A new species of Pseudomacrochiron Reddiah, 1969 (Crustacea: Copepoda: Macrochironidae) associated with scyphistomae of the moon jellyfish Aurelia sp. (Cnidaria: Scyphozoa) off Jap...

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A new species of *Pseudomacrochiron* Reddiah, 1969 (Crustacea: Copepoda: Macrochironidae) associated with scyphistomae of the moon jellyfish *Aurelia* sp. (Cnidaria: Scyphozoa) off Japan

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Abstract A new species of the Macrochironidae Humes & Boxshall, 1996 (Copepoda: Cyclopoida), *Pseudomacrochiron aureliae* n. sp., is described based on adult specimens extracted from the gastrovacular cavity of the scyphistomae of *Aurelia* sp. (Cnidaria: Scyphozoa) collected in the Seto Inland Sea and Ise Bay off the coast of Japan. The new species differs from its congeners by having the following combination of characters: a caudal ramus with a length to width ratio of 3.1; an accessory flagellum on caudal setae II, III and VI; three apical setae on the maxillule; only setae I and II on the maxillary basis; two short spines on the female maxilliped claw (endopod); an armature of III, I, 4 on the terminal exopodal segment of leg 3; an armature of I, II, 2 on the terminal endopodal segment of leg 3; an armature of II, I, 4 on the terminal exopodal segment of leg 4; and a short free exopodal segment of leg 5 (length to width ratio of 1.4) armed with a long seta and short spine. *P. aureliae* n. sp. is the first member of the genus reported from off Japan and from the scyphistomae of its scyphozoan host.

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Introduction

The moon jellyfish genus *Aurelia* Péron & Lesueur is arguably the most well-known taxon of the Scyphozoa (Cnidaria). Its species are distributed worldwide in coastal waters and are the most common jellyfishes displayed in public aquaria (Häussermann et al., 2009). Only two species of *Aurelia*, *A. aurita* Linnaeus and *A. limbata* (Brandt), were considered valid up to the late 1990s (Dawson, 2003), but recent molecular studies of *Aurelia* spp. suggest there are as many as 16 phylogenetic species (Dawson & Jacobs, 2001; Dawson et al., 2005; Ki et al., 2008). Among the latter, *A. aurita* is economically important, as population blooms of this species can interfere with fishing activities and obstruct coastal power-plant intakes (Mills, 2001; Uye, 2004; Lo et al., 2008; Dong et al., 2010). Species of *Aurelia* exhibit an alternation of generations typical of most scyphozoans, involving an asexually reproducing benthic scyphistoma (polyp) stage alternating with a sexual free-swimming medusoid stage that produces planula larvae (Brusca & Brusca, 2003). Although symbionts, such as the amphipod *Hyperia galba* (Montagu) (Hyperiidae) for example, are known to occur on/in the medusae of

Aurelia spp. (see Arai, 1997; Ohtsuka et al., 2009, 2010), none has been reported from their scyphistomae. In this paper, we describe a new copepod species in the cyclopoid genus *Pseudomacrochiron* Reddiah, 1969 (Macrochironidae Humes & Boxshall, 1996) associated with scyphistomae of an unidentified species of *Aurelia* first discovered in Ise Bay off Minami-chita, Aichi Prefecture, Japan, and found later in the Seto Inland Sea off Ohtake, Hiroshima Prefecture, Japan.

Fig. 2 *Pseudomacrochiron aureliae* n. sp., adult female. A, habitus, dorsal; B, fifth pediger and genital double-somite, dorsal; C, right distolateral corner of anal somite and right caudal ramus, ventral; D, rostrum, anterior; E, right antennule (arrowheads indicate aesthetascs; solid circles indicate position of additional aesthetascs in male), ventral; F, right antenna, lateral; G, labrum, anterior; H, left mandible, dorsal; I, right maxillule, posterior. *Scale-bars*: A, 0.3 mm; B, 0.1 mm; C, E–F, 50 μm; D, G, 25 μm; H, 30 μm; I, 10 μm ▶

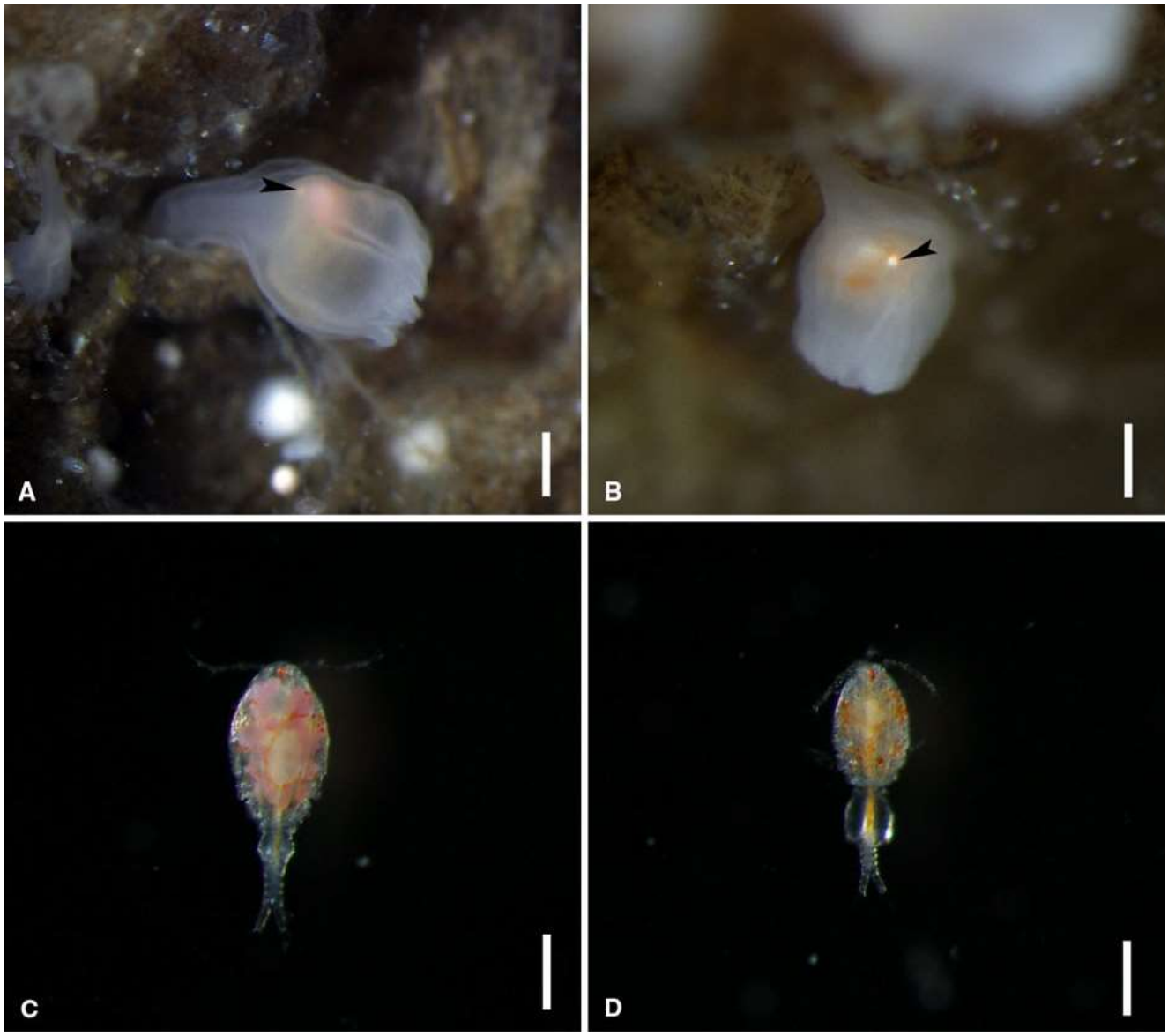
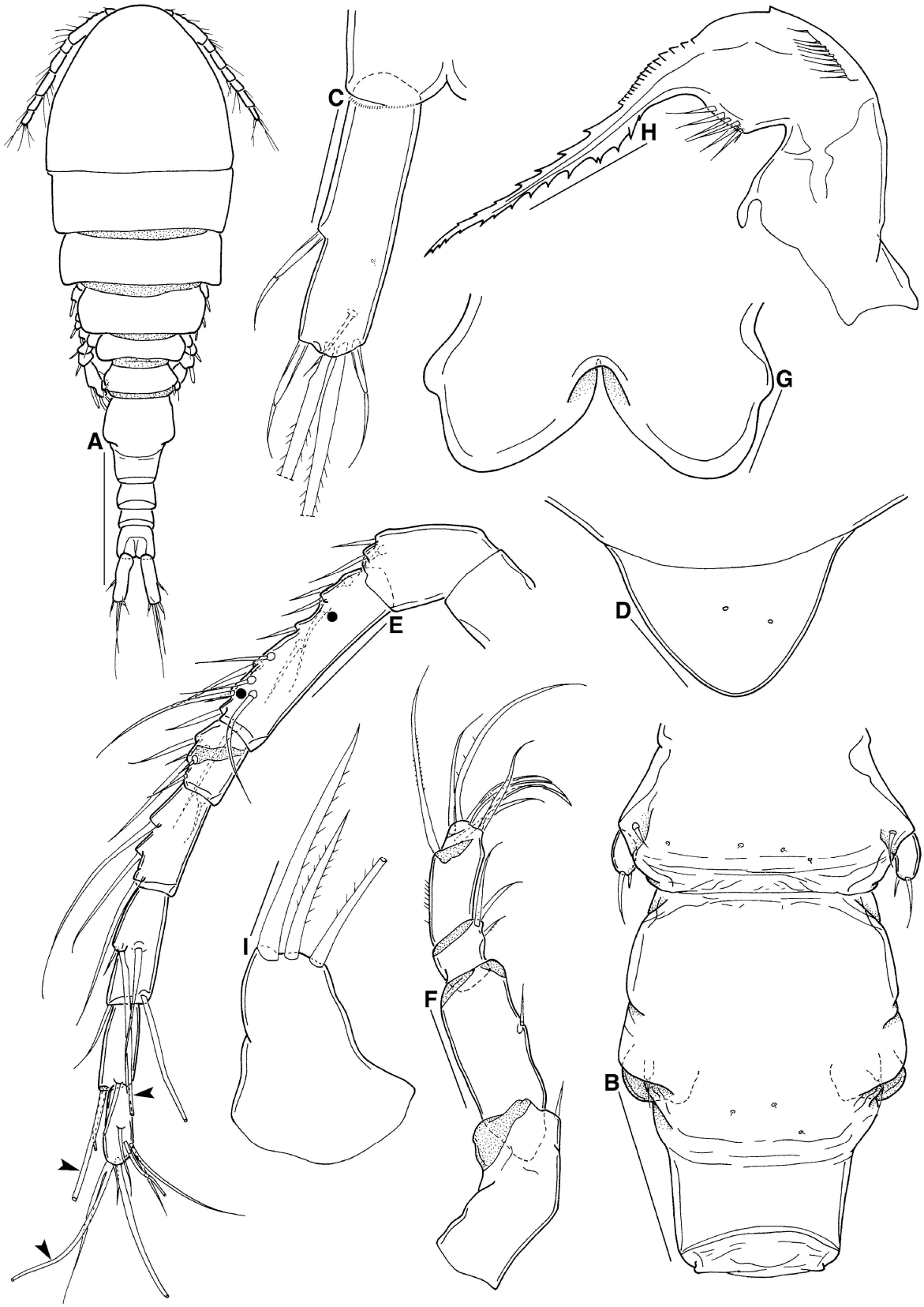


Fig. 1 *Pseudomacrochiron aureliae* n. sp., digital photographs of live specimens collected from Kuba Fishing Port, Ohtake, Japan on 17 May, 2011. A, adult female (arrowhead indicates naupliar eye) inside a scyphistoma of *Aurelia* sp.; B, adult male (arrowhead indicates naupliar eye) inside a scyphistoma of *Aurelia* sp.; C, adult female, dorsal; D, adult male, dorsal. *Scale-bars*: A, 500 μm; B–D, 300 μm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Materials and methods

A clump of Pacific oysters *Crassostrea gigas* (Thunberg) bearing externally attached scyphistomae of *Aurelia* sp. were hand-collected by one of us (A.Y.) from the underside of a pontoon, while SCUBA diving in Toyohama Fishing Port, Oza, Minami-chita, Aichi Prefecture on 23 June, 2010. Clumps of solitary ascidians, *Styela plicata* (Lesueur), with externally attached scyphistomae were also hand-collected by Mariko Takao (Hiroshima University) from the underside of a pontoon, while SCUBA diving in Kuba Fishing Port, Ohtake, Hiroshima Prefecture on 24 December, 2010 and 17 May, 2011, and then kindly forwarded to us for examination. Each sample was isolated in a plastic bottle or plastic bucket in the field and subsequently transported alive to the laboratory for processing. Some live specimens, both *in-situ* and extracted from the host, were photographed using an Olympus DP20 digital camera mounted on an Olympus SZX10 dissection microscope. Each copepod was extracted from individual scyphistoma by gently squeezing the host in an aboral-oral direction with a pair of fine forceps and then pipetted into a glass dish containing seawater. Copepod material from Toyohama Fishing Port was fixed in 5% neutralised formalin and later transferred to 70% ethanol, whereas that from Kuba Fishing Port was fixed and preserved in 70% ethanol.

Preserved copepod specimens were soaked in lactophenol for 2 h prior to examination under an Olympus BX51 phase contrast microscope. Selected specimens were measured intact using an ocular micrometer and/or dissected and examined according to the wooden slide procedure of Humes & Gooding (1964). Measurements given in micrometres, unless otherwise stated, as the mean followed by the range in parentheses. Selected intact specimens and dissected appendages were also drawn with the aid of a drawing tube. Morphological terminology follows Humes & Boxshall (1996).

Copepod material is deposited at the National Museum of Nature and Science (NSMT), Tokyo, Japan.

Pseudomacrochiron aureliae n. sp

Type-host: *Aurelia* sp. [possibly "*Aurelia* sp. 1" based on the geographical distribution pattern of *Aurelia* spp. proposed by Dawson & Jacobs (2001) and Dawson et al. (2005)].

Type-locality: Kuba Fishing Port (34°15′25″N, 132°13′59″E), Seto Inland Sea, Ohtake, Hiroshima Prefecture, Japan.

Other locality: Toyohama Fishing Port (34°42′03″N, 136°56′46″E), Ise Bay, Oza, Minami-chita, Aichi Prefecture, Japan.

Material examined: 4 adult females and 2 adult males, ex 6 scyphistomae of *Aurelia* sp., Kuba Fishing Port, Seto Inland Sea, Ohtake, Hiroshima Prefecture, Japan, 24 December, 2010; 2 adult females and 1 adult male, ex 3 scyphistomae of *Aurelia* sp., Kuba Fishing Port, Seto Inland Sea, Ohtake, Hiroshima Prefecture, Japan, 17 May, 2011; 3 adult females, ex 3 scyphistomae of *Aurelia* sp., Toyohama Fishing Port, Ise Bay, Oza, Minami-chita, Aichi Prefecture, Japan, 23 June, 2010.

Type-material: Holotype female (NSMT-Cr 21680), whole specimen, allotype male (NSMT-Cr 21681), whole specimen, and 4 paratypes (2 females, whole specimens, 1 female, completely dissected and mounted on glass slide, and 1 male, whole specimen) (NSMT-Cr 21682).

Additional material deposited: 3 females, whole specimens, 2 females, completely dissected and each mounted on glass slide, and 1 male, completely dissected and mounted on glass slide (NSMT-Cr 21683–21684).

Site of infection: Within the gastrovascular cavity of the scyphistoma (Fig. 1A,B).

Prevalence: Not determined

Intensity: One copepod per scyphistoma.

Etymology: The specific name is derived from the generic name of the host.

Description (Figs. 1–5)

Adult female

Body 1.37 (1.31–1.42) mm long (excluding caudal setae) and 470 (440–490) wide (n = 4) (Fig. 2A); colour of live specimen in transmitted light pink (Fig. 1C). Prosome composed of broad cephalosome and 4 free and progressively narrower pedigerous somites. Urosome comprised of 5th pedigerous somite, genital double-somite and 3 free abdominal somites. Fifth pediger (Fig. 2B) about twice as wide as long, 80 (70–85) × 169 (150–180). Genital double-somite (Fig. 3B) slightly longer than wide, 177 (155–200) × 170 (160–180), with dorsal cuticular wrinkles

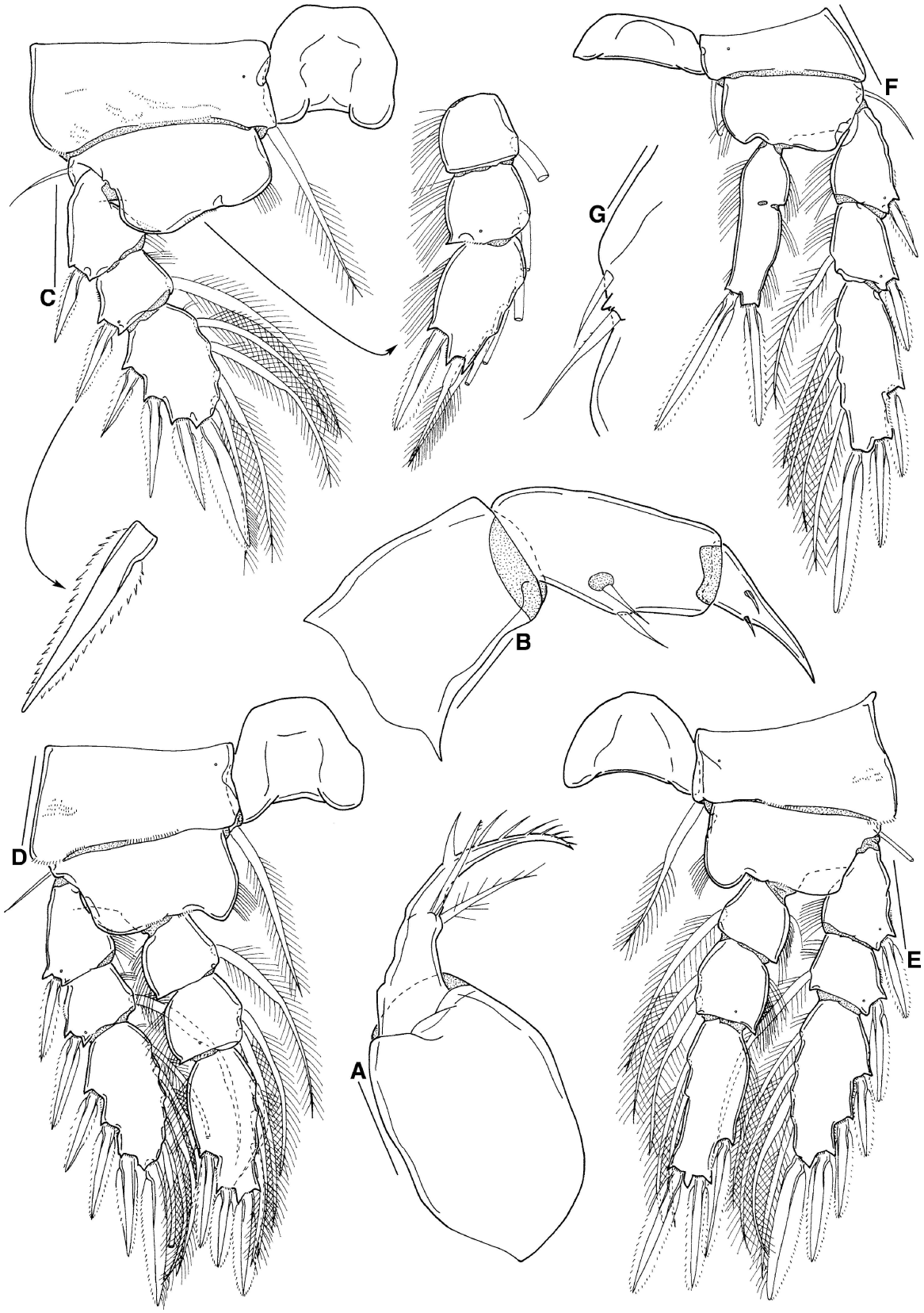
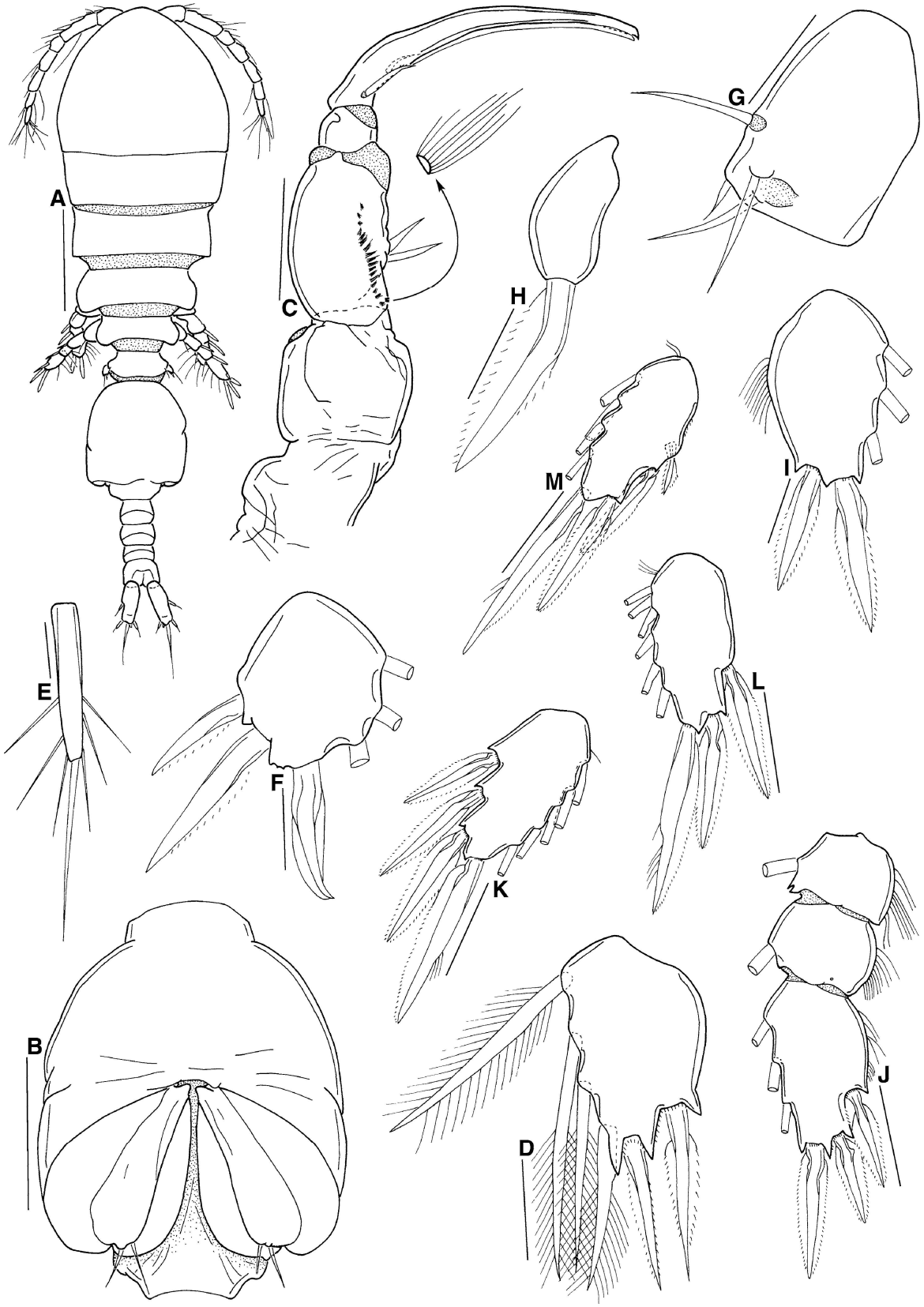


Fig. 3 *Pseudomacrochiron aureliae* n. sp., adult female. A, right maxilla, posterior; B, right maxilliped, posteromedial; C, right leg 1, with endopod shown separately and enlarged view of exopodal spine, anterior; D, right leg 2, anterior; E, left leg 3, anterior; F, left leg 4, anterior; G, right leg 6, lateral. *Scale-bars*: A–B, 25 μm; C–F, 50 μm; G, 10 μm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◀**Fig. 4** *Pseudomacrochiron aureliae* n. sp., adult male (A–D) and adult female (E–M). A, habitus, dorsal; B, genital somite, ventral; C, right maxilliped, with enlarged view of ornamentation on basis, posterior; D, terminal endopodal segment of left leg 1, anterior; E, caudal seta VI, ventral; F, terminal exopodal segment of right leg 1, anterior; G, first segment of right antennule, ventral; H, exopod of right leg 2, anterior; I, terminal endopodal segment of right leg 2; J, endopod of left leg 2, anterior; K, terminal exopodal segment of right leg 3, anterior; L, terminal exopodal segment of left leg 3, anterior; M, terminal exopodal segment of left leg 4, anterior. *Scale-bars*: A, 0.2 mm; B, 0.1 mm; C, J–M, 50 μm; D, F–I, 25 μm; E, 10 μm

located posterior to paired dorsolateral genital apertures. Abdomen 1.8 times longer than wide, 166 (160–175) × 90 (80–95); first 2 free abdominal somites naked; anal somite with row of spinules along posterior margin (Fig. 2C). Caudal ramus (Fig. 2C) 3.1 times longer than wide, 110 (105–115) × 35 (30–40), bearing 6 setae (seta I absent); setae II, III and VI with apical accessory flagellum; setae IV and V ornamented with row of spinules along both margins; seta VII naked.

Rostrum (Fig. 2D) subtriangular, with 2 pores on anterior surface. Antennule (Fig. 2E) 7-segmented, implanted on pedestal, with armature formula 3, 13, 6, 3, 4 + 1 aesthetasc, 2 + 1 aesthetasc and 7 + 1 aesthetasc; all setae naked. Antenna (Fig. 2F) uniramous and 4-segmented; coxobasis with distomedial naked seta; 1st endopodal segment elongate, with medial naked seta; 2nd endopodal segment short, bearing 3 unequal distomedial setae (proximalmost seta semi-pinnate); 3rd endopodal segment ornamented with row of spinules along lateral margin and armed with single outer subapical spinulate seta, 4 apical setae (1 with few spinules; others naked) and 2 apical claws.

Labrum (Fig. 2G) naked, but with small mid-lateral lobe and deep medial incision on posterior margin. Mandible (Fig. 2H) with well-developed proximal notch, row of spinules along linear inner margin, proximal row of spinules, single small tooth at mid-length and distal row of teeth along convex margin, and large denticles along both margins of lash. Maxillule (Fig. 2I) lobate, bearing 1 pinnate and 2 unilaterally pinnate setae. Maxilla (Fig. 3A) 2-segmented; syncoxa robust and unarmed; basis ornamented with large spinules along lateral margin of long tapering lash and bearing setae I and II (former with few apical spinules and latter with long spinules along both margins). Maxilliped (Fig. 3B) 3-segmented; syncoxa large and unarmed; basis about as long as syncoxa, with 2 proximomedial naked setae; endopod forms strong claw, armed with 2 proximal naked spines.

Legs 1–3 (Fig. 3C–E) with trimerous rami; leg 4 (Fig. 3F) with trimerous exopod and unimerous endopod. Armature on rami of legs 1–4 as follows (Roman numerals = spines; Arabic numerals = setae):

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

Leg 1 (Fig. 3C) intercoxal sclerite naked but with rounded protrusion on posterolateral corners. Coxa with single medial pore and spinules on anterior surface and along posterior and posterolateral margins; medial seta plumose. Basis with row of setules along mediodistal margin and spinules about insertion of endopod; lateral seta naked. All exopodal segments with setules along medial margin and spinules about insertion of each spine; middle segment with single pore and short row of spinules along proximolateral margin; all setae plumose and nearly all spines with serrate flange; apical spine on 3rd segment with outer serrated flange and distomedial row of setules. All endopodal segments with setules along lateral margin; 2nd segment with single pore and spinules along posterior margin; 3rd segment with spinules about insertion of lateral spine and apical seta; spine with serrate flange and all setae plumose. Leg 2 (Fig. 3D) similar to leg 1, except as follows: (1) coxa with fewer spinules on anterior surface; (2) basis with mediodistal protrusion; (3) 1st exopodal segment with single pore; (4) middle segment with additional spinules along posterior margin; (5) third exopodal segment and middle endopodal segment each with additional seta; (6) third endopodal segment armed with 3 spines and 3 setae. Leg 3 (Fig. 3E) similar to leg 2, except 1st exopodal segment has spinules along lateral margin, middle exopodal segment without spinules along posterior margin and terminal segment of each ramus more elongate and each with 1 fewer seta. Leg 4 (Fig. 3F) similar to leg 3, except with smaller intercoxal sclerite, naked coxa, shorter and naked inner

coxal seta, naked posterior margin on basis, 1 less spine on terminal exopodal segment and 1-segmented endopod armed with 2 apical spines (outer apical spine 3/4 length of inner apical spine).

Leg 5 (Fig. 2B) composed of protopod completely fused to somite and free exopodal segment; protopodal seta naked; exopod subquadrate, 20.3 (15–25) × 14.7 (14–15), bearing 1 naked seta and 1 naked spine apically (spine about 1/3 length of adjacent seta). Leg 6 (Fig. 3G) rudimentary, represented by genital operculum armed with 1 small spiniform process and 1 naked and 1 semi-pinnate setae.

Adult male

Body 1.11 (1.10–1.12) mm long (excluding caudal setae) and 335 (320–350) wide (n = 2) (Fig. 4A); colour of live specimen in transmitted light orange (Fig. 1D). Prosome composed of broad cephalosome and 4 free pedigerous somites. Urosome comprised of 5th pedigerous somite, genital somite and 4 free abdominal somites. Fifth pediger 2.5 times wider than long [50 (50–50) × 125 (115–135)]. Genital somite (Fig. 4B) longer than wide, 220 (220–220) × 207 (200–215), with ventral pair of genital apertures. Abdomen 2.2 times longer than wide, 167 (165–170) × 75 (70–80). Caudal ramus 2.6 times longer than wide, 85 (80–90) × 32 (30–35), armed as in female.

Antennule similar to that of female, except with armature 13 + 2 aethetascs on 2nd segment (position of aesthetascs indicated by solid circles in Fig. 2E). Maxilliped (Fig. 4C) 4-segmented; syncoxa large and unarmed; basis elongate, bearing row of comb-like structures on posterior surface each composed of numerous, tightly packed setules and 2 naked medial setae; 1st endopodal segment short and unarmed; distal endopodal segment forms long claw, bearing 2 proximal setae and hyaline membrane along concave margin. Terminal endopodal segment of leg 1 (Fig. 4D) armed with 2 spines and 4 setae. Leg 6 (Fig. 4B) modified, represented by genital operculum bearing 2 apical naked setae.

Variability

Four females from Kuba Fishing Port with spinules on caudal seta VI (Fig. 4E). One female from Kuba Fishing Port with 3 spines and 3 setae on terminal exopodal segment of right leg 1 (Fig. 4F). Another female from Kuba Fishing Port with additional seta on 1st segment of right antennule (Fig. 4G), vestigial exopod on right leg 2 (Fig. 4H) and 1 less spine on terminal endopodal segment of right leg 2 (Fig. 4I). One female from Toyohama Fishing Port with 2 distomedial spiniform processes on 1st endopodal segment and 1 less seta on middle endopodal segment of left leg 2 (Fig. 4J), 1 additional seta on terminal exopodal segment of right leg 3 (Fig. 4K), 1 less spine and 2 additional setae on terminal exopodal segment of left leg 3 (Fig. 4L) and 1 additional spine on terminal exopodal segment of left leg 4 (Fig. 4M). Another female from Toyohama Fishing Port with incompletely 3-segmented endopod lacking 2 medial setae on 2nd segment of left leg 3 (Fig. 5A) and shorter endopod on leg 4 (Fig. 5B). One male lacking spiniform process between bases of apical spines on terminal endopodal segment of right leg 3 (Fig. 5C) and with 1 additional spine on terminal exopodal segment of right leg 4 (Fig. 5D) and endopod of left leg 4 (Fig. 5E).

Remarks

There are presently seven species of *Pseudomacrochiron*: *P. parvum* (A. Scott, 1909), *P. fucicolum* (T. Scott, 1912), *P. malayense* (Sewell, 1949), *P. ornatum* (Krishnaswamy, 1952), *P. stocki* Reddiah, 1969, *P. urostenum* Kim, 2000 and *P. pocilloporae* Kim, 2004. The new species shares with *P. urostenum* the combination of a free exopodal segment of leg 5 that is less than twice as long as wide and armed apically with a single seta and spine. This segment in the other congeners is more than three times as long as wide and bears two setae in *P. parvum*, *P. fusicolum* and *P. malayense*, two spines in *P. ornatum* or one seta and one spine in *P. stocki* and *P. pocilloporae*. The new species can be easily distinguished from *P. urostenum* by having a shorter caudal ramus (length to width ratio of 3.1 *vs* 6.3), an accessory flagellum on caudal setae II, III and VI, three apical setae on the maxillule, only setae I and II on the maxillary basis, shorter spines on the female maxilliped claw (endopod), an armature of III, I, 4 on the terminal exopodal segment of leg 3, an armature of I, II, 2 on the terminal endopodal segment of leg 3, an armature of II, I, 4 on the terminal exopodal segment of leg 4 and a

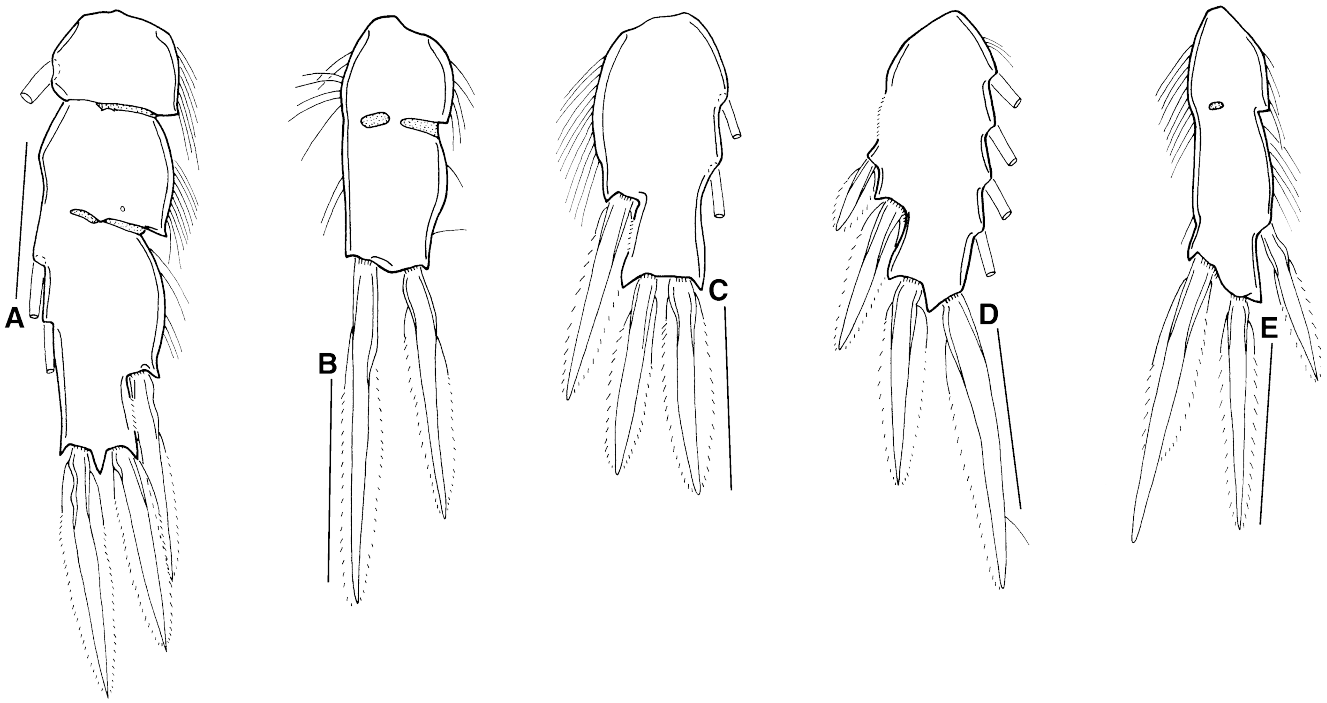

Fig. 5 *Pseudomacrochiron aureliae* n. sp., adult female (A–B) and adult male (C–E). A, endopod of left leg 3, anterior; B, endopod of left leg 4, anterior; C, terminal endopodal segment of right leg 3, anterior; D, terminal exopodal segment of right leg 4, anterior; E, endopod of left leg 4, anterior. *Scale-bars*: A–E, 50 μm

considerably shorter spine on the free exopodal segment of leg 5.

Although members of *Pseudomacrochiron* are generally considered to be associates of scyphozoan cnidarians (Humes & Stock, 1973; Humes & Boxshall, 1996), as is the case, for example, of *P. stocki* from washings of the medusae of the scyphozoan *Chrysaora quinquecirrha* (Desor) (as *Dactylometra quinquecirrha* L. Agassiz) from Madras Marina Beach, India (Reddiah, 1969) and *P. aureliae* n. sp. from the scyphistomae of *Aurelia* sp. from off Japan, one species, *P. pocilloporae*, was recently collected from the scleractinian coral *Pocillopora damicornis* (Linnaeus) at Uraba Island off the Pacific coast of Panama (Kim, 2004). Furthermore, the invertebrate host is unknown for the five remaining congeners: *P. parvum* was collected from plankton and "weed washings" from the Indo-West Pacific (A. Scott, 1909; Sewell, 1949; Ganapati & Shanthakumari, 1961) and *Sargassum natans* (Linnaeus) washings from the Northwest Atlantic (Morris, 1973), *P. fucicolum* from "gulfweed" off St. Helena in the South Atlantic (T. Scott, 1912), *P. malayense* from plankton off the Malay Peninsula and Andaman Islands (Sewell, 1949), *P. ornatum* from plankton off the coast of Madras, India (Krishnaswamy, 1952) and *P. urostenum* from an intertidal mud flat at Jakyak-do Island off Inchon, Korea (Kim, 2000).

Pseudomacrochiron aureliae n. sp. is the first member of the genus and only the second macrochironid reported from Japanese waters; the other macrochironid, *Paramacrochiron japonicum* Humes, 1970, was found on the medusa of the scyphozoan *Thysanostoma thysanura* Haeckel from off Sirahama, Wakayama Prefecture (Humes, 1970). Moreover, *P. aureliae* and *Nitocra medusaea* Humes, 1953 (as *Nitokra medusaea*) (Harpacticoida, Ameiridae) are the only two copepod species reported thus far from *Aurelia* sp.; however, the latter parasite was found on the medusa rather than the scyphistoma of *Aurelia* sp. and off the coast of New Hampshire, USA (Humes, 1953). Research on the population dynamics, life-history and geographical distribution of *P. aureliae* n. sp. in Japanese waters is currently underway and will be dealt with in detail elsewhere.

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