

Pseudocyclops schminkei (Copepoda, Calanoida, Pseudocyclopidae): a new species from Okinawa

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Abstract Both genders of *Pseudocyclops schminkei* n. sp. are described from a pearl fishery aquarium on Zamami Island, Okinawa, Japan; it is the 37th species of the genus. *Pseudocyclops schminkei* sp. nov. differs from other species of the *magnus* species group in the shape of the lobes of distal exopodal segment of the male left leg 5, and the morphology of setae on middle and distal exopodal segment of male right swimming leg 2. Aspects of the morphology of *P. xiphophorus* and *P. bilobatus* are redescribed, and an unnamed *Pseudocyclops* sp. from the Shedd Aquarium in Chicago, IL, is briefly noted. Females of *P. schminkei* sp. nov., *P. xiphophorus* and *Pseudocyclops* sp. could not be separated from each other with the small number of specimens available in this study for the former two species.

Keywords *Pseudocyclops* · New calanoid copepod · Morphology

Introduction

Although most calanoid copepods are planktonic, a significant calanoid fauna is associated with waters immediately above the seabed. In the deep-sea, this benthopelagic fauna is poorly known but diverse (Markhaseva and Ferrari 2005), and its elucidation is expected to require a sustained taxonomic effort (Bradford-Grieve 2004). In coastal marine habitats, benthopelagic calanoids are better known taxonomically. As a result of this knowledge, a general body architecture and limb configuration were proposed for coastal benthopelagic calanoids almost a half century ago, “small size, plump body, short antenna 1, and strong outer spines on the exopods of the swimming legs” (Bowman and González 1961: 37).

Pseudocyclops Brady, 1872 is one of the most speciose and widely distributed of the coastal benthopelagic calanoid genera. It is one of two genera along with *Miheptneria* Andronov, 2007 in the family Pseudocyclopidae Giesbrecht, 1893, which is one of two families along with Ridgewayiidae Wilson, 1958 in the superfamily Pseudocyclopoidea Andronov, 1974. Brady (1872) originally included the only known species that was known at that time, *P. crassiremis* Brady, 1872, in the copepod family Misophriidae because of the configuration of its well-developed first maxilla. However, copulatory openings of both males and females are paired in species of Misophriidae while males of *Pseudocyclops* have a single, asymmetrically positioned copulatory opening. Based on this derived attribute, Giesbrecht (1893) proposed the family Pseudocyclopidae and placed its species in Calanoida. A recent proposal (Andronov 2007) to include in the family Pseudocyclopidae, all of the species in the superfamilies Pseudocyclopoidea and Epacteriscoidea, i.e. those species belonging to the families Pseudocyclopidae, Epacteriscidae, Boholinidae and

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Ridgewayiidae, would increase the number of genera in Pseudocyclopidae to 31.

Species of *Pseudocyclops* are distributed in waters immediately over the seabed from the coastal zone to the edge of the continental shelf (Andronov 1986). They are almost exclusively marine (Markhaseva and Dahms 2004), although a few species have been reported from brackish waters (Zagami et al. 2005, Brugnano et al. 2006, 2009). Among the 36 nominal species that have been assigned to *Pseudocyclops*, excluding 2 nominal subspecies of *P. obtusatus* Brady and Robertson, 1873, only *P. stephoides* Thompson, 1895 has been removed from the genus, to *Thompsonia* Jaume, Fosshagen and Iliffe, 1999. Of the remaining 35 nominal species, 23 were described within a century after the genus was established while 12 species, about one-third, have been described in the last 35 years.

The distribution of species of *Pseudocyclops* is not well understood. Many species are known from a few specimens and most have been reported from only one locality. Three species known regionally are *P. cokeri* Bowman and González, 1961, *P. rostratus* Bowman and González, 1961, and *P. rubrocinctus* Bowman and González, 1961 from the Caribbean Sea and Gulf of Mexico (see Bowman and González 1961; Fosshagen 1968). *Pseudocyclops obtusatus* and its subspecies have been reported from the Atlantic Ocean (Brady and Robertson 1873), the Indian Ocean (Sewell 1932; Ummerkutty 1968), and the Pacific Ocean (Vervoort 1964), but the conspecificity of these specimens has been questioned (Haridas et al. 1994). *Pseudocyclops xiphophorus* Wells, 1967 has been reported as occurring naturally in coastal waters of the Indian Ocean off Mozambique and in Lake Faro, Sicily (see Wells 1967; Zagami et al. 2005; Brugnano et al. 2009) although neither a Lessepsian dispersion (Por 1971) nor an introduction by ship ballast water (Carlton 1985) was considered for either of these populations. A broad distribution for *P. magnus* Esterly, 1911 from Bermuda in the Atlantic Ocean resulted when Nicholls (1944) placed it in synonymy with *P. latens* Gurney, 1927 from the Red Sea, adjacent to the Indian Ocean, despite a notable difference in size between the only female specimen known for each species (0.63 mm vs. 1.1 mm). Yeatman (1975) described female and male specimens, which he attributed to *P. magnus* from St. James, Barbados, extending the distribution of this species appreciably, but again females (0.60–0.68 mm) were notably smaller than Esterly's specimen.

Adults of *Pseudocyclops* spend the greater part of the diel cycle on or near the substrate, although some copepodids may be collected in open water immediately above the seabed for short periods at night. The plump, nearly spherical shape and relatively short first antennae of the copepodid stages may limit their ability to remain in the water column. Post-embryonic development has been described

for only one species, *P. umbraticus* Giesbrecht, 1893 (see Costanzo et al. 2004), but nothing is known about the distribution of the naupliar stages.

In this paper, we describe the new species *Pseudocyclops schminkei*. It is the first species reported from Okinawa and only the third species known from Japanese waters, along with *P. australis* Nicholls, 1944 reported by Tanaka from Kyushu and *P. lepidotus* Barr and Ohtsuka, 1989 originally described from Kyushu.

Specimens and methods

Pseudocyclops schminkei sp. nov.: female holotype (USNM 1115511), male allotype (USNM 1115512), 6 female paratypes (USNM 1115513), and 2 male paratypes (USNM 1115514) are deposited in the Crustacea collection of the Smithsonian Institution's National Museum of Natural History. They were collected with sediment from an aquarium at Kerama Pearl Ltd, a pearl fishery on Zamami Island, Okinawa, Japan on 5 January 2007; the aquarium is used to culture juvenile pearl oysters. Juvenile pearl oysters are collected locally, and maintained in local seawater that is passed through a sand filter before entering the aquarium. In addition to any naturally occurring zooplankton, juvenile pearl oysters are fed a dried artificial food, but this dried food is not considered a source for the copepod (e-mails from N. Iwasaki, 17 and 21 May 2008). For these reasons, the copepods are considered endemic to Zamami Island. The sample with *P. schminkei* sp. nov. was fixed in ca. 5% neutralized formalin immediately after capture, transferred to 70% ethanol, and subsequently transferred into glycerol for slide preparation.

Pseudocyclops bilobatus Dawson, 1977: 6 female paratypes and 5 male paratypes from the Los Angeles County Museum (LACM CR 1975-586.2).

Pseudocyclops xiphophorus Wells, 1967: 1 female paratype and one male paratype from the Natural History Museum (BMNH 1967.8.4.2).

Pseudocyclops sp.: numerous females, males and juvenile copepodids from a culture maintained at the Shedd Aquarium in Chicago, IL (USNM 1123189). The origin of these copepods is not known but they may have been introduced into that aquarium in or on live corals from Fiji, or with live algae from the Caribbean. The aquarium system has been running for over 12 years and these *Pseudocyclops* were first observed about 5 years ago (e-mail from M. Schick, 14 February 2008). Because the origin of these animals in culture is not known, they are described but not named.

All specimens were observed either with phase contrast at 1,250 \times magnification used for preliminary observations and for the line drawings, or with bright field or differential

interference contrast at magnifications of 375–1,875 \times . Some specimens were dissected and stained in chlorazol black E. All drawings were prepared using a camera lucida on a Nikon HFX-DX compound microscope at a magnification of 1,000 \times . Measurements were made with an ocular micrometer. Scale bars in illustrations are in micrometer.

Descriptive terms follow Ferrari (1995) with the exception of maxilla 1, maxilla 2 and maxilliped, which follow Ferrari and Ivanenko (2008). The term “complex” refers to two or more limb segments that are not separated by arthro-dial membranes (Ferrari and Ivanenko 2001, Ferrari and Dahms 2007). A distal segment complex for rami of copepod swimming legs has been proposed by Ferrari and Benforado (1998); complete analyses are given in Ferrari and Dahms (2007). An epicuticular extension of a limb segment is a denticle. Somites are numbered according to their relative developmental age, following Hulsemann (1991). Total length, measured in lateral view and given as prosome length/urosome length = total, includes caudal rami and rostrum but does not include the portion of the prosome that overlaps the urosome. The following abbreviations are used in the descriptions: Cph, cephalosome (cephalic somites 1–5 plus thoracic somite 1); Pr, prosome (cephalosome plus thoracic somites 2–6); Ur, urosome (thoracic somite 7 plus abdominal somites 1–4); Pd1–Pd5, 1st–5th pedigerous somites [thoracic somites 2–6]; Th, thoracic somite; Abd, abdominal somite; A1, antennule; A2, antenna; Md, mandible; Mx1, maxillule; Mx2, maxilla; Mxp, maxilliped [1st thoracopod]; P1–P4, swimming legs 1–4 (thoracopods 2–5); P5, leg 5 (thoracopod 6); on A1, a segment with 1 seta and 1 aesthetasc on a segment is designated 1s + 1ae; “1?” indicates that a setal element was broken so that its identity on A1 could not be determined, and only the scar at the location of its attachment was counted.

Order Calanoida Sars, 1901

Superfamily Pseudocyclopoidea Andronov, 1974

Family Pseudocyclopidae Giesbrecht, 1893

Genus *Pseudocyclops* Brady, 1872

Species *Pseudocyclops schminkei* sp. nov.

Figures 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11

Habitus: Female allotype, 0.40/0.15 = 0.55 mm; 6 female paratypes, 0.43/0.13 = 0.56 mm, 0.46/0.15 = 0.61, 0.43/0.16 = 0.59, 0.41/0.14 = 0.55, 0.45/0.15 = 0.60, 0.46/0.17 = 0.63. Body (Fig. 1a, b) compact; Pr oval in dorsal view, 2.9 times as long as Ur. Cph ventrally with well-developed rostrum (Fig. 1b); Cph and Pd1 separate; thin arthro-dial membrane between Pd4 and Pd5. Urosome (Fig. 2a, b) 4-segmented; genital double-somite, Abd 3, Abd 4 with pleated epicuticular fringe posteriorly; fringe of Abd 4 dorsally lobate (Fig. 1a). Genital double-somite with small point laterally toward anterior edge and ventral ridge posterior to paired, anteroventral oviducal openings; paired

copulatory pores anterior to paired, tooth-like, ventral extensions of epicuticle (Fig. 2b); linear series of indentations from small point to copulatory pore on right side. Anal somite narrow, covered by posterior epicuticular fringe of Abd 4 (Fig. 2a; Table 1).

A1 (Fig. 3a): reaching beyond middle of Pd1; 17 articulating segments armed as follows: 1:14s + 3a; 2: 4s; 3: 2s; 4: 2s; 5: 2s; 6: 2s; 7: 2s; 8: 2s; 9: 2s; 10: 2s; 11: 2s; 12: 2s; 13: 2s; 14: 2s; 15: 4s; 16: 2s; 17: 6s + 1a.

A2 (Fig. 3b): coxa unarmed; basis with distomedial seta. Endopod 3-segmented, proximal segment with 1 medial seta at midlength; middle segment with 5 setae along medial margin and 3 distomedial setae, and lateral and distal denticles; distal segment with 7 terminal setae, and lateral and medial denticles. Exopod appearing 6-segmented; proximal segment to 3rd segment with thin, distal arthro-dial membrane and medial seta; 4th segment apparently a complex with 3 medial setae originating close together; 5th segment apparently a complex with 2 medial setae, at midlength and distally; terminal segment with 3 setae.

Md (Fig. 3c): coxa with hook-like attenuation, coxal gnathobase without seta and with 8 thick teeth; basis with 2 medial setae and medial denticles. Endopod 2-segmented, proximal segment with 4 distomedial setae, distal segment with 10 terminal setae. Exopod 4-segmented, distal segment with 3 setae, remaining segments with 1 medial seta each.

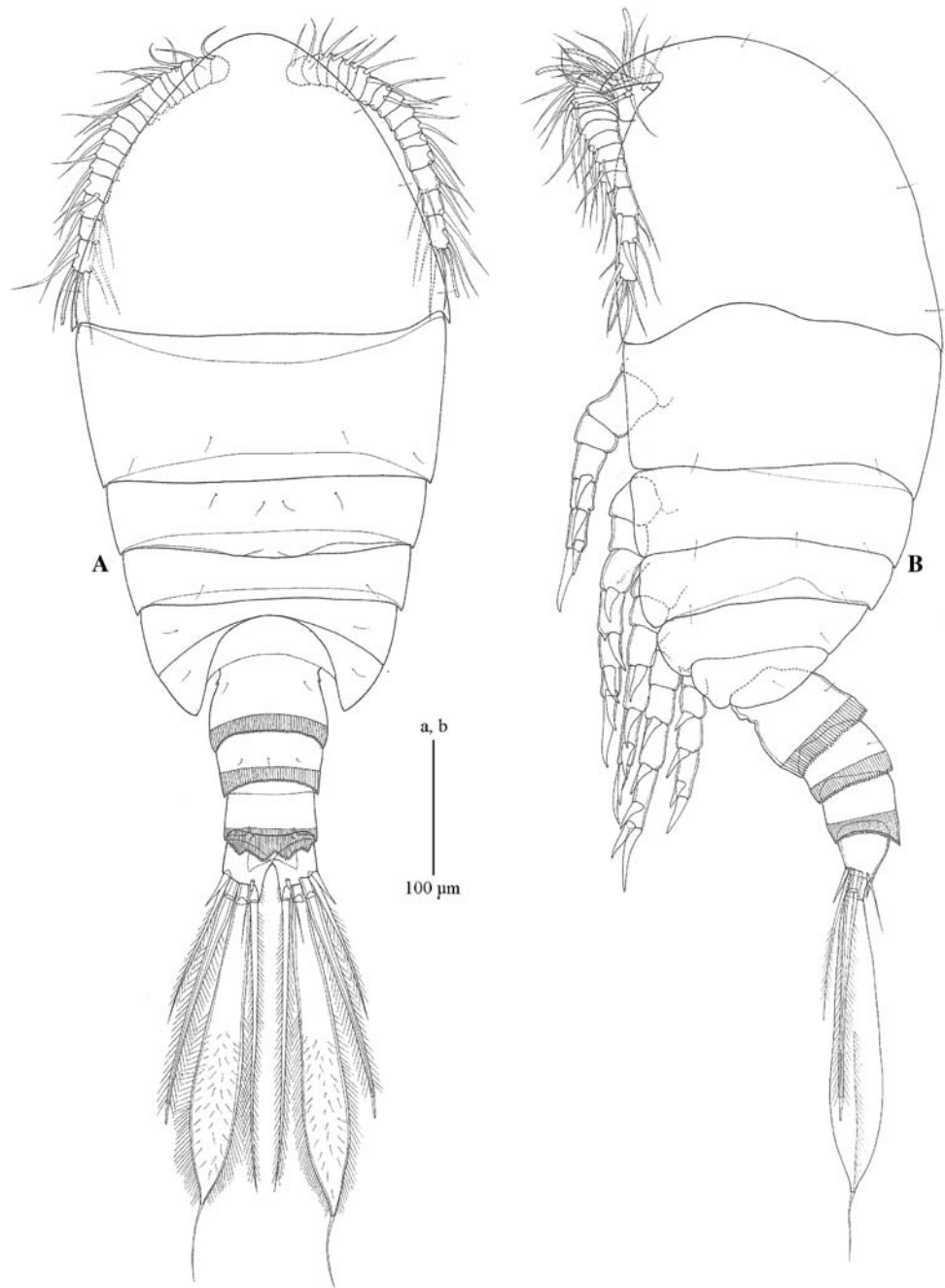
Mx1 (Fig. 4a, b): praecoxal endite extending distally with 5 thick and 3 thin ventral setae, 1 anterior seta and 4 posterior setae; coxal exite with 4 setae, coxal endite with 3 setae; basal exite with 1 seta, proximal endite well-developed with 3 setae, distal endite not extended ventrally with 4 setae; exopod lobate with 4 lateral and 7 terminal setae; endopod 2-segmented, proximal segment with groups of 5 mid-ventral and 4 distoventral setae; distal segment with 6 terminal setae.

Mx2 (Fig. 4c, d): praecoxal endite of syncoxa with 5 setae, coxal endite with 3 setae; proximal and distal basal endites with 3 setae each. Endopod 3-segmented; ventral lobe of proximal segment with 6 setae, middle segment with 1 posteroproximal seta and 2 distoventral setae, distal segment with 5 setae.

Mxp (Fig. 4e): syncoxa with 1, 1, 3 setae on proximal, middle and distal praecoxal endites, respectively, and 2 setae on coxal endite; proximal endite of basis pronounced, with 3 setae, distal endite with 2 setae; endopod 5-segmented with 2 medial, 2 medial, 2 medial, 2 (1 medial, 1 lateral), 4 (1 medial, 2 terminal, 1 lateral) setae.

P1–4 coxa with medial seta; rami 3-segmented (Figs. 5a, b, 6a, b), all with medial seta and lateral spine-like seta on the proximal and middle exopod segments; 1 medial seta on the proximal endopodal segment and 2 medial setae on the middle endopodal segment. Medial setae on exopod and all setae on endopod articulate.

Fig. 1 *Pseudocyclops schminkei* sp. nov. female, allotype. **a** habitus, dorsal; **b** habitus, right lateral



Basis of P1–2 unarmed; of P3 with lateral, spine-like seta; of P4 with lateral seta; basis of P3–4 attenuate distomedially. Distal exopodal complex of P1–2 with 2 lateral spine-like setae, of P3–4 with 3 lateral spine-like setae; distal complex of P1 with 4 medial setae, of P2–4 with 5 medial setae.

Distal endopodal complex of P1 with 1 lateral seta, 2 terminal setae and 3 medial setae; of P2–3 with 2 lateral seta, 2 terminal setae and 4 medial setae; of P4 with 2 lateral seta, 2 terminal setae and 3 medial setae.

P1 without denticles; P2–4 with denticles posteriorly on middle segment of exopod and endopod; P3–4 with

denticles posteriorly on distal segment complex of exopod and endopod. P1 without pores on posterior surface; proximal endopodal segment of P3 with pore on posterior face; distal endopodal complex of P2–4 with pore and thickened integumental ridge internally on posterior face; distal exopodal complex of P3–4 with pore and thickened integumental ridge on posterior face.

P5 (Fig. 6c): intercoxal sclerite with complete row of denticles proximally and broken row of denticles distally; coxa with partial row of denticles laterally and complete row of denticles distally; basis attenuate distomedially with lateral seta. Proximal and middle exopodal segments without

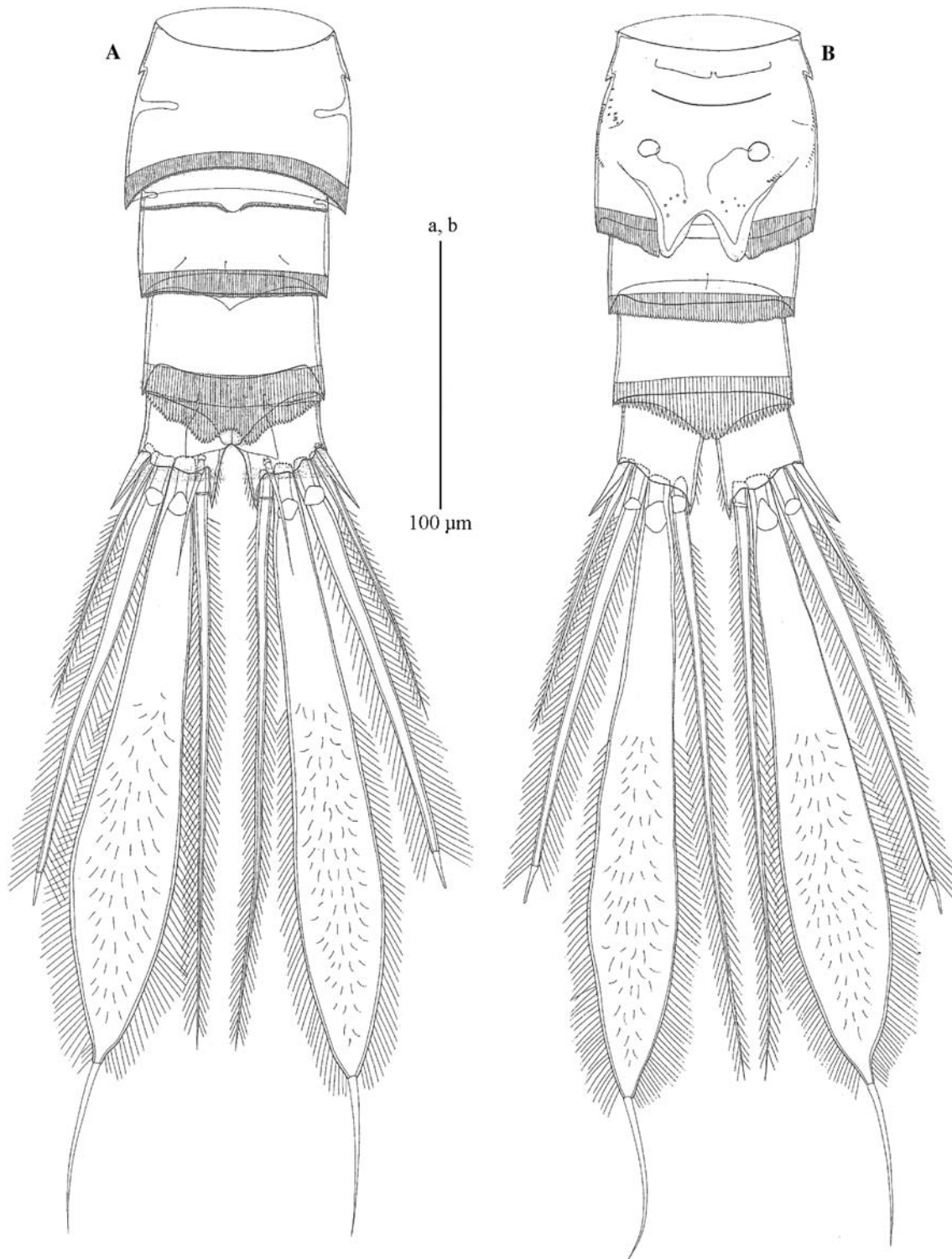


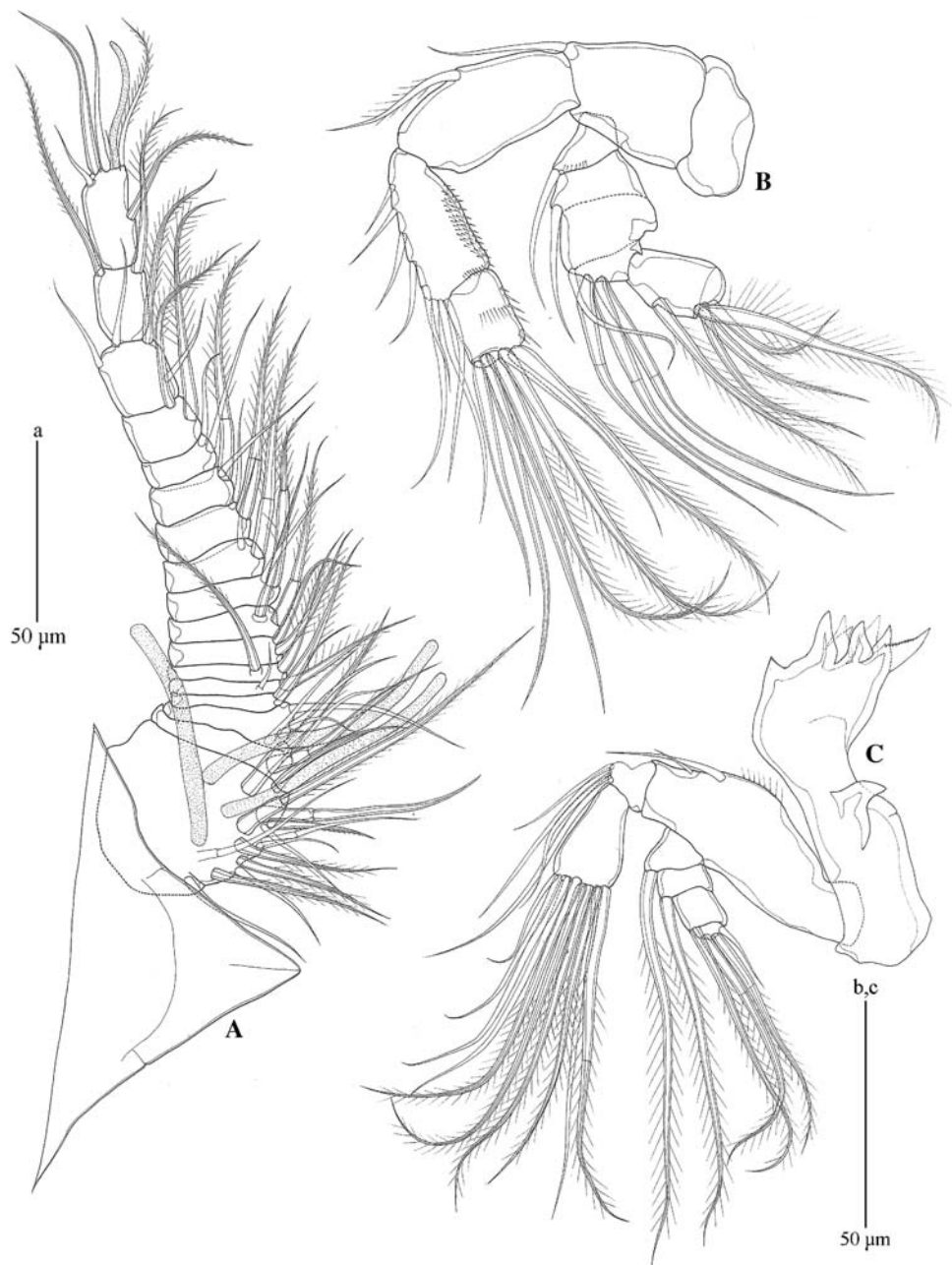
Fig. 2 *Pseudocyclops schminkei* sp. nov. female, allotype. **a** urosome, dorsal; **b** urosome, ventral

medial seta; middle segment with distomedial attenuation; distal complex with 2 lateral, 1 terminal and 1 distomedial spine-like setae, and a pore and thickened integumental ridge on posterior face. Proximal complex of endopod with arthrodial membrane anteriorly, opposite to a proximal row

of denticles posteriorly, distally attenuate medially and laterally, without setae; distal segment attenuate distolaterally and slightly distomedially, with 2 terminal setae.

CR (Fig. 2a, b): posterodorsal margin extending beyond level of insertion of setae; medial attenuation; 1 dorsal, 1

Fig. 3 *Pseudocyclops schminkei* sp. nov. female, allotype. **a** antenna 1, **b** antenna 2, **c** mandible



lateral seta and 4 terminal; lateral setae juxtaposed to 4th terminal seta; 2nd terminal seta from medial broad proximally, thin distally (but see remarks for polymorphism); 3 largest setae with secondary articulation close to their insertion.

Habitus: Male holotype 0.43/0.16 = 0.59 mm; 3 male paratypes 0.43/0.14 = 0.57 mm, 0.42/0.14 = 0.56 mm, 0.42/0.17 = 0.59 mm. Similar to female with the following exceptions. Pr (Fig. 7a, b) 3.0 times as long as Ur. Rostrum articulates at base. Ventrolateral margin of Pd4 extending to posterior edge of Th7. Genital opening represented by posteroventral slit on left side. Posterior border of Th7 and Abd 2–4 (Fig. 8a, b) with pleated epicuticular fringe; fringe

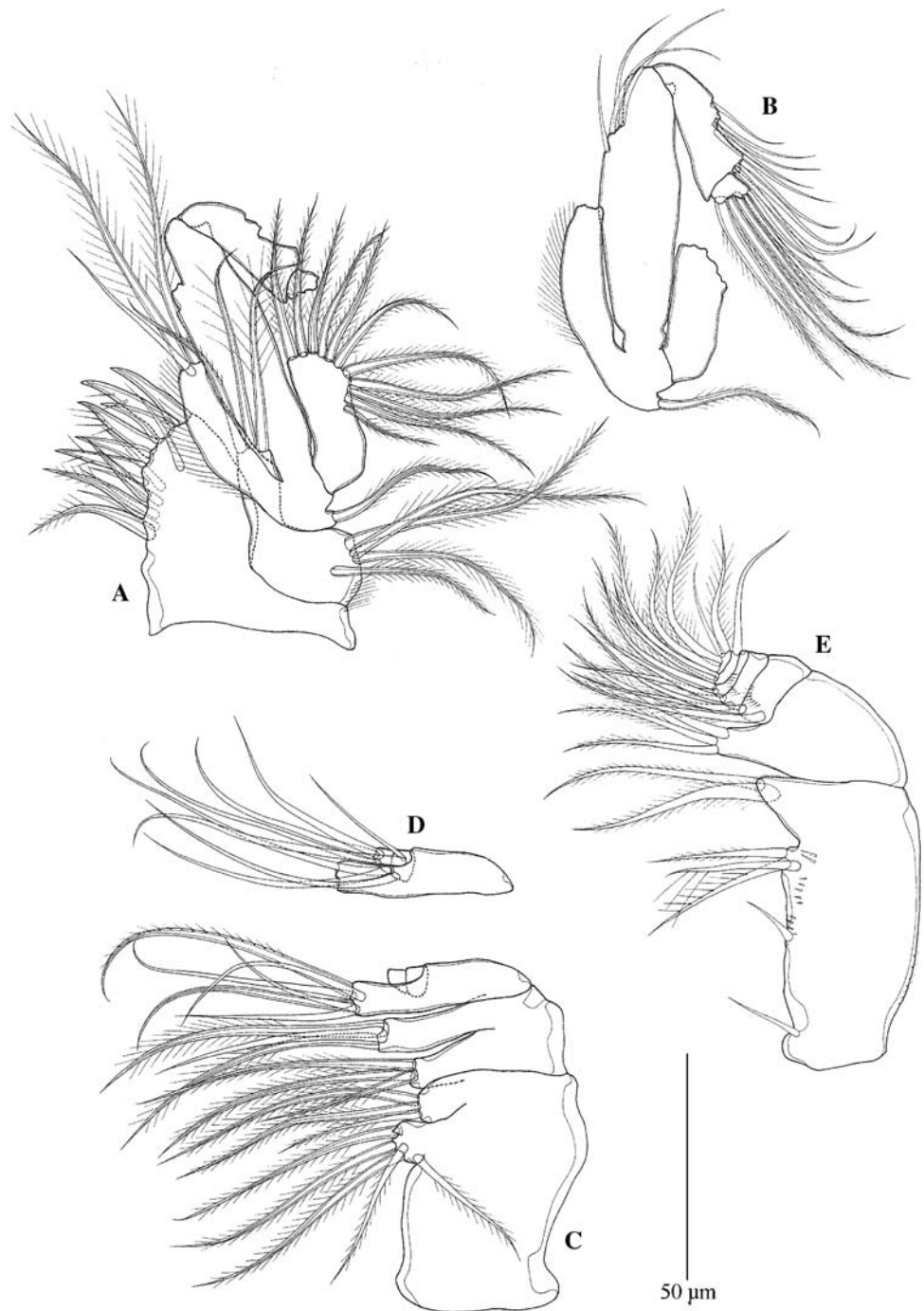
of Th4 lobate dorsally; anal somite (Abd 1) narrow, hidden by posterior epicuticular fringe of adjacent somite.

A1: left similar to female (Fig. 9a); right also of 17 articulating segments (Fig. 9b); armature as follows: 1: 13s + 3a; 2: 2s; 3: 2s; 4: 2s; 5: 2s; 6: 2s; 7: 2s; 8: 2s; 9: 2s; 10: 2s; 11: 2s; 12: 2s; 13: 2s; 14: 2s; 15: 4s; 16: 2s; 17: 6s + 1a; proximal seta on articulating segments 12–14 modified as a broad-based, spine-like seta closely appressed to segment; articulating segment 15 attenuate distally, tip reaching distal end of segment 16.

A2, Mx1, Mx2 and Mxp similar to female.

Md (Fig. 9c): without hook-like attenuation on coxa.

Fig. 4 *Pseudocyclops schminkei* sp. nov. female, allotype. **a** maxilla 1; **b** maxilla 1, basis plus rami; **c** maxilla 2; **d** maxilla 2, endopod; **e** maxilliped, syncoxa

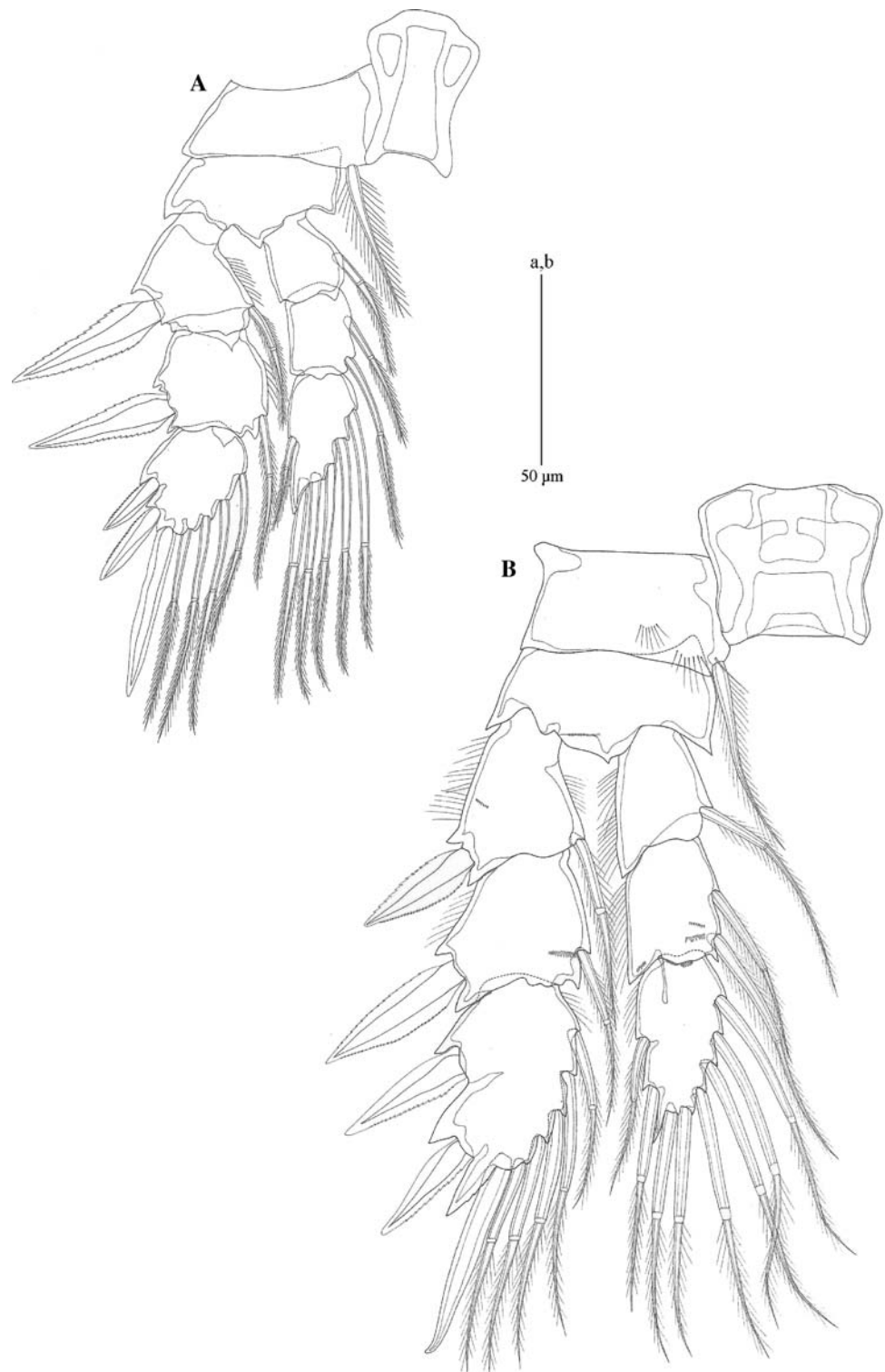


Swimming legs 1, 3, 4 similar to female but with denticles on basis (P1), or coxa, basis and rami (P3, 4).

Swimming leg 2: denticles on coxa, basis and rami. Tip of proximolateral seta on left distal exopodal complex projecting beyond imaginary line between tip of lateral seta on middle exopodal segment and tip of distolateral seta on distal exopodal complex (Fig. 10); tip of proximolateral seta on right distal exopodal complex not reaching that imaginary line.

P5 (Fig. 11a–d): intercoxal plate with ventral, beak-like lobe; right coxa fused to right basis; latter with lateral seta. Right exopod 2-segmented, proximal segment with lateral seta with epicuticular fringe on both sides; broad, blade-like medial seta with incomplete fringe on one side; distal segment thick, curved, spine-like attenuation with medial and lateral seta proximally. Right endopod 1-segmented, quadrate, without setae, with proximal and distal indentation.

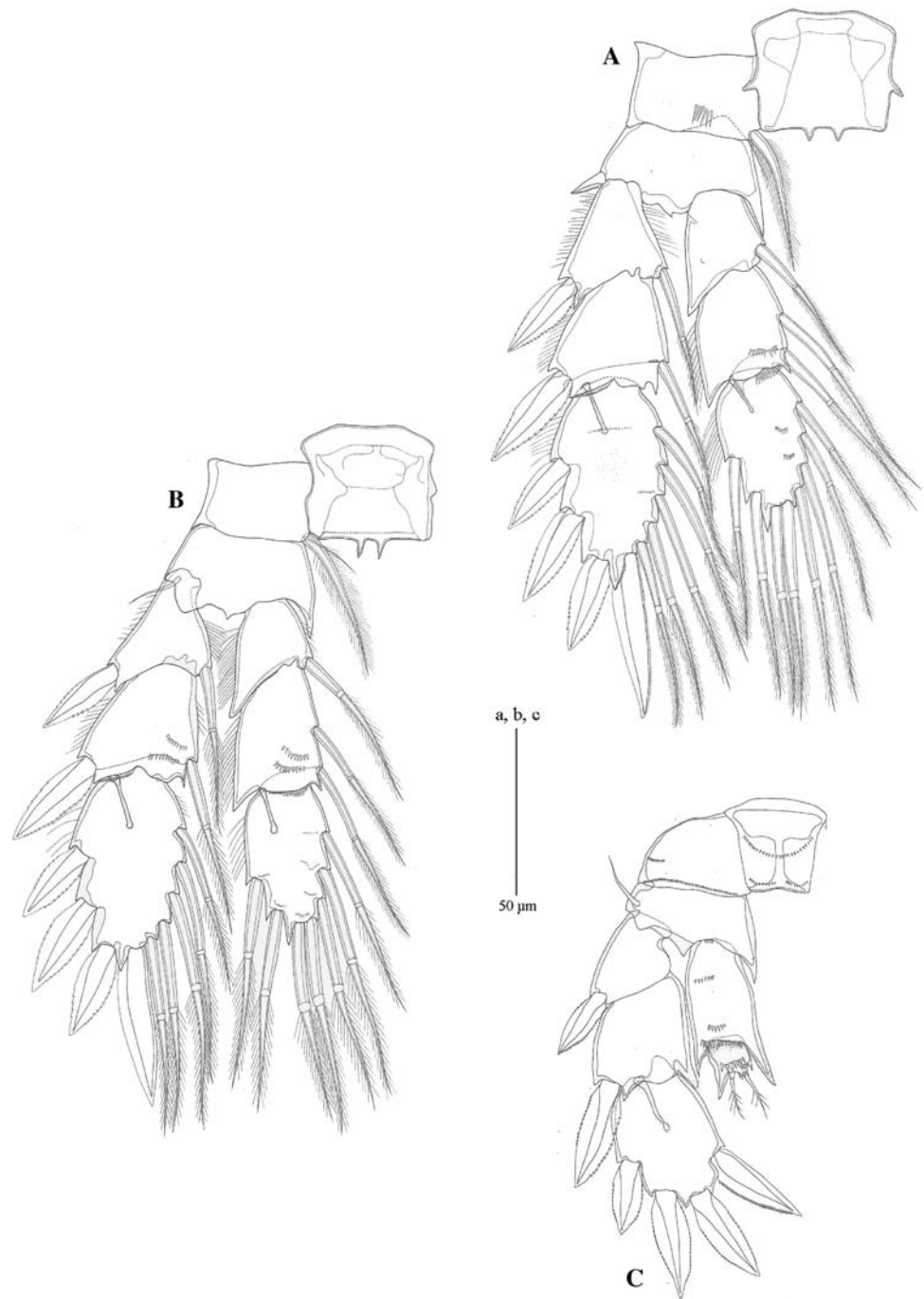
Fig. 5 *Pseudocyclops schminkei* sp. nov. female, allotype. **a** right swimming leg 1, **b** right swimming leg 2



Left coxa fused to left basis; latter with lateral seta; basis with broad attenuation narrowing and folded on itself forming grooved, pointed tip. Left exopod apparently 2-segmented, proximal segment with lateral seta with epicuticular fringe on one side, and medial attenuation with denticles; distal segment with broad, quadrate, proximolateral

lobe with medial denticles, followed by small middle lobe with lateral denticles, and broad, distal lobe flexed 90°; with 2 pointed lobes apically; 1 small seta proximal to quadrate lobe and 1 small seta proximal to flexed lobe. Left endopod 1-segmented, rounded, without setae, with distal, tongue-like lobe.

Fig. 6 *Pseudocyclops schminkei* sp. nov. female, allotype. **a** right swimming leg 3, **b** right swimming leg 4; **c** right leg 5



CR (Fig. 8a, b): 2nd terminal seta thick but tapering smoothly distally.

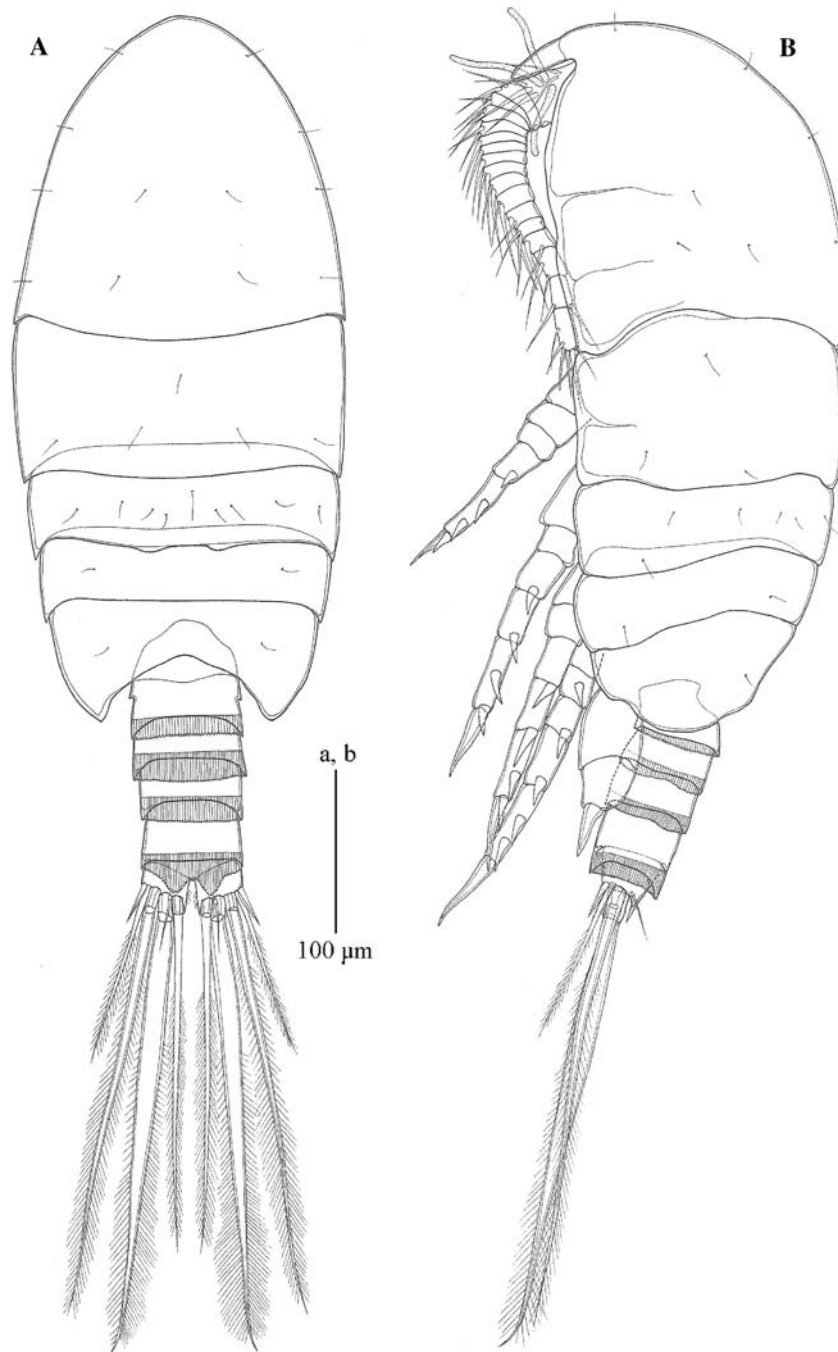
Etymology This species honors the eminent carcinologist Prof. Dr. Horst-Kurt Schminke at the University of Oldenburg, Germany.

Distribution *Pseudocyclops schminkei* sp. nov. is known only from its type locality, Zamami Island, Okinawa, Japan.

Remarks Thirty-six species belonging to *Pseudocyclops* have been described, all from tropical or temperate shallow

waters. Descriptions of many of these species are incomplete. Ohtsuka et al. (1999) established four species groups for 8 of the 35 species: the *lepidotus*-species group (*P. lepidotus*, *P. ornaticauda* Ohtsuka, Fosshagen and Putschakarn, 1999); the *kulai*-species group (*P. kulai* Othman and Greenwood, 1989, *P. ensiger* Ohtsuka, Fosshagen and Putschakarn, 1999); and the *crassiremis*-species group (*P. crassiremis*, *P. bahamensis* Fosshagen, 1968, *P. oliveri* Fosshagen 1968, *P. minutus* Ohtsuka, Fosshagen and Putschakarn, 1999); and the *magnus*-species group (*P. magnus*,

Fig. 7 *Pseudocyclops schminkei* sp. nov. male, holotype. **a** habitus, dorsal. **b** Habitus, left lateral



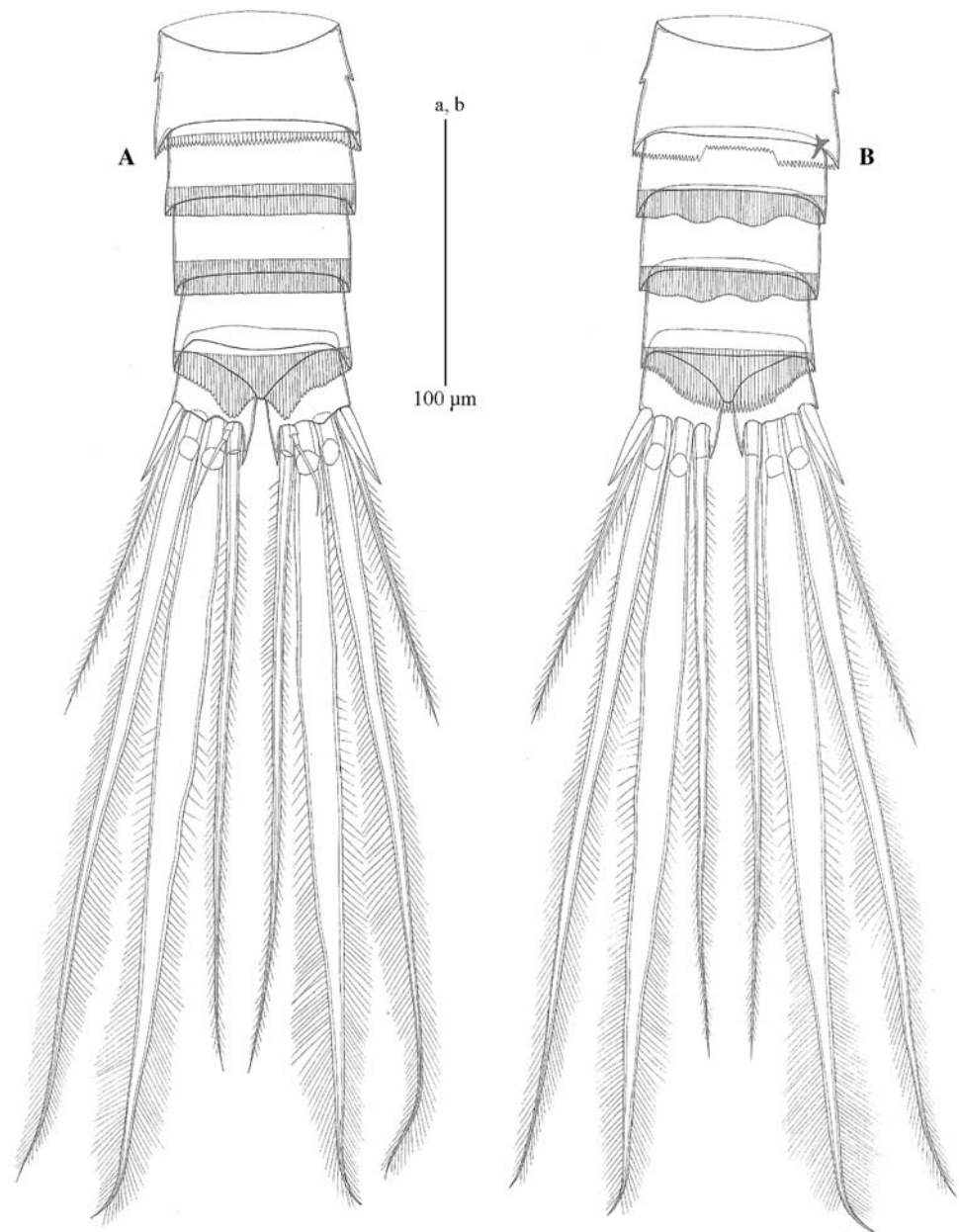
P. latens, *P. xiphophorus*, *P. bilobatus*). No other species group has been proposed subsequently.

Pseudocyclops schminkei sp. nov. belongs to the *magnus*-species group, which includes *P. magnus* from Bermuda (northwestern Atlantic Ocean), *P. latens* from Ismaïlia on the west bank of the Suez Canal (northwestern Indian Ocean), *P. xiphophorus* from Mozambique (western Indian Ocean), *P. bilobatus* from Southern California (northeastern Pacific Ocean). *Pseudocyclops magnus* and *P. latens* are known only from females and for this reason separating either from similar species remains

problematical. *Pseudocyclops magnus* and *P. xiphophorus* have been redescribed, respectively, by Yeatman (1975) and by Zagami et al. (2005) and Brugnano et al. (2009).

Species of the *magnus*-species group share the absence of medial setae on the exopodal segments of female leg 5, the absence of medial seta but with acute attenuations distolaterally and distomedially on the middle endopodal segment of female leg 5, a distal endopodal segment with 1–2 setae and an acute process terminally, female genital double somite with a pair of posteriorly directed processes [here

Fig. 8 *Pseudocyclops schminkei* sp. nov. male, holotype. **a** urosome in dorsal view, **b** urosome in ventral view



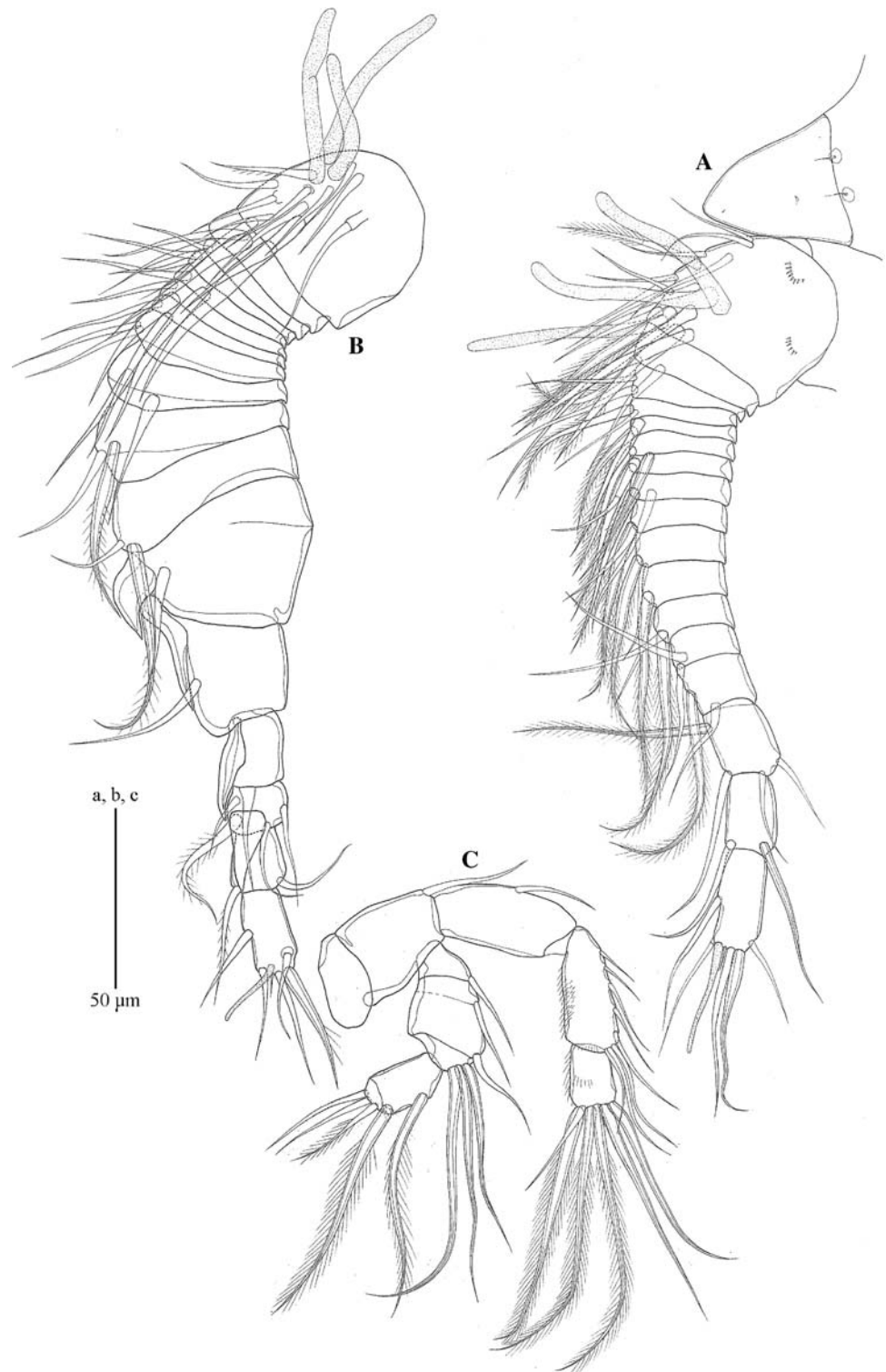
flap-like extensions of the epicuticle] (for *P. magnus*, *P. xiphophorus*, and *P. latens*); a spatulate seta in the 2nd from medial position of female caudal ramus (here spatulate proximally but thinner distally) (for *P. magnus*, *P. xiphophorus*, *P. bilobatus*).

Ohtsuka et al. (1999) hypothesized that the *crassiremis*-species group (*P. crassiremis*, *P. bahamensis*, *P. oliveri*, *P. minutus*) and the *magnus*-species group are derived groups within the genus, sharing: fused 4th and 5th pedigers; an antennule of 16 or 17 articulating segments; male rostrum articulating at base; absence of medial seta on basis of swimming leg 1; 1- or 2-segmented endopod of female leg 5; left endopod of male

leg 5 without setae. *Pseudocyclops schminkei* sp. nov. also shares these character states. *Pseudocyclops costanzo* Baviera, Crescenti and Zagami, 2007, one of two species described since Ohtsuka et al. (1999), appears to belong to this clade but does not appear to belong to the *magnus*-species group; *Pseudocyclops giussanii* Zagami, Brugnano, Costanzo, 2008 is quite different from all other species of the genus.

Pseudocyclops schminkei sp. nov. from Zamami Island, Okinawa, can be separated from the northwestern Atlantic *P. magnus* originally described from Bermuda from female only with body length of 1.1 mm (Esterly 1911). Subsequently the species was reported from

Fig. 9 *Pseudocyclops schminkei* sp. nov. male, holotype. **a** left first antenna in anterior view, **b** right first antenna in anterior view, **c** mandible



Barbados (Yeatman 1975) females were much smaller, 0.60–0.68 mm, males were 0.59–0.62 mm [females of *P. schminkei* sp. nov. 0.55–0.63 mm, males 0.57–0.59 mm]. Females of *P. schminkei* sp. nov. differ from the female of *P. latens* in their distributions; *P. latens* is known only

from the Red Sea, northwestern Indian Ocean (Gurney 1927).

Pseudocyclops schminkei sp. nov., length of female 0.55–0.63 mm, of males 0.56–0.59 mm, is smaller than *P. xiphophorus* females from Mozambique 0.719–0.759 mm

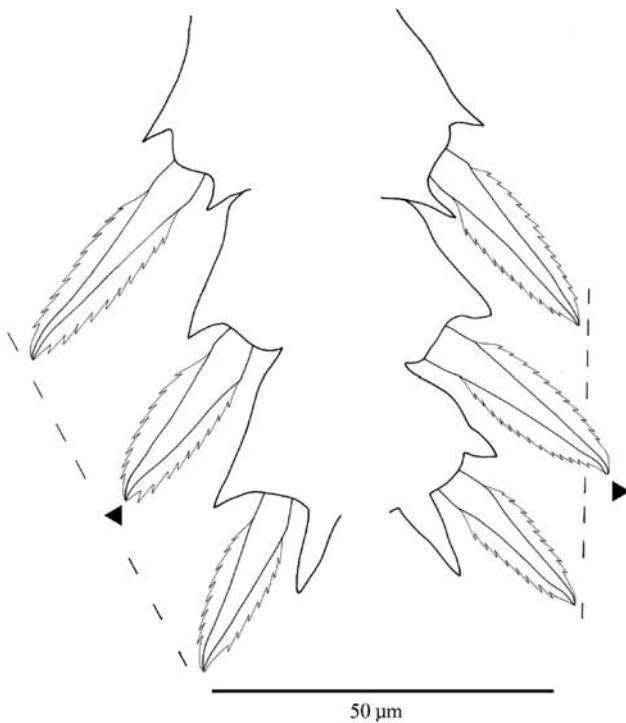


Fig. 10 *Pseudocyclops schminkei* sp. nov. male, holotype. **a** swimming leg 2; lateral margin of left and right middle and distal exopod showing slight difference in length of proximal (*middle*) spine-like seta (*arrowhead*) on distal complex; *imaginary broken lines* for reference

(0.67 mm paratype), males 0.680–0.733 mm (0.65 mm paratype); females from Lake Faro 0.624–0.671 mm, males 0.624–0.656 mm. The proximolateral lobe on the left exopod of male leg 5 of *P. xiphophorus* does not extend distally as far as the corresponding lobe of *P. schminkei* sp. nov. (compare Fig. 12d and Fig. 11d), and the margin of the middle lobe is straight (curved for *P. schminkei* sp. nov.); the shape of the distal lobe and terminal lobes also varies (compare Fig. 12d and Fig. 11d). The epicuticular fringe of the lateral seta on the middle exopodal segment of male right swimming leg 2 is asymmetrical and the proximal lateral seta of the distal segment is curved posteriorly (Fig. 12e, f) (these setae are symmetrical and straight on *P. schminkei* sp. nov.).

Pseudocyclops bilobatus differs significantly from *P. schminkei* sp. nov. The mean length of 49 females of *P. bilobatus* is 0.73 mm, 0.65–0.70 mm here for 6 paratypes, of 48 males 0.65 mm, 0.59–0.61 mm here for 5 paratypes (differences between Dawson's lengths and those given here for paratypes may be the result of Dawson including in his length of prosome that portion of the prosome that overlaps the urosome) [length range of females of *P. schminkei* sp. nov. 0.55–0.63 mm, length range of males 0.57–0.59 mm]. Terminal setae on exopod

of female leg 5 are relatively longer on *P. bilobatus* so that lateral seta appears much shorter than adjacent terminal seta (see Dawson 1977: Fig. 18) [relatively shorter (Fig. 6c) for *P. schminkei* sp. nov.]; the arthroial membrane between proximal and middle endopodal segments of female leg 5 arthroial membrane on *P. bilobatus* is complete anteriorly but without a row of denticles posteriorly (not shown by Dawson 1977: Fig. 18) [restricted anteriorly with a proximal row of denticles on the posterior face (Fig. 6c) of *P. schminkei* sp. nov.]; terminal endopodal segment of female leg 5 of *P. bilobatus* relatively long so that its lateral attenuation extends beyond tip of the medial attenuation of the middle segment (see Dawson 1977: Fig. 18) [terminal endopodal segment of *P. schminkei* sp. nov. relatively short so that its lateral attenuation does not extend past the tip of the medial attenuation of the middle segment (Fig. 6c)]; the paired, ventral extensions of epicuticle of the genital double somite round and more widely separated [of *P. schminkei* sp. nov. tooth-like, and close to one another]; the attenuation of articulating segment 15 of male antenna 1 pointed ventrally (Fig. 13e) [pointed distally (Fig. 9b) on *P. schminkei* sp. nov.]. There are numerous differences in male leg, compare (Fig. 13a–d) for *P. bilobatus* with (Fig. 11a–d) for *P. schminkei* sp. nov., and there is no gender-limited asymmetry for male right swimming leg 2 of *P. bilobatus*.

Discussion

The 2nd terminal seta from medial seta on the caudal ramus of females of *P. schminkei* sp. nov. is polymorphic; as reported here, it is usually broad proximally and thin distally on most females, but on a few specimens it may be thick proximally but tapering smoothly distally, like the males. A similar polymorphism also has been reported for *P. obtusatus asymmetrica* by Ummerkutty 1968 and for *P. xiphophorus* by Brugnano et al. (2009).

Vervoort (1964) initially described a male gender-limited asymmetry of the exopod of swimming leg 2 of *Pseudocyclops*, viz. the distolateral seta on the distal exopodal complex of males of *P. pacificus*. Subsequently, Brugnano et al. (2009) described the gender-limited asymmetry of male right swimming leg 2 of *P. xiphophorus* as a gender-limited dimorphism. In this study, the subtle difference in the proximolateral seta of the distal exopodal complex of swimming leg 2 on males of *P. schminkei* sp. nov. was suggested by the more pronounced morphological asymmetry of the *Pseudocyclops* sp. from the Shedd Aquarium. The Shedd Aquarium in Chicago, IL, USA maintains a population

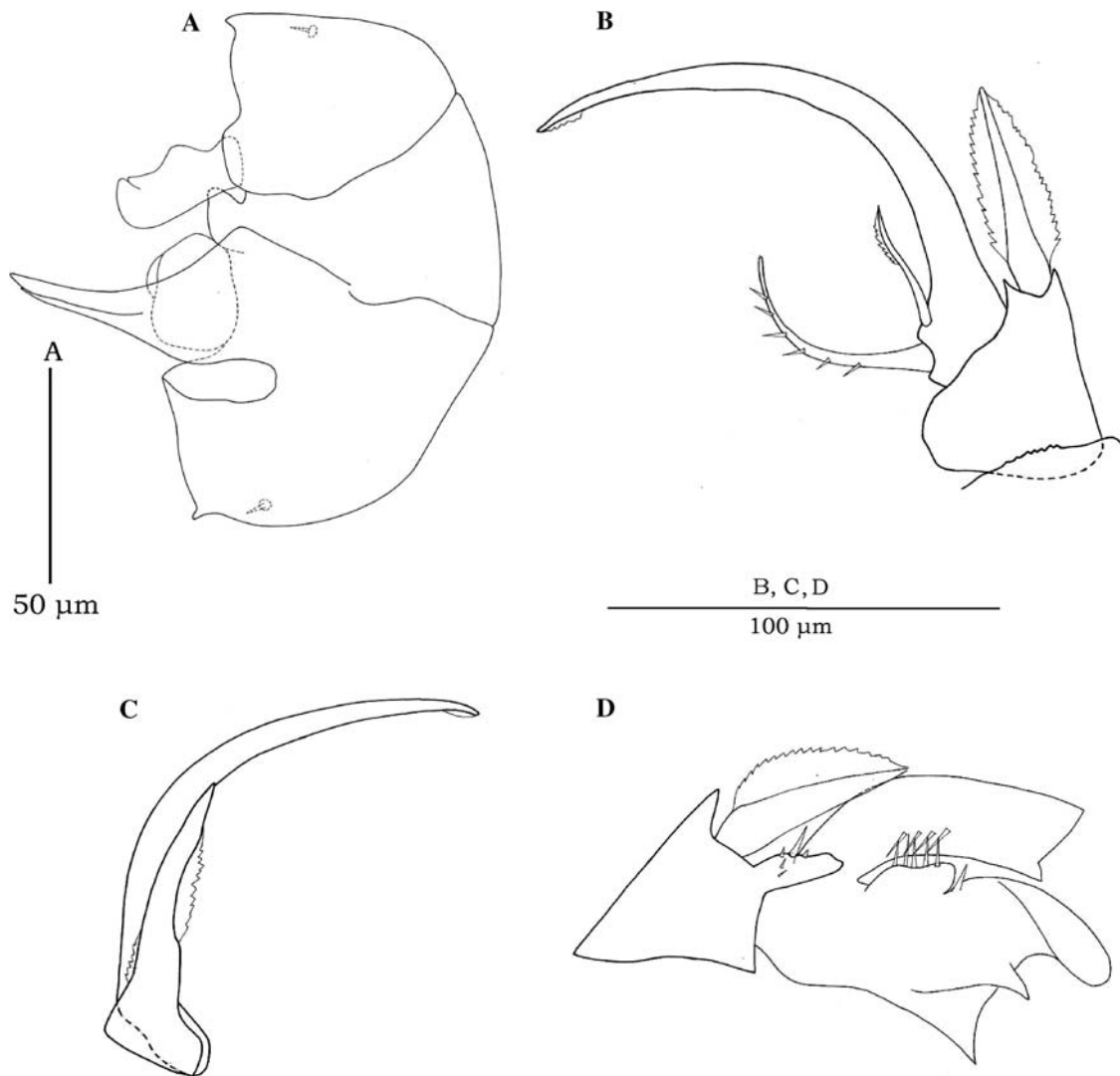


Fig. 11 *Pseudocyclops schminkei* sp. nov. male, holotype; leg 5. **a** protopod and endopods, anterior; **b** right exopod, anterior; **c** right exopod, medial seta of proximal segment and distal segment, posterior; **d** left exopod, anterior

Table 1 Setal formula of four swimming legs and leg 5 are as follows

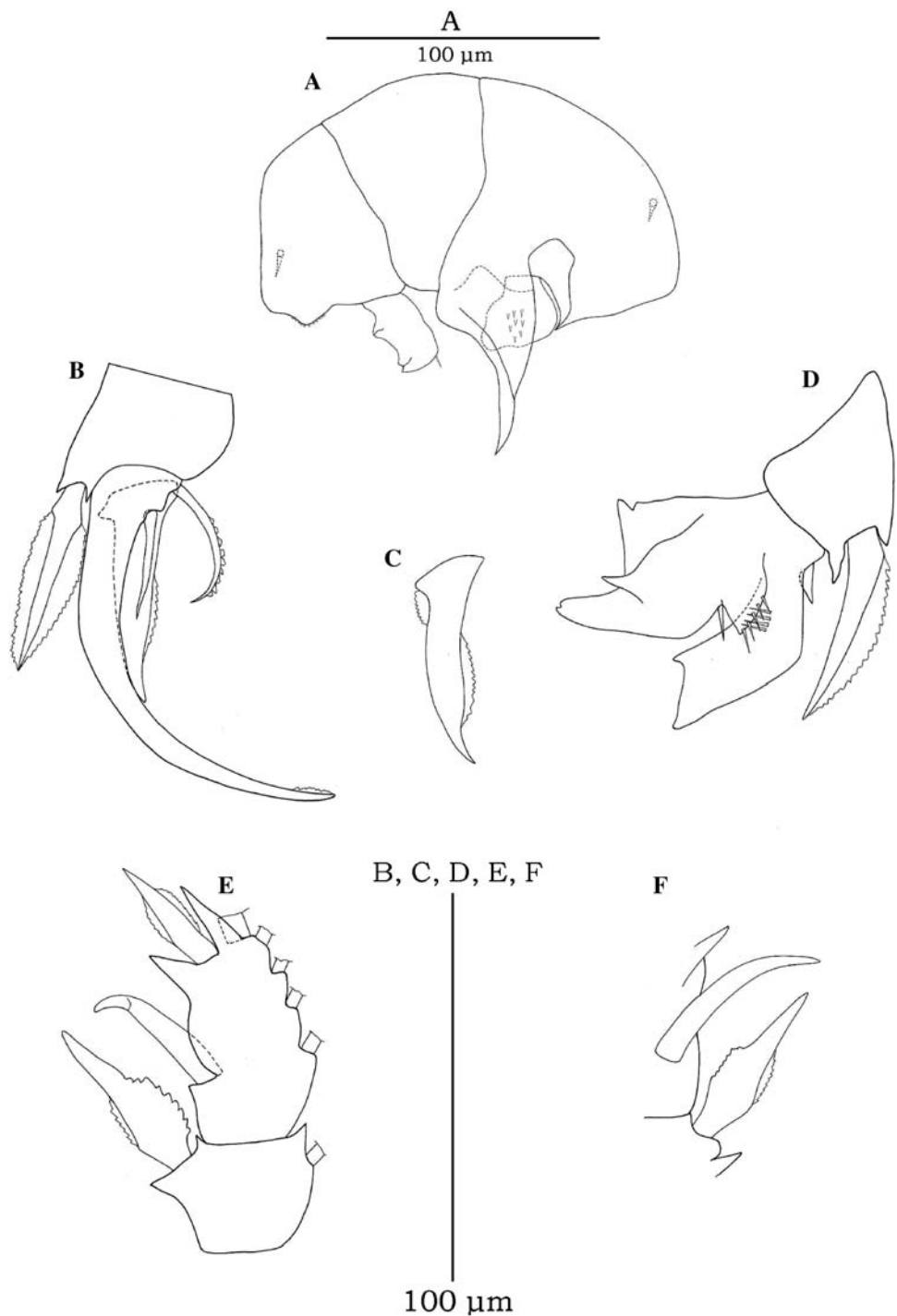
P1: coxa 0–1 basis 0–0	exp 1–1, 1–1, 2–1–4	enp 0–1, 0–2, 1–2–3
P2: coxa 0–1 basis 0–0	exp 1–1, 1–1, 2–1–5	enp 0–1, 0–2, 2–2–4
P3: coxa 0–1 basis 1–0	exp 1–1, 1–1, 3–1–5	enp 0–1, 0–2, 2–2–4
P4: coxa 0–1 basis 0–0	exp 1–1, 1–1, 3–1–5	enp 0–1, 0–2, 2–2–3
P5♀: coxa 0–0 basis 1–0	exp 1–0, 1–0, 2–1–1	enp 0–0, amn, 0–2–0
P5♂l: coxa 0–0 basis 0–1	exp 1–0, nf, 0–0–0	enp nf, nf, 0–0–0
P5♂r: coxa 0–0 basis 0–1	exp 1–1, nf, 1–0–1	enp nf, nf, 0–0–0

nf segment not formed, *amn* arthrodistal membrane not formed

of *Pseudocyclops* sp. as food for larval *Amphiprion* spp. and juvenile *Hippocampus* spp. The seawater system from which the specimens here were isolated has hosted corals and sea grass from the Caribbean Sea and from many tropical localities in the Pacific Ocean, so the

provenance of the species is not known. This population is briefly described because of its more pronounced gender-limited asymmetry of male swimming leg 2. *Pseudocyclops* sp. from the Shedd Aquarium is similar to *P. schminkei* sp. nov. with a length range for females of

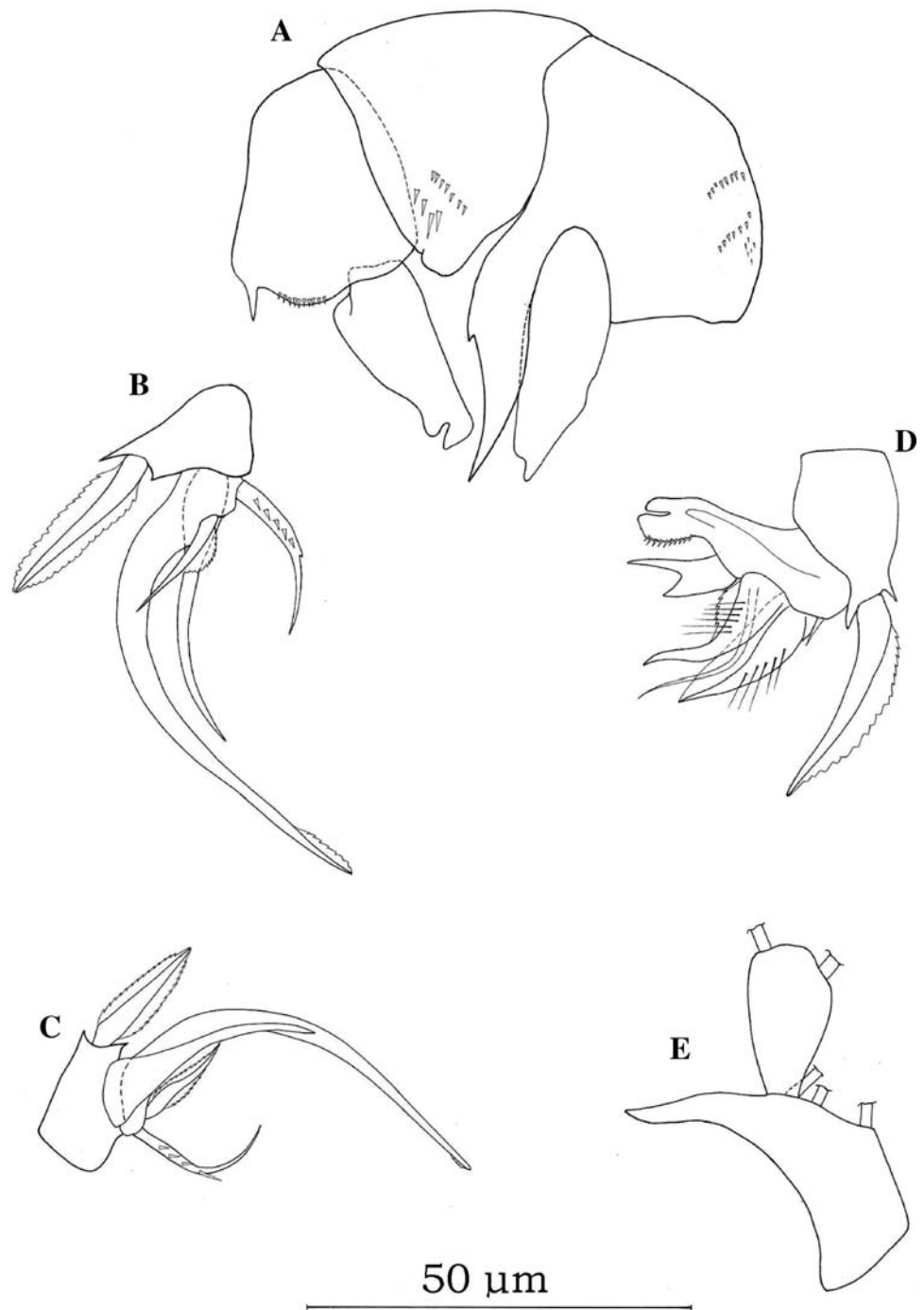
Fig. 12 *Pseudocyclops xiphophorus* Wells, 1967, male paratype; leg 5. **a** protopod and endopods, anterior; **b** right exopod, anterior; **c** right exopod, medial seta of proximal segment, posterior; **d** left exopod, anterior. Right swimming leg 2, **e** middle segment and distal complex of exopod, anterior; **f** lateral seta of middle segment and proximolateral seta of distal complex of exopod, lateral



0.67–0.69 mm and for males of 0.67–0.69 mm. The distal attenuation of articulating segment 15 on right antenna 1 of males reaches beyond segment 16 as it does for *P. schminkei* sp. nov. The intercoxal plate of male leg 5 has a simple, ventral lobe (Fig. 14a), and the distal segment of the right exopod is thick, relative to its length (Fig. 14b, c). The proximolateral lobe of the

distal segment of left exopod is not simply quadrate, and the distal part of the limb is broader (Fig. 14d). The lateral seta on middle exopodal segment of the right swimming leg 2 of males is irregularly swollen (Fig. 14e, f); the proximal seta on distal segment is curved posteriorly, and the lateral margin between the proximal and distal lateral seta is swollen (Fig. 14e, g).

Fig. 13 *Pseudocyclops bilobatus* Dawson, 1977, male paratype; leg 5. **a** protopod and endopods, anterior; **b** right exopod, anterior; **c** right exopod, posterior; **d** left exopod, anterior; **e** terminal two segments of left antenna 1



Brugnano et al. (2009) have proposed that the gender-limited asymmetry for male right swimming leg 2 of *P. xiphophorus* in Lake Faro, Sicily, is a gender-limited dimorphism, although the protocol described for different morphs used in the paternal identity experiments was not exclusive. It also appears that *P. xiphophorus* males from Lake Faro can be divided into two groups based on the

morphology of the attenuation of the left basis (Brugnano et al. 2009: Fig. 9a, d). We have not found evidence for a gender-limited dimorphism among four male specimens of *P. schminkei* sp. nov., admittedly a small sample size, or among 25 male specimens of *Pseudocyclops* sp. from the Shedd Aquarium. We believe that this asymmetry is species specific and exhaustive.

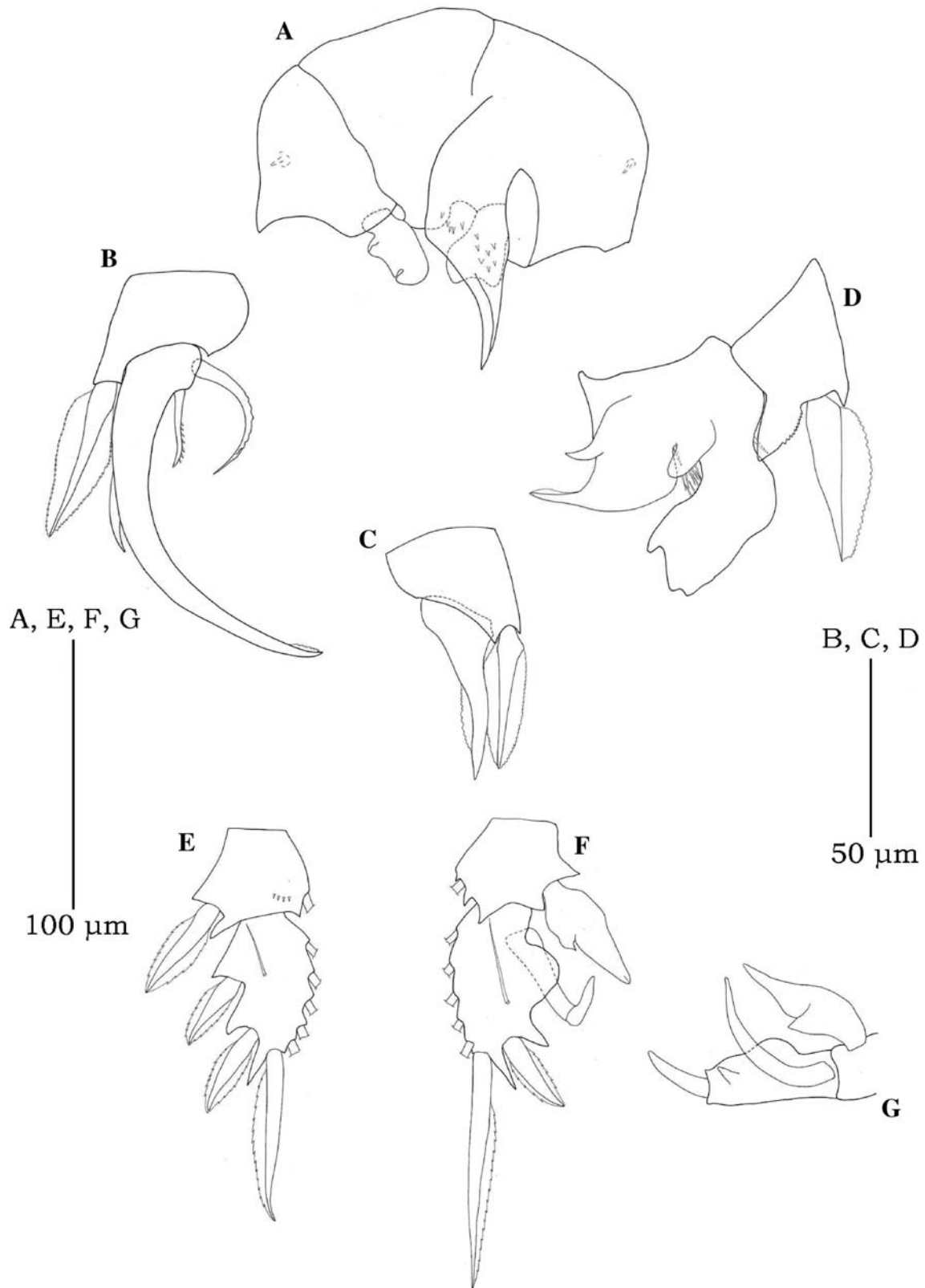


Fig. 14 *Pseudocyclops* sp. male from Shedd Aquarium population. Leg 5. **a** protopod and endopods, anterior; **b** right exopod, anterior; **c** right exopod, proximal segment, posterior; **d** left exopod, anterior. Swimming leg 2, **e** middle segment and distal complex of left exopod,

anterior; **f** middle segment and distal complex of right exopod, anterior; **g** lateral seta of middle segment and proximo- and distolateral seta of distal complex of right exopod, lateral

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