



Three new species of the family Pennellidae (Copepoda: Siphonostomatoida) from gobiid fishes (Actinopterygii: Perciformes) in coastal waters of the western Pacific Ocean

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Abstract

Three new species of pennellid copepods are described based on specimens taken from gobiid fishes. *Creopelates nohmijimensis* n. sp. was found on *Priolepis boreus* (Snyder) in the Seto Inland Sea, Japan. This new species is distinguishable from its sole congener, *C. floridus* Shiino, 1958, by the presence of four finely digitate lobes on the cephalothorax and in having four pairs of legs occurring closely together at the anterior end of the neck. Two new species of *Cardiodectes*, *C. asper* n. sp. and *C. bertrandi* n. sp., were collected, from *Trimma grammistes* (Tomiya) off Izu-Oshima Island, Japan and *Eviota* sp. off the Loyalty Islands, New Caledonia, respectively. *Cardiodectes asper* n. sp. is distinguished from its 12 congeners by the absence of the abdomen, by having a trunk not longer than twice of its width, a cephalothorax with three pairs of lateral lobes, and a pair of neck lobes carrying leg 3 on the posterior surface of their bases. *Cardiodectes bertrandi* n. sp. is identifiable by the presence of two pairs of lateral cephalothoracic lobes, with smaller anterior pairs; a trunk twice as long as wide; and leg 3 located at the posterior end of the anterior neck lobe.

Key words: parasitic Copepoda, pennellid, *Creopelates*, *Cardiodectes*, mesoparasite, Gobiidae, *Priolepis boreus*, *Trimma grammistes*, *Eviota* sp.

Introduction

The family Pennellidae Burmeister, 1835 (Copepoda: Siphonostomatoida) contains 20 genera (Boxshall & Halsey 2004), most of which are known as mesoparasites (Kabata 1979). As several species in this family have negative impacts on commercially important fishes, they have been well studied by previous researchers (e.g. Kabata 1970, 1981). Pennellids have also been described from non-commercial, deep-sea fishes (e.g. Shiino 1958; Izawa 1970, 1977; Boxshall 1986, 1989) but there is little information on pennellids infecting fishes in coastal, shallow waters. Recently, SCUBA diving has become popular, and the number of cases of pennellids being found on coastal marine fishes increased in the Pacific Ocean. In this paper, we describe three new pennellid species, *Creopelates nohmijimensis* n. sp., *Cardiodectes asper* n. sp. and *Cardiodectes bertrandi* n. sp., from three gobiid species collected by SCUBA divers in the coastal waters of the Pacific Ocean off Japan and New Caledonia.

Material and methods

All of the gobiid fishes examined in this study were collected by snorkeling and SCUBA diving. Parasitic copepods (Figs. 1, 4, 8) were carefully removed from the hosts and preserved in 80% ethanol. Copepods were subsequently soaked in lactophenol for 2 days, dissected and examined using the wooden slide method of Humes & Gooding (1964). Drawings were made with the aid of a drawing tube. The terminology follows Huys & Boxshall (1991). The copepod body parts were measured using an ocular micrometer and are given in micrometers as the range followed by the mean and standard deviation in parentheses. Type specimens are

deposited in the crustacean collection of the National Museum of Nature and Science, Tokyo (NSMT) and Muséum national d'Histoire naturelle, Paris (MNHN).

Results

Order Siphonostomatoida Burmeister, 1835

Family Pennellidae Burmeister, 1835

Genus *Creopelates* Shiino, 1958

Creopelates nohmijimensis n. sp.

(Figs 1–3)

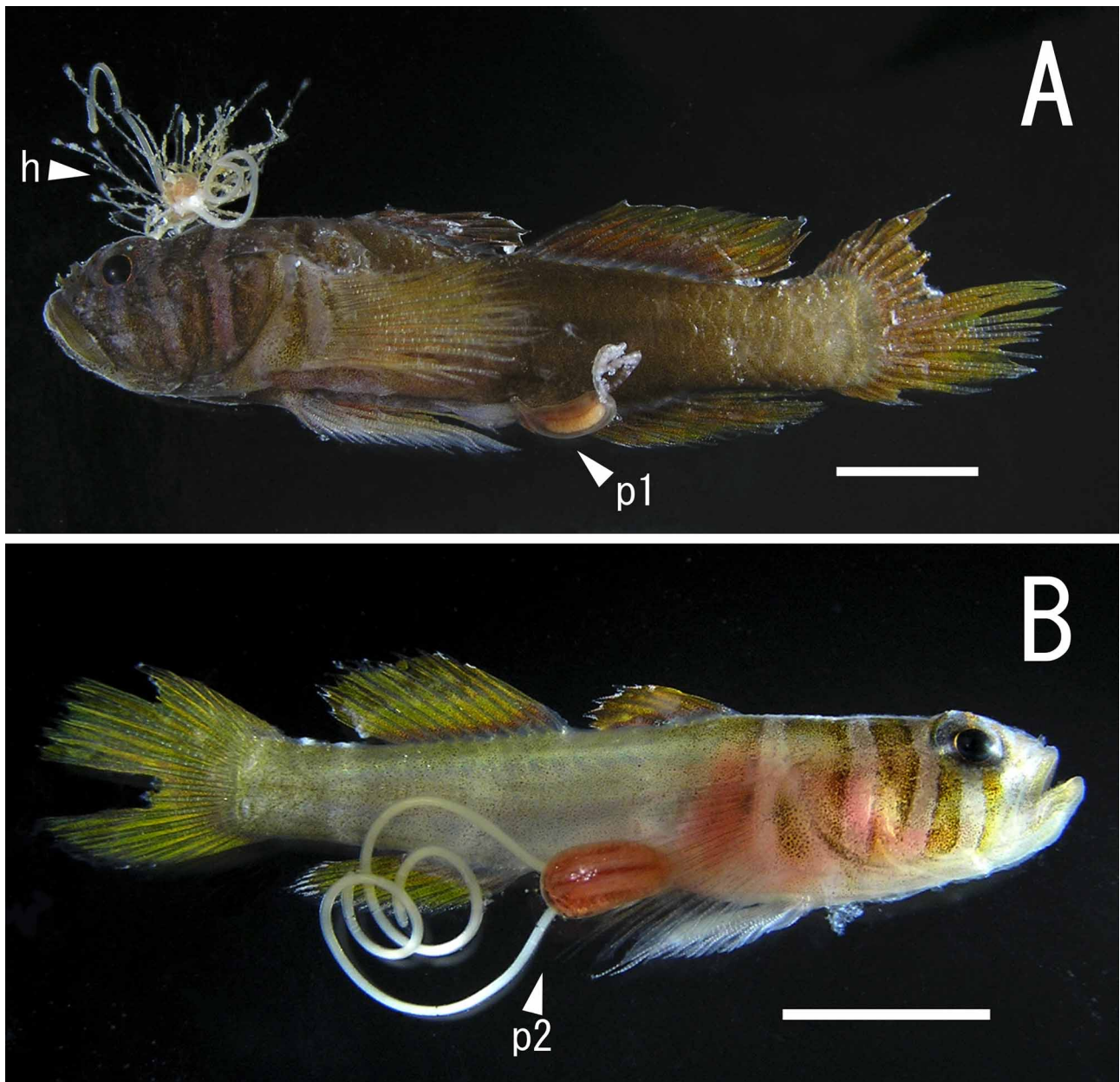


FIGURE 1. *Creopelates nohmijimensis* n. sp., female. A, a specimen of *Priolepis boreus* carrying the holotype (NSMT–Cr 21191) and a paratype (NSMT–Cr 21192), h = holotype (the trunk was infested with hydrozoan epibionts), p1 = paratype; B, a specimen of *P. boreus* carrying a paratype (NSMT–Cr 21192), p2 = paratype. Scale bars: A, B, 500µm.

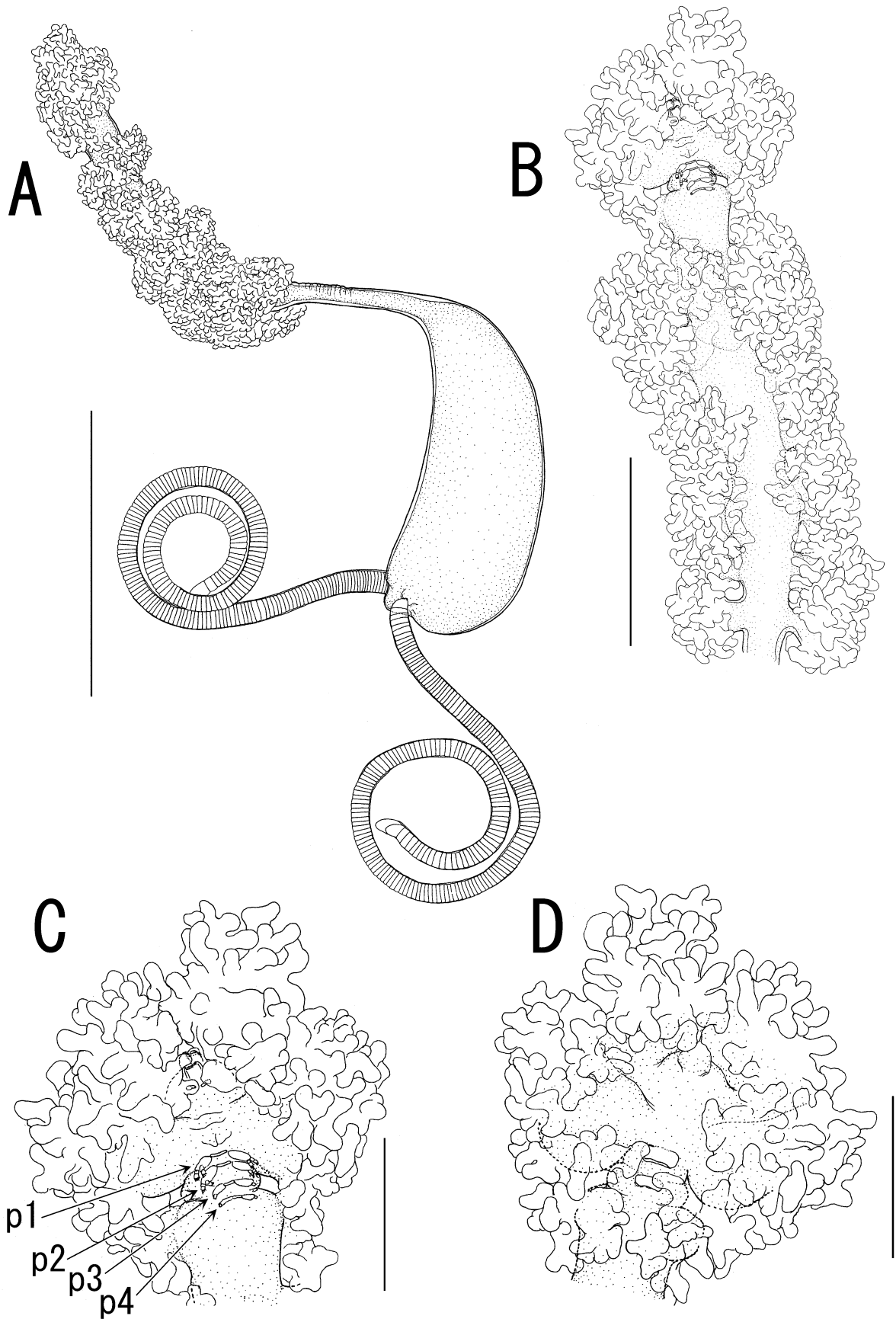


FIGURE 2. *Creopelates nohmijimensis* n. sp., female, holotype NSMT–Cr 21191. A, habitus; B, cephalothorax and neck region, ventral; C, cephalothorax, ventral, p1 = leg 1, p2 = leg 2, p3 = leg 3, p4 = leg 4; D, cephalothorax, dorsal. Scale bars: A, 3000µm; B, 1000µm; C, D, 500µm.

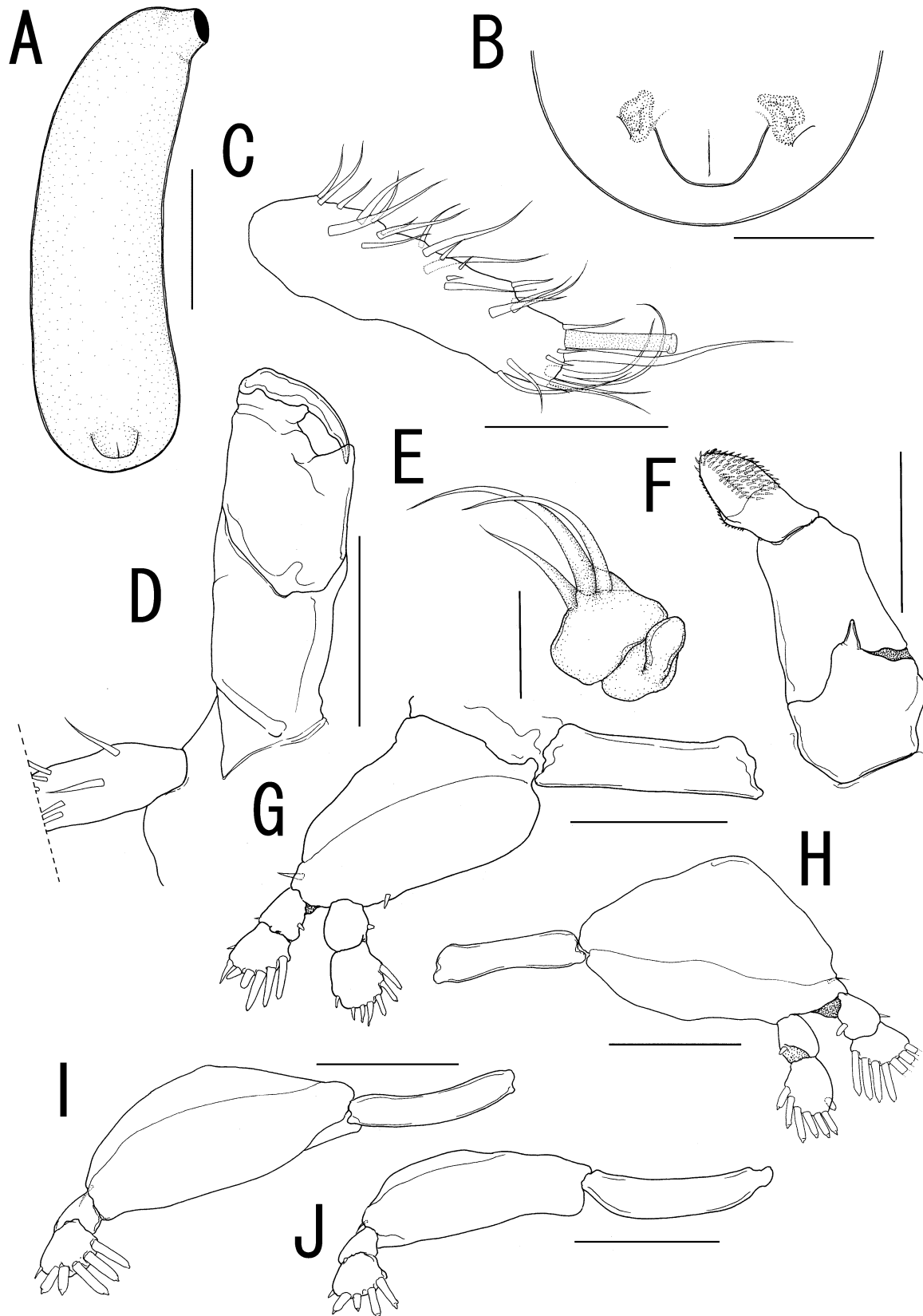


FIGURE 3. *Creopelates nohmijimensis* n. sp., female, holotype NSMT–Cr 21191. A, trunk, ventral; B, posterior part of trunk, ventral; C, antennule, posterior (drawn from a paratype, NSMT–Cr 21192); D, antenna and base of antennule, posterior; E, maxillule; F, maxilla, anterior; G, leg 1 (drawn from a paratype, NSMT–Cr 21192); H, leg 2 (drawn from a paratype, NSMT–Cr 21192); I, leg 3 (drawn from a paratype, NSMT–Cr 21192); J, leg 4 (drawn from a paratype, NSMT–Cr 21192). Scale bars: A, 1000 μ m; B, 400 μ m; C, I, J, 40 μ m; D, G, H, 50 μ m; E, 20 μ m; F, 30 μ m.

Type material. Holotype, female (NSMT–Cr 21191), ex *Priolepis boreus* (Snyder) (Perciformes: Gobiidae), off Irukabana (34°13'N, 132°23'E), Nohmijima Island, Hiroshima, Seto Inland Sea, Japan; 15 m depth; 12 September 2009 by D. Uyeno. Paratypes, 2 females (NSMT–Cr 21192), ex *P. boreus* off Irukabana, Nohmijima Island, Hiroshima, Seto Inland Sea, Japan; 15 m depth; 12 September 2009 by D. Uyeno.

Description of postmetamorphic adult female. Body (Fig. 2A) 7988–8906 (8447 ± 650) long ($n = 3$), curved at border of neck and trunk. Cephalothorax (Fig. 2B–D) shorter than wide [634–724 (679 ± 64) \times 1002–1248 (1086 ± 140)], oval bearing 4 lobes with digitate fringe. Neck region (Fig. 2B) fringed with series of finely digitate lobes, arranged in about ten pairs. Trunk (Fig. 3A) pyriform, longer than wide [3008–3380 (3189 ± 186) \times 984 (0.27984 ± 0)], slightly curved dorsally, with anterior end narrowing towards “neck”, with posterior process (Fig. 3B) located between oviduct orifices. Egg-sac uniseriate, curved on single plain (Fig. 1B).

Antennule (Fig. 3C) situated dorsally in proximity of antenna on anterior tip of cephalothorax; segmentation unclear, bearing 20 setae along anterior margin and 9 setae distally, 2 of which sharing common base, and 1 aesthetasc. Antenna (Fig. 3D) 3-segmented, chelate, typical pennellid; proximal segment unarmed; middle segment bearing pointed protrusion along inner medial margin, terminal segment claw like. Mouth tube located near base of antenna. Maxillule (Fig. 3E) bilobate; inner lobe with 2 distal setae and 1 basal seta; outer lobe bearing globular process. Maxilla (Fig. 3F) 3-segmented; proximal segment bearing 1 distal projection; middle segment without armature; terminal segment covered with rows of spinules on posterior surface incompletely separated. Maxilliped absent.

Legs 1 to 4 situated at anterior end of neck region closely together, not separated by long distances. Legs 1 and 2 (Fig. 3G, H) biramous, with both rami 2-segmented. Legs 3 and 4 (Fig. 3I, J) uniramous, with 2-segmented exopods; leg armature formula as follows:

	Protopod	Exopod	Endopod
Leg 1	1–1	1–1; 7	0–1; 7
Leg 2	1–0	1–1; 7	0–1; 7
Leg 3	1–0	0–0; 6	—
Leg 4	1–0	0–0; 5	—

Some setae on distal segment of legs 1 to 4 blunt with papilliform tip.

Attachment site. The cephalothorax and neck region of the copepod were embedded in the host’s head and trunk musculature, while its trunk and egg sacs protruded into the water (Fig. 1A, B).

Remarks. *Creopelates* is a monotypic genus, hitherto represented by *C. floridus* Shiino, 1958 (see Shiino 1958). The new species, *C. nohmijimensis* **n. sp.** can be easily separated from *C. floridus* by two characters: the cephalothorax bears four lobes ornamented with nodular and branching processes (Fig. 2D), and leg 4 is situated close to the preceding legs.

Etymology. The specific name of the new species, *nohmijimensis*, refers to the type locality, Nohmijima Island in Hiroshima Bay (Seto Inland Sea), known for its high biodiversity.

Genus *Cardiodectes* Wilson, 1917

Cardiodectes asper **n. sp.**

(Figs 4–7)

Type material. Holotype, female (NSMT–Cr 21193), ex *Trimma grammistes* (Tomiya) (Perciformes: Gobiidae), off Akinohama (34°47'N, 139°23'E), Izu-Oshima Island, Tokyo, North Pacific Ocean, Japan; 40 m depth; 18 March 2010 by O. Hoshino. Paratype, 1 female (NSMT–Cr 21194), ex *T. grammistes* off Akinohama, Izu-Oshima Island, Tokyo, North Pacific Ocean, Japan; 40 m depth; 18 March 2010 by O. Hoshino.

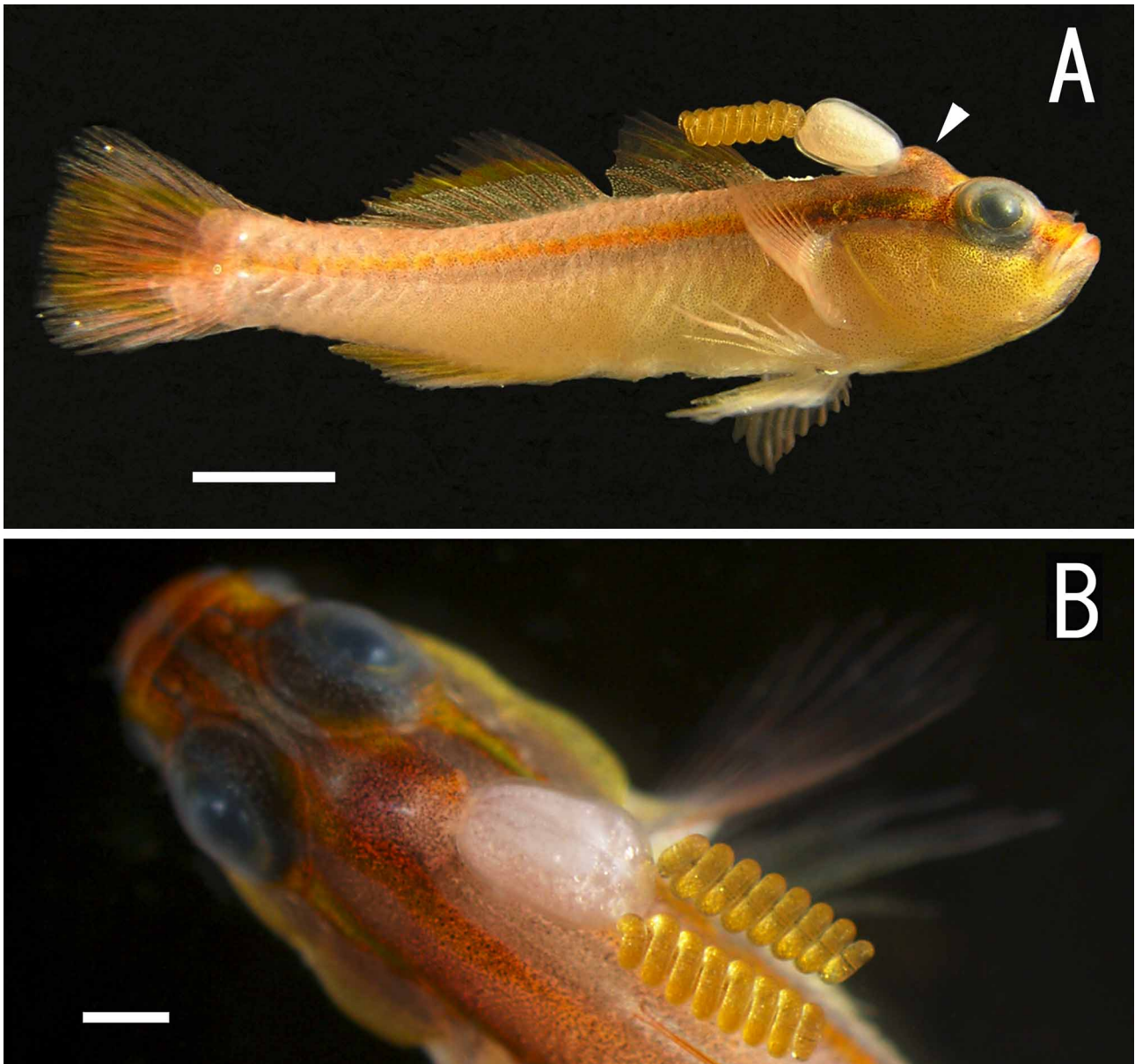


FIGURE 4. *Cardiodectes asper* n. sp., paratype NSMT–Cr 21194. A, a specimen of *Trimma grammistes* carrying the parasite which induced a swelling on the head (arrow); B, the dorsal region of the host's head carrying the parasite. Scale bars: A, 2000 μ m; B, 1000 μ m.

Description of postmetamorphic adult female. Body (Fig. 5A, B) 4093–4344 (4218 ± 177) long ($n = 2$), comprising large cephalothorax, neck region and trunk. Cephalothorax (Fig. 6A, B) slightly longer than wide [1488–1593 (1541 ± 74) \times 1380–1422 (1401 ± 30)], bearing pair of anterior digitiform lobes, expanded laterally forming two pairs of rounded lobes, one small and one large; anterior process nodular and branching, covering anterior half of cephalothorax (Fig. 5A, B, C). Neck region (Figs 5C, 6A, B) narrow, bearing pair of lobes, 90° bending in middle. Trunk (Fig. 5A, B) longer than wide [2535–2664 (2599 ± 91) \times 1581–1715 (1648 ± 94)], oval with convex posterior margin. Egg sac spiral (Fig. 4A, B) unicerate, originating at posterior lateral genital apertures.

Rostrum, antennules, and antennas situated closely to each other at anterodorsal surface of cephalothorax (Fig. 6C, D). Rostrum round (Fig. 6D), present between bases of antennules. Antennule (Fig. 6E) indistinctly segmented, bearing 8 setae mainly on anterior margin; distal tip bearing 8 setae, 4 setae sharing common base between 2 setae and 1 aesthetasc. Antenna (Fig. 6F) 3-segmented, chelate, typical pennellid; proximal segment with highly chitinous ridge on posterior surface; middle segment bearing pointed projection on inner

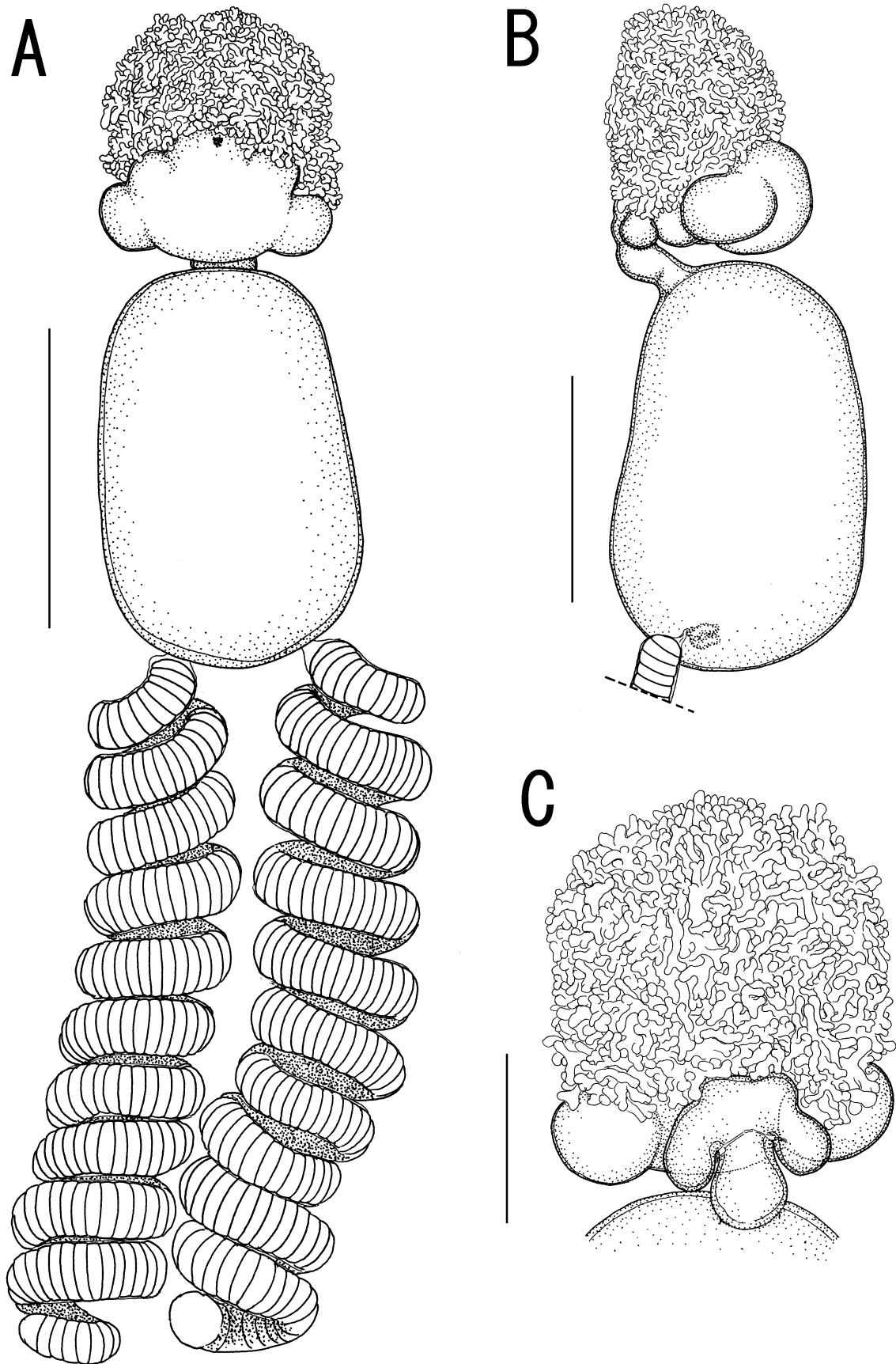


FIGURE 5. *Cardiodectes asper* n. sp., female, holotype NSMT–Cr 21193. A, habitus, dorsal; B, habitus, lateral; C, cephalothorax and neck region, ventral. Scale bars: A, 2000 μ m; B, 1500 μ m; C, 700 μ m.

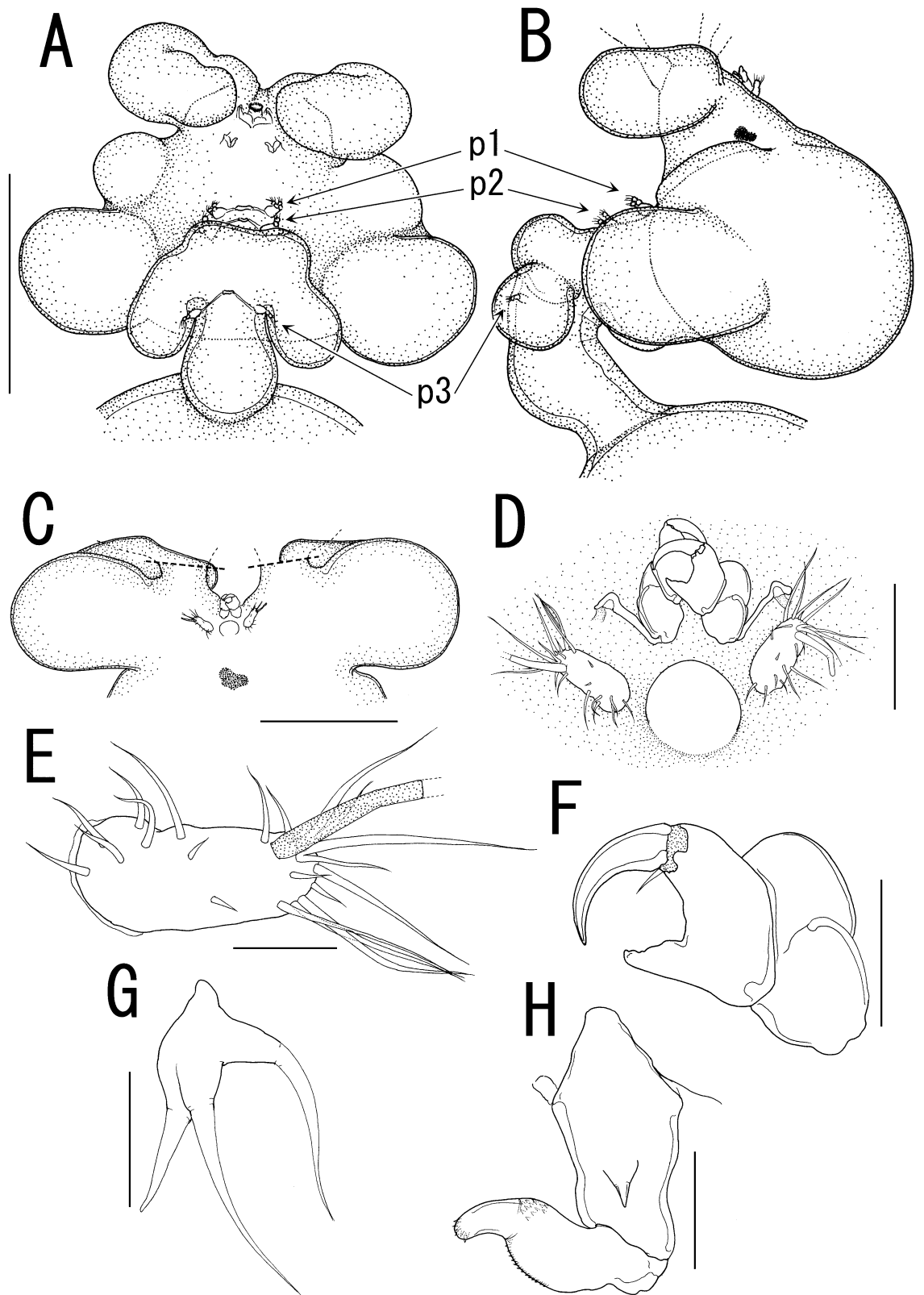


FIGURE 6. *Cardiodectes asper* n. sp., female, holotype NSMT-Cr 21193. A, cephalothorax with digitiform processes removed, ventral, p1 = leg 1, p2 = leg 2, p3 = leg 3; B, cephalothorax with digitiform processes removed and neck region, lateral, p1 = leg 1, p2 = leg 2, p3 = leg 3; C, anterior part of cephalothorax with digitiform processes removed, dorsal; D, antennules, antennae and rostrum; E, antennule, posterior; F, antenna, anterior; G, maxillule; H, maxilla, anterior. Scale bars: A, B, D, 700µm; C, 300µm; E, H, 20µm; F, 30µm; G, 15µm.

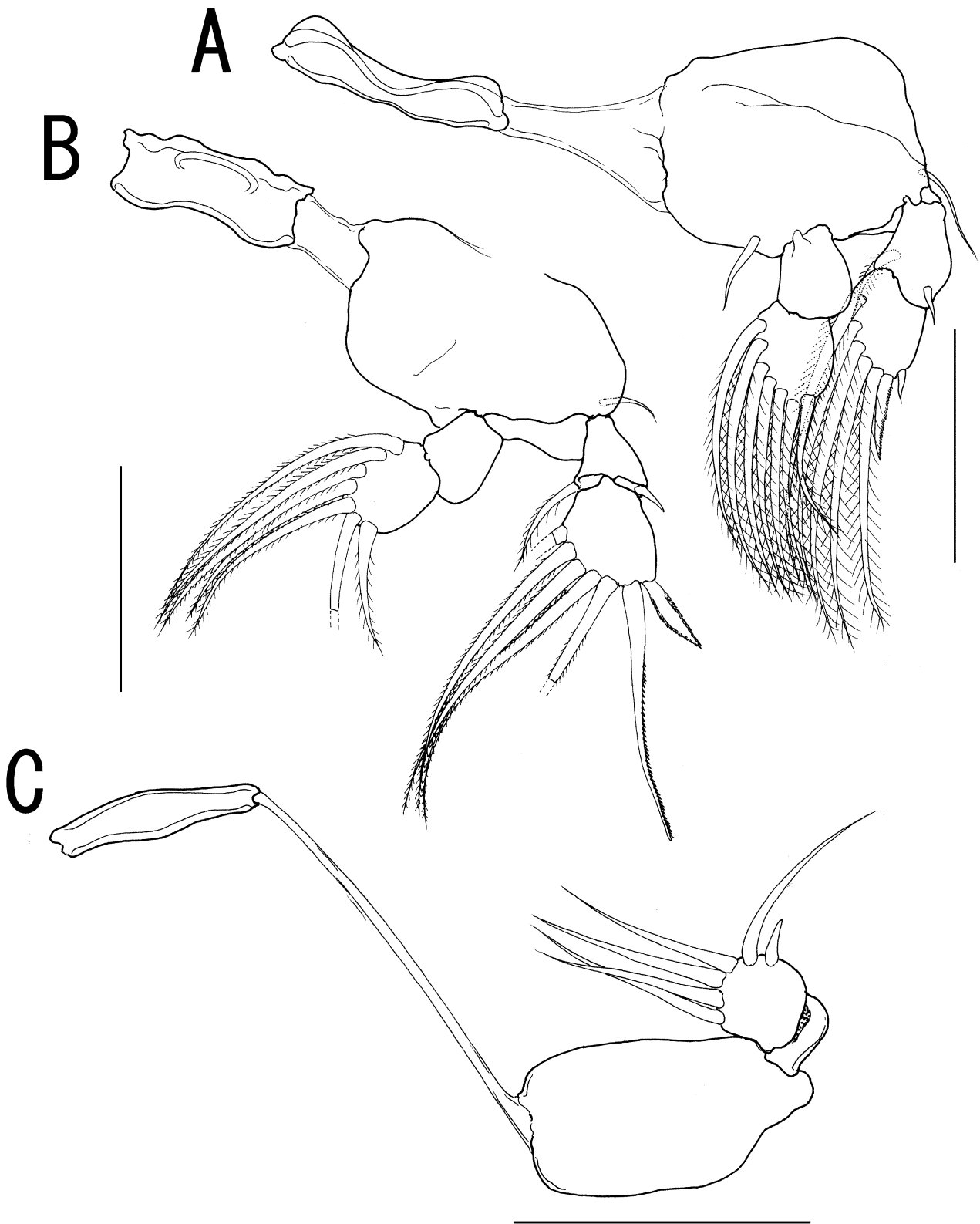


FIGURE 7. *Cardiodectes asper* n. sp., female, holotype NSMT–Cr 21193. A, leg 1; B, leg 2 (drawn from a paratype, NSMT–Cr 21194); C, leg 3 (drawn from a paratype, NSMT–Cr 21194). Scale bars: A, B, C, 50µm.

medial margin; terminal segment claw-like with 1 small seta at base. Mouth tube on anterior part on ventral surface of cephalothorax. Maxillule (Fig. 6G) in form of knob, on laterally to base of mouth tube, bearing 3 modified setal elements, 1 blunt and 2 with slightly swollen bases. Maxilla (Fig. 6H) 3-segmented separated

from mouth tube and maxillule by long gap; proximal segment with pointed process antero-medially; middle segment ornamented with fine spinules posteriorly; terminal segment tongue-shaped, covered with fine spinules on posterior surface. Maxilliped absent.

Legs 1 and 2 (Fig. 7A, B) biramous, situated centrally on cephalothorax (Fig. 6A, B). Leg 3 (Fig. 7C) uniramous, situated behind lobe on neck; endopod absent. Armature formula of all three legs as follows:

	Protopod	Exopod	Endopod
Leg 1	1-1	1-1; 7	0-0; 7
Leg 2	1-0	1-1; 7	0-0; 7
Leg 3	0-0	0-0; 6	—

Protopod of legs 1 to 3 connecting with membranous structure to intercoxal sclerites.

Attachment site. The cephalothorax and neck region of the copepod were embedded in the musculature of the host's head, while its trunk and egg sacs protruded into the water (Fig. 4A, B).

Remarks. The genus *Cardiodectes* currently comprises 12 species, which are separated into two groups, 'medusaeus' group and 'rubosus' group (Izawa 1970; Bellwood 1981). The former contains 6 species, *C. anchorellae* Brian & Gray, 1928, *C. bellottii* (Richiardi, 1882), *C. cristatus* Shiino, 1958, *C. frondosus* Schuurmans Stekhoven, 1937, *C. longicervicus* Shiino, 1958, and *C. medusaeus* (Wilson, 1908), bearing an abdomen. The latter group consists of the remaining 6 species, *C. boxshalli* Bellwood, 1981, *C. hardenbergi* Markevich, 1936, *C. krishnai* Sebastian, 1968, *C. rotundicaudatus* Izawa, 1970, *C. rubosus* Leigh-Sharpe, 1934, and *C. spiralis* Bellwood, 1981, lacking an abdomen. As the new species lacks an abdomen, it belongs to the 'rubosus' group. The species is separated from *C. boxshalli* and *C. krishnai* by having 2 pairs of large lateral lobes on the cephalothorax (Fig. 6A). The trunk of *C. hardenbergi*, *C. rotundicaudatus* and *C. rubosus* is more than twice as long as wide, but the trunk of the new species is shorter than twice the width. The new species resembles *C. spiralis* but differs in the following characters: a well developed neck lobe (Fig. 6B) with leg 3 on the posterior part of the base, and the neck 90° bending in middle.

Etymology. The specific name of the new species, *asper*, refers to the rough cephalothorax with 6 lobes.

Cardiodectes bertrandi n. sp. (Figs 8–10)

Type material. Holotype, female (MNHN–Cp 6047), ex *Eviota* sp. (Perciformes: Gobiidae), Lagoon of Ouvea (20°35'N, 166°26'E), Loyalty Islands, South Pacific Ocean, New Caledonia; 15 m depth; 20 December 2009 by D. Uyeno. Paratype, 1 female (NSMT–Cr 21195), ex *Eviota* sp., Lagoon of Ouvea (20°35'N, 166°26'E), Loyalty Islands, South Pacific Ocean, New Caledonia; 15 m depth; 20 December 2009 by D. Uyeno.

Description of postmetamorphic adult female. Body (Fig. 9A, B) 2183–2579 (2381 ± 280) long (n = 2), comprising large cephalothorax, neck region and trunk. Cephalothorax (Figs 9C, D, 10A) semitriangular in dorsal view, shorter than wide [693–1024 (858 ± 234) × 928–1034 (981 ± 75)], bearing pair of anterior small lobes, expanded laterally forming pair of round large lobes; anterior process nodular and branched. Neck region (Figs 9D, 10A) narrow, bearing 2 tubercles. Trunk (Fig. 9A, B) broad, fabiform, longer than wide [1268–1503 (1385 ± 166) × 954–1085 (1020 ± 92)], slightly constricted at middle level. Egg sacs (Fig. 8A, B) uniseriate, coiled, protruding from oviduct orifices situated on posterolateral margins.

Antennule (Fig. 10B) on anterodorsal surface of cephalothorax; segmentation indistinct, carrying 8 setae along anterior margin; distal tip bearing 7 setae, 2 of which sharing common base, and 1 aesthetasc. Antenna (Fig. 10C) located posterior to antennules, 3-segmented, chelate, typical pennellid; proximal segment with chitinous, longitudinal ridge; middle segment bearing pointed projection on distal tip of inner margin and short chitinous, central ridge; terminal segment claw-like without armature. Mouth tube located on anterior part of ventral surface of cephalothorax. Maxillule (Fig. 10D) knob-like, situated on side of mouth tube,

armed with 2 sharp, tapered processes on distal tip and attenuate process at base. Maxilla (Fig. 10E) 3-segmented, located closely behind of maxillule; proximal segment bearing single distal sharp process on inner margin, ornamented with small spinules around distal margin of posterior surface; middle segment carrying small spinules on distal part of posterior surface; terminal segment almost covered with small spinules on anterior surface. Maxilliped absent.

Legs 1 to 2 (Fig. 10F, G) biramous, situated centrally on cephalothorax (Fig. 10A). Leg 3 (Fig. 10H) uniramous, situated on posterior base of knob on neck region, separated from preceding legs by long gap (Fig. 10A); endopod absent. Armature formula of all three legs as follows:

	Protopod	Exopod	Endopod
Leg 1	1-1	1-1; 7	0-0; 7
Leg 2	1-0	1-1; 7	0-0; 7
Leg 3	0-0	0-0; 6	—

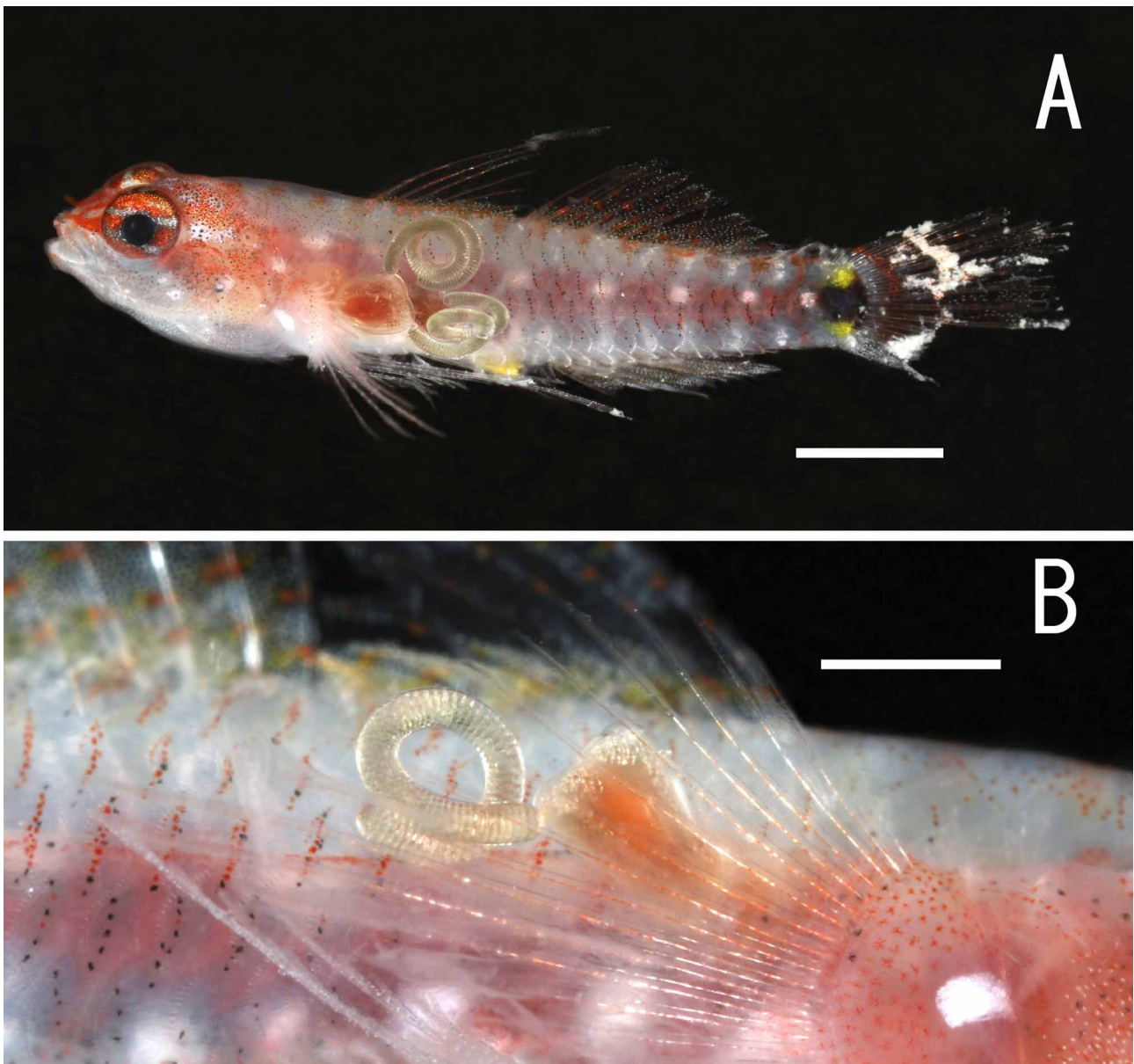


FIGURE 8. *Cardiodectes bertrandi* n. sp., female. A, a specimen of *Eviota* sp. carrying the holotype (MNHN-Cp 6047); B, a specimen of *Eviota* sp. carrying a paratype (NSMT-Cr 21195). Scale bars: A, 2000µm; B, 1000µm.

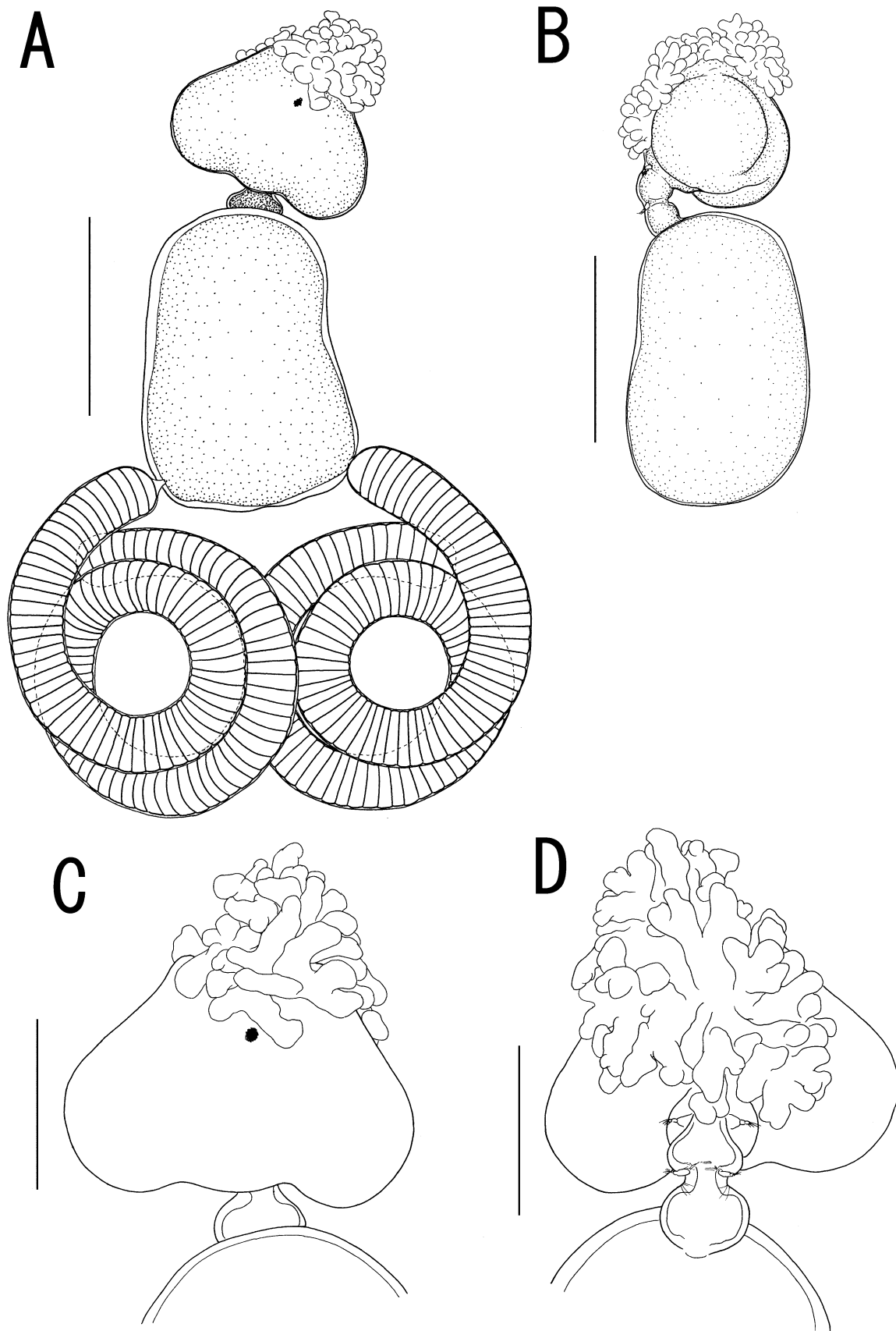


FIGURE 9. *Cardiodectes bertrandi* n. sp., female, holotype MNHN-Cp 6047. A, habitus, dorsal; B, habitus, lateral; C, cephalothorax and neck region, dorsal; D, cephalothorax and neck region, ventral. Scale bars: A, B, 1000 μ m; C, D, 500 μ m.

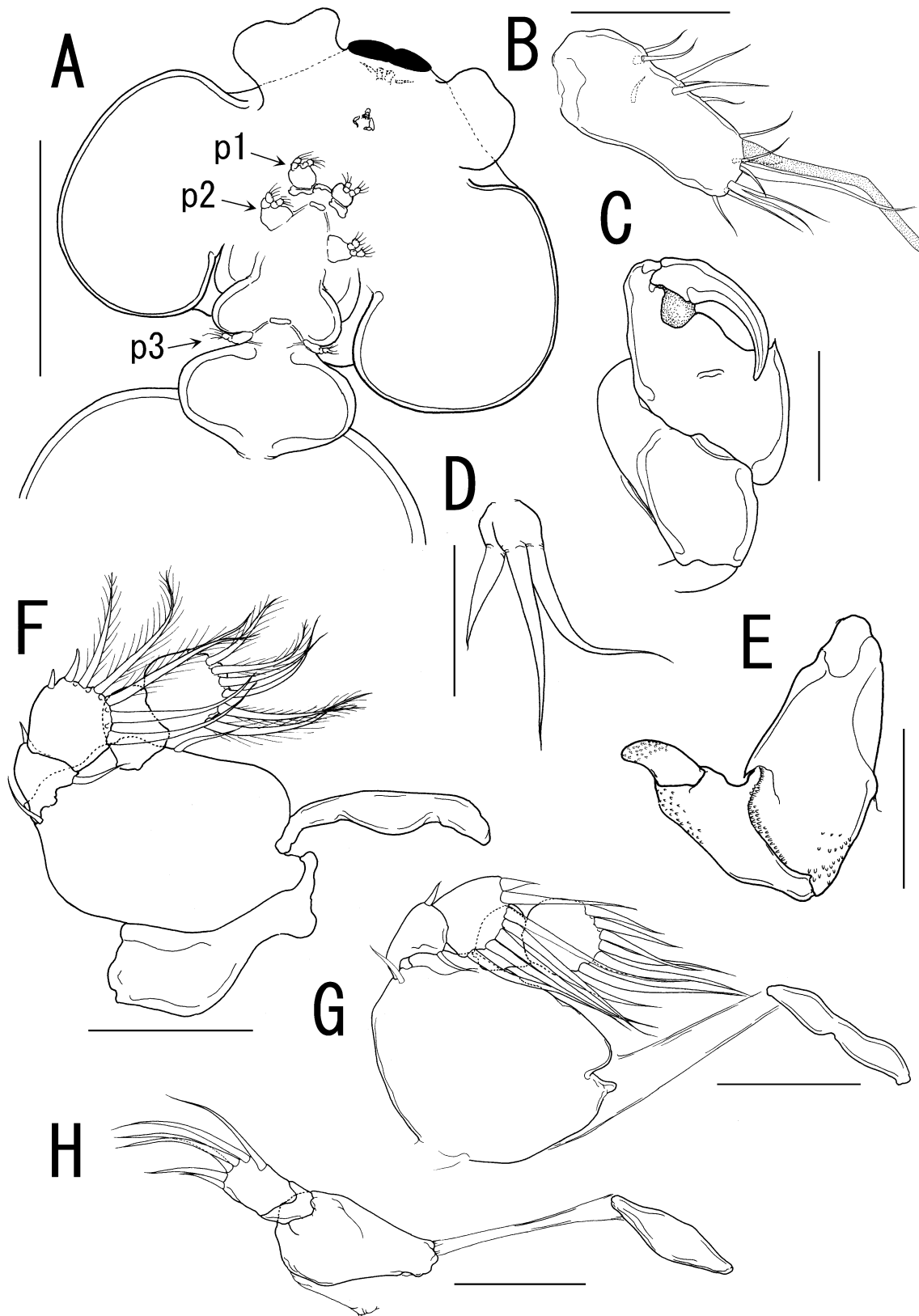


FIGURE 10. *Cardiodes bertrandi* n. sp., female, holotype MNHN-Cp 6047. A, cephalothorax with digitiform processes removed and neck region, ventral (drawn from a paratype, NSMT-Cr 21195), p1 = leg 1, p2 = leg 2, p3 = leg 3; B, antennule, posterior; C, antenna, posterior; D, maxillule; E, maxilla, anterior; F, leg 1 (drawn from a paratype, NSMT-Cr 21195); G, leg 2 (drawn from a paratype, NSMT-Cr 21195); H, leg 3 (drawn from a paratype, NSMT-Cr 21195). Scale bars: A, 400 μ m; B, F, G, H, 30 μ m; C, D, E, 20 μ m.

Anterior side of legs 1 to 3 pressed against ventral surface of each pediger. Protopod of legs 2 to 3 connecting by membranous structures to intercoxal sclerites.

Attachment site. The cephalothorax and neck region of copepod were embedded under the skin, near the pectoral fin of the host (Fig. 8A, B).

Remarks. As stated above, two groups, ‘medusaeus’ group and ‘rubosus’ group have been recognized in the genus *Cardiodectes* by the presence or absence of the abdomen (Izawa 1970; Bellwood 1981). The new species, *C. bertrandi* **n. sp.**, lacks an abdomen and thus is also assigned to the ‘rubosus’ group. The new species bears a pair of small anterior lobes concealed under the nodular processes and a pair of large posterior lobes on the cephalothorax (Fig. 10A), while both these pairs of lobes in *C. asper* **n. sp.** (Fig. 6A, B), *C. hardenbergi*, *C. rotundicaudatus*, *C. rubosus* and *C. spiralis* are large. *Cardiodectes krishnai* differs from the new species by having a trunk about 5 times as long as wide versus less than two times (Fig. 9 A, B). The new species resembles *C. boxshalli* but differs in the following characters: a cephalothorax without a pair of large processes, protopods of legs 2 to 3 not connected to the intercoxal sclerites, and leg 3 situated on the neck region and separated from preceding legs by long gap.

Etymology. The specific name of the new species, *bertrandi*, is dedicated to Dr. Bertrand Richer de Forges, an outstanding carcinologist in New Caledonia, who assisted with the collection of the specimens.

Discussion

Females of the copepods family Pennellidae become excessively transformed during postmating metamorphosis (Kabata 1979; Boxshall & Halsey 2004). The shape of the trunk of females that did not undergo metamorphosis is distinctly different from those of the postmetamorphic females. Females of some species are capable of maturing and spawning before metamorphosis (Izawa 1965; Radhakrishnan 1977; Uyeno & Nagasawa 2010). In this study, *Creopelates nohmijimensis* **n. sp.** is described based on the postmetamorphic females. We also found premetamorphic females but their trunks were not fully grown but were smaller and narrower than those of the postmetamorphic females.

The genus *Creopelates* has hitherto been monotypic and *C. nohmijimensis* **n. sp.** is the second known species in this genus. It is possible that another pennellid, *Haemobaphes dilectus* Leigh-Sharpe, 1934, may also belong to *Creopelates*. This species definitely does not belong to *Haemobaphes* because its neck region bears a pair of branched processes instead of simple processes. Additionally its trunk is not sigmoid and is without lateral processes (Leigh-Sharpe 1934, fig. 36). Instead it has features typical of those of the genus *Creopelates* (Shiino 1958; present study). Unfortunately, the original description of *H. dilectus* by Leigh-Sharpe (1934) lacks much information about the neck region and cephalothorax. It is thus difficult at this moment to confirm the taxonomic position of this species.

Almost all pennellids are known as mesoparasites of fishes (Kabata 1979) and their negative impact on the hosts have been reported (e.g., Kabata & Forrester 1974; Nagasawa & Maruyama 1986; Becheikh *et al.* 1997), e.g. *Cardiodectes medusaeus* (Wilson, 1917) is known to reach the heart of the host (Kabata 1970; Perkins 1983). In this study, the three new species belonging to *Creopelates* and *Cardiodectes* were found to have inserted the anterior part of their bodies into the host’s musculature. The cephalothorax of *C. asper* **n. sp.** was found above the host’s cranium, and the head skin around the affected area was swollen (Fig. 4, arrow). The cephalothorax and neck region of *Cardiodectes bertrandi* **n. sp.** are short and these were found immediately posterior to the host’s pectoral girdle (Fig. 8). *Creopelates nohmijimensis* **n. sp.** reached the host’s vertebrae or cranium. These copepods may have some pathological effects and may stress their hosts since the observed infected gobiids looked slightly emaciated or weaker than non-infected hosts and frequently had a damaged caudal fin (Figs 1 A, B, 8A).

Parasitic copepods of marine fishes are now often observed by SCUBA divers. In this study, we described two new species, *Cardiodectes asper* **n. sp.** and *C. bertrandi* **n. sp.**, of parasitic copepods on gobiids caught by SCUBA divers in the coastal waters of the Pacific Ocean. Almost all gobiid fishes are of little importance to fisheries. Furthermore, the members of this family are generally small, rarely exceeding 50 cm (Akihito *et*

al. 2000). These factors may have contributed to the limited research done on the parasitic fauna of gobiids. Only a few parasitic copepod species have been reported from gobiid fishes, especially from the sublittoral zone. However, the family Gobiidae currently comprises about 268 genera and 2,121 species (Nelson 2006) with a worldwide geographical distribution, excluding the Arctic and Antarctic areas (Akihito *et al.* 2000). Therefore, it is highly probable that many undescribed species of parasitic copepods, including pennellids, will be found in the future and SCUBA divers could make an important contribution to the discovery of these parasites.

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