



Two new species of *Panaietis* (Copepoda: Cyclopoida: Anthessiidae) associated with vetigastropods (Gastropoda) in coastal waters of southern Japan

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Abstract

Two new species of the genus *Panaietis* (Copepoda: Cyclopoida: Anthessiidae) inhabiting the inside of the mouth cavities of marine snails are described from shallow waters of southern Japan. *Panaietis bobocephala* **sp. nov.** collected from the small abalone, *Haliotis asinina* (Vetigastropoda: Lepetellida: Haliotidae), is mainly characterized by the well-developed posterolateral corners of tergite on first pediger, the pointed spines on legs 1 to 5, the maxilla with two teeth, and the leg armature formula. *Panaietis flavellata* **sp. nov.** from *Angaria neglecta* (Vetigastropoda: Trochida: Angariidae) is characterized by the combination of following: leg 5 is situated on ventral side of the fifth pediger, inner margin of the second segment of antenna greatly protruded, and the leg armature formula.

Key words: new species, Copepoda, *Panaietis*, Vetigastropoda, abalone, mouth cavity, esophagus, Ryukyu Islands

Introduction

Anthessiidae (Cyclopoida) is the major copepod family of parasites or commensals on marine mollusks (Boxshall & Halsey 2004). Currently, the family consists of six genera (*Anthessius* Della Valle, 1880, *Discanthessius* Kim, 2009, *Katanthessius* Stock, 1960, *Neanthessius* Izawa, 1976; *Panaietis* Stebbing, 1900; and *Rhinomolgus* Sars, 1918). Most species inhabit bivalves and gastropods but a few species are found on other taxa (*i.e.*, fish and alpheid shrimps), or were collected from weed washings or in plankton tows (*e.g.*, Avdeev & Kazatchenko 1986; Conradi *et al.* 2012). The members of the genus *Panaietis* have been reported mainly in mouth cavities and esophagi of vetigastropods collected from coastal waters (*e.g.*, Stebbing 1990; Monod 1932; Monod & Dollfus 1934; Yamaguti 1936; Izawa 1976; Ho 1981; Kim 1998; Uyeno 2016).

During the last decade, the author has conducted field surveys to explore the copepod diversity associated with marine invertebrates in the coastal regions of Japan. Of many parasitic and commensal copepods found from a series of surveys, ten species from four families were described from mollusk hosts (Uyeno & Nagasawa 2012a, 2012b; Uyeno 2016; Uyeno *et al.* 2016; Uyeno & Hirose 2018). In this study, two new species of *Panaietis* are described based on specimens collected from two species of vetigastropods in coastal waters of southern Japan.

Materials and methods

The hosts of the copepods, *i.e.*, the gastropods, were collected from rocky shores using SCUBA or snorkel in the coastal waters of southern Japan. In the laboratory, copepods were carefully removed from the hosts and fixed in 80% ethanol during a week, and then transferred to 99% ethanol for preservation. For observation of morphology, copepods were soaked in lactophenol for 24 h before dissection and examined using a modified version of the wooden slide method by Humes & Gooding (1964). Drawings were made with the aid of a drawing tube. The body parts of copepods were measured by an ocular micrometer, given in mm: variability is presented as the range exhibited by paratypes and other material followed by the mean and standard deviation in parentheses. All specimens examined in this study are deposited in the crustacean collection of the National Museum of Nature and Science, Tsukuba (NSMT), Japan.

Results

Family Anthessiidae Humes, 1986

Genus *Panaietis* Stebbing, 1900

Panaietis bobocephala sp. nov.

(Figs 1–3)

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Type material. Holotype: adult female (NSMT-Cr 26677), ex *Haliotis asinina* L. (Vetigastropoda: Lepetellida: Haliotidae), off Shirahama Beach (28°11'N, 129°16'E), the Oshima Strait, Amami Ohshima Island, 7 August 2015, leg. D. Uyeno, H. Uyeno, and M. Arai. Allotype: adult male (NSMT-Cr 26678), collection data same as holotype. Paratypes: 2 adult females and 1 adult male (NSMT-Cr 26679), collection data same as holotype.

Other material examined. 1 adult female (NSMT-Cr 26680), ex *H. asinina*, off Onna (26° 26'N, 127°46'E), the East China Sea, Okinawa, 26 October 2010, leg. D. Uyeno and T. Kobayashi.

Holotype adult female. Body (Fig. 1A) cycloform, 5.74 long, flattened dorso-ventrally with greatest width at first pediger; external segmentation distinct. Cephalosome wider than long, 1.06 × 2.05. First to fourth pedigers and six urosomites free.

Tergite of first pediger bearing pair of well-developed posterolateral lobes with pointed tip. Prosoma 2.60 long. Genital somite (Fig. 1A, B) wider than long, 0.49 × 1.13, bearing pair of posterolateral lobes; paired genital openings situated on dorsal side (Fig. 1C). Abdomen (Fig. 1A, B) composed of four free somites, 0.33 × 0.64, 0.35 × 0.65, 0.38 × 0.71, and 0.74 × 0.63, respectively. Caudal ramus (Fig. 1A, B, D) 3.50 times longer than wide, 0.70 × 0.20, bearing six setae. Egg sac (Fig. 1A) multiseriate, slightly curved.

Rostral area (Fig. 1E) without distinct apex. Antennule (Fig. 1F, G) 7-segmented; armature formula 4, 15, 3, 4, 6 + 1 aesthetasc, 2 + 1 aesthetasc, 7 + 1 aesthetasc; all setae naked. Antenna (Fig. 1H) 3-segmented, composed of coxobasis and 2-segmented endopod; coxobasis bearing single naked seta on distal margin; first endopodal segment bearing single inner protrusion with apical seta; second endopodal segment bearing three simple setae and single spatulate seta on inner margin, plus terminal claw, three claw-like spines, and two setae on distal tip. Labrum (Fig. 2A) bilobate. Mandible (Fig. 2B) bearing single lash-like seta with row of fine spinules on outer margin and apical serrated lash with two basal hyaline teeth. Maxillule (Fig. 2C) represented by unsegmented lobe bearing inner protrusion and two long and two short elements. Maxilla (Fig. 2D) 2-segmented; proximal segment rod-like, unarmed; distal segment bearing two sharp teeth and two basal setae. Maxilliped (Fig. 2E) indistinctly 2-segmented, composed of unarmed stout proximal portion and elongate distal portion with three small elements (Fig. 2E, F).

Legs 1 to 4 (Fig. 2G–J) biramous, bearing 3-segmented rami. Leg armature formula as follows:

	Coxa	Basis	Exopod	Endopod
Leg 1	0-0	1-0	I-0; I-0; III, I, 3	0-0; 0-0; II, I, 3
Leg 2	0-0	1-0	I-0; I-0; III, I, 3	0-0; 0-0; II, I, 3
Leg 3	0-0	1-0	I-0; I-0; III, I, 3	0-0; 0-0; III, I, 3
Leg 4	0-0	1-0	I-0; I-0; III, I, 3	0-0; 0-0; II, I, 2

Intercostal sclerites (Fig. 2G–J) of legs 1 to 4 unarmed. All spines pointed. Both rami bearing pointed processes on outer margins. First and second endopodal segments of four legs bearing row of fine spinules on distal margins. Leg 5 (Fig. 3A) 2-segmented; proximal segment incompletely fused to fifth pediger with small simple seta; distal segment elongate bearing three small conical spines and single seta. Leg 6 not found.

Allotype adult male. Body (Fig. 3B) cycloform, 3.38 long, flattened dorso-ventrally with greatest width at cephalosome and first pediger; external segmentation distinct. Cephalosome (Fig. 3B) wider than long, 0.74 × 1.25. First to fourth pedigers and four free urosomites. Posterolateral corners of tergite on first pediger not well developed as that of female (Fig. 3B). Prosoma (Fig. 3B) 1.61 long. Genital somite (Fig. 3B) wider than long, 0.26 × 0.58, with paired genital opercula (Fig. 3C). Abdomen composed of four free somites, 0.21 × 0.49, 0.19 × 0.48, 0.20 × 0.47, and 0.38 × 0.42, respectively. Caudal ramus (Fig. 3B) 3.69 times longer than wide, 0.53 × 0.14, with six setae.

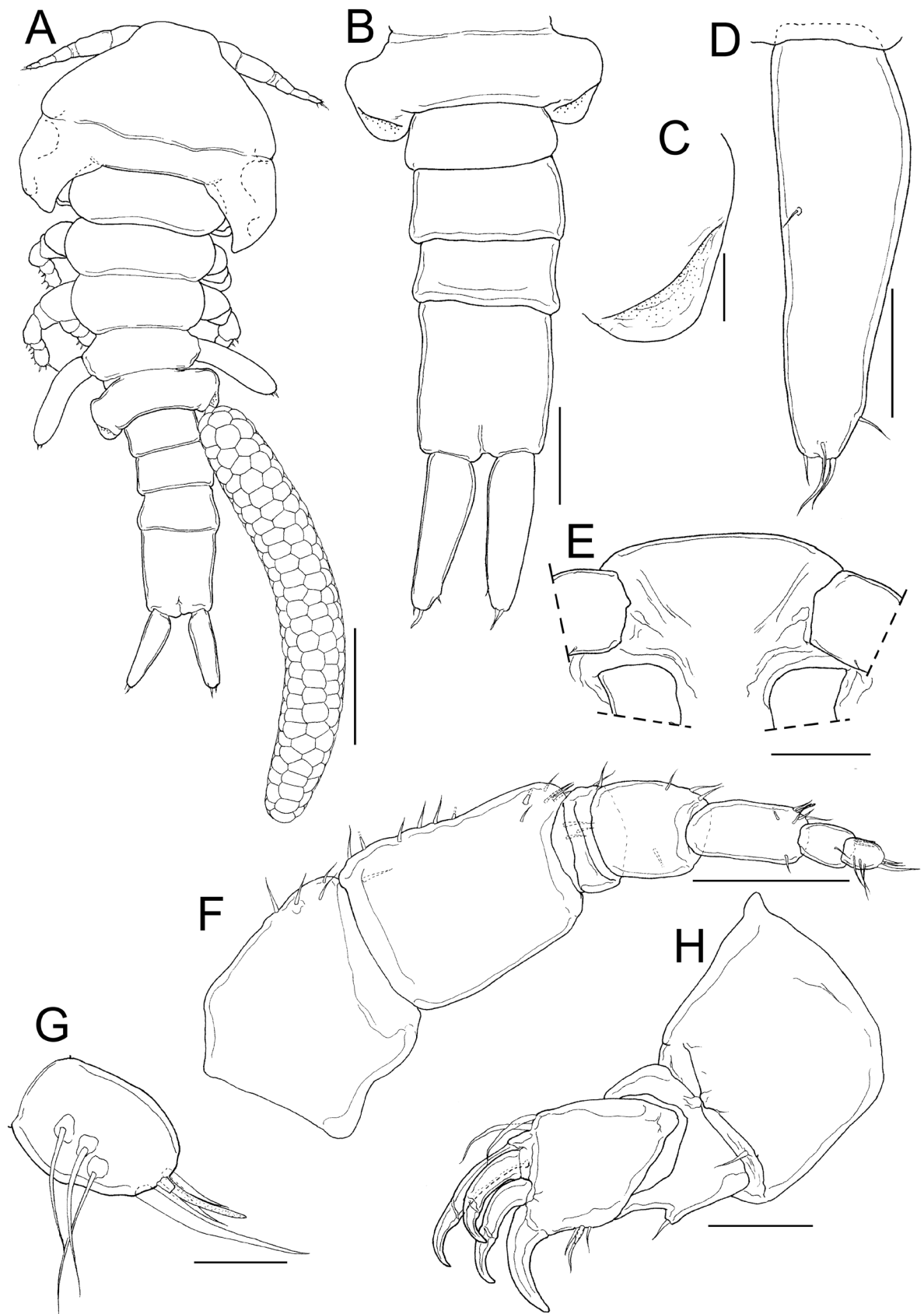


FIGURE 1. *Panaietis bobocephala* sp. nov., adult female, holotype NSMT-Cr 26677. A, habitus, dorsal; B, urosome, dorsal; C, right genital aperture, dorsal; D, left caudal ramus, dorsal; E, rostral area, ventral; F, left antennule, posterior; G, distal segment of left antennule; H, right antenna, anterior. Scale bars: A, 1.0 mm; B, 0.4 mm; C, H, 0.1 mm; D, F, 0.2 mm; E, 0.3 mm; G, 0.02 mm.

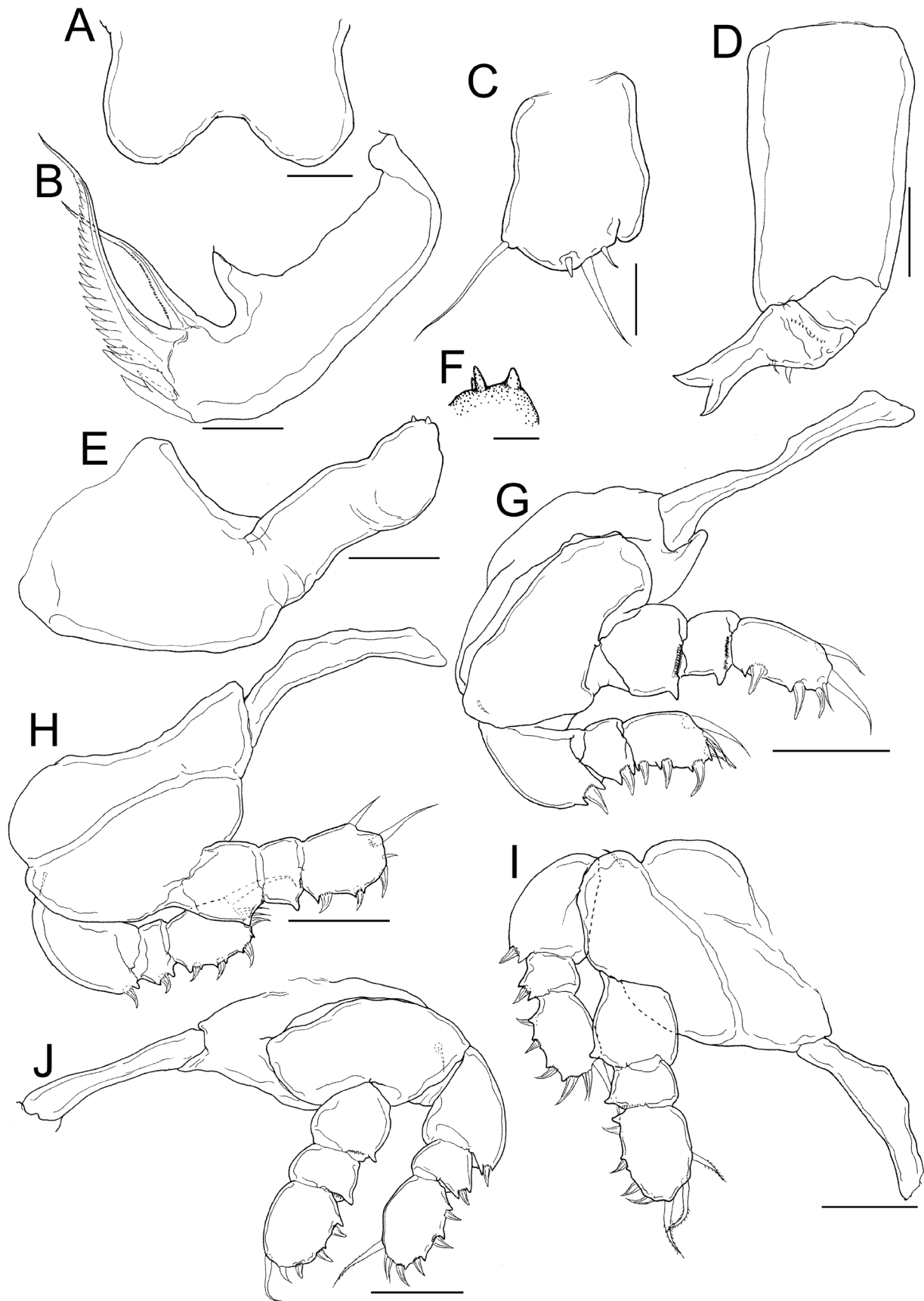


FIGURE 2. *Panaietis bobocephala* sp. nov., adult female, holotype NSMT-Cr 26677. A, labrum; B, left mandible, anterior; C, right maxillule, anterior; D, left maxilla, anterior; E, right maxilliped, anterior; F, distal tip of right maxilliped; G, right leg 1, anterior; H, right leg 2, anterior; I, right leg 3, anterior; J, left leg 4, anterior. Scale bars: A, D, E, 0.05 mm; B, 0.04 mm; C, 0.03 mm; F, 0.01 mm; G–J, 0.2 mm.

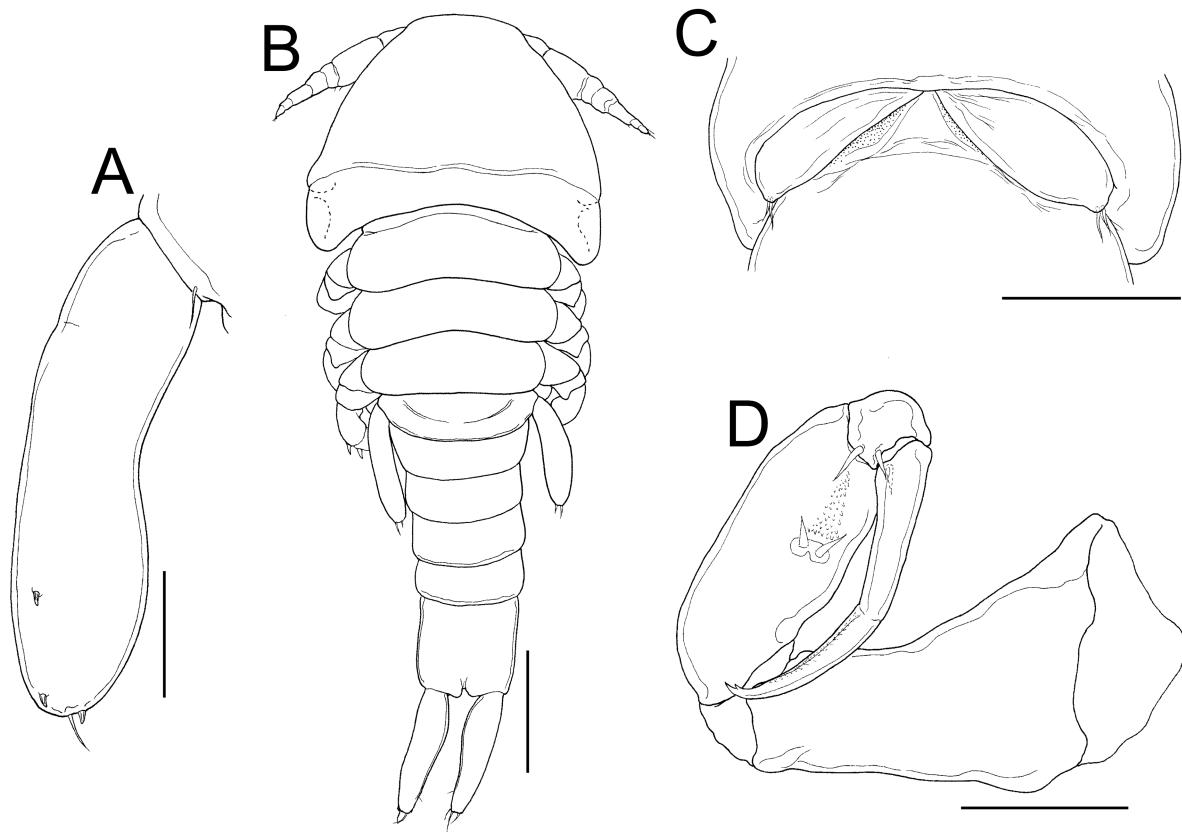


FIGURE 3. *Panaietis bobocephala* **sp. nov.**, adult female, holotype NSMT-Cr 26677 (A) and adult male, allotype NSMT-Cr 26678 (B–D). A, left leg 5, dorsal; B, habitus, dorsal; C, genital somite, ventral; D, right maxilliped. Scale bars: A, C, 0.2 mm; B, 0.5 mm; D, 0.1 mm.

Antennule, antenna, mandible, and maxilla as in female. Maxilliped (Fig. 3D) 4-segmented; first segment rod-like; second segment bearing two setae; third segment small with two elements; terminal claw curved bearing single basal seta, pointed process near distal tip, and row of fine spinules on inner margin. Armature formula of legs 1 to 4 as in female. Leg 5 as in female. Leg 6 (Fig. 3C) represented by two simple setae on genital operculum.

Variability. The morphology of the female paratypes and other material as in the holotype. The measurements of the body parts of paratypes and other material ($n = 3$) are as follows: body length 5.52–7.05 (6.07 ± 0.85); cephalosoma length 0.83–0.98 (0.92 ± 0.08); cephalosoma width 1.45–1.86 (1.70 ± 0.22); prosoma length 2.46–3.20 (2.73 ± 0.41); genital somite length 0.41–0.46 (0.43 ± 0.03); genital somite width 1.03–1.08 (1.05 ± 0.02); first urosomite length 0.25–0.52 (0.35 ± 0.15); first urosomite width 0.56–0.65 (0.60 ± 0.05); second urosomite length 0.30–0.49 (0.41 ± 0.10); second urosomite width 0.57–0.70 (0.62 ± 0.07); third urosomite length 0.19–0.43 (0.32 ± 0.12); third urosomite width 0.61–0.72 (0.65 ± 0.06); anal somite length 0.59–0.72 (0.64 ± 0.06); anal somite width 0.50–0.69 (0.58 ± 0.10); caudal ramus length 0.69–0.77 (0.72 ± 0.04); caudal ramus width 0.19–0.22 (0.20 ± 0.01). Caudal ramus 3.46–3.60 (3.54 ± 0.07) times longer than wide.

The morphology of the male paratype as in the allotype. The measurements of the body parts of the paratype ($n = 1$) are as follows: body length 3.71; cephalosoma length 0.69; cephalosoma width 1.41; prosoma length 1.67; genital somite length 0.28; genital somite width 0.59; first urosomite length 0.24; first urosomite width 0.54; second urosomite length 0.24; second urosomite width 0.51; third urosomite length 0.18; third urosomite width 0.50; anal somite length 0.49; anal somite width 0.42; caudal ramus length 0.57; caudal ramus width 0.16. Caudal ramus 3.52 times longer than wide.

Remarks. *Panaietis bobocephala* **sp. nov.** differs from *P. incamerata* Stebbing, 1900, *P. yamagutii* Izawa, 1976, *P. doraconis* Uyeno, 2016, and *P. satsuma* Uyeno, 2016 by having pointed spines on rami of legs 1 to 5 (vs. spatulate spines, Izawa 1976; Uyeno 2016). *Panaietis haliotis* Yamaguti, 1936 is distinguished from the new species by having following characters: the posterolateral corners of tergite on first pediger not protruded (vs. well-devel-

oped and protruded posteriorly); the maxilla bears three or four teeth on distal segment (vs. two teeth); leg 3 bears two setae on the third endopodal segment (vs. three setae); leg 4 bears three spines on the third endopodal segment (vs. two spines) (see Yamaguti 1936; Ho, 1981).

Attachment site. Mouth cavity and esophagus.

Etymology. The specific name of the new species, *bobocephala*, is the compound word of “bob” and “cephala” since the cephalosome and the first pediger of the copepod is reminiscent of a “bob” hairstyle.

Newly established Japanese name for species. Mimigai-no-haramushi.

Panaietis flavellata sp. nov.

(Figs 4–6)

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Type material. Holotype: adult female (NSMT-Cr 26681), ex *Angaria neglecta* Poppe & Goto (Vetigastropoda: Trochida: Angariidae), Akamizu (31°15'N, 130°15'E), off Satsuma Peninsula, Kagoshima, the East China Sea, Japan, 4 May 2016, leg. D. Uyeno. Paratypes: 1 adult female (NSMT-Cr 26682), ex *A. neglecta*, Akamizu (31°15'N, 130°15'E), off Satsuma Peninsula, Kagoshima, the East China Sea, Japan, 3 August 2016, leg. D. Uyeno; 1 adult female (NSMT-Cr 26683), ex *A. neglecta*, off Nomaike (31°25'N, 130°8'E), Satsuma Peninsula, Kagoshima, the East China Sea, Japan, 16 December 2018, leg. D. Uyeno; adult female (NSMT-Cr 26684), ex *A. neglecta*, off Cape Bonomisaki (31°15'N, 130°13'E), Satsuma Peninsula, Kagoshima, the East China Sea, Japan, 2 January 2019, leg. D. Uyeno and H. Uyeno.

Holotype adult female. Body (Fig. 4A) cyclopiform, 3.01 long; external segmentation distinct. Cephalosome incompletely separated from first pediger, wider than long, 0.53×0.77 . First to fourth pedigers and six urosomites free; third and fourth pedigers wider than cephalosome. Prosome 1.52 long. Genital somite bearing pair of lateral lobes (Fig. 4A, B), 0.26×1.01 ; paired genital openings situated on dorsal side. Abdomen composed of four free somites, 0.19×0.48 , 0.18×0.46 , 0.12×0.39 , and 0.35×0.37 , respectively. Caudal ramus (Fig. 4A, C) 2.40 times longer than wide, 0.43×0.18 , with six minute setae.

Rostral area triangular without distinct apex. Antennule (Fig. 4D) 7-segmented; armature formula 6, 16, 4, 4, 4 + 1 aesthetasc, 2 + 1 aesthetasc, 7 + 1 aesthetasc; all setae simple. Antenna (Fig. 4E) 3-segmented, composed of coxobasis and 2-segmented endopod: coxobasis large, bearing simple distal seta; first endopodal segment bearing well developed conical protrusion with simple apical seta; second endopodal segment bearing four setae on inner margin and terminal claw, three claw-like spines, and three long distal setae on distal margin. Labrum (Fig. 4F) broad, bilobed. Mandible (Fig. 4G) bearing single lash-like seta with row of fine spinules on one of margin and apical serrated lash with two basal hyaline teeth. Maxillule (Fig. 4H) represented by unsegmented lobe bearing inner elongate protrusion tipped with minute element, outer basal seta, and three short distal elements. Maxilla (Fig. 4I) 2-segmented; proximal segment rod-like, unarmed; distal segment bearing five sharp teeth and two basal setae. Maxilliped (Fig. 4J) 2-segmented, composed of unarmed stout proximal portion and distal portion.

Legs 1 to 4 (Fig. 5A–D) biramous, bearing 3-segmented rami. Leg armature formula as follows:

	Coxa	Basis	Exopod	Endopod
Leg 1	0-0	1-0	I-0; I-0; III, I, 3	0-0; 0-0; II, I, 3
Leg 2	0-0	1-0	I-0; I-0; III, I, 3	0-0; 0-0; II, I, 2
Leg 3	0-0	1-0	I-0; I-0; III, I, 3	0-0; 0-0; III, I, 1
Leg 4	0-0	1-0	I-0; I-0; III, I, 3	0-0; 0-0; III, I, 1

Intercoxal sclerites (Fig. 5A–D) of legs 1 to 4 unarmed. All spines spatulate. Proximal and middle endopodal segments of legs 1 to 4 bearing pointed protrusions on outer margin. Leg 5 (Fig. 5E) 2-segmented, situated on posteroventral surface of pediger (Fig. 4A); proximal segment incompletely fused to fifth pediger with small simple seta on outer margin; distal segment elongate bearing three spatulate spines and single seta. Leg 6 represented by simple seta at genital opening.

Male. Unknown.

Variability. The morphology of the female paratypes as in holotype. The measurements of the body parts of paratypes ($n = 3$) are as follows: body length 2.57–3.17 (2.83 ± 0.37); cephalosome length 0.48–0.55 (0.51 ± 0.05); cephalosome width 0.64–0.79 (0.72 ± 0.11); prosome length 1.37–1.65 (1.51 ± 0.20); genital somite length

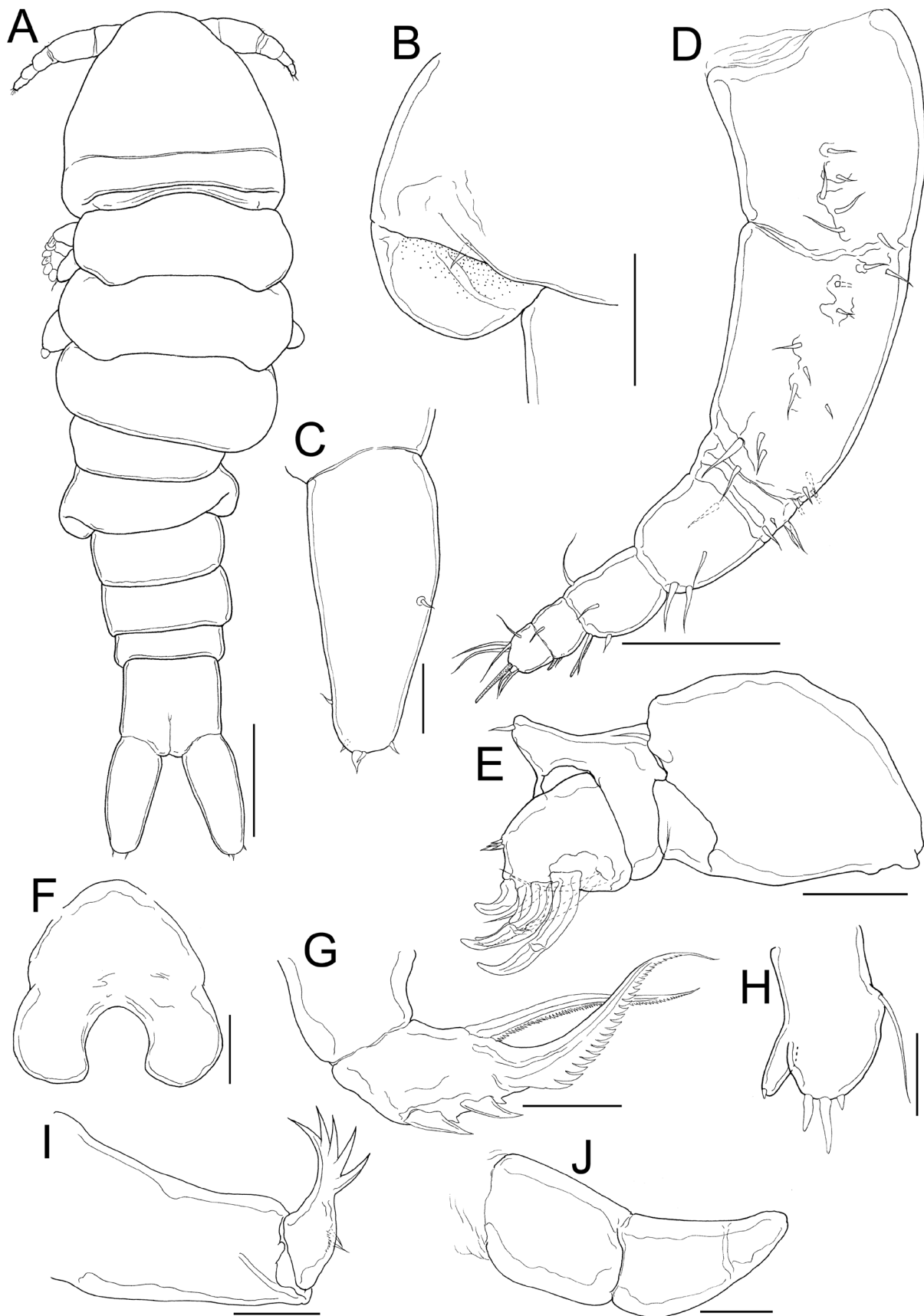


FIGURE 4. *Panaietis flavellata* sp. nov., adult female, holotype NSMT-Cr 26681. A, habitus, dorsal; B, left genital aperture and leg 6, dorsal; C, right caudal ramus, dorsal; D, left antennule, posterior; E, left antenna, anterior; F, labrum; G, left mandible, posterior; H, left maxillule, anterior; I, right maxilla, anterior; J, right maxilliped, anterior. Scale bars: A, 0.4 mm; B–D, 0.1 mm; E, F, 0.05 mm; G, H, 0.03 mm; I, 0.04 mm. J, 0.02 mm.

0.21–0.26 (0.24 ± 0.04); genital somite width 0.56–0.64 (0.60 ± 0.06); first urosomite length 0.13–0.21 (0.17 ± 0.06); first urosomite width 0.41–0.46 (0.43 ± 0.05); second urosomite length 0.13–0.25 (0.19 ± 0.08); second urosomite width 0.40–0.44 (0.42 ± 0.03); third urosomite length 0.14–0.20 (0.17 ± 0.05); third urosomite width 0.36–0.36 (0.36 ± 0.00); anal somite length 0.27–0.30 (0.28 ± 0.02); anal somite width 0.34–0.37 (0.35 ± 0.02); caudal ramus length 0.43–0.45 (0.44 ± 0.01); caudal ramus width 0.14–0.16 (0.15 ± 0.01). Caudal ramus 2.65–3.13 (2.89 ± 0.34) times longer than wide.

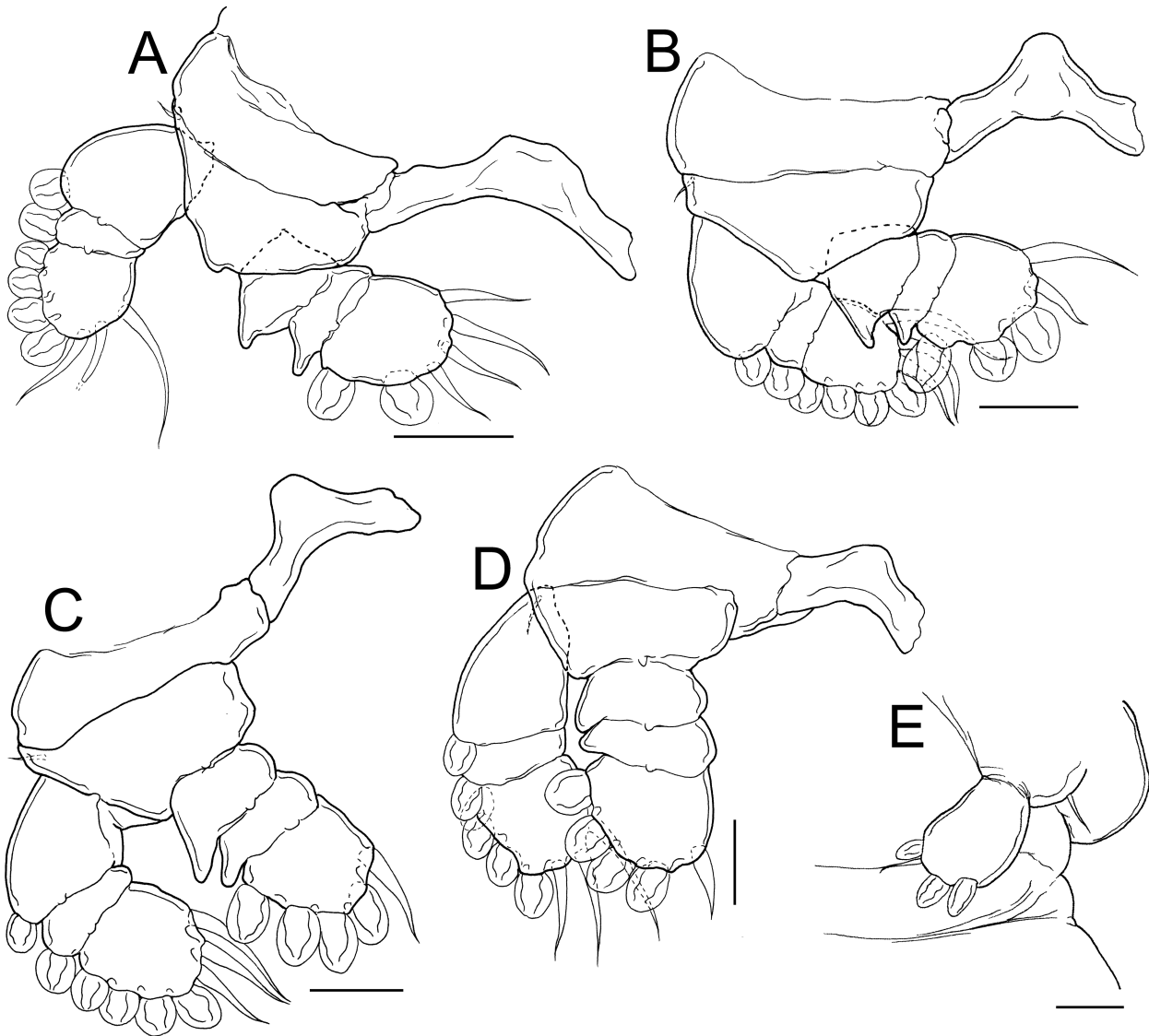


FIGURE 5. *Panaietis flavellata* sp. nov., adult female, holotype NSMT-Cr 26681. A, right leg 1, anterior; B, right leg 2, anterior; C, right leg 3, anterior; D, right leg 4, anterior; E, left leg 5, anterior. Scale bars: A–D, 0.1 mm; E, 0.05 mm.

Remarks. Of all its congeners, *Panaietis flavellata* sp. nov. shares leg 5 situated on the posteroventral side of the fifth pediger only with *P. yamagutii* (Yamaguti 1936; Izawa 1976; Ho 1981; Kim 1998). The new species clearly differs from *P. yamagutii* by following characters: inner margin of second segment of antenna greatly protruded at base of small seta (vs. not protruded); leg 3 endopod bearing single seta on third endopodal segment (vs. two setae) (Yamaguti 1936; Izawa 1976).

Attachment site. Mouth cavity to esophagus.

Etymology. The specific name of the new species, *flavellata*, refers to the spatulate and fan shaped spines on legs.

Newly established Japanese name for species. Katabegai-no-haramushi.

Discussion

Since establishment of *Panaietis* by Stebbing (1990) based on *P. incamerata* found from an unidentified gastropod in Papua New Guinea, six species have added to the genus (Yamaguti 1936; Izawa 1976; Uyeno 2016; present study). It has been discussed that the taxonomic affiliation of *Conchocheres malleolatus* Sars, 1918 which originally described as a member of Clausiidae by Sars (1918) from off the western coast of Norway. Monod & Dollfus (1932) considered *Conchocheres* as a junior synonym of *Panaietis* without substantial reasons. Uyeno (2016) followed this but there was no basis to support. When Anthessiidae was established by Humes (1986), *Panaietis* was added as a member of the family. However, Humes (1986) excluded *Conchocheres* from Anthessiidae on the basis of the mandible without a long lash, the absence of maxilliped in the female, and the leg 5 bearing an exopod only with three setae instead of three spines and a seta. Since Humes (1986) could not examine specimens, he mentioned that further examination of specimens are required to elucidate correct affiliation of *Conchocheres*. Although there is a difference in leg armature, Boxshall & Halsey (2004) tentatively placed *Conchocheres* in Myicolidae because of some similarities on the antenna and the caudal rami. In addition to the Humes' (1986) grounds, there are several differences between the original description of *C. malleolatus* and all seven species of *Panaietis* (Sars 1918; Izawa 1976; Ho 1981; Humes 1986; Uyeno 2016; present study, Table 1). This means that at least *C. malleolatus* is not be a member of *Panaietis*. Although all members of *Panaietis* are found from mouth cavity and esophagus of veti-gastropods (e.g., Yamaguti 1936; Ho 1981; Uyeno 2016; present study), *C. malleolatus* was found from the mantle cavity of the cuspidariid bivalve, *Cuspidaria obesa* (Lovén) (as *Neaera obesa*). This fact may reflect differences in the taxonomic affiliation.

The nominal species of *Panaietis* were mainly reported from coastal waters in Indo-Pacific and the adjacent regions, and there are distributional records of all congeners from Japan (e.g., Stebbing 1990; Monod 1932; Monod & Dollfus 1934; Yamaguti 1936; Izawa 1976; Ho 1981; Kim 1998; Uyeno 2016; present study). Despite all the host gastropods being common species in coastal regions of Japan, four of these copepod species were only recently described (Uyeno 2016; present study). This perhaps indicates that the cryptic and extraordinary attachment sites, and behavior of *Panaietis* have resulted in their being overlooked in many geographical areas. Further research is needed to reveal true species diversity and distribution of these copepods.

TABLE 1. Female characters distinguishing *C. malleolatus* from seven nominal species of *Panaietis* constructed based on Sars (1918), Izawa (1976), Ho (1981), Uyeno (2016), and present study.

Character	<i>C. malleolatus</i>	<i>Panaietis</i> spp.
Distal claws of antenna	1 apical claw with 1 small denticle at base	1 apical plus 3 claws without denticles
Mandible	without long lash	with 1 long lash
Maxilliped	absent	present
Coxae of legs 1, 2, and 4	with inner seta	without seta
2nd exopodal segments of legs 1, 2, and 4	with inner seta	without seta
3rd exopodal segments of legs 1, 2, and 4	with 3 spines and 4 to 5 setae	with 4 spines and 3 setae
1st and 2nd endopodal segments of legs 1, 2, and 4	with 1 to 2 inner setae	without seta
Setae on rami of legs 1, 2, and 4	plumose	naked or slightly plumose
Leg 5 exopod	with 3 setae	with 3 spines and 1 seta

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