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Article in *Zoosymposia* · December 2012

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## ***Asterocheres siphunculus*, a new species of Asterocheridae (Copepoda, Siphonostomatoida) associated with *Eucidaris tribuloides* (Lamarck, 1816) (Echinodermata, Echinoidea) in Brazil**

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### **Abstract**

*Asterocheres* Boeck, 1859 is the most speciose genus within the copepod family Asterocheridae Giesbrecht, 1899. Its main hosts are sponges, cnidarians, bryozoans, and echinoderms. Among the latter there are records of *Asterocheres* associations with some species of the echinoid genus *Eucidaris* Pomel, 1883. Despite the wide distribution of *Eucidaris tribuloides* (Lamarck, 1883) in the coastal waters of Brazil, no records exist as yet of any copepod associated with this species. *Asterocheres siphunculus* **sp. nov.** is described herein based on samples collected from *E. tribuloides* sampled from two different sites off the coast of Salvador city, Bahia state, in northeastern Brazil. The new species shares a 20-segmented antennule with 20 congeners, but differs from them by having a very short siphon that reaches the insertion of the maxilla, a very wide rostrum that occupies the entire area between the antennules, and a pedigerous somite 4 with pointed and narrow posterolateral corners and a concave posterior margin.

**Key words:** Associated copepod, symbiotic fauna, sea urchin, Cidaridae

### **Introduction**

Although there are some families among the order Siphonostomatoida Burmeister, 1835, such as Brychiopontiidae Humes, 1974, Calverocheridae Stock, 1968, Cancerillidae Giesbrecht, 1897, Micropontiidae Gooding, 1957, Nanaspidae Humes & Cressey, 1959, and Stellicomitidae Humes & Cressey, 1958, that live exclusively in association with echinoderms (Boxshall & Halsey 2004), the family Asterocheridae Giesbrecht, 1899, especially members of its type genus *Asterocheres* Boeck, 1860, can be commonly found associated with many invertebrate hosts (Ivanenko & Smurov 1997; Johnsson 2002; Johnsson *et al.* 2002; Kim 2010). For example, *Asterocheres unicus* Johnsson, 2001 has been recorded from irregular echinoids and ascidians, and *A. spinopaulus* Johnsson, 1998 and *A. spongus* Johnsson, 2002 were found in the washings of crinoids but also from sponges and bryozoans. Exclusively associated with echinoderms, *A. crinoidicola* Humes, 2000, *A. pilosus* Kim, 2004, and *A. unioviger* Kim, 2010 are included, together with *A. trisetatus* Kim, 2010 (found in association with a sponge), in a group called the “*crinoidicola* group”, which is characterized by a distal prolongation on the third endopodal segment of leg 1 (Kim 2010). Within this group, *A.*

*pilosus* and *A. unioviger* were found in association with the sea urchins *Eucidaris thouarsii* (Agassiz & Desor, 1846) from the Pacific coast of Panama and *E. tribuloides* (Lamarck, 1816) from the Caribbean region, respectively (Kim 2004, 2010). According to Kim (2010) both species may have diverged since the formation of the Panama isthmus from a common ancestor, which was probably associated with the ancestral sea urchin of both *E. thouarsii* and *E. tribuloides*. While *E. thouarsii* occurs in the Pacific Ocean, *E. tribuloides* is distributed along the western Atlantic Ocean, ranging from Cape Hatteras in North Carolina (USA), through the Caribbean region, and reaching as far as Rio de Janeiro, Brazil (Serafy 1979). The present work describes a new species of *Asterocheres* associated with *E. tribuloides* in the northeastern region of Brazil, which documents for the first time an asterocherid associated with this host in the South Atlantic Ocean.

## Material and methods

Twenty specimens each of *E. tribuloides* were hand-collected in depths ranging from 2 to 7 m from submerged coral reefs at Boa Viagem Beach (13°00'37"S, 38°31'58"W) on 2 March 2010 and at Barra Beach (13°00'37"S, 38°31'58"W) on 5 August 2010 in Salvador City, Bahia State (Fig. 1). The hosts were immediately placed in a plastic bucket filled with sea water and sealed with a plastic lid on each field occasion, and then transported back to shore where 100% ethanol was slowly added to the sample to achieve a 5% concentration. After a few hours in the lab, the echinoids were rinsed by vigorously shaking them in the solution. The debris was then filtered through a 100 µm mesh net, fixed with 70% ethanol, and sorted for copepods under a dissection microscope.



**FIGURE 1.** Sampling sites in Todos-os-Santos Bay, Salvador city, Bahia, Brazil: 1, Boa Viagem Beach; 2, Barra Beach.

A subsample of copepod specimens was cleared in lactic acid, measured, stained in Black Chlorazol E, dissected, and mounted permanently in CMC-9® (Masters Chemical Company Inc.) mounting media. All drawings were made with the aid of a drawing tube fitted on an Olympus CH30 compound microscope. For the armature formula of legs 1–4, Roman numerals represent spines and Arabic numerals indicate setae. For the description of the antennule, Roman numerals indicate the ancestral segments (Huys & Boxshall 1991). The abbreviations P1–P6 refer to legs 1–6.

Type material was deposited in the Museu de Zoologia of the Universidade Federal da Bahia (MZBA).

## Results

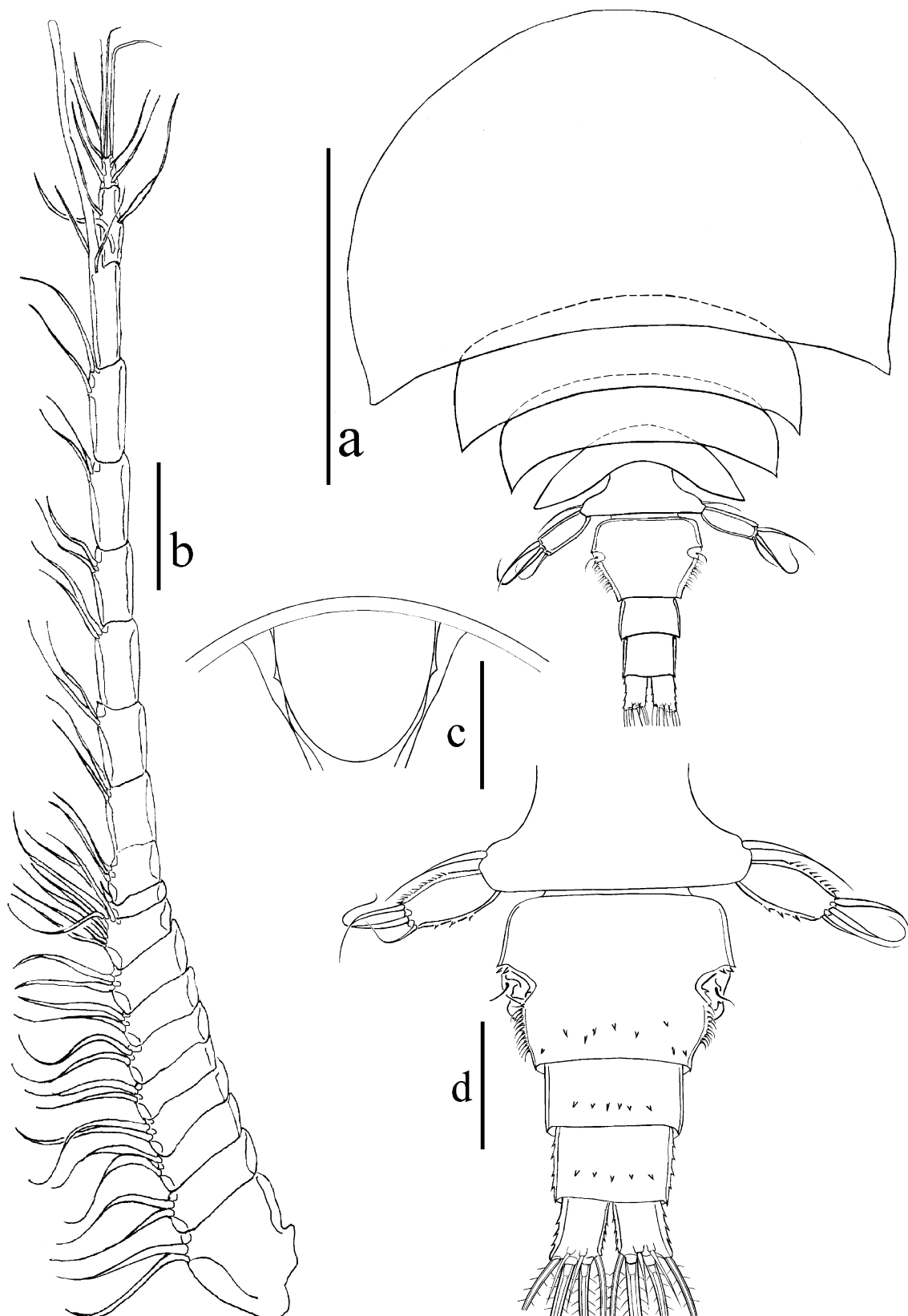
### *Asterocheres siphunculus* sp. nov.

(Figs 2–5)

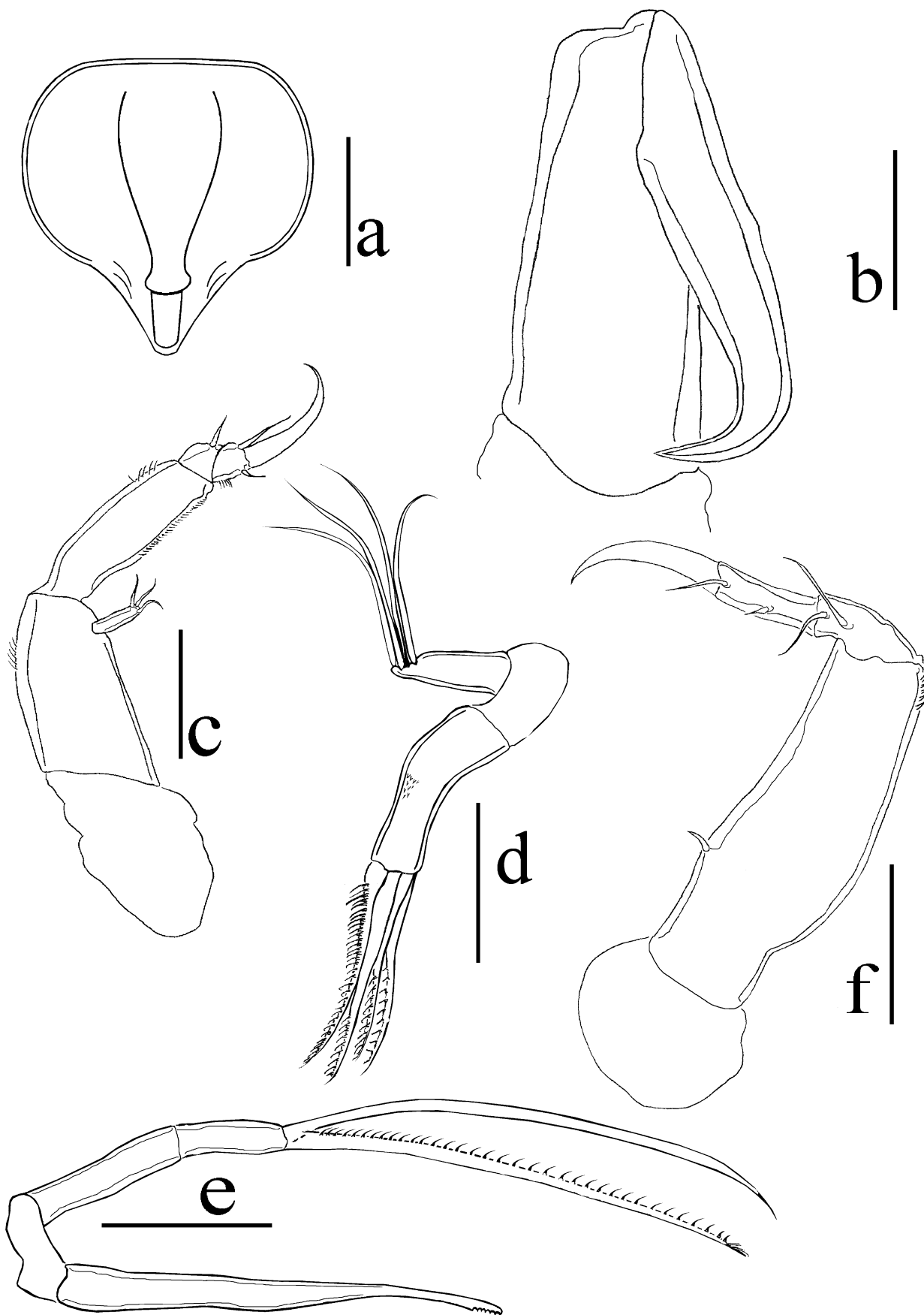
**Material examined.** ♀ Holotype (UFBA 401 CRU), ♂ allotype (UFBA 402 CRU), 3 ♀ paratype (UFBA 403 CRU), and 3 ♂ paratype (UFBA 404 CRU), from *Eucidaris tribuloides*, Boa Viagem Beach, Salvador, Bahia, Brazil, collected by Rodrigo Johnsson, Elizabeth G. Neves, Roberta Canário, Marcos M. Nogueira and Cristiano Bahia, 2 March 2010; 3 ♀ paratype (UFBA 405 CRU) and 2 ♂ paratype (UFBA 406 CRU), from *E. tribuloides*, Barra Beach, Salvador, Bahia, Brazil, collected by Vinícius Queiroz and Cristiano Bahia, 5 August 2010.

**Female.** Mean body length (excluding caudal setae) 1176 µm (1334–1018 µm) and mean body width 798 µm (881–715 µm) (based on 7 specimens). Body (Fig. 2a) cycloform, dorsoventrally flattened, prosome wider than long, and urosome cylindrical. Pedigerous somite 1 fused to cephalosome to form cephalothorax and with slightly projected epimera. Pedigerous somites 2 and 3 slightly concealed anteriorly under the preceding somite and with slightly pointed epimera. Pedigerous somite 4 smaller than others, sharply pointed posterolaterally, and with concave posterior margin. Prosome length:width ratio 0.9:1. Urosome (Fig. 2d) composed of 4 somites. Genital double-somite 129 µm long, with length:width ratio 0.7:1, vestigial P6 mid-laterally located, spinules along anterior margin of genital openings and near posterior margin, and row of setules along posterolateral margins. Two postgenital somites each wider than long (45 × 70, 50 × 56 µm, respectively) and with transverse row of spinules near posterior margin; anal somite with additional spinules along outer margins. Prosome:urosome length ratio 2.5:1. Caudal rami longer than wide, 50 × 29 µm, with spinules along inner and outer margins and armed with 2 naked and 4 plumose setae. Length of setae II–VII (seta I absent) 102, 136, 181, 190, 145 and 102 µm, respectively.

Rostrum (Fig. 2c) large, rounded distally, and measuring 93 × 125 µm. Antennule (Fig. 2b) 418 µm long (not including setae) and 20-segmented. Length of segments: 50, 14, 14, 14, 10, 10, 13, 16, 13, 7, 14, 23, 25, 28, 25, 28, 32, 40, 27, and 10 µm, respectively. Segmental homologies and armature as follows: 1(I)-2; 2(II)-2; 3(III)-2; 4(IV)-2; 5(V)-2; 6(VI)-2; 7(VII)-2; 8(VIII)-2; 9(IX–XII)-7; 10(XIII)-1+spine; 11(XIV)-2; 12(XV)-2; 13(XVI)-2; 14(XVII)-2; 15(XVIII)-2; 16(XIX)-2; 17(XX)-2; 18(XXI)-2+ae; 19(XXII–XXV)-3; 20(XXVI–XXVIII)-8. Segment XIII reduced and partially covered by distal expansion of preceding segment. Aesthetasc 81 µm long. Antenna (Fig. 3c) 278 µm long (including distal claw); coxa 37 µm long; basis 86 µm long. Exopod 1-segmented, 19 µm long, and armed with 1 subapical and 2 apical naked setae. Endopod 3-segmented; first segment 67 µm long, unarmed, but ornamented with setules on outer and inner margins; second segment 19 µm long, armed with subdistal naked seta. Third segment 19 µm long, with proximal row of spinules, 2 naked subdistal setae, and 50 µm long, terminal curved claw. Oral cone (Fig. 3a) very short, 45 µm long (including siphon), and reaching insertion of maxilla. Mandible (Fig. 3e) with 2-segmented palp; both segments slender, 45 and 31 µm long, respectively. Second segment with 2 long distal setae (1 naked, other unilaterally spinulated). Mandibular stylet 136 µm long, proximally stout, and armed with 7 terminal teeth. Maxillule (Fig. 3d) bilobed; inner lobe 31 µm long, stout, and



**FIGURE 2.** *Asterocheres siphunculus* sp. nov., female holotype (UFBA 401 CRU). a, body, dorsal view; b, antennule; c, rostrum; d, urosome, dorsal view. Scale bars: a = 500  $\mu$ m; b–c = 50  $\mu$ m; d = 125  $\mu$ m.



**FIGURE 3.** *Asterocheres siphunculus* sp. nov., female holotype (UFBA 401 CRU). a, oral cone; b, maxilla; c, antenna; d, maxillule; e, mandible; f, maxilliped. Scale bars: a–f = 50 µm.

armed with 4 distal naked setae. Outer lobe 54  $\mu\text{m}$  long, also stout, and with small patch of spinules and 4 distal, unilaterally spinulated setae. Maxilla (Fig. 3b) 316  $\mu\text{m}$  long, consisting of 148  $\mu\text{m}$  long syncoxa and 168  $\mu\text{m}$  long, distally curved claw. Maxilliped (Fig. 3f) 4-segmented and 369  $\mu\text{m}$  long; syncoxa 32  $\mu\text{m}$  long and unarmed; basis 189  $\mu\text{m}$  long, bearing proximal spine and 5 spinules distally. Endopod 2-segmented, each 40  $\mu\text{m}$  long; proximal segment with 2 naked setae; distal segment with 2 naked setae and distally curved, claw-like element measuring 68  $\mu\text{m}$  long.

P1–P4 (Fig. 4a–4d) biramous, with 3-segmented rami. Armature formula of P1–P4 as follows:

	Coxa	Basis	Exopod	Endopod
P1	0–1	1–1	I–1; I–1; III,2,2	0–1; 0–2; 1,2,3
P2	0–1	1–0	I–1; I–1; III,I,4	0–1; 0–2; 1,2,3
P3	0–1	1–0	I–1; I–1; III,I,4	0–1; 0–2; 1,1+I,3
P4	0–1	1–0	I–1; I–1; III,I,4	0–1; 0–2; 1,1+I,2

P1 (Fig. 4a) with setules along outer margin of each ramus; outer margin of exopod and endopod of P2–P4 with serrations and setules, respectively. Inner coxal seta of P2, outer basal seta of P2 and P4, and setae on rami of P1–P4 plumose (Fig. 4b, d); all others naked.

P5 (Fig. 4e) with free exopodal segment bearing 3 naked distal setae and serrations along outer and inner margins. Protopod incorporated into somite and represented by outer naked seta (Fig. 2d).

**Male.** Mean body length (excluding caudal setae) 863  $\mu\text{m}$  (859–867  $\mu\text{m}$ ) and mean body width 647  $\mu\text{m}$  (645–649  $\mu\text{m}$ ) (based on 6 specimens). Body (Fig. 5a) similar to that of female. Prosome length:width ratio 1.3:1. Urosome (Fig. 5c) composed of 5 somites. Genital somite 88  $\mu\text{m}$  long, with length:width ratio 0.7:1, vestigial P6 posterolaterally located, and spinules along outer margins. All three postgenital somites wider than long, 22  $\times$  52, 27  $\times$  50 and 34  $\times$  52  $\mu\text{m}$ , respectively (Fig. 5c). Anal somite with 2 spinules along outer margins and tooth-like projection on each distal corner. Prosome:urosome length ratio 1.9:1. Caudal rami longer than wide, 29  $\times$  22  $\mu\text{m}$ , and armed as in female.

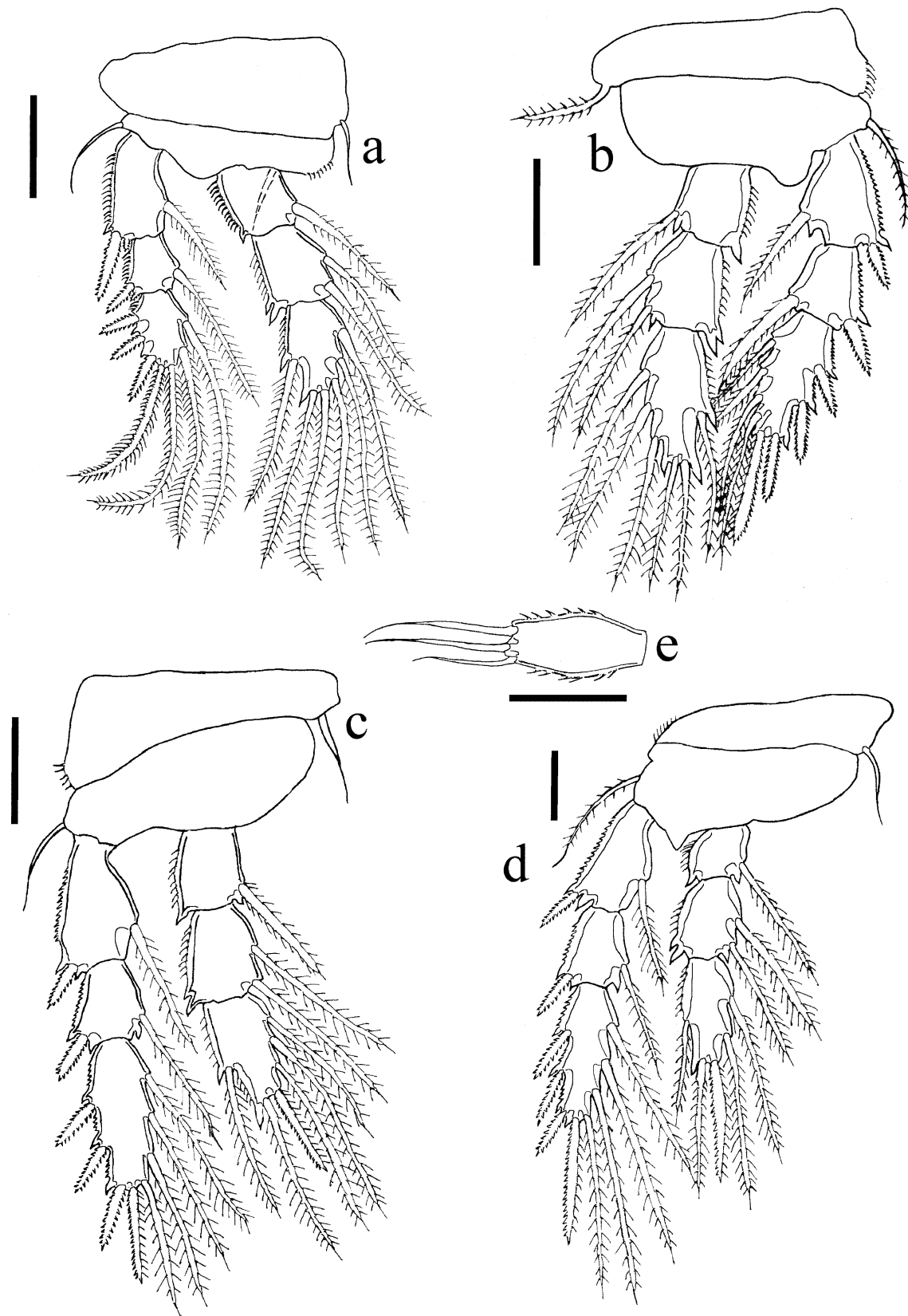
Antennule (Fig. 5b) 342  $\mu\text{m}$  long (not including setae) and 18-segmented. Length of segments: 40, 10, 12, 11, 11, 11, 10, 12, 7, 7, 13, 21, 22, 25, 22, 46, 38, and 19  $\mu\text{m}$ , respectively. Segmental homologies and armature as follows: 1(I)-2; 2(II)-2; 3(III)-2; 4(IV)-2; 5(V)-2; 6(VI)-2; 7(VII)-2; 8(VIII)-2; 9(IX–XII)-5; 10(XIII)-1+spine; 11(XIV)-2; 12(XV)-2; 13(XVI)-2; 14(XVII)-2; 15(XVIII)-2; 16(XIX–XX)-4; 17(XXI–XXV)-2+ae; 18(XXVI–XXVIII)-6. Aesthetasc 93  $\mu\text{m}$  long. Maxilliped (Fig. 5d) with unarmed syncoxa; basis with inner projection and spinules on outer margin. Endopod 2-segmented; proximal segment with 2 naked setae; distal segment with 1 naked seta and long claw.

**Etymology.** The specific name “*siphunculus*” refers to the short siphon of the new species.

**Remarks.** Kim (2010) recently provided a preliminary review of the genus *Asterocheres*: he offered a more defined diagnosis of *Asterocheres* based primarily on the setation pattern on the rami of legs 1 to 4, and recognized 45 species as valid, 15 as insufficiently described, and 12 as species inquirendae. He also established 14 new species of *Asterocheres* based on material collected from Madagascar by the late Dr. Arthur G. Humes and from the West Indies by Dr. Humes and Dr. Richard U. Gooding.

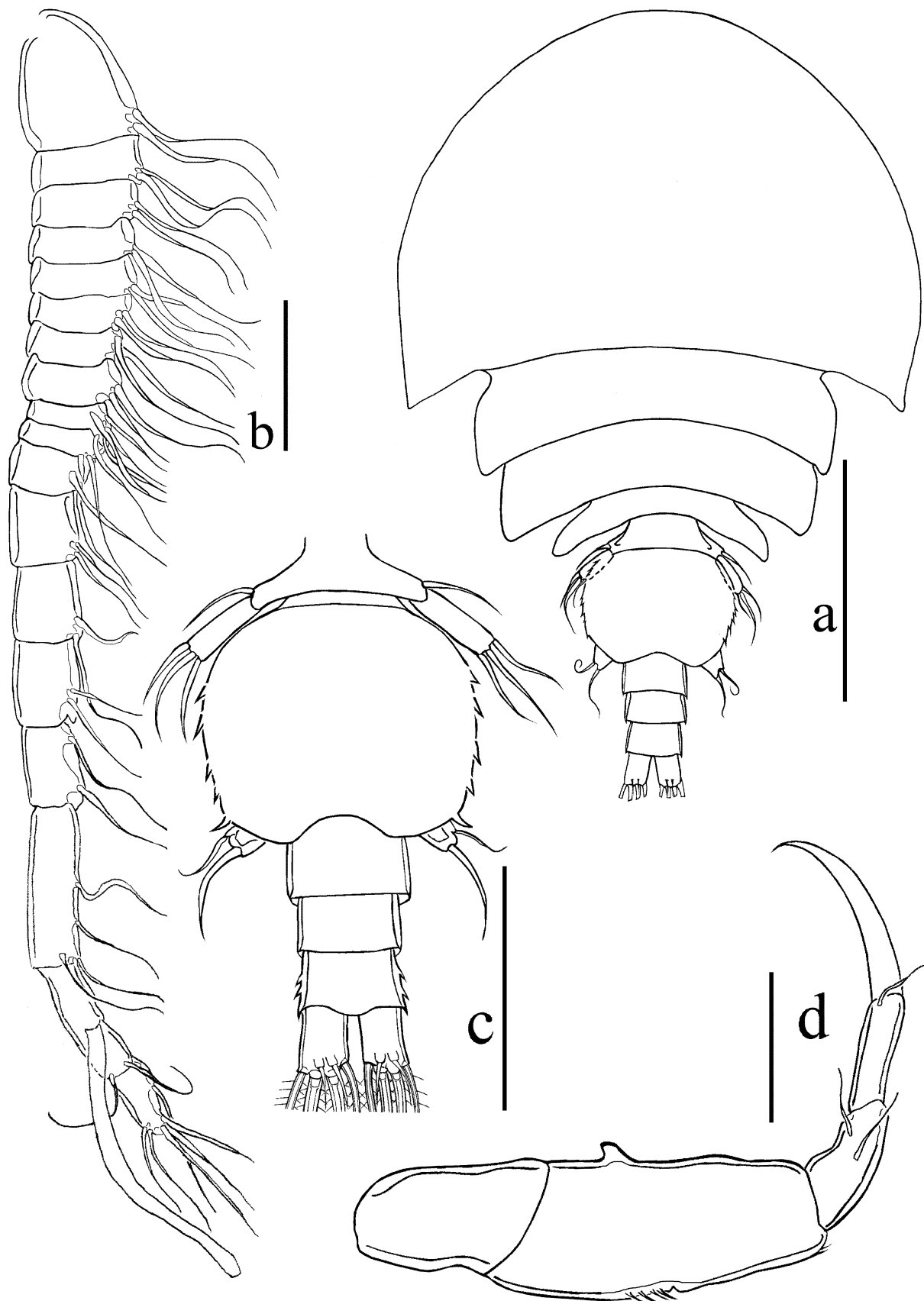
Five additional new species were described since Kim (2010): *Asterocheres antillensis* Varela, 2010; *Asterocheres cubensis* Varela, 2010; *Asterocheres faroensis* Crescenti, Baviera & Zarcone, 2010; *Asterocheres fernandezmillerai* Varela, 2010; and *Asterocheres tarifensis* Conradi & Bandera, 2011. *Asterocheres antillensis* does not fit into the diagnosis of the genus as presented by Kim

(2010), as it has a different setation pattern in legs 2 and 3. As such, this species is treated herein as a species inquirenda. The genus *Asterocheres*, therefore, consists of 63 valid species.



**FIGURE 4.** *Asterocheres siphunculus* sp. nov., female holotype (UFBA 401 CRU). a, P1; b, P2; c, P3; d, P4; e, P5. Scale bars: a–e = 50  $\mu$ m.





**FIGURE 5.** *Asterocheres siphunculus* sp. nov., male allotype (UFBA 402 CRU). a, body, dorsal view; b, antennule; c, urosome, dorsal view; d, maxilliped. Scale bars: a = 250  $\mu$ m; b–d = 50  $\mu$ m.

The new species described herein is unambiguously assigned to *Asterocheres* since it has all the key characters, particularly the same setation pattern of legs 1 to 4, for the genus as redefined by Kim (2010). *Asterocheres siphunculus* **sp. nov.** shares a 20-segmented antennule with the following 21 valid congeners: *A. boeckii* (Brady, 1880); *A. bulbosus* Malt, 1991; *A. canui* Giesbrecht, 1897; *A. complexus* Stock, 1960; *A. corneliae* Schirl, 1973; *A. crinoidicola* Humes, 2000; *A. dentatus* Giesbrecht, 1897; *A. galeatus* Kim, 2010; *A. indivisus* Kim, 2010; *A. neptunei* Johnsson, 2001; *A. oricurvus* Kim, 2010; *A. planus* Kim, 2010; *A. sensilis* Kim, 2010; *A. simplex* Schirl, 1973; *A. siphonatus* Giesbrecht, 1897; *A. stimulans* Giesbrecht, 1897; *A. stocki* Nair & Pillai, 1984; *A. tenuipes* Kim, 2010; *A. tricuspis* Kim, 2010; *A. trisetatus* Kim, 2010; and *A. ventricosus* (Brian, 1928).

The new species differs from those 21 species as follows. The oral cone in the new species is quite short and reaches as far as the insertion of the maxilla. In contrast, *A. bulbosus* and *A. dentatus* have a siphon reaching the base of the maxilliped (Giesbrecht 1897, Malt 1991), *A. galeatus* has the siphon reaching between the maxilliped and P1, and *A. boeckii*, *A. canui*, *A. complexus*, *A. corneliae*, *A. neptunei*, *A. oricurvus*, *A. simplex*, *A. siphonatus*, *A. stimulans*, *A. stocki*, and *A. ventricosus* have a siphon reaching to, at least, the insertion of P1 (Brady 1880; Giesbrecht 1897; Brian 1928; Stock 1960; Schirl 1973; Nair & Pillai 1984; Johnsson 2001; Kim 2010).

Features of the mandible, maxillule, maxilla, maxilliped, P1, and P5 can also be used to distinguish the new species from several of its congeners. *Asterocheres indivisus*, *A. planus*, and *A. sensilis* have a 1-segmented mandibular palp (Kim 2010) instead of a 2-segmented palp as in *A. siphunculus* **sp. nov.** *Asterocheres trisetatus* possesses only 3 distal setae on the inner lobe of the maxillule, whereas *A. siphunculus* **sp. nov.** has 4. Additionally, *A. siphunculus* **sp. nov.** has 4 distal setae on the outer lobe of the maxillule, whereas *A. complexus*, *A. galeatus*, *A. indivisus*, *A. oricurvus*, *A. planus*, *A. sensilis*, *A. tenuipes*, and *A. tricuspis* possess 5, of which one is very short. Furthermore, *A. crinoidicola* differs from the new species by having 4 distal unequal setae (vs. 4 subequal in *A. siphunculus* **sp. nov.**) on the outer lobe of the maxillule. The distal claw of the maxilla is more curved in *A. planus* than in *A. siphunculus* **sp. nov.** Lastly, *A. siphunculus* **sp. nov.** has an unarmed coxa on the maxilliped unlike the unisetose maxilliped coxa found in *A. bulbosus*, *A. complexus*, *A. corneliae*, *A. crinoidicola*, *A. galeatus*, *A. indivisus*, *A. oricurvus*, *A. planus*, *A. sensilis*, *A. siphonatus*, *A. stocki*, *A. tenuipes*, *A. tricuspis*, and *A. trisetatus*.

The apomorphic long inner basal seta of P1 in *A. tricuspis* (Kim 2010) is absent in *A. siphunculus* **sp. nov.** The setation of P1 also differs between *A. boeckii* and *A. siphunculus* **sp. nov.**: the inner seta on the basis is absent in the former species. *Asterocheres tenuipes* has a 2-segmented P5 (Kim 2010) rather than a 1-segmented P5 as in the new species, and *A. canui* and *A. stocki* have 2 setae on the free exopodal segment of P5 while *A. siphunculus* **sp. nov.** has 3 setae.

*Asterocheres unioviger* has been found in association with the same host species (*E. tribuloides*) as *A. siphunculus* **sp. nov.** However, the former can be easily differentiated from the latter by the following characters: (1) the presence of a projection on the third endopodal segment of P1 as in *A. crinoidicola* and *A. trisetatus* (a diagnostic feature for members of the “*crinoidicola* group”); (2) the inner lobe of the maxillule bears 5 terminal setae; (3) the distal claw on the maxilla bears one small setule; and (4) the 19-segmented antennule (Kim 2010). Moreover, the fourth pedigerous somite of *A. siphunculus* **sp. nov.** is sharply pointed on the posterolateral corners and distinctly concave along the posterior margin, which are not present in neither *A. unioviger* nor in any other congener.

## Acknowledgements

The authors thank Prof. K. Nagasawa (Hiroshima University), Dr. D. Tang (Hiroshima University) and Dr. J. Kalman Passarelli (Cabrillo Marine Aquarium) for the opportunity of participating in and presenting this study at the 1<sup>st</sup> International Workshop on Symbiotic Copepoda. The authors are also grateful to two anonymous reviewers for their useful comments. R. J. also thanks FAPESB for financial support (APR0137/2010).

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