

FOUR NEW SPECIES OF *PENICULISA* WILSON, 1917 (COPEPODA: SIPHONOSTOMATOIDA: PENNELLIDAE) PARASITIC ON COASTAL MARINE FISHES IN JAPANESE WATERS

Daisuke Uyeno and Kazuya Nagasawa*

Graduate School of Biosphere Science, Hiroshima University, 1-4-4 Kagamiyama, Higashi-Hiroshima, Hiroshima 739-8528, Japan.
e-mail: ornatus@hiroshima-u.ac.jp

ABSTRACT: Four new species of *Peniculisa* Wilson, 1917, are described from marine fishes caught in coastal waters of southwestern Japan. *Peniculisa elongata* n. sp., *Peniculisa crassa* n. sp., and *Peniculisa uchinah* n. sp. are distinguishable from *Peniculisa furcata* (Krøyer, 1863), *Peniculisa bellwoodi* Boxshall, 1989, and *Peniculisa wilsoni* Radhakrishnan, 1977, in the lack of rami on legs 1 to 4, the lack of leg 5, and the possession of a trunk with prominent anterior shoulders. *Peniculisa elongata* n. sp. is separated from the remaining 2 known and 3 new congeners, *Peniculisa bicaudata* Shiino, 1956, *Peniculisa shiinoi* Izawa, 1965, *P. crassa* n. sp., *Peniculisa ohirugi* n. sp., and *P. uchinah* n. sp. by a pair of long, slender caudal processes, a compact cephalothorax, and its trunk with posteroventral lobes projecting posteriorly. *Peniculisa crassa* n. sp. can be discriminated from them by its pair of short, thick caudal processes, a comparatively large and thick cephalothorax in relation to its body, and its abdominal processes widest at base. *Peniculisa uchinah* n. sp. is distinguished from all other congeners by the possession of a pair of relatively long, slender, and proportionately long caudal processes, and a long abdominal process widest near the posterior end. *Peniculisa ohirugi* n. sp. is identified by a pair of long, divergent abdominal processes extending the tip of caudal rami, and by the location of leg 4 on the neck region.

Peniculisa include species of pennellid copepods (Siphonostomatoidea). There are 5 species in the genus: *Peniculisa bellwoodi* Boxshall, 1989, *Peniculisa bicaudata* Shiino, 1956, *Peniculisa furcata* (Krøyer, 1863), *Peniculisa shiinoi* Izawa, 1965, and *Peniculisa wilsoni* Radhakrishnan, 1977. *Peniculisa bellwoodi* was reported from a perciform fish, and the remaining 4 species were described from tetraodontiform fishes (Krøyer, 1863; Wilson, 1906; Leigh-Sharpe, 1934; Shiino, 1956; Izawa, 1965; Radhakrishnan, 1977; Boxshall, 1989; Izawa, 1997). Species identification of *Peniculisa* is very difficult because of their featureless bodies. Important identification characters for these 5 species are mainly the shape and size of the body and caudal process, and the presence or absence of anterior shoulders on the trunk. In the present paper, 4 new species of *Peniculisa* are described from 8 species of coastal marine fishes collected in Japanese waters.

MATERIALS AND METHODS

Marine fishes were collected by rod and line or during SCUBA diving in coastal waters of southwestern Japan from September 2005 to June 2009. Parasitic copepods infecting the fishes (Fig. 1) were carefully removed from the hosts and preserved in 80% ethanol or 10% formalin. Specimens were soaked in lactophenol for a half, to a whole, day, then dissected and examined using the wooden slide method of Humes and Gooding (1964). Drawings were made with the aid of a drawing tube. Morphological terminology follows Huys and Boxshall (1991). The following copepod body parts were measured using an ocular micrometer and are given in millimeters as the range, followed by the mean and standard deviation in parentheses: total length (=maximum length of the body, including the caudal processes on the trunk); body length (=maximum length of the body, from the anterior tip of cephalothorax to posterior end of abdominal process); cephalothorax length (=maximum length of the cephalothoracic shield); cephalothorax width (=maximum width of the cephalothoracic shield); trunk length (=maximum length of the trunk, excluding the neck); trunk width (=maximum width of the trunk, excluding the neck); caudal process length (=maximum length of caudal processes on the trunk); caudal process width (=maximum width of caudal processes on the trunk); abdominal process length (=maximum length of the abdominal process).

Received 20 November 2009; revised 22 February 2010; accepted 2 March 2010.

*To whom correspondence should be addressed.

DOI: 10.1645/GE-2395.1

Type specimens are deposited in the crustacean collection of the National Museum of Nature and Science, Tokyo (NSMT), and the University of the Ryukyus Museum, Fujukan (RUMF), Okinawa. The scientific names of fishes follow those listed by Hayashi (2002a, 2002b, 2002c) and Aonuma and Yoshino (2002).

DESCRIPTIONS

Peniculisa elongata n. sp.

(Figs. 2–3)

Diagnosis (based on 7 postmetamorphic adult females): Body (Fig. 2A) slender, 2.19–2.50 (2.36 ± 0.10) in length, with long caudal processes on trunk, total length 4.07–4.50 (4.24 ± 0.19), covered with sclerotised cuticle. Cephalothorax (Fig. 2B) oval, swollen slightly at posterolateral angles, longer than wide (0.43–0.46 [0.45 ± 0.02] × 0.26–0.28 [0.27 ± 0.01]), with constriction on posterior $\frac{3}{4}$. Nauplius eye conspicuous. Short neck region (Fig. 2B) comprising first to third pedigerous somites. Fourth pedigerous somite incorporated into trunk. Trunk slender, cylindrical, longer than wide (1.54–1.81 [1.70 ± 0.09] × 0.68–0.80 [0.75 ± 0.05]), with slender caudal processes (1.92–2.39 [2.17 ± 0.15] × 0.18–0.23 [0.20 ± 0.02]) on posterolateral corners and posteroventral lobes with prominent tip (Fig. 2C). Abdominal process (Fig. 2C) 0.24–0.30 (0.26 ± 0.02) long, bilobed, ending at posterior end of trunk (Fig. 2C). Caudal rami located on abdominal process carrying 5 setae. Egg-sacs uniseriate.

Antennule absent. Antenna (Fig. 3A) 2-segmented; proximal segment with 2 distal processes; terminal claw without armature. Maxillule (Fig. 3B) knob with 2 distal setules. Maxilla (Fig. 3C) 2-segmented; proximal segment without armature; distal segment curved with rows of fine setae and setulose, blunt distal tip. Maxilliped absent. Legs 1 to 4 (Fig. 3D–G) represented by blunt triangular protopod without rami. Some specimens with 1 small, simple seta on posterior margin of leg 1. Leg 3 often bearing claw-like distal process. Leg 4 with claw-like process on distal tip. Leg 5 absent.

Taxonomic summary

Type host: *Ostracion cubicus* L. (Tetraodontiformes: Ostraciidae).

Site: Caudal fin rays (Fig. 1A).

Type locality and collection date: Off Seragaki (26°30'N, 127°52'E), Okinawa-jima Island, Okinawa, East China Sea, Japan, 1 July 2007.

Specimens deposited: Holotype female, NSMT-Cr 20931, 3 paratype females, NSMT-Cr 20932, 3 paratype females, RUMF-ZC-01073.

Etymology: The specific name of the new species, *elongata*, refers to its slender body.

Remarks

Peniculisa elongata n. sp. differs from *P. bicaudata* and *P. wilsoni* in having longer and slender caudal processes. In *P. bicaudata* and *P. wilsoni*,

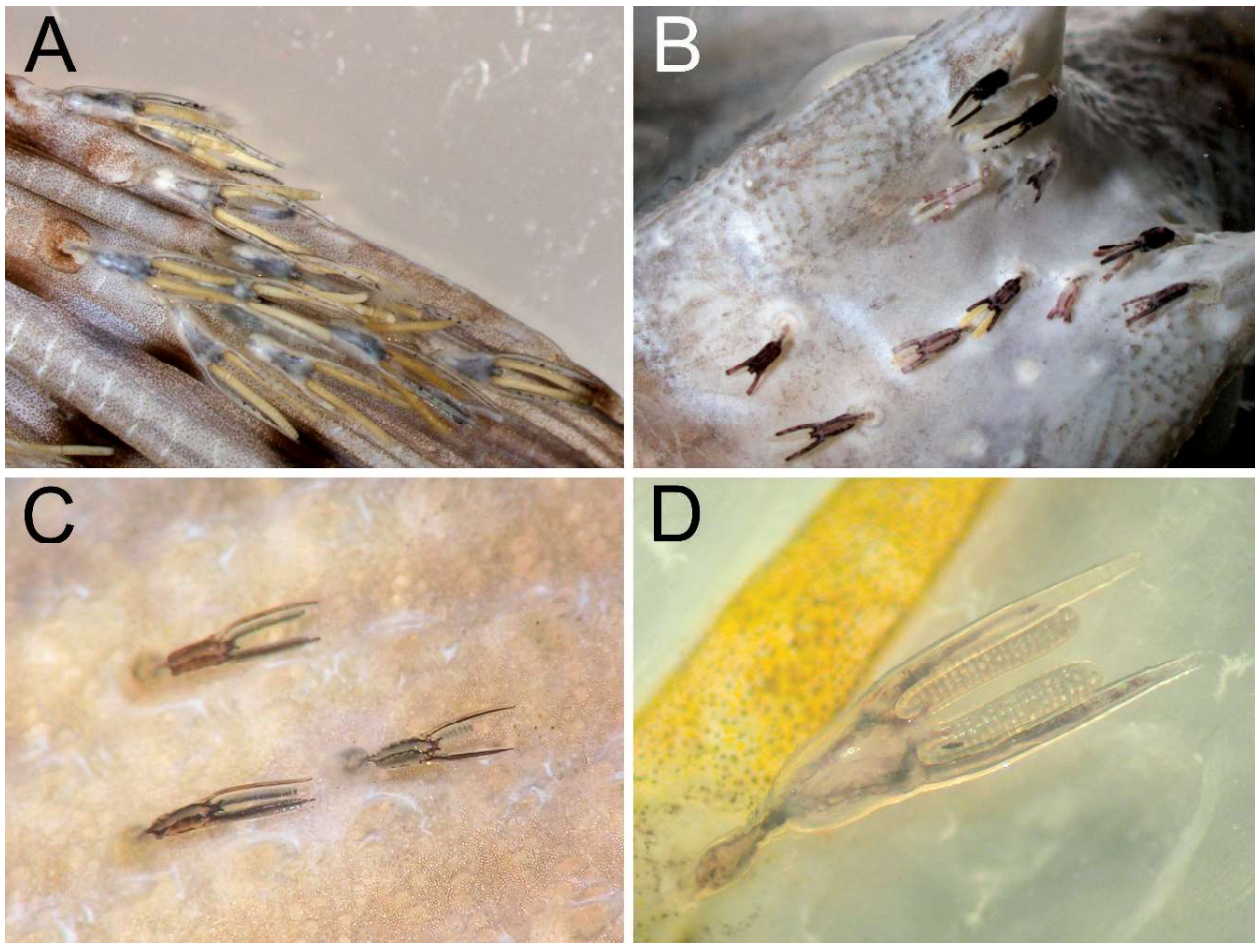


FIGURE 1. Infection by four new species of *Peniculisa* on fish. (A) *Peniculisa elongata* n. sp. on the fin rays of a boxfish; (B) *Peniculisa crassa* n. sp. on the head of a boxfish; (C) *Peniculisa uchinah* n. sp. on the body surface of a triggerfish; (D) *P. uchinah* n. sp. on the fin rays of a filefish.

the caudal processes are consistently shorter than the trunk in postmetamorphic females (Shiino, 1956; Radhakrishnan, 1977). In *P. shiinoi*, the caudal processes are as long as or longer than the trunk, but the new species has more slender processes (Izawa, 1965). Furthermore, *P. shiinoi* is more compact than the new species. *Peniculisa bellwoodi* has a slender body and caudal processes and lacks anterior shoulders and a distinct boundary at the anterior end of the trunk, which are discrete when compared to the new species. *Peniculisa furcata* can be easily distinguished from the new species by legs 1 to 4, which possess 2 minute, segmented rami and more divergent caudal processes. Leigh-Sharpe (1934) identified 2 specimens from *Ostracion meleagris* Shaw (as *O. punctatus*) as *P. furcata*, but Shiino (1956) and Izawa (1965) pointed out the possibility that these specimens were not identical to *P. furcata*. Leigh-Sharpe (1934, Fig. 26) illustrated long, slender caudal processes and well-developed posterior lobes on the abdominal process. Both the caudal and the abdominal processes of the new species resemble Leigh-Sharpe's specimens, which, however, are different from the new species in having a long neck with a gap separating legs 2 to 3.

***Peniculisa crassa* n. sp.**
(Figs. 4–5)

Diagnosis (based on 12 postmetamorphic adult females): Body (Fig. 4A) rounded, fusiform, 1.71–2.10 (1.89 ± 0.14) in length, with long caudal processes in trunk, total length 2.41–3.30 (2.83 ± 0.27), covered with sclerotized cuticle. Cephalothorax (Fig. 2B) oval, swollen slightly at posterolateral angles, longer than wide (0.33–0.46 [0.40 ± 0.04] × 0.22–0.27 [0.25 ± 0.02]), with constriction on posterior ¼. Nauplius eye

conspicuous. Short neck region (Fig. 4B) comprising first to third pedigerous somites. Fourth pedigerous somite incorporated into cylindrical trunk. Trunk rotundiform, cylindrical, gradually wider posteriorly, with prominent anterior shoulders, often laterally swollen at posterior ¾, longer than wide (1.20–1.49 [1.33 ± 0.09] × 0.16–0.19 [0.17 ± 0.01]), bearing blunt, divergent, caudal processes on posterolateral corners and posteroventral lobes (Fig. 4C). Caudal processes longer than wide (0.83–1.39 [1.11 ± 0.19] × 0.20–0.25 [0.23 ± 0.02]). Trunk terminating in dorsally located, bilobed abdominal processes (Fig. 4C). Abdominal process expanded at base and gradually narrowing posteriorly; length 0.20–0.25 (0.23 ± 0.02). Caudal rami located on abdominal process carrying more than 4 setae. Egg-sacs uniseriate.

Antennule absent. Antenna (Fig. 5A) 2-segmented; proximal segment with 2 distal processes; terminal claw without armature. Maxillule (Fig. 5B) knob with 2 distal setules. Maxilla (Fig. 5C) 2-segmented; proximal segment without armature; distal segment curved with rows of fine setae and setulose, blunt distal tip. Maxilliped absent. Legs 1 to 4 (Fig. 5D–G) represented by blunt triangular protopod with fissure on surface, lacking rami. Some specimens with unguiform tip on legs 1 to 3. Leg 4 with unguiform distal tip. Leg 5 absent.

Taxonomic summary

Type host: *Lactoria fornasini* (Bianconi) (Tetraodontiformes: Ostraciidae).

Sites: Body surface and fin rays (Fig. 1B).

Type locality and collection date: Off Nishidomari (32°46'N, 132°43'E), Kochi, North Pacific Ocean, Japan, 7 July 2009.

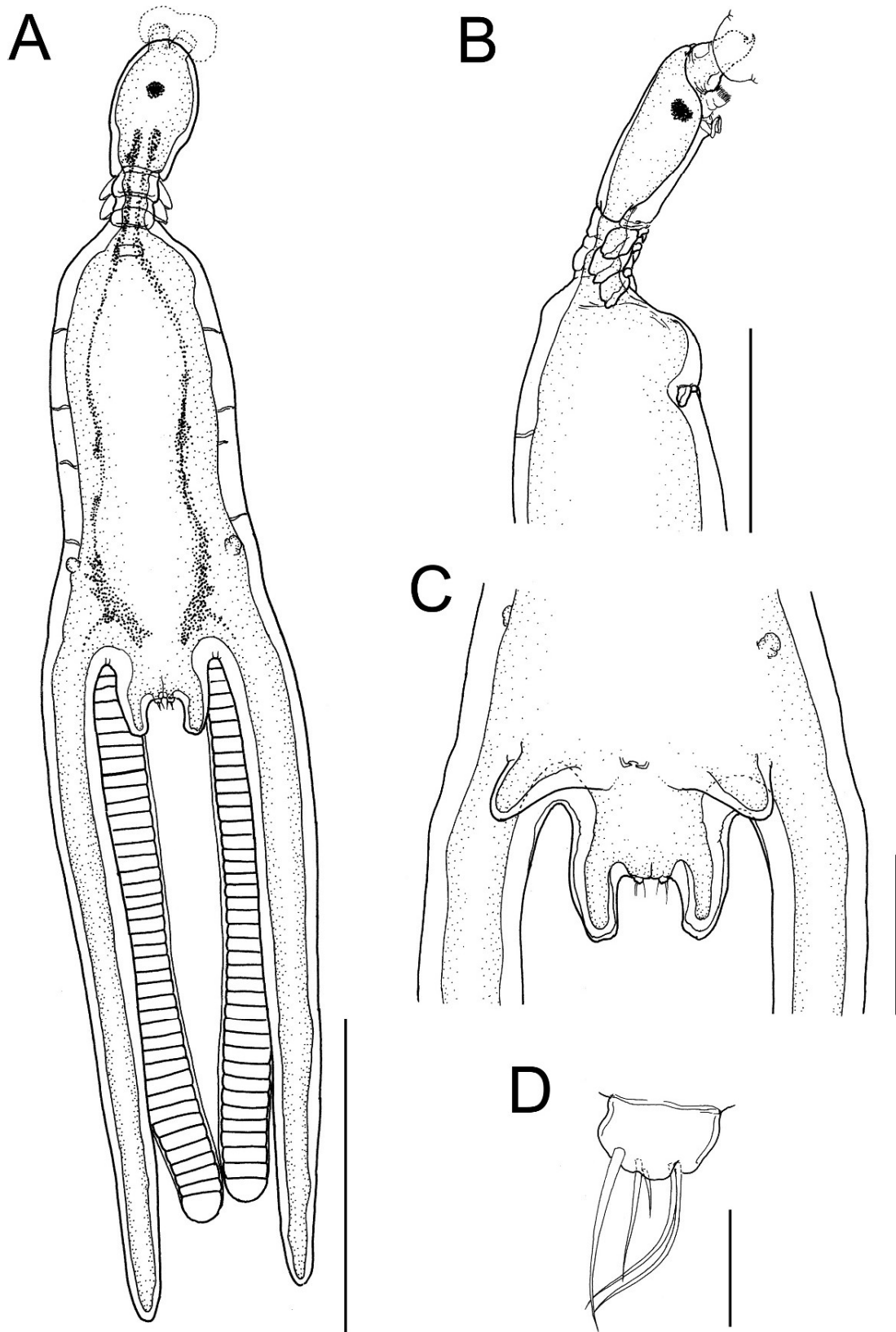


FIGURE 2. *Peniculisa elongata* n. sp., postmetamorphic female, holotype NSMT-Cr 20931. (A) Habitus, dorsal. (B) Cephalothorax and free thoracic somites, lateral. (C) Posterior end of trunk, ventral. (D) Caudal ramus, dorsal. Scale bars: A, 1 mm; B, 0.5 mm; C, 0.3 mm; D, 0.02 mm.

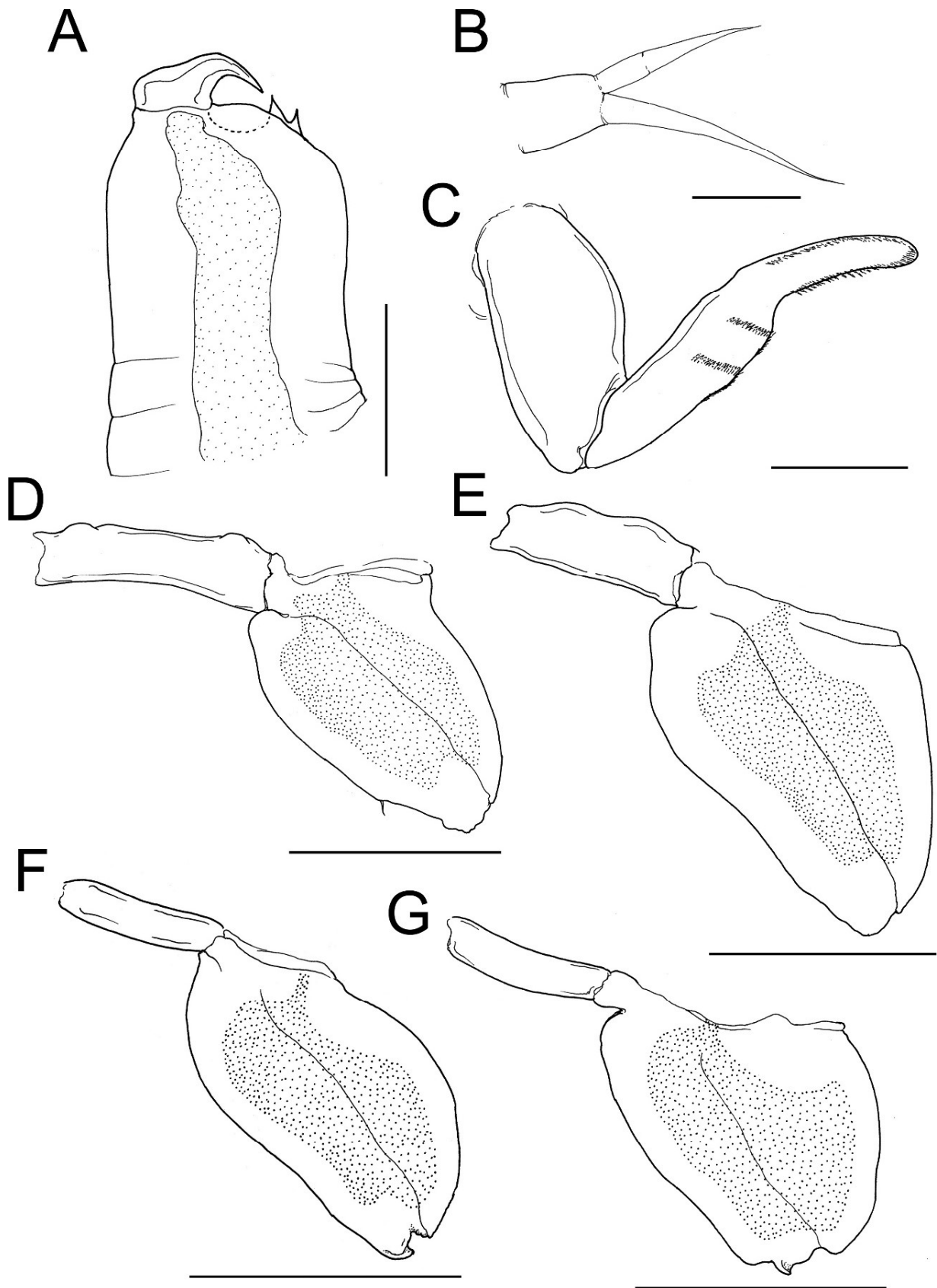


FIGURE 3. *Peniculisa elongata* n. sp., postmetamorphic female, holotype NSMT-Cr 20931. (A) Antenna, dorsal. (B) Maxillule. (C) Maxilla, anterior. (D) Leg 1. (E) Leg 2. (F) Leg 3. (G) Leg 4. Scale bars: A, G, 0.05 mm; B-C, 0.02 mm; D-F, 0.07 mm.

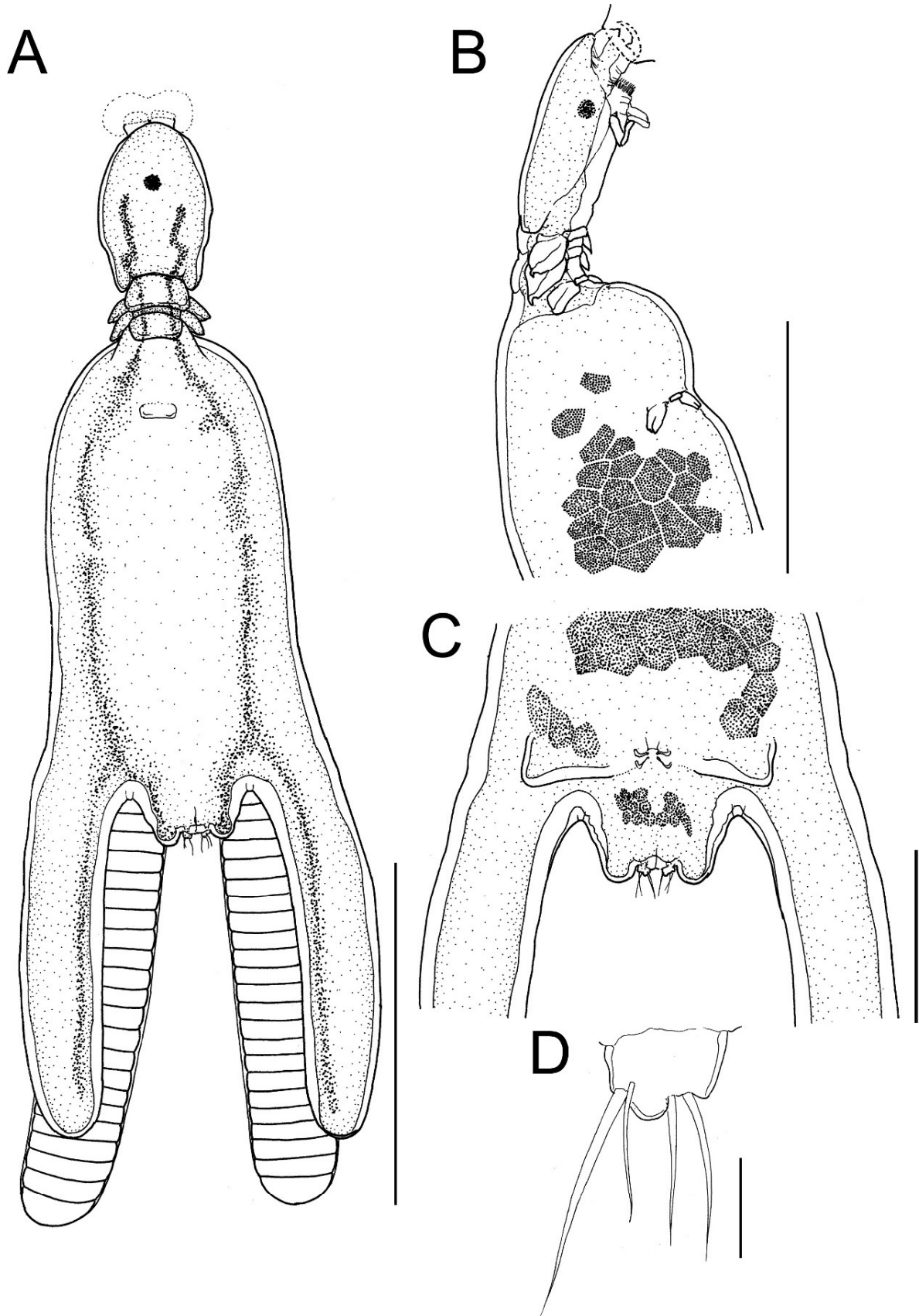


FIGURE 4. *Peniculisa crassa* n. sp., postmetamorphic female, holotype NSMT-Cr 20933. (A) Habitus, dorsal. (B) Cephalothorax and free thoracic somites, lateral. (C) Posterior end of trunk, ventral. (D) Caudal ramus, dorsal. Scale bars: A, 0.8 mm; B, 0.5 mm; C, 0.3 mm; D, 0.02 mm.

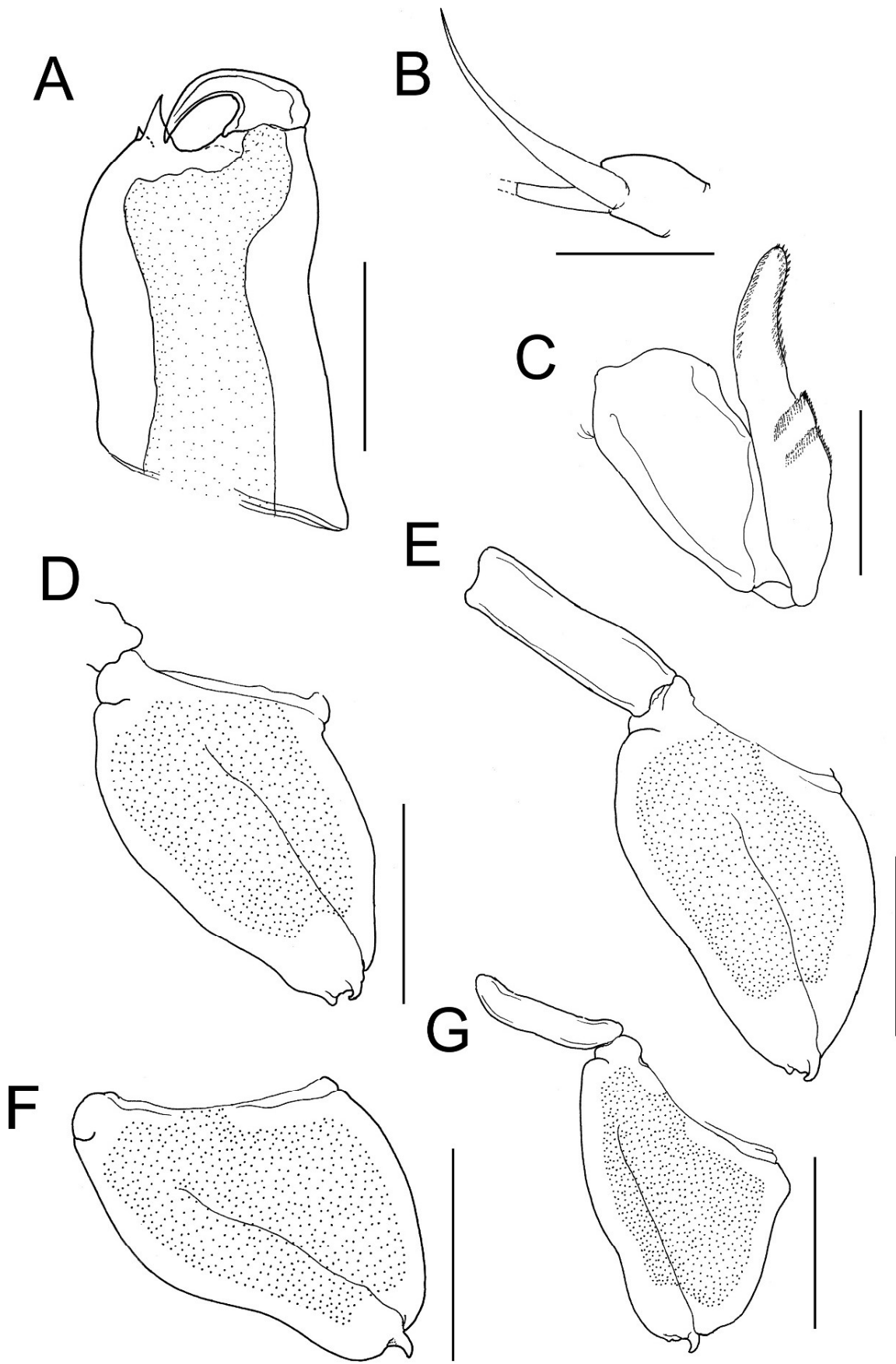


TABLE I. Percentages of body parts of postmetamorphic females of *Peniculisa elongata* n. sp., *Peniculisa crassa* n. sp., *Peniculisa uchinah* n. sp., and *Peniculisa ohirugi* n. sp. The data are shown as minimum–maximum (mean \pm standard deviations).*

	Copepods			
	<i>Peniculisa elongata</i> (n = 7)	<i>Peniculisa crassa</i> (n = 12)	<i>Peniculisa uchinah</i> (n = 13)	<i>Peniculisa ohirugi</i> (n = 2)
In % BL				
CEL	17.84–21.05 (19.02 \pm 1.01)	19.11–22.87 (21.17 \pm 1.19)	19.33–25.59 (22.31 \pm 1.63)	13.62–15.35 (14.49 \pm 1.23)
CEW	10.46–12.28 (11.34 \pm 0.64)	12.35–15.43 (13.31 \pm 0.90)	11.09–15.71 (13.67 \pm 1.26)	8.17–9.54 (8.86 \pm 0.97)
CPL	80.13–100.00 (92.06 \pm 9.15)	43.56–72.27 (58.98 \pm 9.98)	62.61–90.12 (77.73 \pm 9.15)	47.86–48.13 (48.00 \pm 0.19)
APL	3.53–5.67 (4.87 \pm 0.85)	1.60–4.51 (2.83 \pm 0.95)	2.75–5.05 (4.00 \pm 0.69)	7.45–8.07 (7.76 \pm 0.44)
In % CPL				
CPW	7.85–10.78 (9.17 \pm 1.10)	11.47–21.61 (16.18 \pm 3.36)	10.52–14.43 (12.37 \pm 1.24)	7.45–8.07 (7.76 \pm 0.44)

* Abdominal process length (APL), body length (BL), caudal process length (CPL), caudal process width (CPW), cephalothorax length (CEL), and cephalothorax width (CEW).

Specimens deposited: Holotype female, NSMT-Cr 20933, 11 paratype females, NSMT-Cr 20934.

Etymology: The specific name of the new species, *crassa*, refers to its short, thick trunk and caudal processes.

Remarks

The new species differs from *P. furcata* by the lack of rami on legs 1 to 4. The specimens identified as *P. furcata* by Leigh-Sharp (1934) are differentiated from the new species in having slender, long caudal processes and a neck region with a gap separating legs 2 to 3. *Peniculisa bellwoodi* and *P. shiinoi* differ from the new species in having long caudal processes in relation to the trunk; *P. bicaudata* and *P. wilsoni* the caudal processes shorter than a trunk, but *P. bicaudata* is separated from the new species by having a 3-segmented antennule. *Peniculisa wilsoni* has a trunk without prominent anterior shoulders, which is different from that of the new species. In *P. elongata* n. sp., the caudal processes are longer than those of the new species with a percentage of caudal process length/body length (80.13–100.00 [96.26 \pm 7.13] vs. 43.56–72.27 [58.98 \pm 9.98]) being higher. They are also more slender than those of the new species with the percentage of caudal process width/caudal process length (7.85–10.78 [9.17 \pm 1.10] vs. 11.47–21.61 [16.18 \pm 3.36]) being lower (Table I; Fig. 10A, B). *Peniculisa elongata* n. sp. possesses a slightly smaller cephalothorax than the new species; the percentage of cephalothorax length/body length ranges from 17.84–21.05 (19.02 \pm 1.01) in *P. elongata* (vs. 19.11–22.87 [21.17 \pm 1.19] in the new species), and the percentage of cephalothorax width/body length ranges from 10.46–12.28 (11.34 \pm 0.64) (vs. 12.35–15.43 [13.31 \pm 0.90]) (Table I; Fig. 10C, D).

Peniculisa uchinah n. sp.

(Figs. 6–7)

Diagnosis (based on 13 postmetamorphic adult females): Body (Fig. 6A) slender, 1.29–1.78 (1.52 \pm 0.16) in length, with long caudal processes on trunk, total length 2.23–2.90 (2.51 \pm 0.24), covered with sclerotised cuticle. Cephalothorax (Fig. 6B) oval, swollen slightly at posterolateral angles, longer than wide (0.28–0.37 [0.34 \pm 0.03] \times 0.19–0.23 [0.21 \pm 0.01]). Nauplius eye conspicuous. Short neck region (Fig. 6B) comprising first to third pedigerous somites. Fourth pedigerous somite incorporated into cylindrical trunk. Trunk short, sub-cylindrical, wider posteriorly, with prominent anterior shoulders, longer than wide (0.86–1.28 [1.03 \pm 0.14] \times 0.39–0.56 [0.49 \pm 0.05]), bearing caudal processes on posterolateral corners and posteroventral lobes (Fig. 6C). Caudal processes slender, slightly incurved, 1.00–1.39 (1.17 \pm 0.14) long, 0.12–0.17 (0.14 \pm 0.01) wide. Trunk terminates in dorsally located, bilobed abdominal processes (Fig. 6C). Abdominal process gradually expanding posteriorly, 0.11–0.18

(0.15 \pm 0.03) long. Caudal rami (Fig. 6D) located on abdominal process carrying at least 3 setae with 2 knobs. Egg sac uniseriate.

Antennule absent. Antenna (Fig. 7A) 2-segmented; proximal segment with 2 distal processes; terminal claw without armature. Maxillule (Fig. 7B) knob with 2 distal setules. Maxilla (Fig. 7C) 2-segmented; proximal segment without armature; distal segment curved with rows of fine setae and setulose, blunt distal tip. Maxilliped absent. Legs 1 to 4 (Figs. 7D–G) represented by blunt triangular protopod with fissure on surface, without armature. Leg 5 absent.

Taxonomic summary

Type host: *Sufflamen fraenatum* (Latreille) (Tetraodontiformes: Balistidae).

Other hosts: *Balistoides conspicillum* (Bloch and Schneider) (Tetraodontiformes: Balistidae), *Rhinecanthus aculeatus* (L.) (Tetraodontiformes: Balistidae), *S. bursa* (Bloch and Schneider), *S. chrysopterygum* (Bloch and Schneider), and *Pervagor melanocephalus* (Bleeker) (Tetraodontiformes: Monacanthidae).

Sites: Body surface and fin rays (Fig. 1C–D).

Type locality and collection date: Off Minna-jima Island (26°38'N, 127°48'E), Okinawa, East China Sea, Japan, 25 July 2007.

Other localities and collection dates: Off Ankyaba (28°6'N, 129°20'E), Kakeroma-jima Island, Kagoshima, North Pacific Ocean, 27 May 2005; off Odo Beach (26°5'N, 127°42'E), Okinawa-jima Island, Okinawa, North Pacific Ocean, 1 September 2005; off Ikema-jima Island (24°56'N, 125°14'E), Okinawa, East China Sea, 20 December 2005; off Zamami-jima Island (26°13'N, 127°17'E), Okinawa, East China Sea, 27 May 2006; off Seragaki (26°30'N, 127°52'E), Okinawa-jima Island, Okinawa, East China Sea, 4 July 2007.

Specimens deposited: Holotype female, NSMT-Cr 20935, 1 paratype female (from off Minna-jima Island), NSMT-Cr 20936, 5 paratype females (from off Ankyaba), NSMT-Cr 20937, 1 paratype female (from off Zamami-jima Island), NSMT-Cr 20938, 1 paratype female (from off Seragaki), NSMT-Cr 20939, 1 paratype female (from off Ikema-jima Island), NSMT-Cr 20940, 3 paratype females (from off Odo Beach), RUMF-ZC-01074.

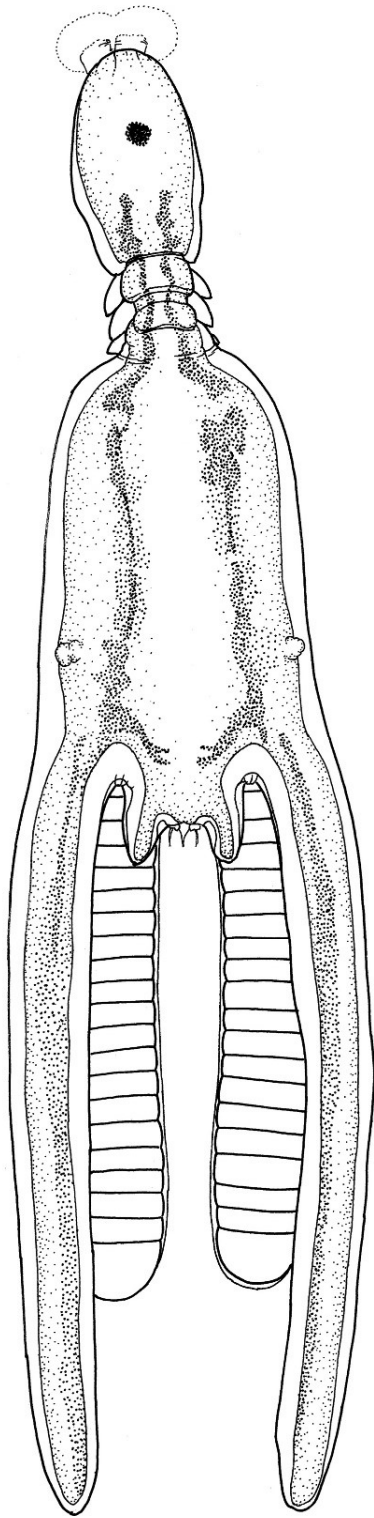
Etymology: The specific name of the new species, *uchinah*, is one of the vernacular names for Okinawa, Japan.

Remarks

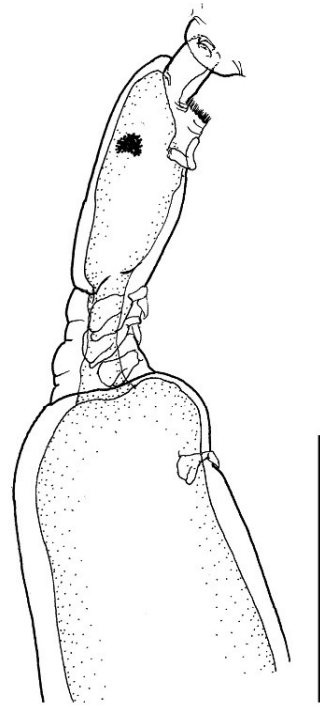
The new species differs from *P. bicaudata* and *P. wilsoni* in having caudal processes consistently longer than the trunk. The new species is differentiated from *P. shiinoi* by the lack of a unguiform process on legs 1 to 4. *Peniculisa furcata* is easily separated from the new species by the

FIGURE 5. *Peniculisa crassa* n. sp., postmetamorphic female, holotype NSMT-Cr 20933. (A) Antenna, dorsal. (B) Maxillule. (C) Maxilla, anterior. (D) Leg 1. (E) Leg 2. (F) Leg 3. (G) Leg 4. Scale bars: A, D–F, 0.05 mm; B, 0.02 mm; C, 0.03 mm; G, 0.04 mm.

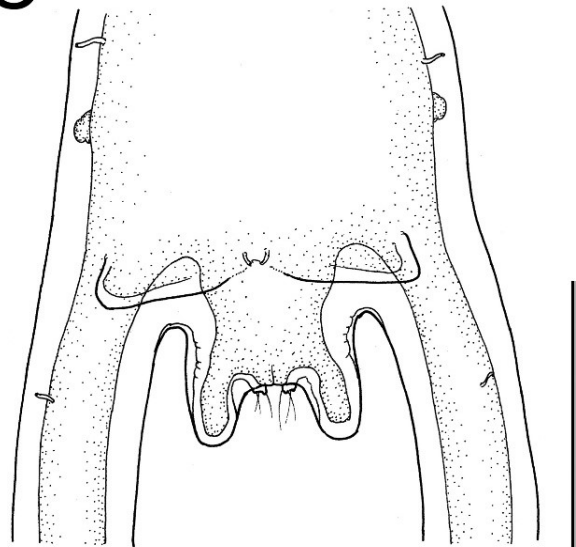
A



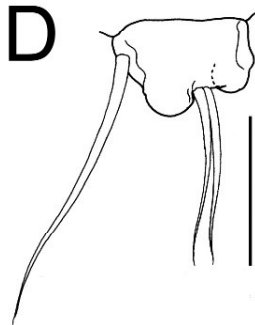
B



C



D



possession of rami on legs 1 to 4. The specimens identified as *P. furcata* by Leigh-Sharpe (1934) bear a gap separating legs 3 to 4, which is not shared with the new species. The new species differs from *P. bellwoodi* by the lack of leg 5 and the possession of a distinct boundary between the trunk and neck. *Peniculisa elongata* is distinct from the new species by the possession of the trunk with posteroventral lobes projecting posteriorly and long and slender caudal processes in relation to the body; the percentage of caudal process length/body length ranges from 80.13–100.00 (92.06 ± 7.13) in *P. elongata* n. sp. (vs. 62.61–90.12 [77.73 ± 9.15] in the new species) and the percentage of caudal process width/length 7.85–10.78 (9.17 ± 1.10) (vs. 10.52–14.43 [12.37 ± 1.24]). The cephalothorax of *P. elongata* n. sp. is more compact than that of the new species; the percentage of cephalothorax length/body length ranges from 17.84 to 21.05 (19.02 ± 1.01) in *P. elongata* n. sp. (vs. 19.33–25.59 [22.31 ± 1.63] in the new species) and the percentage of cephalothorax width/body length 10.46 to 12.28 (11.34 ± 0.64) (vs. 11.09–15.71 [13.67 ± 1.26]) (Table I; Fig. 10C, D). The new species is separated from *P. crassa* n. sp. by the abdominal process, which is longer and gradually diverges posteriorly; the percentage of abdominal process length/body length ranges from 2.75 to 5.05 (4.00 ± 0.69) in the new species (vs. 1.60–4.51 [2.83 ± 0.95] in *P. crassa*). The new species has longer and more slender caudal processes than those of *P. crassa*; the percentage of caudal process length/body length ranges from 62.61 to 90.12 (77.73 ± 9.15) in the new species (vs. 43.56–72.27 [58.98 ± 9.98] in *P. crassa*) and the percentage of caudal process width/length ranges from 10.52 to 14.43 (12.37 ± 1.24) (vs. 11.47–21.61 [16.18 ± 3.36]) (Table 1, Fig. 10A, B, E).

***Peniculisa ohirugi* n. sp.**

(Figs. 8–9)

Diagnosis (based on 2 postmetamorphic adult females): Body (Fig. 8A) slender, 1.85–1.97 (1.91 ± 0.09) long, with long caudal processes on trunk, total length 1.97–2.04 (2.00 ± 0.05). Cephalothorax (Fig. 8B) oval, swollen slightly at posterolateral angles, longer than wide ($0.27\text{--}0.28$ [0.28 ± 0.01] \times $0.16\text{--}0.18$ [0.17 ± 0.01]). Nauplius eye conspicuous. Short neck region (Fig. 8B) comprising 1st to 4th pedigerous somites without distinct boundary between neck and trunk. Trunk cylindrical, longer than wide (1.57 [1.57 ± 0.01] \times 0.28 [0.28 ± 0]) bearing slender, sharp, divergent, slightly incurved, caudal processes on posterolateral corner, knob-like posteroventral lobes and 2 small simple setae (Fig. 8C). Caudal processes 0.89–0.94 (0.92 ± 0.04) long, 0.07–0.08 (0.07 ± 0.01) wide. Trunk terminates in dorsally located, abdominal process greatly divergent, as almost long as caudal processes; length 0.79–0.87 (0.83 ± 0.06). Caudal rami located on abdominal process carrying 5 setae. Egg sacs uniseriate.

Antennule absent. Antenna (Fig. 9A) 2-segmented; proximal segment with 2 distal processes; terminal claw small, without armature. Maxillule (Fig. 9B) knob with 2 distal setae. Maxilla (Fig. 9C) 2-segmented; proximal segment without armature; distal segment curved with single small process. Maxilliped absent. Legs 1 to 4 (Fig. 9D–G) represented by blunt triangular protopod with fissure on surface, lacking rami. Legs 1 to 3 with unguiform tips. Holotype specimen bearing 2 and 1 setae on legs 1 and 2, respectively. Leg 5 absent.

Taxonomic summary

Type host: *Pomacentrus nagasakiensis* Tanaka (Perciformes: Pomacentridae).

Site: Scales on body surface (Fig. 1B).

Type locality and collection date: Off Murote Beach (33°0'N, 132°30'E), Ehime, Bungo Channel, Japan, 14 November 2007. Collected by Hiroataka Toyohara.

Other collection date: 28 October 2007. Collected by Hiroataka Toyohara.

Specimens deposited: Holotype female, NSMT-Cr 20941, 1 paratype female, NSMT-Cr 20942.

Etymology: The specific name of the new species, *ohirugi*, is derived from a Japanese name of the Burma mangrove. The body shape of the new species closely resembles a flower of the Burma mangrove.

Remarks

The new species is easily distinguishable from all other 8 congeners by 2 unique characters, i.e., the abdominal process are almost long as the caudal processes, and leg 4 located at the terminal area of the neck region without space between legs 3 and 4.

DISCUSSION

Five valid species are currently known from *Peniculisa*, and 4 new species are described in this paper. Of the 4 new species, *P. elongata*, *P. crassa*, and *P. uchinah* are similar in body form, and the differences are very minor between them. In previous studies (Shiino, 1956; Izawa, 1965; Radhakrishnan, 1977; Boxshall, 1989), the proportional length of the caudal process was used as one of the important characters for identification. This is also the case for 4 new species described in this study, but the species of *Peniculisa* show a wide variation in length of the caudal processes, which depends on the level of metamorphosis (Izawa, 1965; Radhakrishnan, 1977). In the present paper, descriptions of the 4 new species are made based only on postmetamorphic females, but many non-postmetamorphic females were found during the study, and the developmental level of their caudal processes is not uniform. It is thus desirable that the caudal processes should be used carefully as a morphological character for identification. Furthermore, in this study, the proportional length of the abdominal process to the body is used as an important character for the discriminating of *P. uchinah* n. sp. The proportion of the cephalothorax to the body is also useful for the description of *P. elongata*. However, these proportions are sometimes similar to each other between species, and thus identification is often difficult. For accurate identification, molecular analysis may be helpful.

At present, *Peniculisa* contains 9 species. Of these, 7 species (*P. bicaudata*, *P. furcata*, *P. shiinoi*, *P. wilsoni*, *P. elongata*, *P. crassa*, and *P. uchinah*) are the parasites of tetraodontiform fishes (Krøyer, 1863; Wilson, 1906; Leigh-Sharpe, 1934; Shiino, 1956; Izawa, 1965; Radhakrishnan, 1977; this study), whereas the remaining 2 species (*P. bellwoodi*, *P. ohirugi* n. sp.) occur on pomacentrid fishes (Boxshall, 1989; this study).

ACKNOWLEDGMENTS

We thank Associate Professor Tetsuo Yoshino, Professor Yuichi Hirose, Associate Professor Mamoru Toda, Assistant Professor Tohru Naruse, and Takeshi Sasaki, University of the Ryukyus and Fumihito Iwase, Biological Institute of Kuroshio, Kuroshio Biological Research Foundation, for assistance and permission to use their laboratory facilities. We acknowledge Shigeo Nakamura, University of the Ryukyus, Tomofumi Nagata, Okinawa Environmental Research and Technology, and Hiroataka Toyohara, Kochi University, for help with collection of specimens. We would like to thank Professor Susumu Ohtsuka, Hiroshima University, for valuable suggestions during the study. Part of this work received financial support from the Ocean Exposition Commemorative Park Management Foundation, Okinawa, and Kuroshio Biological Research Foundation, Kochi.

FIGURE 6. *Peniculisa uchinah* n. sp., postmetamorphic female, holotype NSMT-Cr 20935. (A) Habitus, dorsal. (B) Cephalothorax and free thoracic somites, lateral. (C) Posterior end of trunk, ventral. (D) Caudal ramus, dorsal. Scale bars: A, 1 mm; B, 0.5 mm; C, 0.3 mm; D, 0.02 mm.

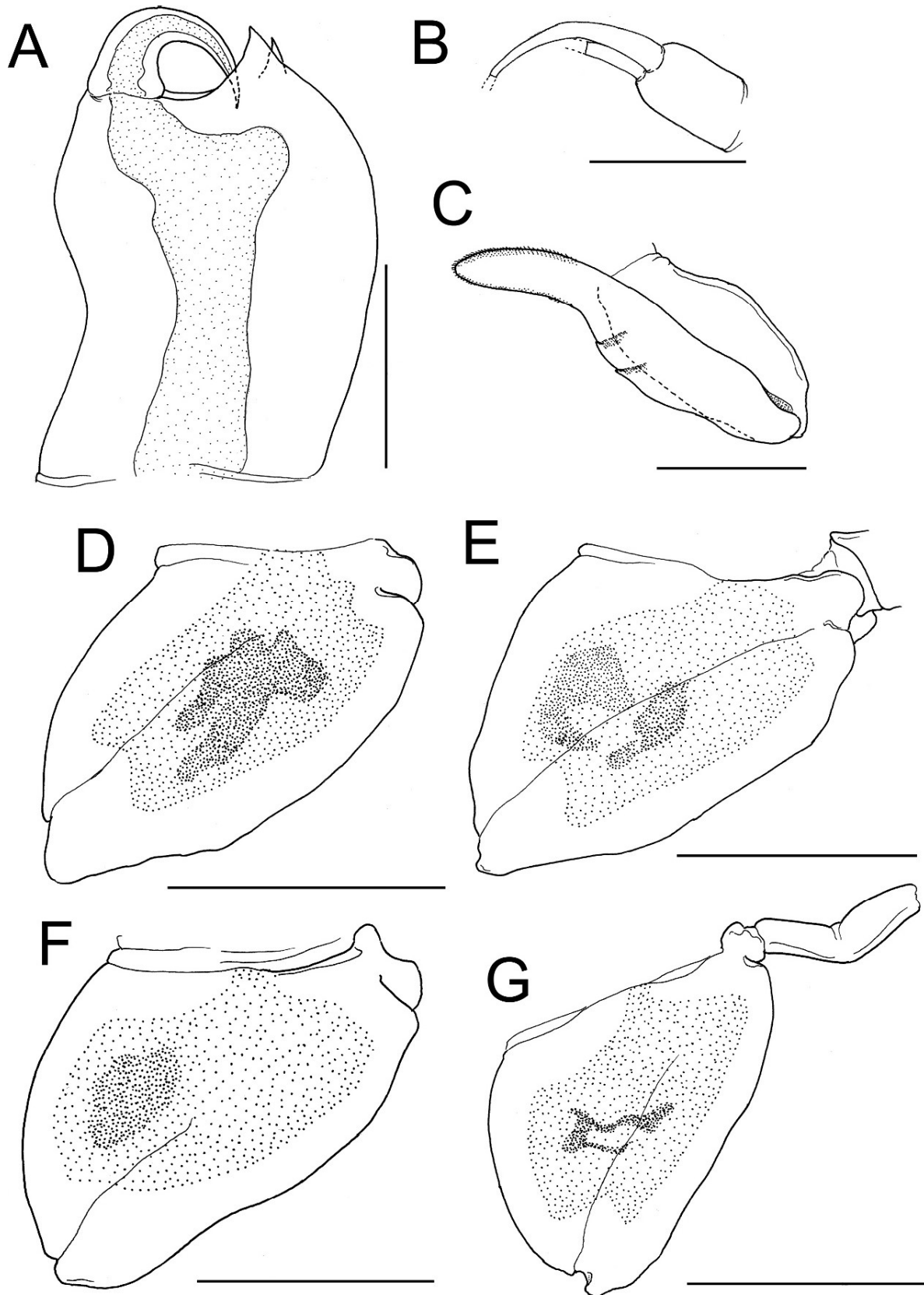


FIGURE 7. *Peniculisa uchinah* n. sp., postmetamorphic female, holotype NSMT-Cr 20935. (A) Antenna, dorsal. (B) Maxillule. (C) Maxilla, anterior. (D) Leg 1. (E) Leg 2. (F) Leg 3. (G) Leg 4. Scale bars: A, F-G, 0.04 mm; B-C, 0.02 mm; D-E, 0.05 mm.

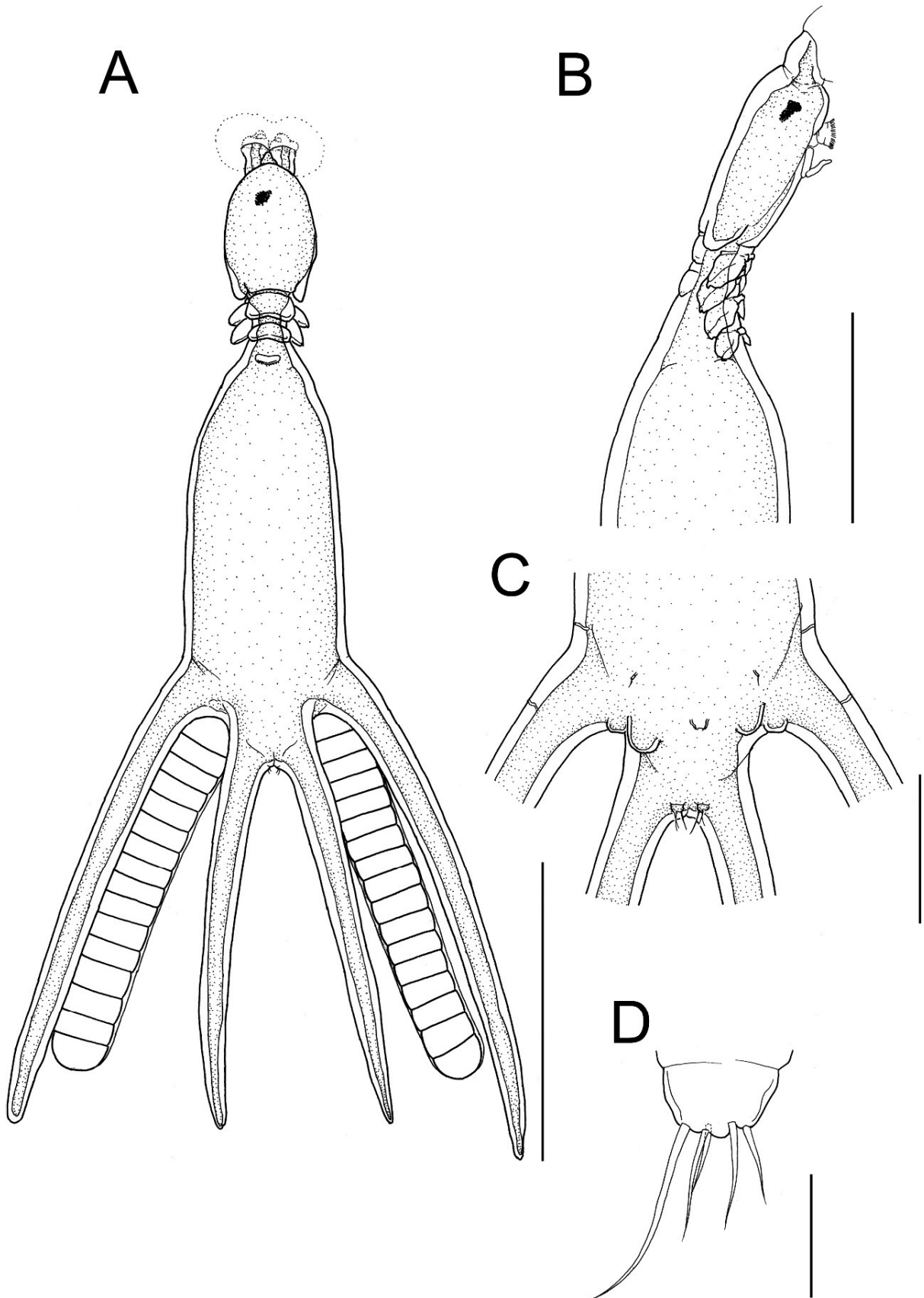


FIGURE 8. *Peniculisa ohirugi* n. sp., postmetamorphic female, holotype NSMT-Cr 20941. (A) Habitus, dorsal. (B) Cephalothorax and free thoracic somites, lateral. (C) Posterior end of trunk, ventral. (D) Caudal ramus, ventral. Scale bars: A, 0.6 mm; B, 0.3 mm; C, 0.2 mm; D, 0.02 mm.

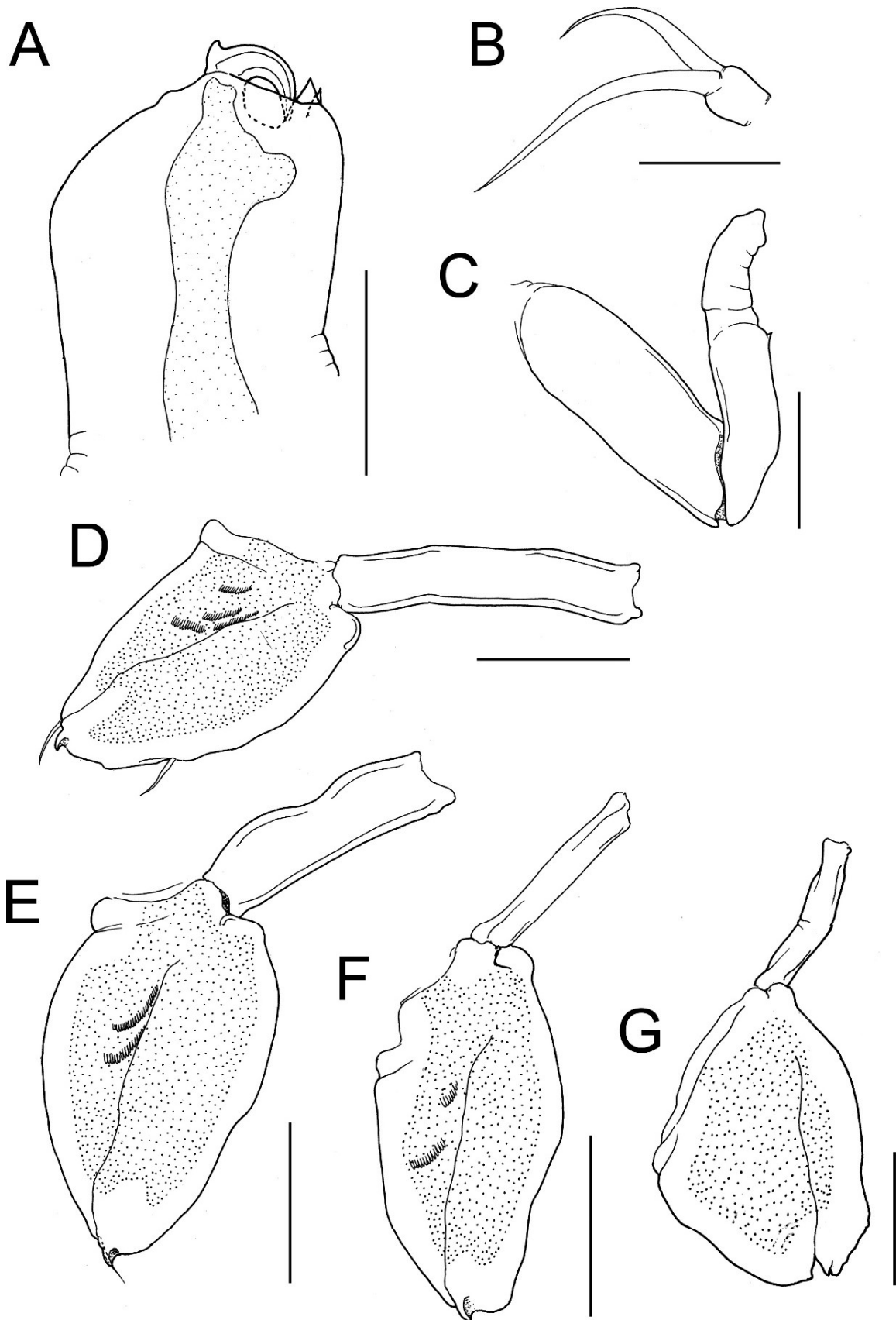


FIGURE 9. *Peniculisa ohirugi* n. sp., postmetamorphic female, holotype NSMT-Cr 20941. (A) Antenna, dorsal. (B) Maxillule. (C) Maxilla, anterior. (D) Leg 1. (E) Leg 2. (F) Leg 3. (G) Leg 4. Scale bars: A, 0.04 mm; B-C, 0.02 mm; D-F, 0.03 mm; G, 0.02 mm.

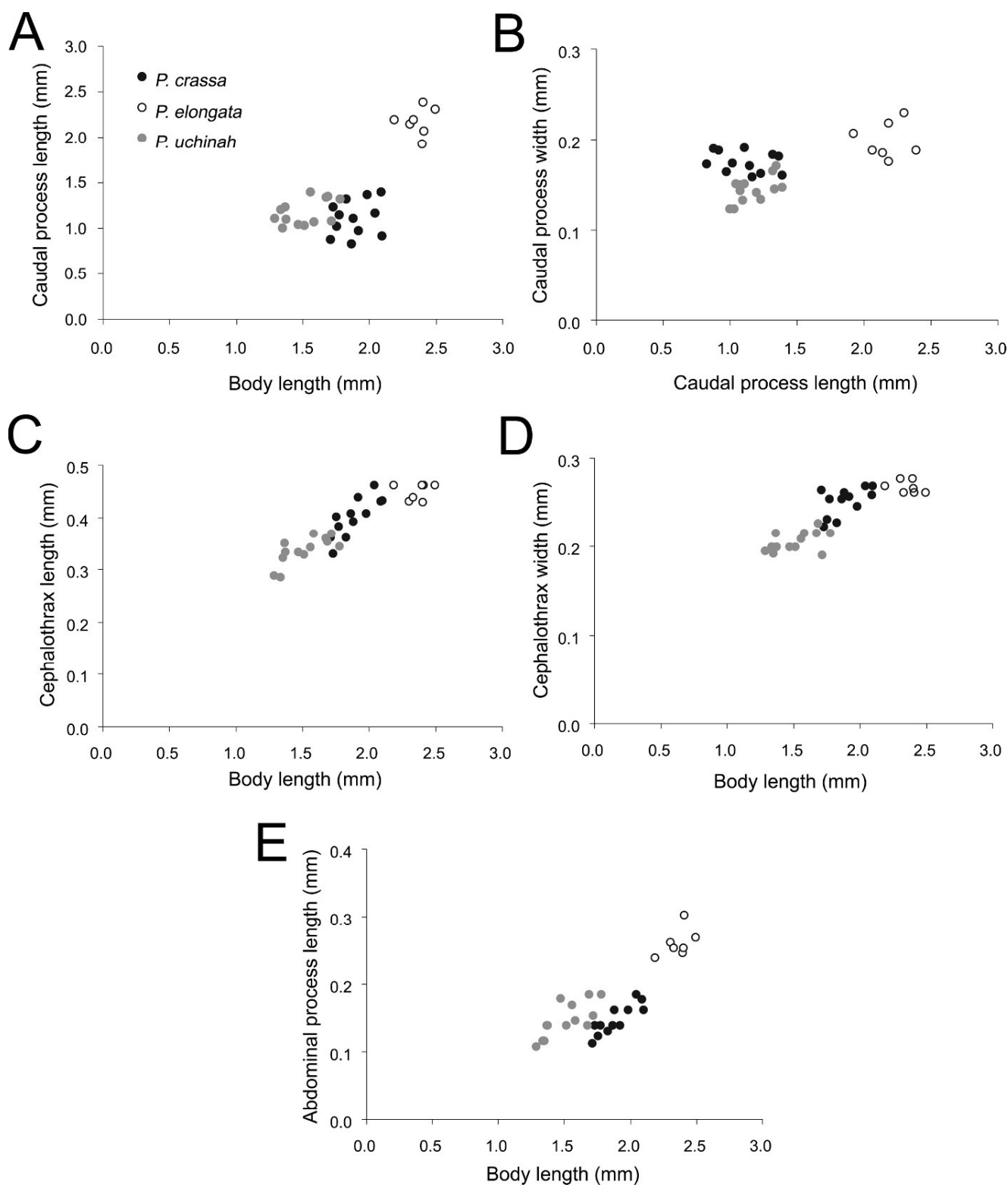


FIGURE 10. Allometric growth of the caudal process, cephalothorax and abdominal process of *P. elongata* n. sp., *P. crassa* n. sp., and *P. uchinah* n. sp. White circle, *P. elongata*; black circle, *P. crassa*; gray circle, *P. uchinah*. Relationships of the (A) body length to the caudal process length, (B) caudal process length to the caudal process width, (C) body length to the cephalothorax length, (D) body length to the cephalothorax width, and (E) body length to the abdominal process length are shown.

LITERATURE CITED

- AONUMA, A., AND T. YOSHINO. 2002. Pomacentridae. *In* Fishes of Japan with pictorial keys to the species, English edition, T. Nakabo (ed.). Tokai University Press, Tokyo, Japan, p. 918–950.
- BOXSHALL, G. A. 1989. Parasitic copepods of fishes: A new genus of the Hatschekiidae from New Caledonia, and new records of the Pennellidae, Sphyrriidae and Lernanthropidae from the south Atlantic and south Pacific. *Systematic Parasitology* **13**: 201–222.
- HAYASHI, M. 2002a. Balistidae. *In* Fishes of Japan with pictorial keys to the species, English edition, T. Nakabo (ed.). Tokai University Press, Tokyo, Japan, p. 1396–1402.
- . 2002b. Monacanthidae. *In* Fishes of Japan with pictorial keys to the species, English edition, T. Nakabo (ed.). Tokai University Press, Tokyo, Japan, p. 1414–1416.
- . 2002c. Ostraciidae. *In* Fishes of Japan with pictorial keys to the species, English edition, T. Nakabo (ed.). Tokai University Press, Tokyo, Japan, p. 1414–1416.
- HUMES, A. G., AND R. U. GOODING. 1964. A method for studying the external anatomy of copepods. *Crustaceana* **6**: 238–240.
- HUYS, R., AND G. A. BOXSHALL. 1991. Copepod evolution. Ray Society, London, U.K., 468 p.
- IZAWA, K. 1965. A new parasitic copepod of the genus *Peniculisa* Wilson from Seto, Wakayama Prefecture, Japan. *Reports of the Faculty of Fisheries, Prefectural University of Mie* **5**: 365–373.
- . 1997. The copepodid of *Peniculisa shiinoi* Izawa, 1965 (Copepoda, Siphonostomatoida, Pennellidae), a single free-swimming larval stage of the species. *Crustaceana* **70**: 911–919.
- KRØYER, H. 1863. Bidrag til kundskab om snyltekrebsene. *Naturhistorisk Tidsskrift* **3**: 75–426.
- LEIGH-SHARPE, W. H. 1934. The copepoda of the siboga expedition. Part II. Commensal and parasitic copepoda. *Siboga Expedition, Monograph* **29b**: 1–43.
- RADHAKRISHNAN, S. 1977. Description of a new species of *Peniculisa* including its immature stages. *Hydrobiologia* **52**: 251–255.
- SHIINO, S. M. 1956. Copepods parasitic on Japanese fishes. 7. *Peniculus* and *Peniculisa*. *Japanese Journal of Zoology* **11**: 593–608.
- WILSON, C. B. 1906. Report on some parasitic Copepoda collected by Professor Herdman, at Ceylon, in 1902. Report to the Government of Ceylon on the Pearl Oyster Fisheries of the Gulf of Manaar **5**: 189–210.