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Doridicola similis (Copepoda: Poecilostomatoida: Rhynchomolgidae) Associated with *Sepioteuthis* sp. (Cephalopoda: Myopsida: Loliginidae), New to Japan

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Female and male specimens of *Doridicola similis* Ho and Kim, 2001 (Copepoda: Poecilostomatoida: Rhynchomolgidae) from the gills of the loliginid squid *Sepioteuthis* sp. (called *shiro-ika*) (Cephalopoda: Myopsida: Loliginidae) in coastal Pacific waters of central Japan are described as a new country record. This collection represents the second record of *D. similis* and expands its distribution range from the Gulf of Thailand (type locality) northeast to the western North Pacific Ocean off central Japan.

Key Words: *Doridicola similis*, *Sepioteuthis* sp., new country record, symbiotic copepod, cephalopod.

Introduction

The symbiotic copepods of cephalopods are poorly known in Japan [see Nagasawa (1993) for the known parasites of Japanese cephalopods]. Originally, *Lichomolgus sepiiae* Izawa, 1976 was described from the gills of *Sepia esculenta* Hoyle, 1885 (Sepiida: Sepiidae) in Tanabe Bay, Wakayama Prefecture, central Japan (Izawa 1976). Ho (1980) transferred this copepod species to *Metaxymolgus* Humes and Stock, 1972 (see also Ho 1983), but more recently, it has been placed in *Doridicola* Leydig, 1853 (Humes and Stock 1983; Izawa 1986; Ho and Kim 2001). Other than this, Avdeev (1982, 1986) described five species of tishid copepods (Harpacticoida) taken mostly from deep-water octopods off the Pacific coasts of Honshu and Hokkaido, Japan: *Cholidyella incisa* Avdeev, 1982 (generic name initially misspelled as *Cholydiella*) from *Graneledone* sp. (Megaleledonidae); *C. breviseta* Avdeev, 1986 from *Opisthoteuthis californiana* Berry, 1949 (Opisthoteuthidae); *C. nesisi* Avdeev, 1986 from *Muusoctopus profundorum* (Robson, 1932) (as *Benthoctopus profundorum*) (Enteroctopodidae) and *M. fuscus* (Taki, 1964) (as *B. fuscus*); *Brescianiana rotundus* Avdeev, 1982 from *Graneledone* sp.; and *Octopinella tenacis* Avdeev, 1986 from *B. profundorum* (Enteroctopodidae), *Octopus longispadiceus* (Sasaki, 1917) (Octopodidae), and *Octopus* sp.

Here we report on recently collected female and male *Doridicola similis* Ho and Kim, 2001 from the gills of loliginid squids in coastal Pacific waters of central Japan. This copepod so far has been reported only from Thailand (Ho and Kim 2001). We thus report *D. similis* as a new country record and provide a morphological description of the specimens.

Materials and Methods

Two individual squids, which were later identified as *Sepioteuthis* sp. 2 (called *shiro-ika*, see Imai and Aoki 2012) based on molecular analysis (Satoshi Tomano, Graduate School of Biosphere Science, Hiroshima University personal communication), were collected by lure fishing in Owase Bay (34°05'37.7"N, 136°14'45.2"E) off the coast of Hiki-Motoura, Kihoku, Mie Prefecture, Honshu, central Japan, on 21 July 2015. The dorsal mantle length (DML) of each squid was recorded, and the gills were removed from both specimens, and transported on ice to the laboratory at Hiroshima University, Higashi-Hiroshima, Hiroshima Prefecture, where copepods were carefully removed from the gills and fixed in 70% ethanol. Five females and 10 males of copepods were later soaked in lactophenol, dissected, and observed using the wooden slide method of Humes and Gooding (1964). Drawings were made with the aid of a drawing tube fitted on an Olympus BX51 compound microscope. Measurements are given as the range followed by the mean in parentheses. Morphological terminology follows mainly Humes and Boxshall (1996). Voucher specimens are deposited in the Crustacea collection of the National Museum of Nature and Science, Tsukuba, Ibaraki Prefecture, Japan (NSMT-Cr 25448 for four females and 25449 for four males).

Doridicola similis Ho and Kim, 2001
(Figs 1–3)

Doridicola similis Ho and Kim, 2001: 80–84, figs 1–3 (type locality: Gulf of Thailand).

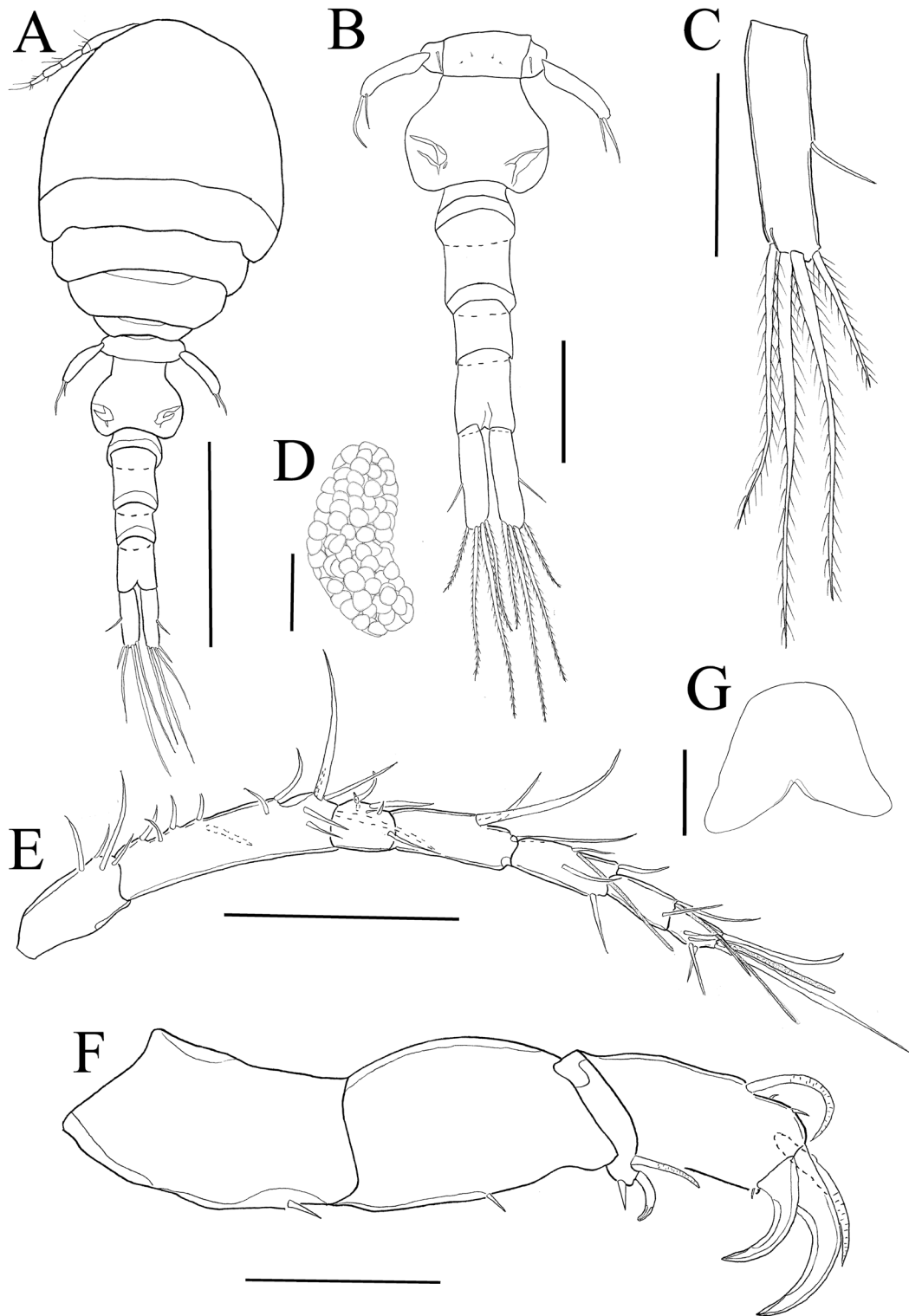


Fig. 1. *Doridicola similis*, female (NSMT-Cr 25448). A, habitus, dorsal; B, urosome, dorsal; C, caudal ramus, dorsal; D, egg sac; E, antennule; F, antenna; G, labrum. Scale bars: A, 500 μm ; B, D, 200 μm ; C, G, 50 μm ; D, E, 100 μm .

Description of female. Body (Fig. 1A) cyclopiform, 1.45–1.65 (1.54) mm long (excluding setae on caudal rami) and 0.55–0.63 (0.59) mm wide (greatest width of cephalothorax) (measurements based on 5 specimens). Prosome (Fig. 1A) comprising cephalosome and four pedigerous somites. Anterior margin of cephalothorax smoothly rounded. Cephalosome separated by dorsal furrow from first pedigerous

somite, with protrusions at posterolateral corners of latter. First to fourth pedigerous somites progressively decreasing in size. Urosome (Fig. 1B) 5-segmented. Fifth pedigerous somite wider than long. Genital double somite (Figs 1B, 3C) wider than long, respectively 200–250 (235) \times 190–235 (210) μm , with anterodorsal bulge and posterolateral egg-sac attachment areas. Three free abdominal somites (Fig.

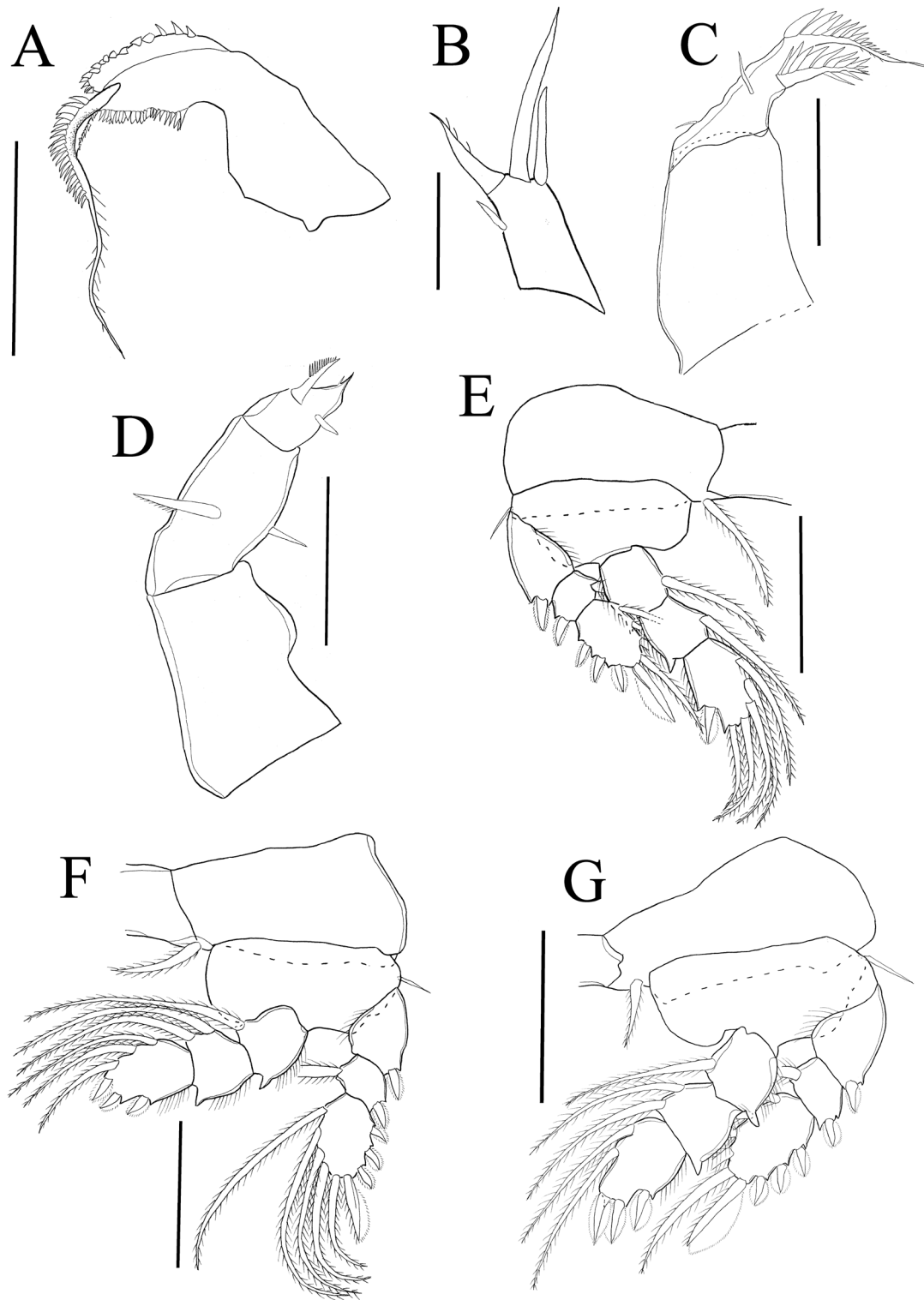


Fig. 2. *Doridicola similis*, female (NSMT-Cr 25448). A, mandible; B, maxillule; C, maxilla; D, maxilliped; E, leg 1; F, leg 2; G, leg 3. Scale bars: A, C, D, 50 μ m; B, 10 μ m; E–G, 100 μ m.

1B) 85–150 (110) \times 105–123 (116), 75–103 (92) \times 95–105 (102), and 128–138 (133) \times 98–113 (107) μ m long and wide, respectively. Caudal rami (Fig. 1C) 3.80–4.12 (4.00) times longer than wide, 165–185 (177) \times 40–45 (44) μ m, and bearing 4 plumose setae at posterior extremity and 2 additional short setae (1 on outer lateral margin and other near posterior extremity). Egg sac (Fig. 1D) elliptical and slightly

curved, 540 \times 240 μ m ($n=1$).

Antennule (Fig. 1E) 7-segmented, with armature formula: 4, 13, 6, 3, 4+1 aesthetasc, 2+1 aesthetasc, and 7+1 aesthetasc. Antenna (Fig. 1F) 4-segmented, with armature formula: 1, 1, 2+1 small claw, and 5+2 large, unequal claws. Labrum (Fig. 1G) with pair of large posteroventral lobes. Mandible (Fig. 2A) with shallow proximal notch; inner mar-

Table 1. Armature formula of legs 1–4 of *Doridicola similis* Ho and Kim, 2001, adult female, spines and setae indicated in Roman and Arabic numerals, respectively.

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

gin linear with row of short, thick spinules; convex margin with 3 outer scales followed by row of short, thick spinules; terminal lash long, tapering, bilaterally spinulose. Maxillule (Fig. 2B) with 2 terminal and 2 subterminal setae, one of former with spinules. Maxilla (Fig. 2C) 2-segmented; syncoxa unarmed; basis with large seta (seta I) bearing long spinules on both margins, simple seta (seta II) on posterior surface, and simple small seta (seta III) on outer margin of base; terminal lash armed along one side with large spinules. Maxilliped (Fig. 2D) 3-segmented; syncoxa largest, unarmed; basis carrying small simple seta and longer unilaterally spinulate seta; free endopodal segment terminating in barbed spiniform process with long spinulate spine and short simple seta at base.

Legs 1–4 (Figs 2E–G, 3A) biramous with 3-segmented rami, except for 2-segmented endopod of leg 4. Armature formula of legs 1–4 shown in Table 1.

Leg 5 (Fig. 3B) consisting of elongate free segment with 2 unequal simple setae at tip. Leg 6 (Fig. 3C) represented by 2 small naked setae in posterodorsal area of genital double somite.

Description of male. Body (Fig. 3D) cycloform, 1.29–1.49 (1.38) mm long (excluding setae on caudal rami) and 0.39–0.46 (0.42) mm wide (measurements based on 10 specimens). Prosome 5-segmented and urosome 6-segmented. Genital somite wider than long, 235–295 (267) × 210–235 (227) μ m. Caudal rami 3.25–3.63 (3.41) times longer than wide. Antenna (Fig. 3E) similar to that of female but proximal half of inner margin of second segment ornamented with small spinules.

Maxilliped (Fig. 3F) 4-segmented, subchelate; syncoxa unarmed; basis with row of spinules and 2 inner setae; free endopodal segment smallest, unarmed; terminal claw bearing lamellae near tip and 2 unequal setae near base. Leg 5 (Fig. 3G) tipped with 2 unequal simple setae. Leg 6 (Fig. 3H) represented by small lobe bearing 2 ventral naked setae at posterolateral corner of genital somite.

Host. *Sepioteuthis* sp. 2 (called *shiro-ika*, see Imai and Aoki 2012) (Cephalopoda: Myopsida: Loliginidae)

Locality. Western North Pacific Ocean, Owase Bay off the coast of Hiki-Motoura, Kihoku, Mie Prefecture, Honshu, central Japan.

Site. Gills.

Number of copepods per squid. Forty-one and 91 individuals each on the two squids examined (220 and 205 mm DML).

Remarks. As indicated by Ho and Kim (2001), the three species of *Doridicola* reported from cephalopods, *viz.*,

Doridicola longicauda (Claus, 1860) from *Sepia officinalis* Linnaeus, 1758 in Europe (Ho 1983), *Doridicola similis* Ho and Kim, 2001 from *Sepioteuthis lessoniana* Férussac in Lesson, 1831 in Thailand (Ho and Kim 2001), and *D. sepiiae* from *Sepia esculenta* in Japan and Korea (Izawa 1976; Kim 1998), are morphologically very similar, but they are distinguished from each other by the length-to-width ratio of the female caudal rami: 2.2, 4.22, and 3.18 times longer than wide, respectively (see also the next paragraph). In the female specimens examined in this study, this value ranges from 3.80 to 4.12 (mean: 4.00) and is almost identical to that in *D. similis*. Our specimens are also separated from *D. longicauda* and *D. sepiiae* by the absence of a protrusion on the anterior margin of the cephalothorax. It is thus reasonable to identify our specimens as *D. similis*, although the following slight differences are found between Japanese and Thai specimens: (1) scales are present on the convex margin of the mandible in the Japanese female specimens but absent in the Thai females, and (2) a seta on the basis of the leg 4 is naked in the Japanese female specimens but barbed in the Thai females.

Ho and Kim (2001) reported, based on Izawa (1976), that the length-to-width ratio of the female caudal rami of *D. sepiiae* was 3.18:1, which, however, differs from the value (“nearly 3.5 times”) reported by the latter author (p. 92). One possible explanation for this difference is that Ho and Kim (2001) did not notice Izawa’s (1976) printed data, and they measured the caudal ramus using Izawa’s fig. 1. We obtained a similar ratio (3.13:1 as the average for the left and right caudal rami) from this figure. Using material of *D. sepiiae* from Korea, Kim (1998) reported a ratio of 3.22:1.

In the original description of *D. similis*, Ho and Kim (2001) misidentified maxillary seta III and seta I as “seta I” and “seta III”, respectively, both having been originally defined by Humes and Boxshall (1996: 178, fig. 1). Ho and Kim (2001) also misreported the female’s leg 4 (fig. 3A), free segment of leg 5 (fig. 3B), and genital area (fig. 3c) as those of the male in their figure caption.

Discussion

The present collection of *D. similis* represents the second record of the species and a new country record in Japan, which expands its distribution range from the Gulf of Thailand (Ho and Kim 2001) northeast to the western North Pacific Ocean off central Japan. Although the two locations are distantly separated from each other and belong to the tropical and temperate regions, respectively, the sampling site in Japan is constantly affected by a warm current, the Kuroshio, flowing from the Philippines, which may allow *D. similis* to occur there.

The Japanese stock of squids previously known as *Sepioteuthis lessoniana* is divided into three species, *viz.*, *Sepioteuthis* sp. 1 (called *aka-ika*), *Sepioteuthis* sp. 2 (*shiro-ika*), and *Sepioteuthis* sp. 3 (*kua-ika*), by external morphological features (including the shape of their egg capsules) and molecular data. *Sepioteuthis* sp. 2 is widely distributed in coastal

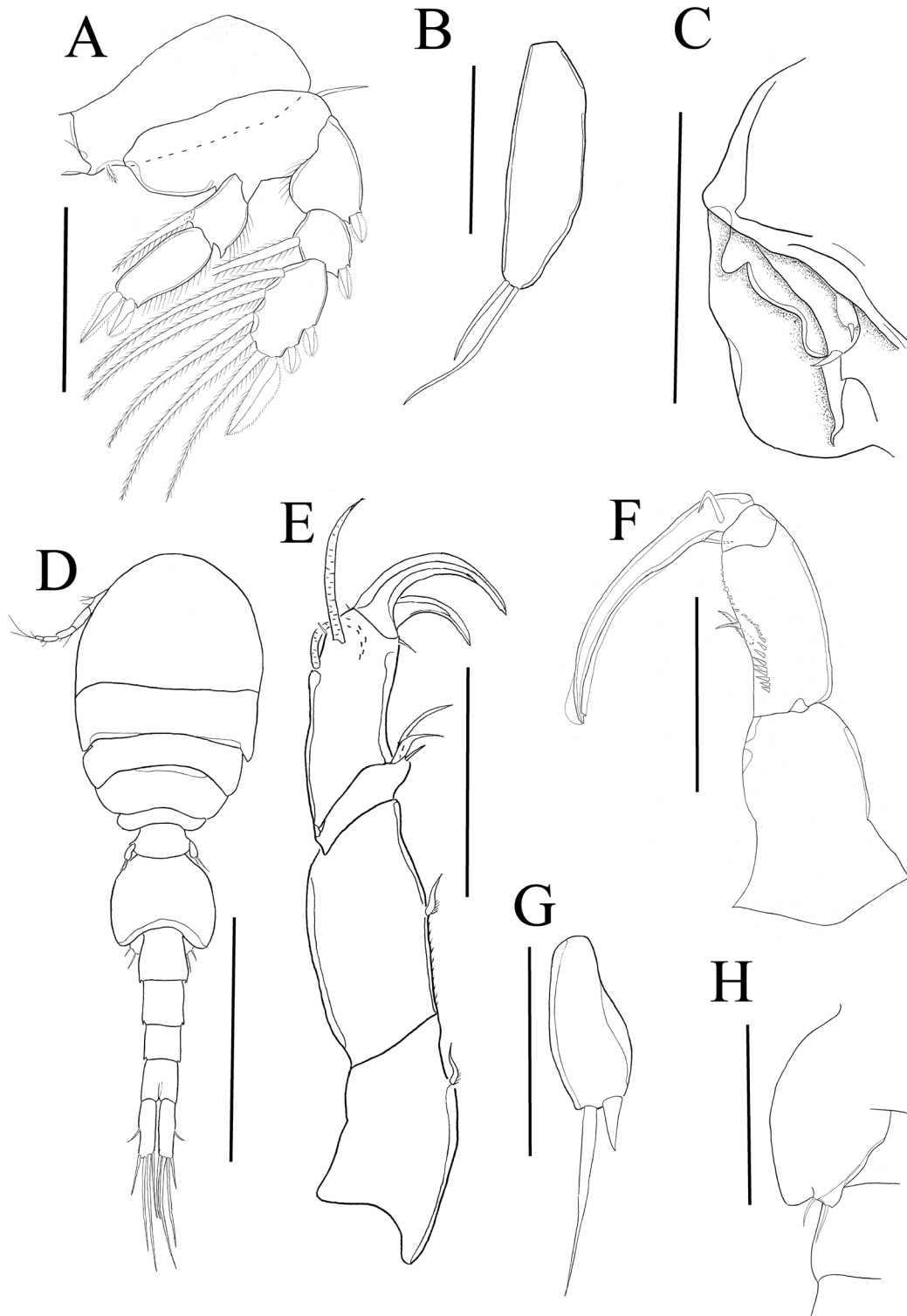


Fig. 3. *Doridicola similis*. A–C, female (NSMT-Cr 25448): A, leg 4; B, free segment of leg 5; C, posterior surface of genital double-somite and leg 6, dorsal. D–H, male (NSMT-Cr 25449): D, habitus, dorsal; E, antenna; F, maxilliped; G, free segment of leg 5; H, part of genital somite and leg 6, ventral. Scale bars: A–C, 100 μ m; D, 500 μ m; E, F, 100 μ m; G, 50 μ m; H, 200 μ m.

waters of the East China Sea, the Sea of Japan, and the western North Pacific Ocean along the Japanese Archipelago from the Ryukyu Islands in the south to southern Hokkaido in the north, while *Sepioteuthis* sp. 1 and *Sepioteuthis* sp. 3 occur off the Ryukyu Islands and the Ogasawara Islands (Izuka *et al.* 1994, 1996; Imai and Aoki 2012; Tomano *et al.*

2015). In this study, we collected *D. similis* from *Sepioteuthis* sp. 2 caught in the Pacific waters of central Japan. It is desirable to study the occurrence of *D. similis* on these closely related host species from different locations in order to document its host utilization and geographical distribution patterns in Japanese waters.

More than 160 species in 36 families and five orders of cephalopod have been recorded from Japanese waters (Kubodera 1997). Of these species, only five nominal and three unidentified species, namely *Sepia esculenta* (Sepioidae: Sepiidae), *Sepioteuthis* sp. 2 (Myopsida: Loliginidae), *Graneledone* sp., *Octopus longispadiceus*, *Octopus* sp. (Octopoda: Octopodidae), *Opisthoteuthis californiana* (Octopoda: Opisthoteuthidae), *Muusoctopus profundorum*, and *M. fuscus* (Octopoda: Enteropodidae), have been reported to harbor a total of seven species of symbiotic copepod (Izawa 1976; Avdeev 1982, 1986; this study; see the Introduction herein). Much remains to be studied on the symbiotic copepod fauna of Japanese cephalopods.

Acknowledgments

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