

***Apocyclops ramkhamhaengi* sp. nov. (Copepoda: Cyclopoida) in a Culture Originating from Brackish Waters of Chang Island, Trat Province, Thailand**

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Supawadee Chullasorn, Pawana Kangtia, Khwanruan Pinkaew, and Frank D. Ferrari (2008) *Apocyclops ramkhamhaengi* sp. nov. (Copepoda: Cyclopoida) in a culture originating from brackish waters of Chang Island, Trat Province, Thailand. *Zoological Studies* 47(3): 326-337. A new brackish-water planktonic copepod belonging to the family Cyclopidae of the Copepoda, *Apocyclops ramkhamhaengi* sp. nov., is described from a culture originating off Chang I., Trat Province, Thailand. The new species is the first record of this genus from Thailand and the 4th species of the genus from Asia. Antenna 2 with an endopod of 2 segments separates *A. ramkhamhaengi* sp. nov. from *A. dengizicus* (Lepeshkin). A posterolateral, rounded projection of pediger 4, and a simple line of spinules ventrally on pediger 5 separates *A. ramkhamhaengi* sp. nov. from *A. royi* (Lindberg). A slight posterolateral projection on pediger 3 and a series of ridges dorsally on the basis of maxilla 2 are unique for *A. ramkhamhaengi* sp. nov., and separate it from *A. borneonensis* Lindberg.
<http://zoolstud.sinica.edu.tw/Journals/47.3/326.pdf>

Key words: *Apocyclops ramkhamhaengi*, New species, Thailand.

The cyclopoid copepod family Cyclopidae is a successful and diverse family of over 830 species (Dussart and Defaye 2006) in 62 genera. Within the Cyclopidae, the genus *Apocyclops* belongs to a lineage diagnosed by swimming leg rami whose development is truncated so that both the exopod and endopod have fewer than 3 articulating segments (Ferrari 1998). The endopod of the maxilliped is also truncated during development of species of this genus as well as related genera (Ferrari 1998, Ferrari and Ivanenko 2001). Lindberg (1942) established the subgenus *Cyclops* (*Apocyclops*), and later raised its rank (Lindberg 1955b). There are now 11 nominal species and 3 nominal subspecies, although recent unpublished theses (Arnofsky 1996, Botelho 1999) have noted several synonyms. The genus *Apocyclops* includes species found in continental brackish and

hypersaline waters throughout the world (Arnofsky 1996).

Presently, 3 species of *Apocyclops* are recognized from Asia (Botelho 1999): *A. dengizicus* (Lepeshkin), *A. royi* (Lindberg), and *A. borneonensis* Lindberg. Lepeshkin (1900) described *A. dengizicus* (as *Cyclops dengizicus*) from hypersaline waters of continental central Asia. *Apocyclops royi* was described as *Cyclops* (*Metacyclops*) *royi* from Salsette, an island in the Arabian Sea off the west coast of India (Lindberg 1940). Later, Lindberg (1955a) described *A. borneonensis* from Tarakan, a marshy island situated in the eastern Celebes Sea off the northeastern coast of Borneo. Itô (1957) described *A. japonensis* Itô from eel ponds on Ise Bay in Mie Prefecture, Japan; in the same publication, he introduced the synonym *A. japonicus* Itô. Botelho

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(1999) placed *A. japonensis* in synonymy with *A. borneonensis*, a decision which is followed here. Recently, a species of *Apocyclops* with a 2 segmented endopod on antenna 2 was collected from Chang I. in the Gulf of Thailand off Trat Province of eastern Thailand. The female specimens are similar to *A. royi* and are described here as a new polymorphic species of *Apocyclops*.

MATERIALS AND METHODS

Ovigerous females from plankton samples originally collected from Chang I. (12.5°N, 102.2°E), Trat Province, Thailand, have been maintained in culture through many generations by staff of the Institute of Marine Science, Burapha University, Chonburi Province, Thailand. Adult females and males were fixed in 4% formalin for 24 h and subsequently preserved in ethanol. For examination, specimens were cleared in lactic acid and stained with chlorazol black E (see Ferrari 1995). All dissections were made with a dissecting

microscope. Specimens were examined with a compound microscope using bright-field or differential-interference contrast optics. All drawings were made with a camera lucida. The description is based on a female holotype, a male allotype, and several other specimens of both genders which give an indication of the polymorphisms that may be expressed in this species. For long-term preservation, the holotype and paratype were mounted in glycerol on sealed slides.

SPECIES DESCRIPTION

Order Cyclopoida Sars, 1913
Family Cyclopidae Rafinesque, 1815
Genus *Apocyclops* Lindberg, 1942
***Apocyclops ramkhamhaengi* sp. nov.**
 (Figs. 1-11)

Type locality: Brackish water at Chang I., Trat Province, eastern Thailand (12.5°N, 102.2°E).

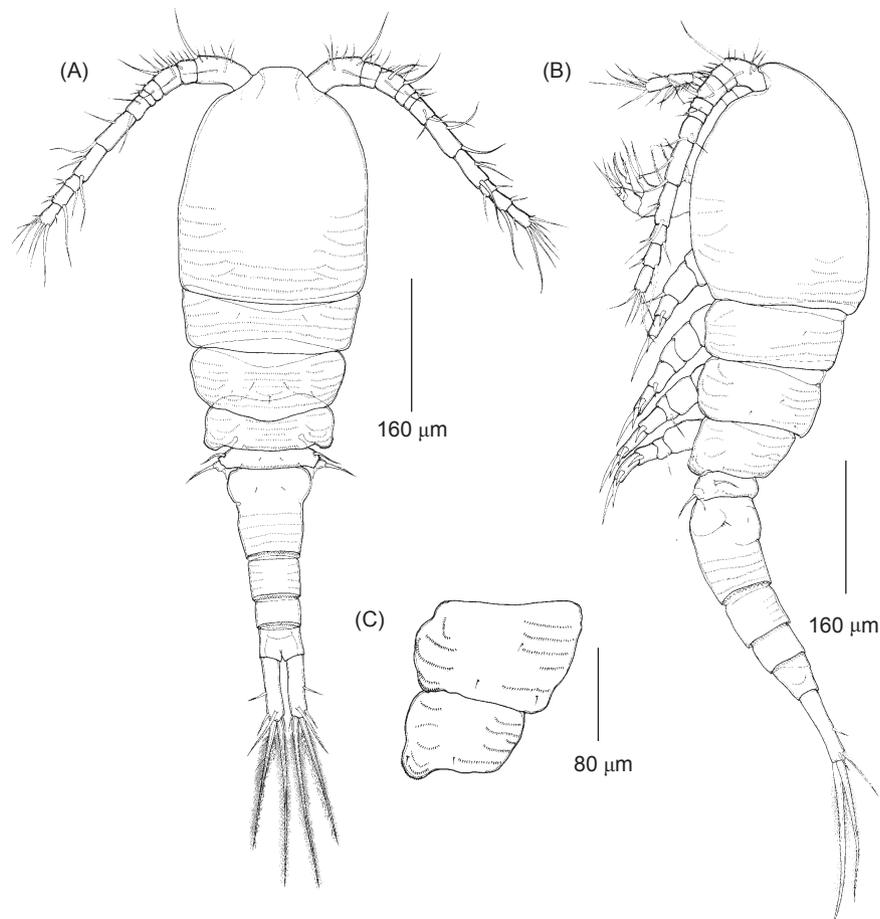


Fig. 1. *Apocyclops ramkhamhaengi* sp. nov. Female. (A) Habitus, dorsal view; (B) habitus, left lateral view; (C) pedigers 3 and 4, right lateral view; only a few exoskeletal indentations are indicated on the posterolateral projection.

Type specimens: A dissected holotype ♀ (USNM 1107777) and a dissected allotype ♂ (USNM 1107778), plus 3 dissected ♀♀ in 3 vials, 2 dissected ♂♂ in 2 vials, 1 ♀, 6 ♂♂, 1 juvenile copepodid V in 1 vial, and 40 slides (USNM 1107779) are deposited in the Department of Invertebrate Zoology, National Museum of Natural History, Smithsonian Institution, Washington, DC, USA.

Etymology: The species is named after Ramkhamhaeng who was a king of Thailand.

Adult female: Length of holotype 0.93 mm (from anterior margin of cephalothorax to posterior margin of caudal rami); length range of 12 specimens 0.95-1.03 mm; ratio of prosome to urosome 1.3-1.7.

Habitus (Figs. 1A, B): Prosome comprising cephalothorax unarticulated with pediger 1 plus articulating pedigers 2-4. Anterior urosome slightly narrower than posterior prosome; prosome-urosome boundary not well defined. Anterior surface of cephalothorax and pedigers 2-4 with minute indentations of exoskeleton beginning dorsally and dorsolaterally as parallel circumferential lines but which form a reticulated pattern laterally and lateroventrally. Ventrolateral corner of pediger 3 (= 4th thoracic somite) a slightly rounded projection; ventrolateral corner of pediger 4 (= 5th thoracic somite) a more distinctly rounded projection pointing laterally; both projections with indentations as part of a reticulated pattern (Fig. 1C).

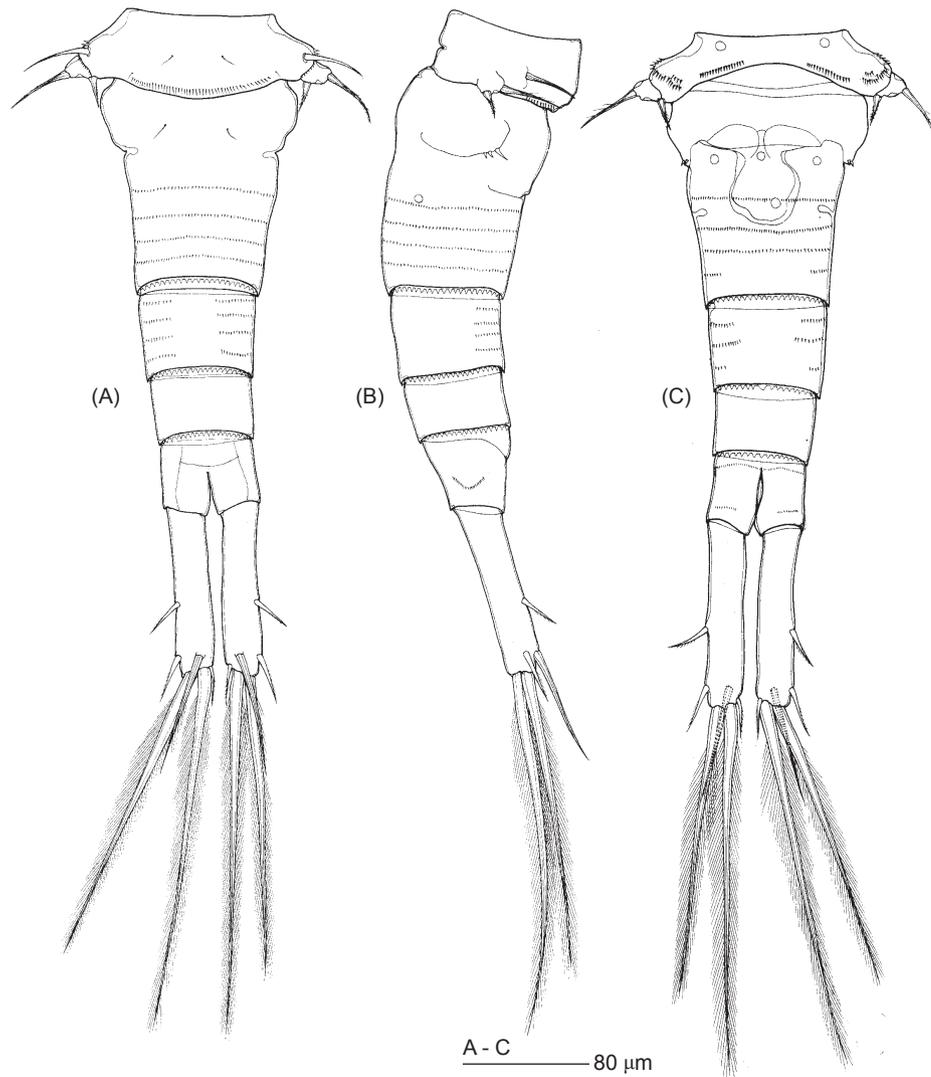


Fig. 2. *Apocyclops ramkhamhaengi* sp. nov. Female. (A) Urosome, dorsal view; (B) urosome, left lateral view; (C) urosome, ventral view.

Urosome (Figs. 2A-C) of 5 articulating parts; pediger 5 with a ventral group of spinules near base of leg 5 and a line of spinules ventrally on each side extending toward midline; lines of spinules not meeting at ventral midline. Genital double-somite in dorsal view expanded bluntly anterolaterally; medioventrally with copulatory pore and lateral oviducal openings; area anterior to oviducal opening poorly sclerotized; section posterior to oviducal opening with 3-5 lines of indentations. Following articulating abdominal somite with 3 or 4 lines of indentations. Anal somite with spinules posteroventrally, without indentations; anal operculum with transverse rows of spinules ventrally.

Rostrum: Simple ventral flap juxtaposed to labrum.

Antennule (Fig. 3A): 11 segmented with 8-4-6-2-2-2-3-3-2-3-7 setal elements; segments 8 and 10 with seta/aesthetasc pair; segment 11 with bifid sensory seta.

Antenna (Fig. 3B): With short, unarmed coxa; allobasis with 3 medial setae, and lateral spinules. Exopod as 1 long, lateral plumose seta reaching beyond distal edge of endopod. Endopod with 2 articulating segments; proximal segment with 10 setae along medial edge; distal segment with 7 terminal setae.

Mandible (Fig. 3C): Coxa with well-developed gnathobase of 4 pairs of tooth-like attenuations plus proximal seta. Palp with 1 small smooth seta and 2 long plumose setae.

Maxillule (Figs. 4A, B): Praecoxal endite with 10 setae on medial surface as follows: 1 long, thick

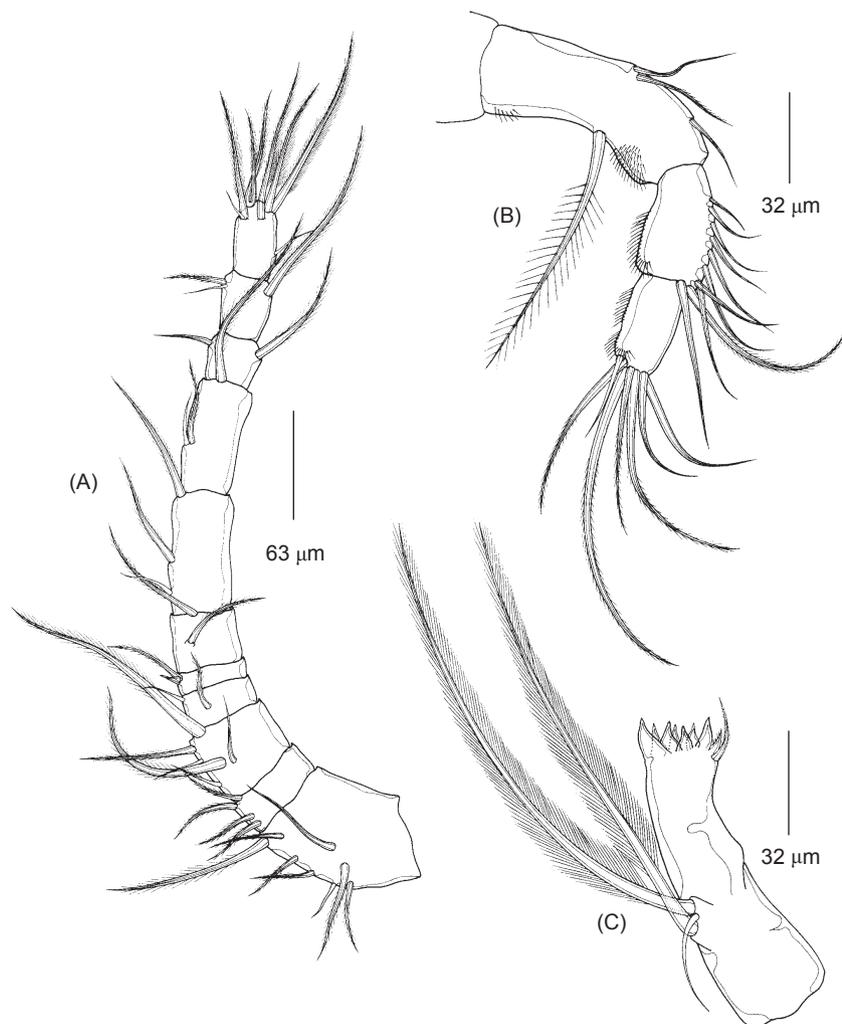


Fig. 3. *Apocyclops ramkhamhaengi* sp. nov. Female. (A) Antennule (the aesthetasc is the smaller of the paired, lateral elements on segments 8 and 10); (B) antenna; (C) mandible.

seta with setules proximally; 1 small, thin seta; 2 small, thin setae; 2 small, thick setae; distally 4 large, thick setae perpendicular to proximodistal axis. Coxal exite with 1 seta; endite with 1 thick seta with setules and 2 thin setae. Palp represented by 3 setae.

Maxilla (Fig. 4C): Syncoxa with coxal endite bearing 2 setae; basis with a series of sclerotized ridges dorsally, proximal endite with 1 seta; distal endite with 2 setae. Ramus apparently 3 segmented; proximal segment usually medially attenuated with 1 proximomedial seta and 1 anterior seta (but see comments on polymorphisms); middle segment with 2 long, medial setae; distal segment with 1 long, medial seta and 2 small, terminal setae.

Maxilliped (Fig. 4D): 4 segmented; syncoxa with 3 plumose setae and area of small spinules;

basis with 2 setae and area of small spinules dorsally. Proximal endopodal segment with 1 medial seta; distal segmental complex with 1 medial, 1 terminal, and 1 lateral setae.

P1 (Fig. 5A): Coxa rectangular with 1 medial, plumose seta; interpodal bar between left and right coxa unarmed. Basis with 1 medial pinnate seta and a 1 smooth seta laterally. Exopod 2 segmented; proximal segment with 1 lateral pinnate seta and 1 short, medial plumose seta; distal segment with 3 lateral pinnate setae, 1 terminal seta, and 4 long, plumose, medial setae. Endopod 2-segmented; proximal segment with 1 long, plumose, medial seta; distal segment usually with 1 lateral pinnate seta, terminally with 1 small, thick plus 1 long plumose setae, and with 3 long, plumose setae medially (but see comments on polymorphisms).

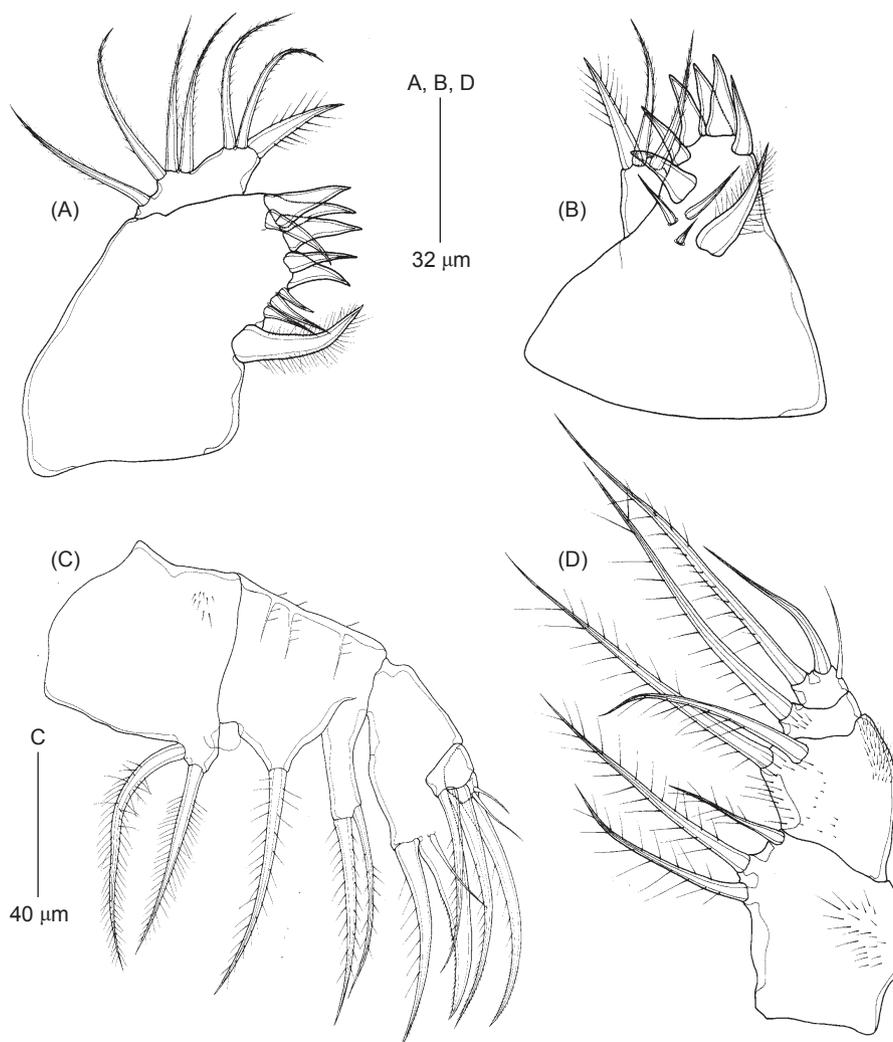


Fig. 4. *Apocyclops ramkhamhaengi* sp. nov. Female. (A) Maxillule; (B) maxillular precoxa, ventral view; (C) maxilla; (D) maxilliped.

P2 (Fig. 5B): Coxa rectangular with 1 medial, plumose seta; interpodal bar posteriorly with short spinules, irregularly placed distolaterally, and a line of longer spinules along middle part of interpodal bar. Basis with 1 smooth, distolateral seta. Exopod 2 segmented; proximal segment with 1 lateral pinnate setae, 1 short, medial plumose seta and posterior spinules; distal segment with 3 lateral, pinnate setae, 1 thick, terminal seta, and 5 long, plumose, medial setae. Endopod 2 segmented; proximal segment with 1 long, plumose, medial seta and posterior spinules; distal segment usually with 1 lateral pinnate seta, terminally with 1 small, thick plus 1 long plumose setae, and with 4 long, plumose setae medially.

P3 (Fig. 5C): Similar to P2; interpodal bar posteriorly with short spinules distally, and line of small, proximal spinules.

P4 (Fig. 5D): Coxa rectangular with 1 distomedial seta and 2 areas of spinules posteriorly; interpodal bar with spinules on 2 ridges. Basis laterally with 1 smooth seta and medially with spinules. Exopod 2 segmented; proximal segment with 1 lateral pinnate seta and posterior spinules; distal segment with 2 lateral, pinnate setae, 1 thick, terminal seta, 5 long, plumose, medial setae and posterior spinules. Endopod 2 segmented; proximal segment with 1 long, plumose, medial seta; distal segment usually with 1 lateral pinnate seta, terminally 1 small,

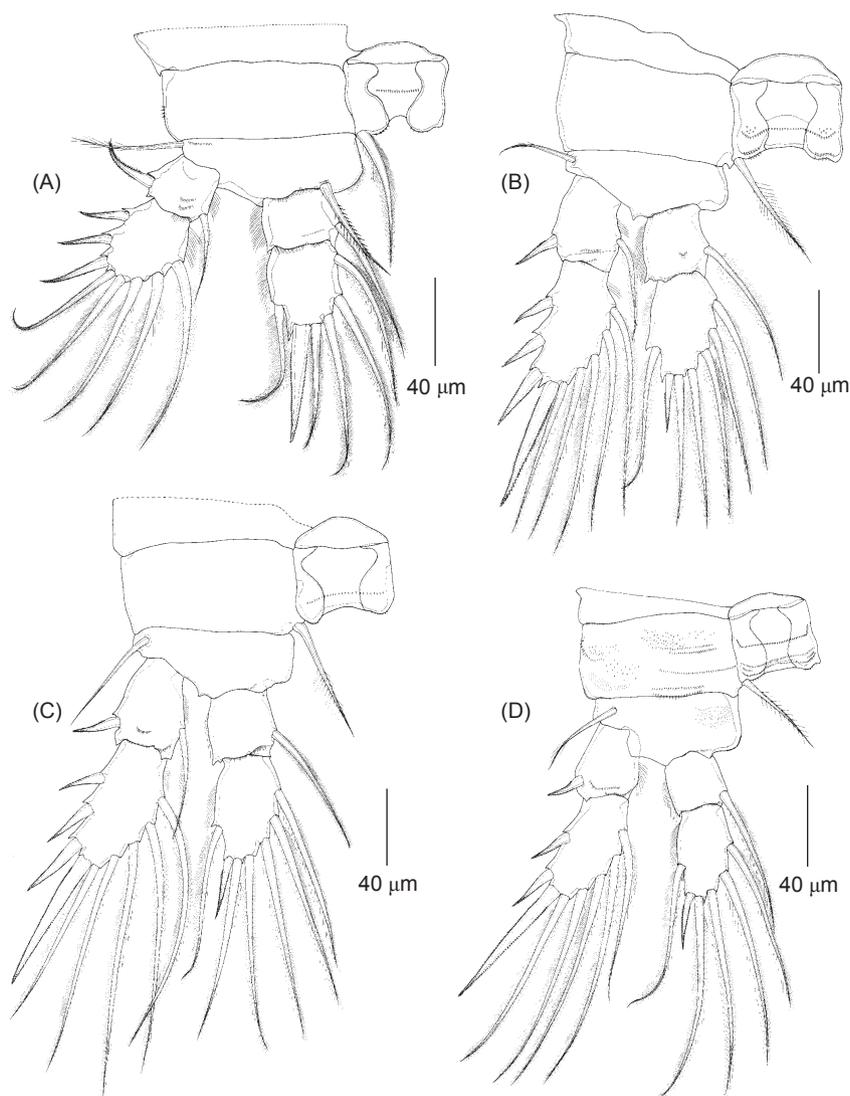


Fig. 5. *Apocyclops ramkhamhaengi* sp. nov. Female. (A) P1, anterior view; (B) P2, posterior view; (C) P3, posterior view; (D) P4, posterior view.

thick plus 1 long, plumose setae, and with 3 long, plumose setae medially.

P5 (Fig. 2B): Interpodal bar absent; basis fused to 6th thoracomere with lateral seta dorsolaterally; exopod with 1 terminal seta and 1 seta on posterior face.

P6 (Fig. 1B): Three setae on operculum of oviducal opening on genital double-somite.

Caudal rami (Figs. 2A-C): Ratio of length, along lateral margin, to width, at level of proximal lateral seta, 5:1; with 2 lateral, 1 dorsal, and 3

terminal setae; inner terminal seta small.

Male. Length of allotype 0.74 mm (from anterior margin of cephalothorax to posterior margin of caudal rami); length range of 8 other specimens 0.73-0.76 mm; ratio of prosome to urosome 1.2-1.3.

Habitus (Figs. 6A, B): Body smaller and more slender than female; in dorsal view, prosome indistinguishable in width from urosome. Surface of cephalothorax and pedigers 2-4 with indentations in pattern similar to female. Ventrolateral corner

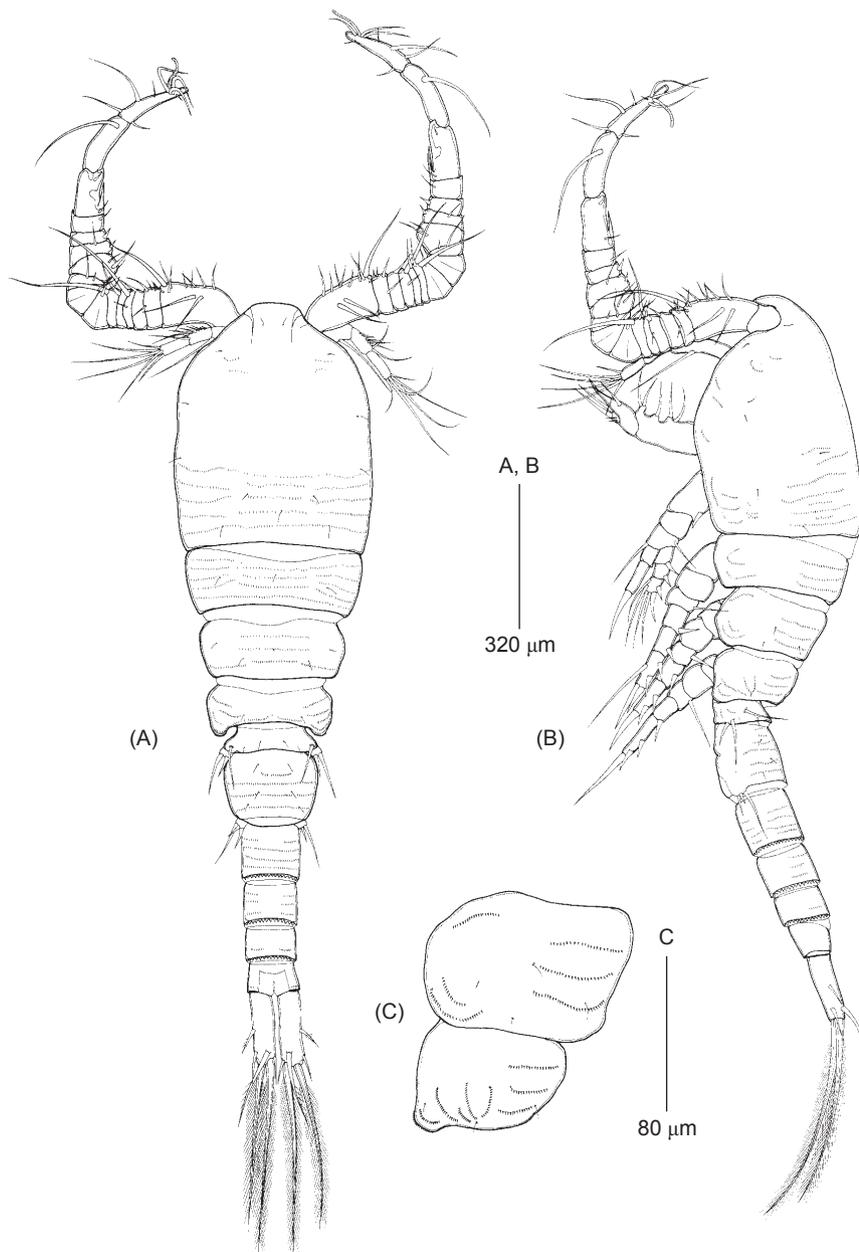


Fig. 6. *Apocyclops ramkhamhaengi* sp. nov. Male. (A) Habitus, dorsal view; (B) habitus, left lateral view; (C) pedigers 3 and 4, right lateral view, only a few exoskeletal indentations are indicated on the posterolateral projection.

of pediger 3 not projected; ventrolateral corner of pediger 4 with a distinctly rounded projection posterolaterally. Urosome (Figs. 7A, B) of 6 somites. Pediger 5 similar to female, with a ventral group of spinules near base of leg 5 and a line of spinules ventrally on each side of midline; lines of spinules not meeting at ventral midline. Genital somite with lines of indentations dorsally and ventral genital openings. Anterior abdominal somite with lines of indentations dorsally and laterally. Following 2 abdominal somites with 2

lines of indentations dorsally and laterally. Anal somite without indentations; operculum well developed, with transverse rows of small spinules.

Rostrum: As in female.

Antennule (Fig. 8A): 16 articulating segments with 11, 4, 1, 2, 1, 2, 1, 1, 2, 2, 2, 2, 1, 2, 1, and 9 setal elements; modified seta on segment 14 attenuate proximally and distally from a broad base; distal segment with terminal aesthetasc. Segments 6-9 a complex proximal geniculation; distal geniculation between segments 14 and 15.

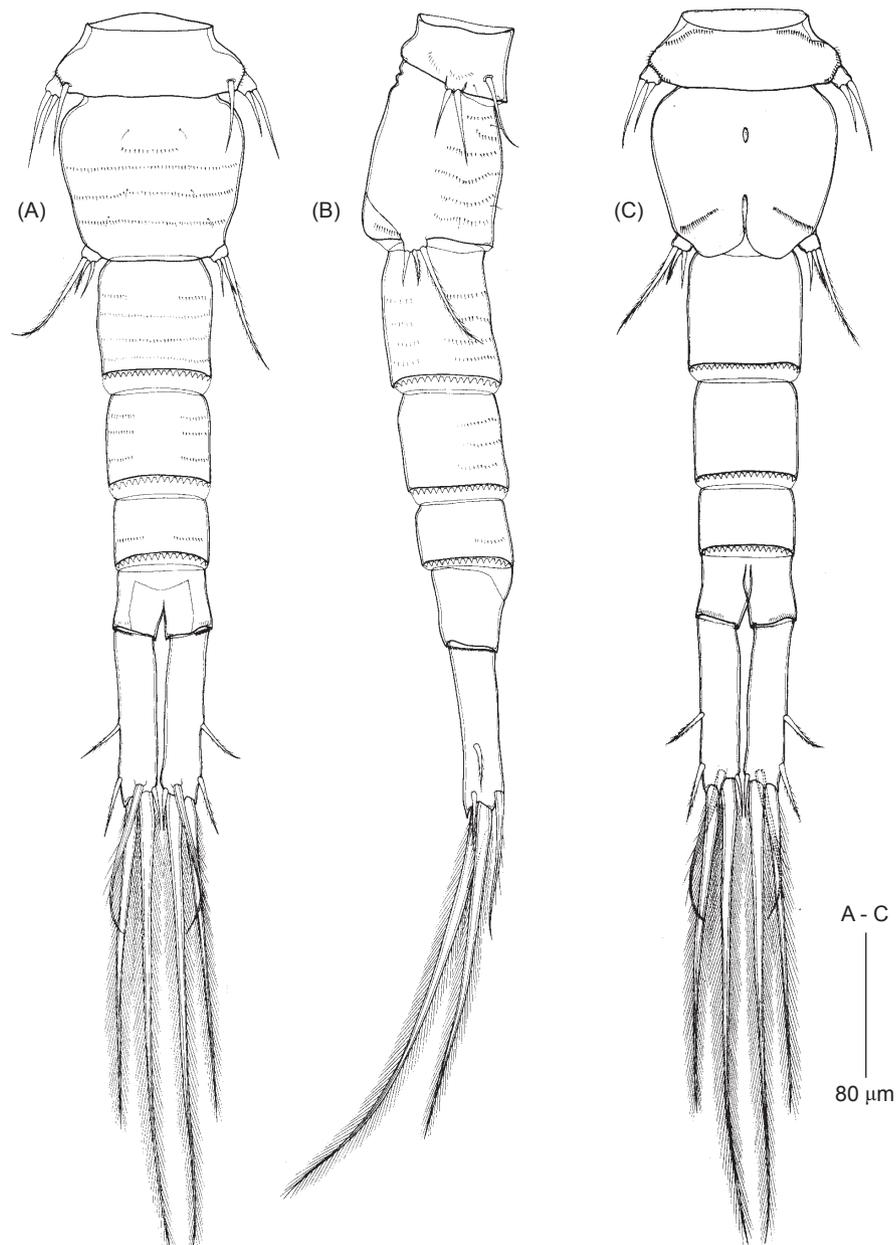


Fig. 7. *Apocyclops ramkhamhaengi* sp. nov. Male. (A) Urosome, dorsal view; (B) urosome, left lateral view; (C) urosome, ventral view.

Arthroial membrane between segments 6 and 7, 7 and 8, and 8 and 9 more developed dorsally (face opposite setae); part of distal margin of segment 9 drawn out into a collar-like extension.

Antenna (Fig. 8B): As in female except proximal free endopodal segment with 8 setae.

Mandible and maxillule: As in female.

Maxilla: As in female, but see discussion of polymorphisms.

Maxilliped: As in female.

P1: As in female, but see discussion of polymorphisms.

P2: As in female, but see discussion of polymorphisms.

P3, P4, P5: As in female.

P6 (Fig. 7C): Protopod expanded medially as flap covering genital pore; ramus bearing 3 setae.

Caudal rami (Figs. 7A-C): Ratio of length, along lateral margin, to width, at level of proximal lateral seta, 4:1; setation as in female.

DISCUSSION

Apocyclops ramkhamhaengi shares an endopod of antenna 2 with 2 articulating segments with the Asian *A. borneoensis* and *A. royi*. The endopod of antenna 2 of *A. dengizicus* is 3-segmented, and the proximal segment articulates with the basis (Mirabdullayev and



Fig. 8. *Apocyclops ramkhamhaengi* sp. nov. Male. (A) Antennule; (B) antenna.

Stuge 1998). For species with 2 articulating segments, the allobasis includes the proximal segment of a 3 segmented endopod. *Apocyclops ramkhamhaengi* shares with *A. borneoensis* a rounded posterolateral projection on pediger 4, and a simple line of spinules ventrally on pediger 5; there is no projection on *A. royi*, and the spinules on pediger 5 do not extend ventrally toward the midline (see Botelho 1999). There is a rounded ventrolateral projection of the 4th thoracic somite on *A. ramkhamhaengi*, a series of ridges dorsally on the basis of maxilla 2, and no spinules ventrally on the caudal ramis. *Apocyclops borneoensis* is not reported to have a projection of the 4th thoracic somite or a series of ridges dorsally on the basis of maxilla 2, but it possesses a distinctive set of spinules on the caudal ramus.

Apocyclops ramkhamhaengi also has fewer spinules on the posterior surface of the interpodal bar and coxa of swimming legs 2-4 than does *A. borneoensis*.

Indentations on the exoskeleton of species of *Apocyclops* do not contrast well with those parts of the exoskeleton lacking indentations. As a result, the pattern of indentations is often difficult to observe on cleared and stained specimens. The pattern is best observed looking laterally to a direct line of sight through stained specimens. On the cephalothorax and pedigers 2-4, the pattern of exoskeletal indentations begins as a series of parallel lines dorsally and dorsolaterally, but the parallel lines break up into a reticulated pattern laterally and lateroventrally. On pediger 6, and the anterior and following 2 abdominal somites, the exoskeletal indentations form circumferential lines.

Specimens of *A. ramkhamhaengi* studied here exhibited significant polymorphic variations in the maxilla, and swimming legs 1 and 2 of both females and males. Polymorphism of the

maxilla was expressed in the proximal endopodal segment which is the 3rd articulating segment. In some specimens of *A. ramkhamhaengi* and most cyclopids in general, the segment is produced distally and medially resulting in a thick, tapering, curved attenuation (Fig. 4C); there is an anterior seta toward the base of the attenuation and a 2nd seta proximally and medially. Maxilla 2 of several female and male specimens had an attenuation that was much thicker at its base (Fig. 9A). In another female and 2 male specimens, the attenuation was absent, but a thick, curved seta was present (Fig. 9B). The proximomedial seta was absent from 2 females, and in one of those females, the anterior seta was also absent.

Setation of swimming legs 1 and 2 may vary among specimens or asymmetrically on the left and right legs of the same specimen. We believe that the setation observed and described above is the usual developmental outcome for species of *Apocyclops* (see Valderhaug and Kewalramani 1979, Chang and Lei 1993, Ferrari 1998). However, the distal endopodal segment of the left swimming leg 1 of 1 female (Fig. 10A) had 4 plumose setae medially, 1 plumose seta and 1 pinnate spine terminally, and 1 plumose seta laterally; the right distal endopodal segment bore 3 plumose setae medially, 1 plumose seta and 1 pinnate spine terminally, and 1 plumose seta laterally. The left distal endopodal segment of another female (Fig. 10B) bore 2 plumose setae medially, 1 plumose seta and 1 pinnate spine terminally, and 2 plumose setae laterally, and the proximal endopodal segment of this limb bore a 2nd seta distally; the right endopod bore 3 plumose setae medially, 1 plumose seta and 1 pinnate spine terminally, and 1 plumose seta laterally. In extreme cases (Figs. 11A, D), the exopod and endopod of a swimming leg were not separated,

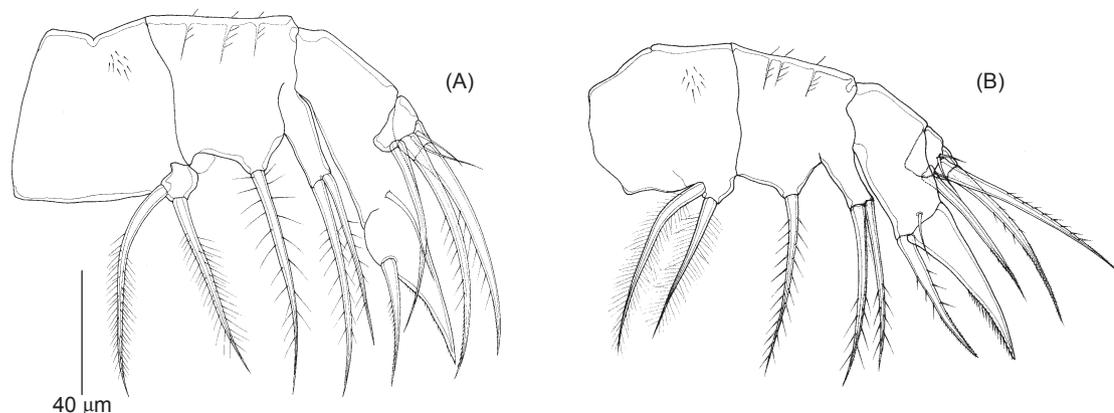


Fig. 9. *Apocyclops ramkhamhaengi* sp. nov. (A, B) Variations in female maxilla.

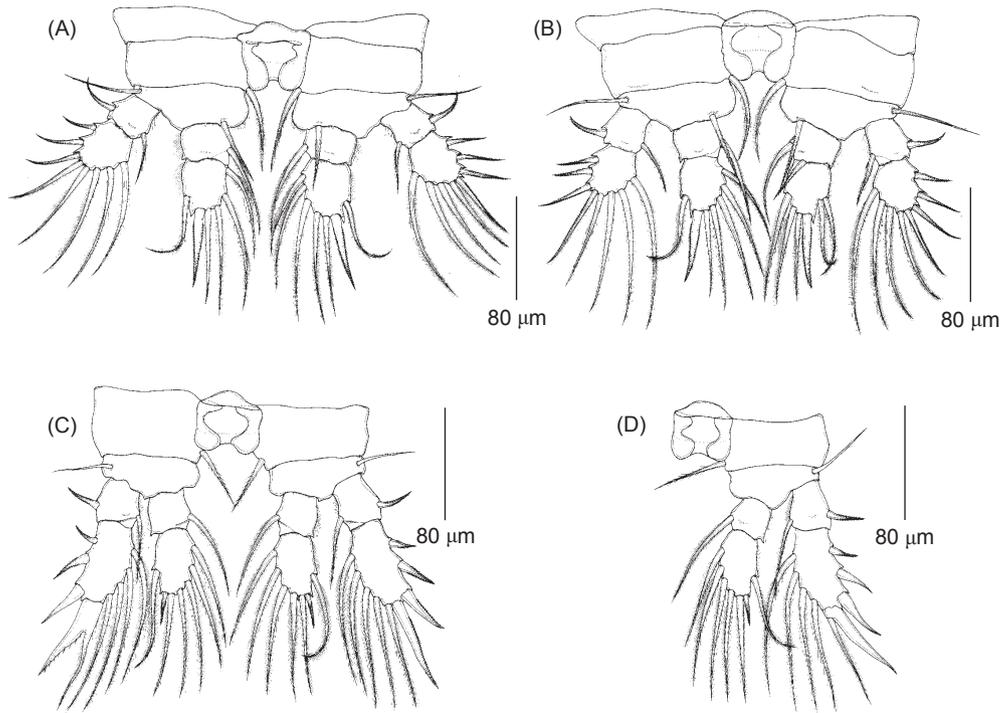


Fig. 10. *Apocyclops ramkhamhaengi* sp. nov. (A, B) Variations in female P1; (C) variation in female P2; (D) variation in male P2.

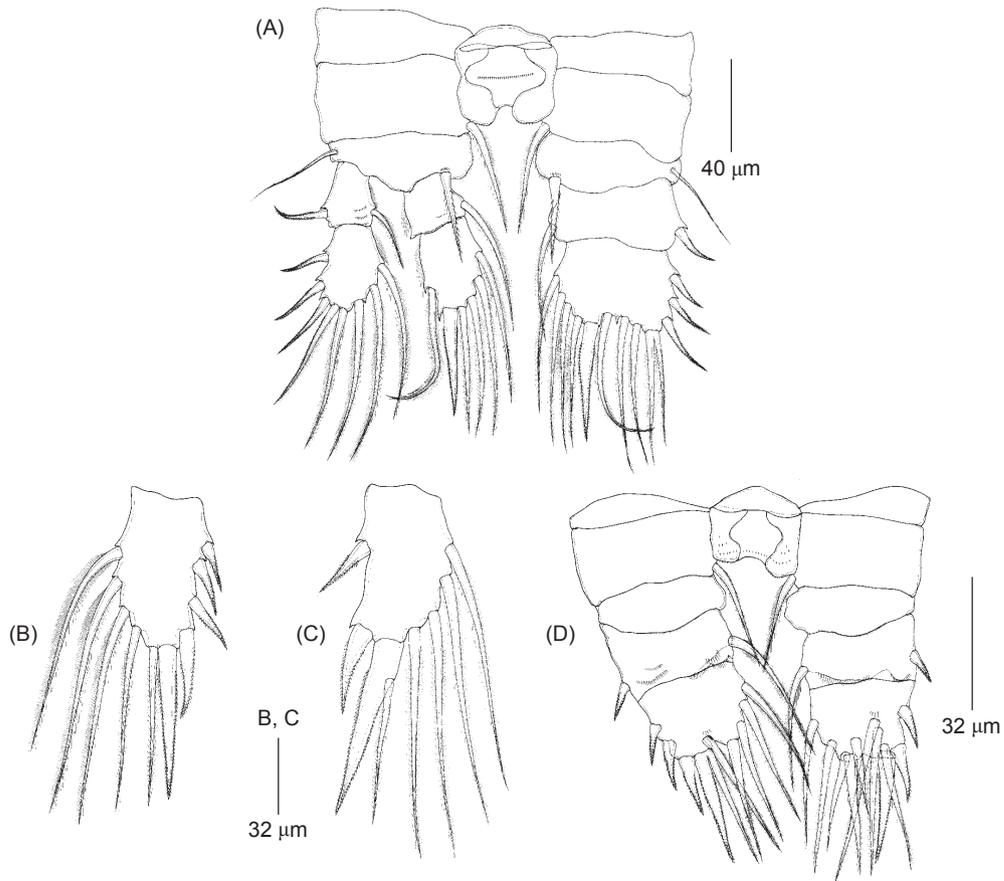


Fig. 11. *Apocyclops ramkhamhaengi* sp. nov. (A) Variation in female P1; (B, C), variations in female P2; (D) variation in female P3.

and the limb looks like a large setose bud (Ferrari 2000) but with more setae. On swimming leg 1 of 1 specimen (Fig. 11A), the exopod and endopod of left limb were fused, although the rami of the right limb remained separate, permitting a comparison of the setation. On the limb with fused rami, an arthrodial membrane separated the presumed proximal segments of the limb anteriorly but not posteriorly. The endopod bore 6 setae, including a distal lateral one, the same number as the contralateral limb. The exopod bore 7 setae, and the terminal seta of the exopod was bifurcate; the 3 medial setae, one on the proximal segment and two on the distal segment appeared not to have formed.

Swimming leg 2 with an exopod possessing only 4 medial setae was found on 1 specimen whose terminal seta was bifurcate (Fig. 10C). The terminal exopodal seta on the distal exopodal segment also may be modified. On another specimen, a plumose seta was inserted toward the base of the terminal seta (Fig. 10D); this inserted seta on swimming leg 2 co-occurred with only 4 medial setae on the distal segment and only 2 lateral setae on the distal segment.

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