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Daisuke Uyeno
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# A New Species of the Enigmatic Copepod Genus *Lernaeascus* (Cyclopoida: Philichthyidae), Parasitic on Angelfishes (Actinopterygii: Pomacanthidae) from the Ryukyu Islands, Japan

Daisuke Uyeno[1,2,5], Danny Tang[3], and Kazuya Nagasawa[4]

*[1] Florida Museum of Natural History, University of Florida, 1659 Museum Rd., Gainesville, Florida 32611, USA*
*E-mail: daisuke.uyeno@gmail.com*
*[2] Current affiliation: Graduate School of Science and Engineering, Kagoshima University,*
*1-21-35 Korimoto, Kagoshima 890-0065, Japan*
*E-mail: daisuke.uyeno@gmail.com*
*[3] Environmental Laboratory and Ocean Monitoring Division, Orange County Sanitation District,*
*10844 Ellis Avenue, Fountain Valley, California 92708-7018, USA*
*[4] Graduate School of Biosphere Science, Hiroshima University,*
*1-4-4 Kagamiyama, Higashi-Hiroshima, Hiroshima 739-8528, Japan*
*[5] Corresponding author*

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*Lernaeascus kabuto* sp. nov. (Cyclopoida: Philichthyidae) is described based on specimens of both sexes collected from two species of angelfish (Actinopterygii: Pomacanthidae), the purplemask angelfish *Centropyge venusta* (Yasuda and Tominaga, 1969) and the yellow angelfish *C. heraldi* Woods and Schultz, 1953, caught in the East China Sea near Kumejima Island, Japan. *Lernaeascus kabuto* sp. nov. is easily distinguished from its congener, *L. nematoxys* Claus, 1886, by the following characters: the male has a pair of elongate, distomedially notched dorsal plates on the second pedigerous somite, four abdominal somites, a pair of dorsal hamuli on the third abdominal somite, a non-bifurcate genital operculum, a curved proximal antennulary segment, a naked maxillule, a maxilla without a posteriorly-directed process on the syncoxa, and the endopod of leg 1 modified into a simple spine; and the female has a triangular antenna, a styliform process on the labrum, and three setae on the exopods of legs 1 and 2.

**Key Words:** *Lernaeascus kabuto* sp. nov., parasitic copepod, mucous canal, *Centropyge* spp., KUMEJIMA 2009 Expedition.

## Introduction

The Philichthyidae presently include nine genera and 87 species of highly modified, bizarre-looking copepods (Walter and Boxshall 2015). Among the nine genera, *Colobomatus* Hesse, 1873 is the most speciose, with 70 species. Species of *Colobomatus*, *Colobomatoides* Essafi and Raibaut, 1980, *Leposphilus* Hesse, 1866, *Philichthys* Steenstrup, 1862, *Procolobomatus* Castro Romero, 1994, and *Sphaerifer* Richiardi, 1874 occur in the subcutaneous spaces associated with the sensory canals of the lateral line and/or skull bones of marine actinopterygian fishes (Kabata 1979; Boxshall and Halsey 2004). By contrast, species of *Ichthyotaces* Shiino, 1932 and *Sarcotaces* Olsson, 1872 reside within a cyst in the host tissue (Shiino 1932; Izawa 1974; Boxshall and Halsey 2004), while the single known species of *Lernaeascus* Claus, 1886 inhabits the mucous canals underneath the scales of its flatfish host (Claus 1886, 1887).

The monotypic *Lernaeascus* is hitherto known from only the whiskered sole *Monochirus hispidus* Rafinesque, 1814 (as *Solea monochir* Bonaparte, 1833) in European waters (Claus 1886, 1887, 1888; Dollfus 1927). Although Yamaguti (1963) established the Lerneascidae (sic) to accommodate *Lernaeascus nematoxys* Claus, 1886, this family is currently considered a junior synonym of Philichthyidae (Kabata 1979; Boxshall and Halsey 2004). Recently, we discovered an undescribed species of *Lernaeascus* parasitizing specimens of the purplemask angelfish *Centropyge venusta* (Yasuda and Tominaga, 1969) and the yellow angelfish *C. heraldi* Woods and Schultz, 1953 caught in the East China Sea off Kumejima Island, Japan, during the Kumejima Marine Biodiversity Expedition (a.k.a. KUMEJIMA 2009 Expedition, see Naruse *et al.* (2012)). Additional *Lernaeascus* material was subsequently collected in 2010 from a purplemask angelfish captured off Kumejima Island. In this study, this new species of *Lernaeascus* collected from these angelfish is described based on specimens of both sexes.

## Materials and Methods

Angelfish were caught with a gill net positioned at the bottom of a cliff and/or with a hand net on a reef flat in November 2009 during the KUMEJIMA 2009 Expedition and in August 2010 off Kumejima Island, central Ryukyu Islands, Japan. Each host fish was bathed in freshwater post-capture and then the bathwater was poured through a fine net (100 µm); the contents retained in the net were transferred to a petri dish filled with tap water and any copepod specimens were removed from the petri dish under a dissecting microscope and fixed/preserved in 80% ethanol. Specimens were soaked in lactophenol for 10 to 12 h before being dissected and observed using the method of Humes and Gooding (1964). Measurements (in µm) were taken using an ocular micrometer and are given as the range followed by the mean plus standard deviation in parentheses. Drawings were made with the aid of a drawing tube. Type specimens are deposited in the crustacean collection of the National Museum of Nature and Science, Tsukuba (NSMT), Ibaraki, Japan, the Kagoshima University Museum (KAUM), Kagoshima, Japan and the University of the Ryukyus Museum, Fujukan (RUMF), Okinawa, Japan. The scientific and common names of fishes follow Froese and Pauly (2015).

### ***Lernaeascus kabuto*** sp. nov.
(Figs 1–4)

**Type material.** Holotype male (NSMT-Cr 24277) and allotype female (NSMT-Cr 24278), ex *Centropyge venusta* (Yasuda and Tominaga) (Perciformes: Pomacanthidae), East China Sea, off Torishima Islet (26°19′N, 126°49′E), Kumejima Island, Ryukyu Islands, Japan, 40 m depth, 19 November 2009, leg. D. Uyeno. Paratypes: 2 males and 1 female (NSMT-Cr 24279), collection data as for holotype and allotype; 1 male (KAUM-AT-211), collection data as for holotype and allotype; 1 male (NSMT-Cr 24280), ex *C. heraldi* Woods and Schultz (Perciformes: Pomacanthidae), East China Sea, off Torishima Islet (26°5′N, 127°42′E), Kumejima Island, Ryukyu Islands, Japan, 8 m depth, 16 November 2009, leg. D. Uyeno; 1 male (RUMF-ZC 03913), ex *C. venusta*, East China Sea, off Shichugama (26°20′N, 126°50′E), Kumejima Island, Ryukyu Islands, Japan, 15 m depth, 25 August 2010, leg. D. Uyeno, Y. Fujita and I. Nakayoshi.

**Description of holotype male.** Body (Fig. 1A) dorsoventrally compressed, 1179 long (including caudal rami), composed of 11 somites. Cephalosome (Fig. 1A) subquadrate, slightly constricted at mid-length, longer than wide 273×222. Second pedigerous somite (Fig. 1B) bearing paired wing-like dorsal plates, each with inner subterminal notch. Urosome 586 long, composed of fifth pediger, genital somite, and four abdominal somites. Genital somite wider than long 79×132. Third abdominal somite (Fig. 1D) bearing dorsal hamulus on each posterolateral corner. Caudal ramus (Fig. 1D) bearing six setae.

Antennule (Fig. 1E) 4-segmented; proximal segment robust, elongate and anteriorly curved; armature formula 12, 3, 2+1 aesthetasc, 7+1 aesthetasc. Antenna (Fig. 1F, G) 4-segmented, consisting of coxobasis and 3-segmented endopod; coxobasis rod-like, unarmed; proximal endopodal segment rod-like, bearing three small and three large, highly sclerotised, squamate denticles on anterior surface; middle endopodal segment small, bearing large claw-like spine, seta, and large denticulate process; terminal endopodal segment bearing three claw-like spines and three setae on tip. Labrum (Fig. 2A) broad, slightly indented in middle of posterior margin. Mandible (Fig. 2A) unsegmented, bearing serrate apical blade. Paragnath absent. Maxillule (Fig. 2A) small, conical, with subterminal process and blunt tip. Maxilla (Fig. 2A) 2-segmented, comprising syncoxa and basis; syncoxa robust and elongate; basis represented by terminal blade with serrate anterior margin. Maxilliped absent.

Legs 1 and 2 (Fig. 2B, D) biramous, composed of coxa, basis, 2-segmented exopod, and spiniform endopod; armature formula of legs shown in Table 1. First exopodal segment of legs 1 and 2 (Fig. 2C, E) ornamented with small process on outer margin. Endopods of legs 1 and 2 (Fig. 2B, D) rudimentary, each represented by robust spine. Leg 3 (Fig. 2F) fused to third pediger, comprising two basal setae and unsegmented, exopod armed with two long, simple terminal setae. Legs 4 and 5 absent. Leg 6 (Fig. 1C) represented by posteroventral genital operculum (Fig. 1C), armed with minute subterminal seta.

**Variability of male morphology.** Morphology of body parts of paratypes as in holotype. Measurements of body parts of paratypes (n=5) as follows: body length 1037–1375 (1206±144); cephalosome length 225–346 (294±50); cephalosome width 159–335 (268±74); urosome length 518–658 (570±68); genital somite length 68–84 (78±6); genital somite width 107–146 (131±15).

**Description of allotype female.** Body (Fig. 3A) vermiform, 2210 long (including caudal rami), composed of cephalosome and trunk. Cephalosome (Fig. 3B, F) conical, longer than wide 234×159, with blunt frontal margin, having elliptical corrugated pad on dorso-apical surface and corrugated surface medial and lateral to antenna. Trunk (Fig. 3A, C) slightly curved, terminating in small abdomen, ornamented with longitudinal dorsal rows of serrate, crescentic plates on right side and patch of dorsal corrugations near posterior end. Genital field (Fig. 3D) with laterally paired copulatory pores. Caudal ramus (Fig. 3C, E) fused with abdomen, bearing five setae.

Antennule (Fig. 3G) 2-segmented; proximal segment longest and slightly constricted at mid-length; armature formula 17+1 aesthetasc, 6+1 aesthetasc. Antenna (Fig. 3F, H) apparently 1-segmented, arising from mid-ventral surface of cephalosome, triangular with medial conical process, lateral digitate process, and apical spine. Labrum (Fig. 4A) with broad base produced into postero-median styliform process. Mandible (Fig. 4A) unsegmented, bearing serrate apical blade. Paragnath and maxillule absent. Maxilla (Fig. 4A) 2-segmented; proximal segment (syncoxa) triangular, unarmed; terminal segment (basis) armed with 2 subequal serrate blades. Maxilliped absent.

Legs 1 and 2 (Fig. 4B, C) each comprising knob-like protopod carrying lateral seta and rod-like, 1-segmented exopod, latter bearing three distal setae on leg 1 and single medial and two distal setae on leg 2. Leg 3 (Fig. 4D) vestigial, represented by two setae. Legs 4 and 5 absent.

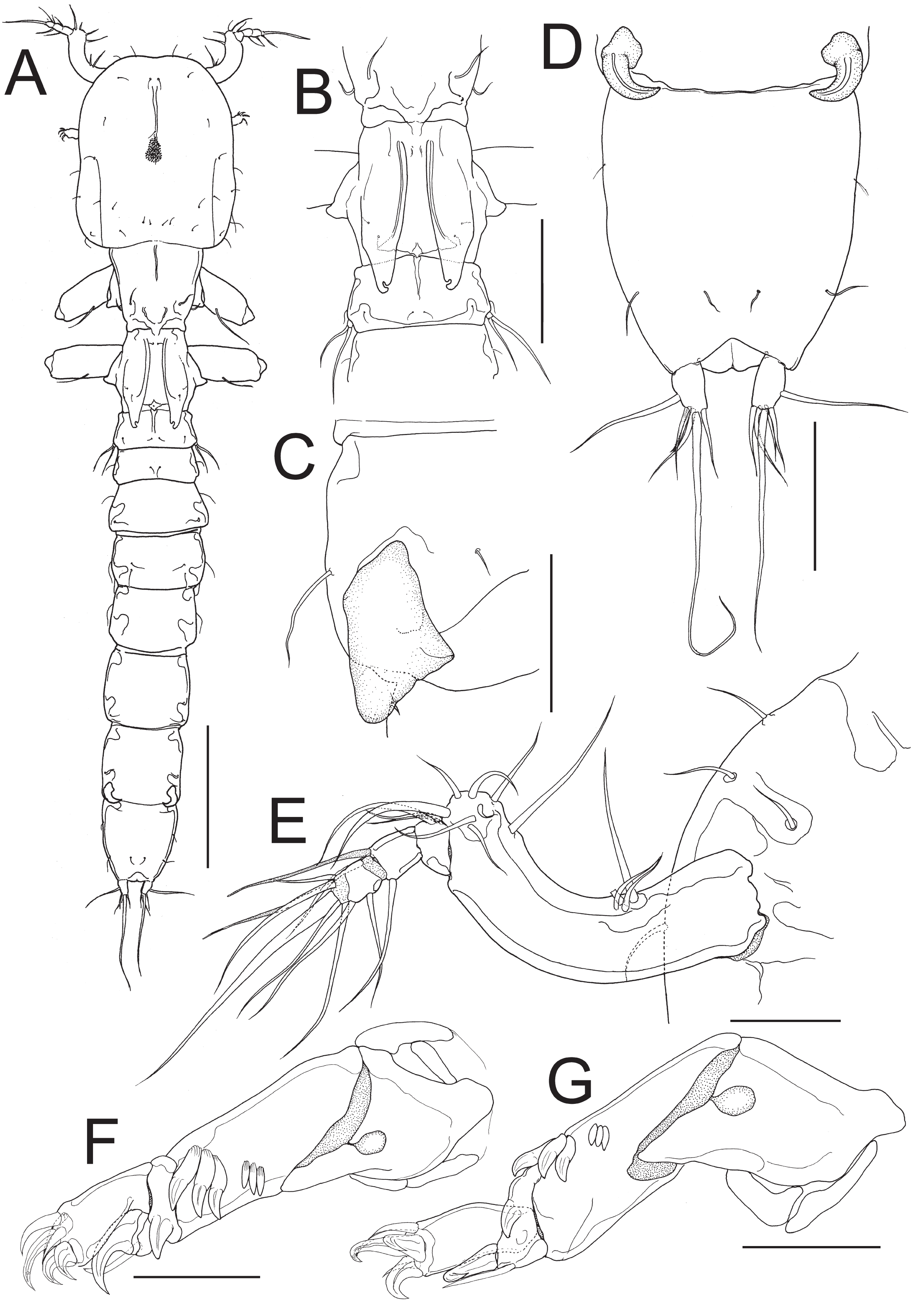

Fig. 1. *Lernaeascus kabuto* sp. nov., adult male, holotype (NSMT-Cr 24277). A, Habitus, dorsal; B, prosomites 2–5, dorsal; C, right side of genital somite, ventral; D, posterior part of urosome, dorsal; E, frontal region of cephalothorax and right antennule, ventral; F, right antenna, lateral; G, same, posterior. Scale bars: 200 µm for A; 100 µm for B; 50 µm for C; 30 µm for D–G.

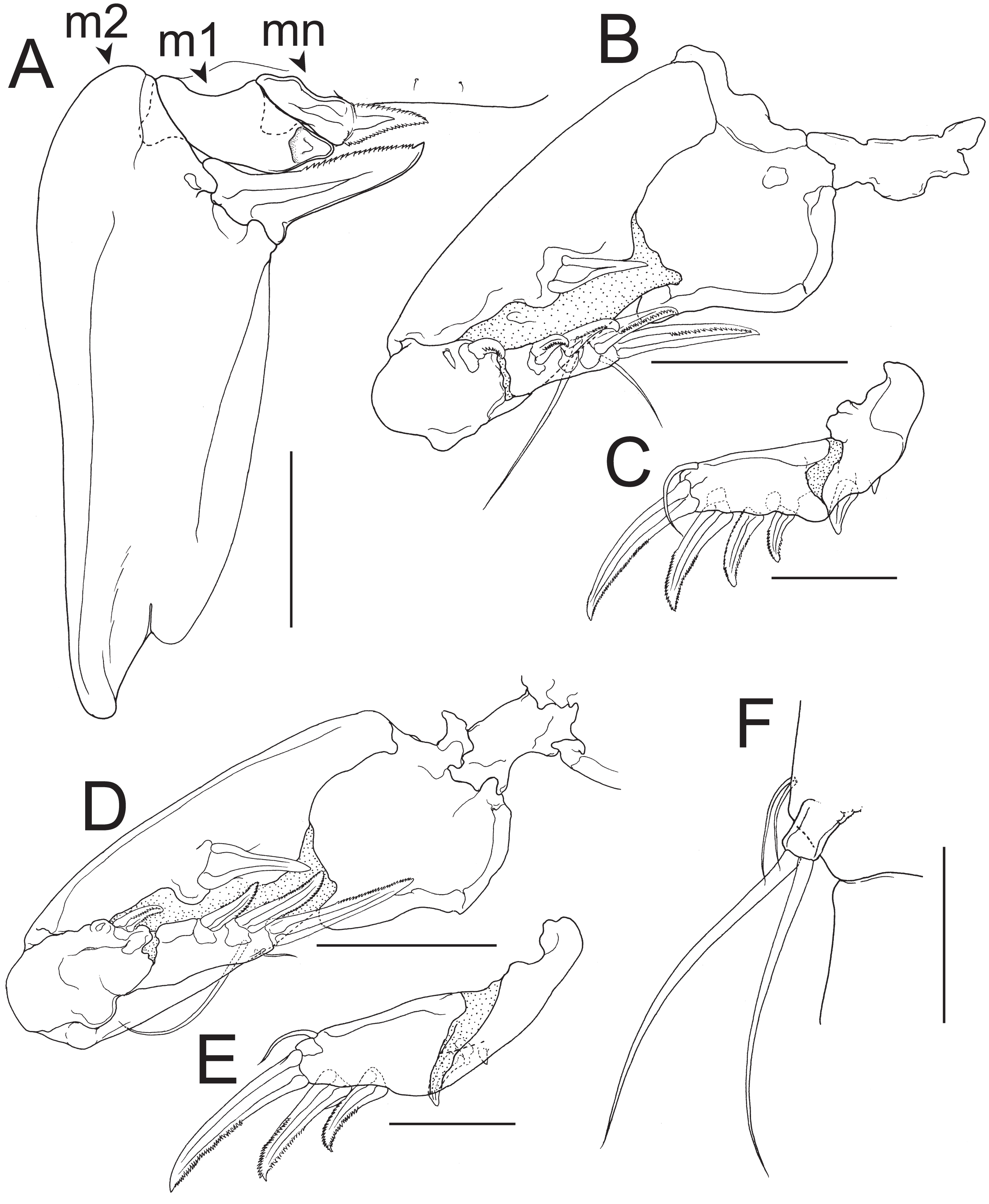

Fig. 2. *Lernaeascus kabuto* sp. nov., adult male, holotype (NSMT-Cr 24277). A, Mouth parts (mn, right mandible; m1, right maxillule; m2, right maxilla), ventral; B, right leg 1, anterior; C, exopod of right leg 1, posterior; D, right leg 2, anterior; E, exopod of right leg 2, posterior; F, right leg 3, ventral. Scale bars: 40 µm for A; 50 µm for B, D; 30 µm for C, E, F.

**Variability of female morphology.** Morphology of body parts of paratype as in allotype. Measurements of paratype (n=1) as follows: body length 1964; cephalosome length 217; cephalosome width 118.

**Etymology.** The specific name *kabuto*, a noun in apposition, the Japanese name for the helmets worn by Japanese warlords and alludes to the shape of the male cephalothorax and the associated curved, elongate antennules.

**Infection site.** Unknown.

**Remarks.** The new species is included in *Lernaeascus*, as it shares a number of characters in common with *L. nematoxys*, such as a vermiform body in females that is

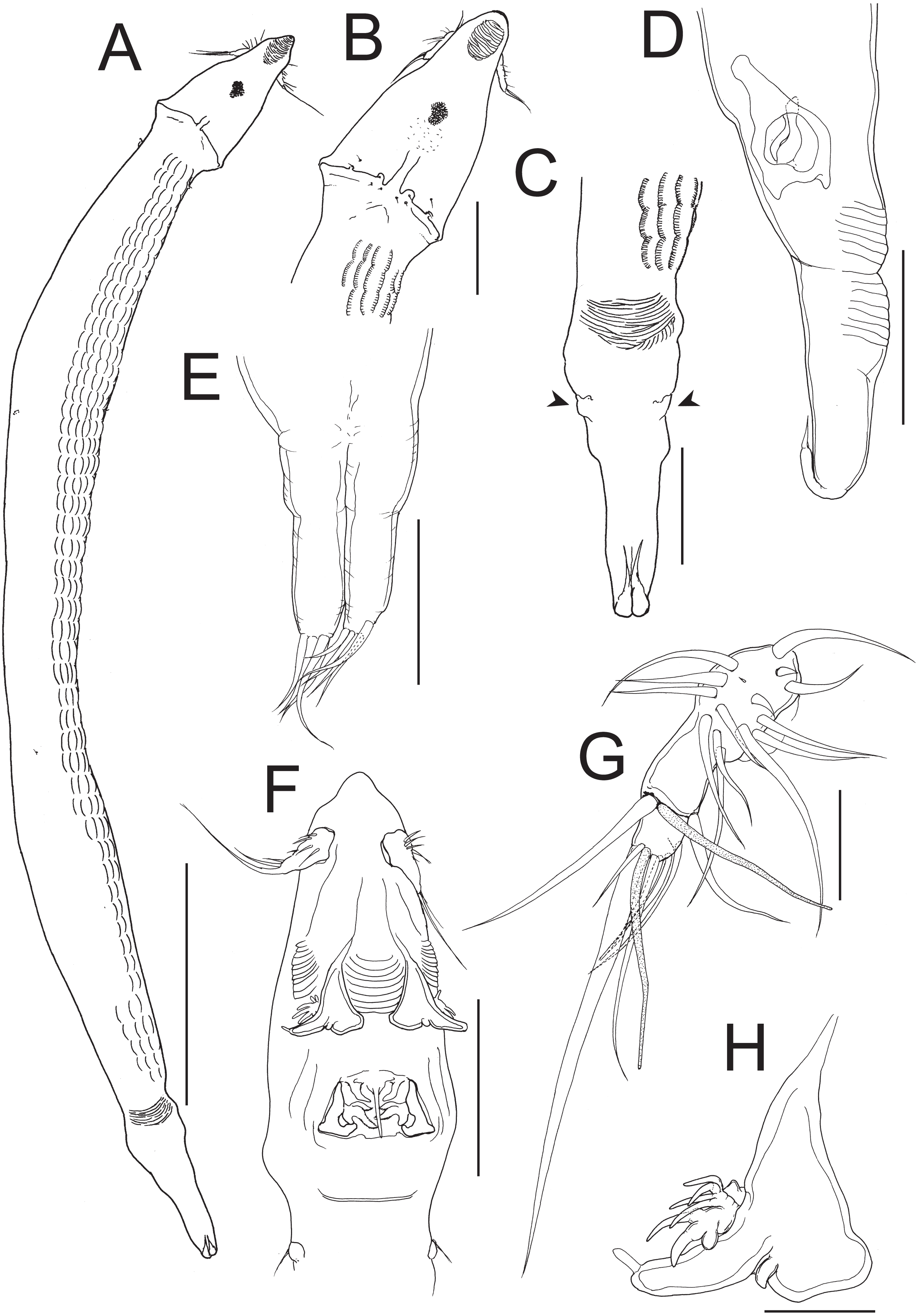

Fig. 3. *Lernaeascus kabuto* sp. nov., adult female, allotype (NSMT-Cr 24278) (A–D, F, G) and paratype (NSMT–Cr 24279) (E, H). A, Habitus, dorsal; B, anterior part of body, dorsal; C, posterior part of trunk, dorsal with, arrowhead indicating position of copulatory pores; D, same, lateral; E, caudal rami, dorsal; F, head region, ventral; G, right antennule, posterior; H, right antenna, posterior. Scale bars: 400 μm for A; 100 μm for B–D, F; 30 μm for E; 20 μm for G, H.

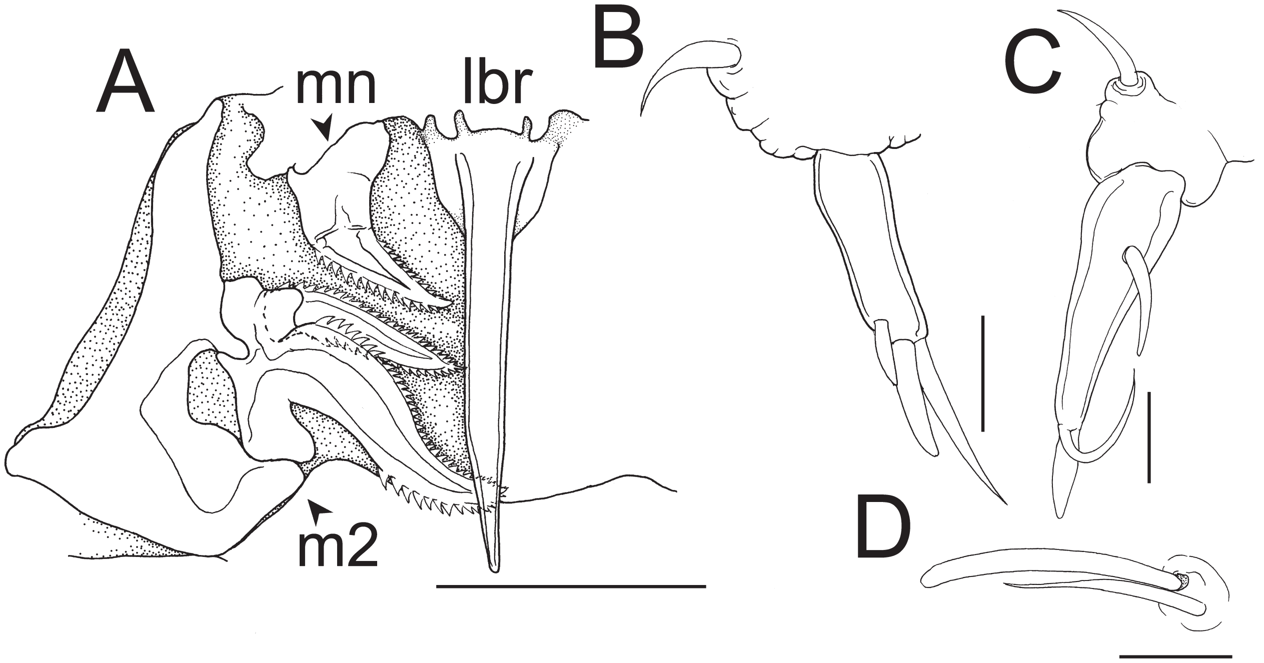

Fig. 4. *Lernaeascus kabuto* sp. nov., adult female, allotype (NSMT-Cr 24278). A, Mouth parts (lbr, labrum; mn, right mandible; m2, right maxilla), ventral; B, right leg 1, anterior; C, right leg 2, anterior; D, right leg 3, anterior. Scale bars: 20 µm for A; 10 µm for B–D.

Table 1. Armature formulae of legs 1 and 2 of *Lernaeascus kabuto* sp. nov., holotype, adult male, NSMT-Cr 24277. Arabic numerals refer to the number of setae, Roman numerals refer to the number of spines.

| | Coxa | Basis | Exopod | Endopod |
|---|---|---|---|---|
| Leg 1 | 0–0 | 1–0 | I–0; III, I, 1 | I |
| Leg 2 | 0–0 | 1–0 | I–0; II, I, 1 | I |

composed of a cephalosome, a long trunk embossed with multiple rows of scale-like cuticular structures, and a short abdomen and in males a pair of dorsal plates on the second pediger. *Lernaeascus kabuto* sp. nov. is easily distinguishable from *L. nematoxys* by differences in (1) the proportions, segmentation, and ornamentation of the urosomites and the structure of the dorsal plates, antennule, labrum, maxillule, maxilla, leg 1, and leg 6 of the male, as well as (2) the ornamentation of the cephalosome and structure of the antenna, labrum, and first two pairs of legs of the female (Table 2).

**Newly established Japanese name for both the genus and the species.** Senchu-modoki

## Discussion

*Lernaeascus nematoxys*, the type species of the genus, was originally described based on specimens of both sexes collected from the mucous canals underlying the scales of the whiskered sole *Monochirus hispidus* (Soleidae) (Claus 1886, 1887, 1888). Dollfus (1927) later reported, but did not redescribe, this copepod from the same host species collected off Nice, France. Although the type locality of *L. nematoxys* was not reported in the original description, Dollfus (1927) speculated that Claus' specimens of the type host were obtained from the Adriatic or the Mediterranean Sea. *Lernaeascus kabuto* was collected from the body washings of two species of Pomacanthidae from the East China Sea. Although it is plausible that *L. kabuto* occurs in the mucous canals of its host as in *L. nematoxys*, further studies are needed to ascertain the specific infection site of the new taxon.

Even though the description of *L. nematoxys* by Claus (1888) demonstrated many unique features of the genus (*e.g.*, the elongate female body covered with crescent structures on the surface; the female rostrum with a pointed projection), the mouthparts and appendages were insufficiently described. Hence, the discovery of *L. kabuto* as the second member of the genus promotes our understanding of the body plan and small morphological details of the genus. The males of both species of *Lernaeascus* are less modified than the females, as is typical for other members of the Philichthyidae, and distinct characters shared by both sexes are not found except for the unsegmented mandible with a serrate blade (see Claus 1888; present study). Nonetheless, the males of *L. nematoxys* and *L. kabuto* differ markedly from the known males of other philichthyid genera in several respects. The second pediger of *L. nematoxys* and *L. kabuto* bears a pair of dorsal plates instead of posterolateral processes. The mandible of both species is small and apically serrate instead of large, smooth and falcate, while the large maxilla is robust and bears an apical blade instead of being small, weak and armed with either one or two spinulate elements.

The antennule of adult poecilostome cyclopoids is typically 7-segmented, with the ancestral segmentation and armature pattern as follows: I–V: 5, VI–XIII: 15, XIV–XVII:

Table 2. Morphological comparisons between *Lernaeascus nematoxys* Claus, 1886 and *L. kabuto* sp. nov. based on Claus (1888) and the present study.

| Character | *L. nematoxys* | *L. kabuto* sp. nov. |
|---|---|---|
| Male | | |
| Genital somite proportion | Wider than fifth pediger and abdominal somites | As wide as fifth pediger and abdominal somites |
| Number of abdominal somites | Three | Four |
| Dorsal hamuli on third abdominal somite | Absent | Present |
| Dorsal plates on second pediger | Broad and posteriorly bifurcate | Elongate and distomedially notched |
| First antennulary segment | Straight | Curved |
| Labrum | With four posteromedian processes | With smooth posterior margin |
| Maxillule | Armed with apical element | Armed with subterminal process |
| Spiniform process on maxillary syncoxa | Present | Absent |
| Leg 1 endopod | Distally bifurcate | Spiniform |
| Leg 6 (genital operculum) | Distally bifurcate | Not bifurcate |
| Female | | |
| Antenna | Large, unarmed claw | Triangular, with proximal processes and apical spine |
| Corrugated surfaces on ventral surface of cephalosome | Absent | Present |
| Labrum | Armed with T-shaped process | Armed with styliform process |
| Number of setae on leg 1 exopod | Four | Three |
| Number of setae on leg 2 exopod | Four | Three |

5, XVIII–XX: 3, XXI–XXIV: 4, XXV: 2+1 aesthetasc, and XXVI–XXVIII: 7+1 aesthetasc (Boxshall and Huys 1998). Therefore, the 4-segmented antennule of the male (with armature of 12, 3, 2+1 aesthetasc and 7+1 aesthetasc) and 2-segmented antennule of the female (with armature of 17+1 aesthetasc and 6+1 aesthetasc) of *L. kabuto* probably represent, respectively, ancestral segments I–XX, XXI–XXIV, XXV, and XXVI–XXVIII on the male and I–XXV and XXVI–XXVIII on the female.

The male of *L. kabuto* has an antennule with an elongate proximal segment that is curved anteriorly, and it might function in grasping something. Male poecilostome cyclopoids lack a distal geniculation on the antennules for grasping the female, but typically have large, raptorial maxillipeds that are used to grasp the female during mate guarding and copulation (Huys and Boxshall 1991). It is presently unclear how male philichthyids grasp females during mating as their maxillipeds are either small and feeble, as in *Procolobomatus hemilutjani* Castro Romero, 1994, *Sarcotaces shiinoi* Izawa, 1974 and some species of *Colobomatus*, or absent altogether, as in *L. kabuto* (*e.g.*, Izawa 1974; Castro Romero 1994; present study). Although it is conceivable that the males of most philichthyid genera use their large, falcate mandibles to grasp females during mating, it is uncertain how this could be achieved in males of *Lernaeascus*, which have comparatively weak mandibles. The curved antennule of the male of *L. kabuto* may work to grasp or cling to female during mating; however, that of *L. nematoxys* is short and straight. Alternatively, it may be an adaptation for life in their microhabitat on/in the host. Either way, further studies are needed to elucidate the mating behavior of male philichthyids.

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