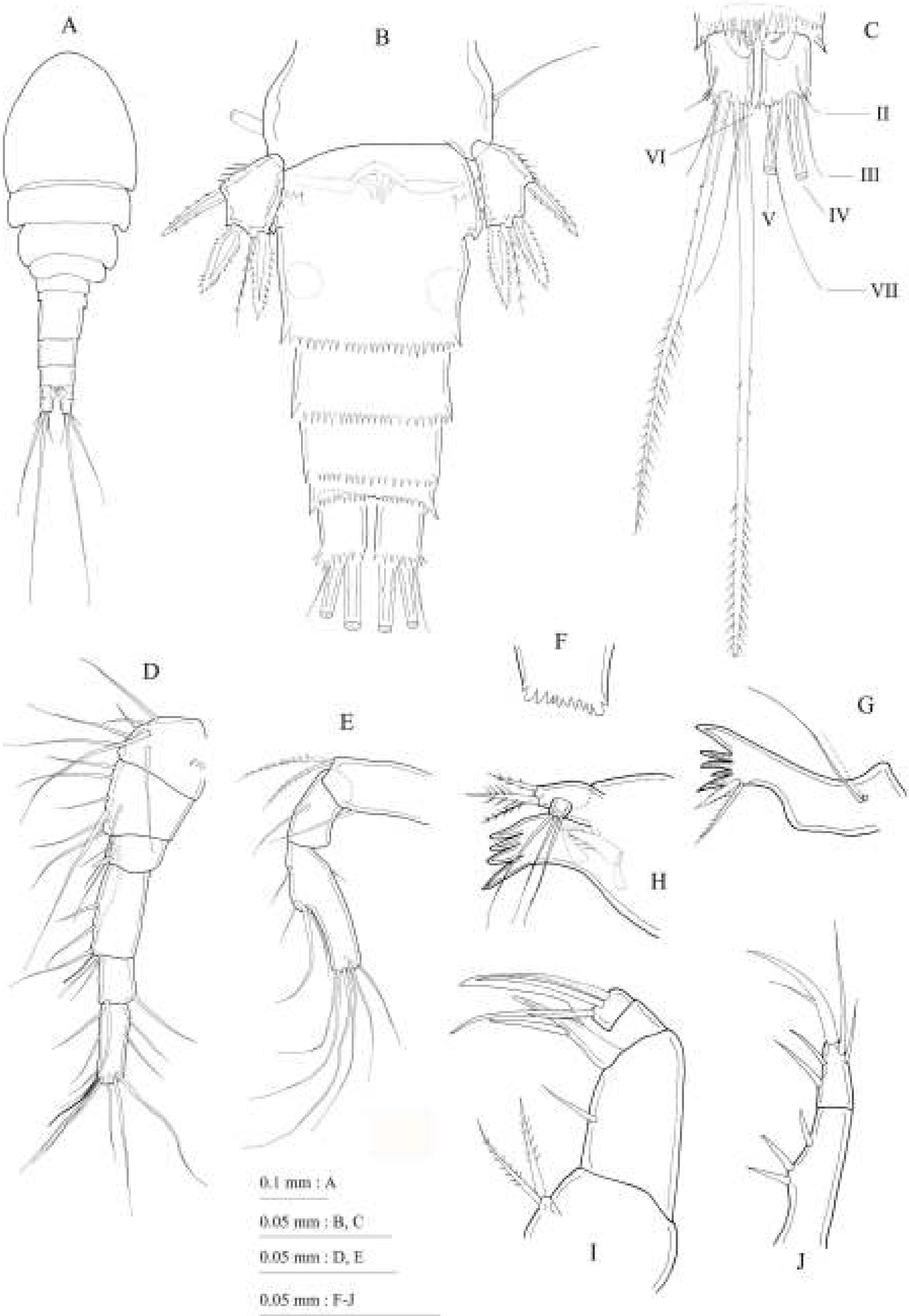

Fig. 3

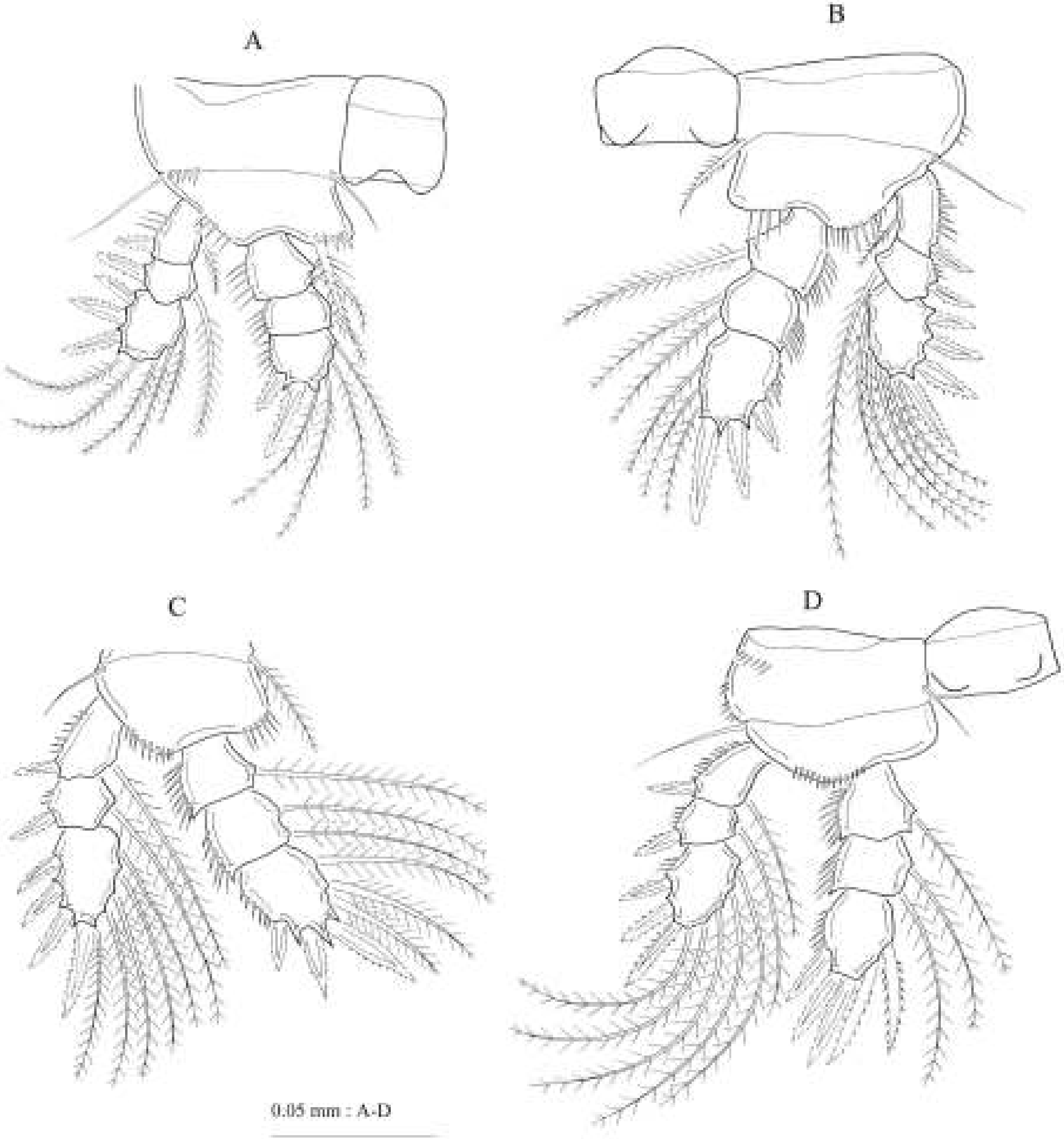

Fig. 4