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Article in *Journal of Natural History* - March 2013

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## Redescription of five *Asterocheres* species (Copepoda: Siphonostomatoida) and a description of a new species discovered in the collections of the Zoological Museum of Amsterdam

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(Received 10 October 2011; final version received 18 October 2012; first published online 18 February 2013)

This paper re-examines the type material of five *Asterocheres* Boeck, 1859 species from the collection of Jan Stock deposited in the Zoological Museum of Amsterdam and describes a new species, *Asterocheres hoi*. Some taxonomically important appendages of these species are redescribed and illustrated. The most striking discrepancies with the original descriptions have been observed in: (1) the segmentation of antennule, antenna and mandibular palp; (2) the omission of some elements in various oral appendages such as the antenna, maxillule, maxilla and maxilliped; (3) the presence or not of a flaccid element on the maxilla; (4) the length of the siphon and the shape of the stylet. The redescribed species, *Asterocheres genodon* Stock, 1966, *Asterocheres halichondriae* Stock, 1966, *Asterocheres maxillatus* Stock, 1987, *Asterocheres proboscideus* Stock, 1966 and *Asterocheres scutatus* Stock, 1966, were also compared with their closest congeners.

<http://www.zoobank.org/urn:lsid:zoobank.org:pub:1E9F6B4E-ADE0-4A84-91EB-222D391E88D7>

**Keywords:** Copepoda; Siphonostomatoida; symbionts; Jan Stock's collection

### Introduction

The Asterocheridae Giesbrecht, 1899 is the largest family of the siphonostomatoid copepods that uses marine invertebrates as hosts, with about 200 species. This family exploits the diversity of marine invertebrate organisms as potential hosts and can be found associated with molluscs, bryozoans, corals, echinoderms, polychaetes, sponges and ascidians (Ivanenko and Smurov 1997; Johnsson and Bustamante 1997). *Asterocheres* Boeck, 1859 is the largest genus within the family as it contains nearly 30% of the known species (approximately 72 nominal species). However, many of these species are poorly or incompletely described (Stock 1966; Ho 1984; Humes 1996a; Ivanenko and Smurov 1997; Boxshall and Halsey 2004; Kim 2004b, 2005, 2010). As such, these descriptions are unreliable for comparative purposes. Most of these poorly known species have not been recorded since their original descriptions and future studies may be based on type material deposited in different museums. The number of *Asterocheres* species has increased at a rapid pace, with about 35 new members described since 2000 (Humes 2000; Johnsson et al. 2001; Johnsson 2002; Kim 2004a, 2004b, 2005, 2010; Bandera et al. 2005, 2007; Bispo et al. 2006; Conradi et al. 2006; Conradi and Bandera 2011). In contrast, only 15 poorly known species have

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been redescribed within the same time period (Ivanenko and Ferrari 2003; Bandera and Conradi 2009a, 2009b, 2009c; Kim 2010).

As Kim (2010) pointed out, it is necessary to consider the validity of the nominal species of *Asterocheres*, so the definition of the genus needs to be strict. He sorted the 72 nominal species into: valid species (45 species), incompletely described species that are hardly comparable with congeners (15 species) and *species inquirendae*, which are hardly considered to belong to *Asterocheres* (12 species). The species belonging to the last two groups need to be re-examined for morphological details before placing them in a particular genus.

A partial revision of the genus *Asterocheres* Boeck, 1859, based on type material deposited in various museums, was recently initiated to clarify the confused systematic and phylogenetic relationships of this genus. The present paper deals with the redescription of some species deposited in the Zoological Museum of Amsterdam by Jan Stock. Although this material belong to the group of valid species, the re-examination of their holotypes showed some discrepancies with their respective original descriptions and, furthermore, one of them turned out to be a new species.

### Material and methods

The condition of the type material of the *Asterocheres* deposited in the Zoological Museum of Amsterdam varies according to species. When the dissected specimens were not in good enough condition to make detailed descriptions of some appendages, an additional specimen was dissected in lactic acid, stained with Chlorazol black E (Sigma C-1144), examined as a temporary mount in lactophenol, and finally sealed with Entellan as a permanent mount.

All figures were drawn with the aid of a camera lucida on a Leica DMLB differential interference microscope. All appendage segments and setation elements were named and numbered using the system established by Huys and Boxshall (1991). Mean body length of the copepod was measured from anterior margin of rostrum to posterior margin of caudal rami.

### Results

#### *Asterocheres genodon* Stock, 1966 (Figure 1)

#### *Material examined*

Holotype female (ZMA-Co.100.956) and seven paratype females (ZMA-Co.100.956b) associated with the sponge *Haliclona* sp. at Chenal du Trou d'Eau Douce (Mauritius) at 6–10 m depth collected 7 February 1964, by J.H. Stock.

#### *Description*

*Female.* Body cyclopiform, with oval cephalothorax and cylindrical urosome (fig. 6A; Stock 1966 and fig. 39A; Kim 2010). Mean body length 880  $\mu\text{m}$  (810–940  $\mu\text{m}$ ) and

maximum width 520  $\mu\text{m}$  (490–550  $\mu\text{m}$ ), based on five specimens. All appendages as redescribed by Kim (2010), except for antennule and maxillule.

Antennule 21-segmented (Figure 1A), about 450  $\mu\text{m}$  long. Segmental fusion pattern as follows (roman numerals indicating ancestral segments): 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+1 spiniform element, 11(XIV)-1+1 spine, 12(XV)-2, 13(XVI)-2, 14(XVII)-2, 15(XVIII)-2, 16(XIX)-2, 17(XX)-2, 18(XXI)-2+1 aesthetasc, 19(XXII)-2, 20(XXIII-XXIV)-4 and 21(XXV-XXVIII)-7. Segment 10(XIII) reduced and partly overlapped by distal expansion of compound segment 9(IX-XII).

Maxillule bilobed (Figure 1B). Inner lobe three times longer and wider than outer. Inner lobe with tuft of long spinules medially and row of spinules laterally, bearing five terminal setae, one of them short and naked. Outer lobe with two subterminal setae (one of them barbed) and two plumose terminal setae.

Male described by Kim (2010).

### Remarks

This species, which lives associated with the sponge *Haliclona* sp. in Chenal du Trou d'Eau Douce (Mauritius), was collected by Jan Stock in 1964 and described and illustrated in 1966. Recently, this species has been thoroughly redescribed by Kim (2010) with material from Madagascar collected by A.G. Humes. Despite this exhaustive redescription, the study of the holotype has revealed two small discrepancies in the oral appendages: (1) the segmental fusion pattern of antennule in female is 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+1 spiniform element, 11(XIV)-1+1 spine, 12(XV)-2, 13(XVI)-2, 14(XVII)-2, 15(XVIII)-2, 16(XIX)-2, 17(XX)-2, 18(XXI)-2+1 aesthetasc, 19(XXII)-2, 20(XXIII-XXIV)-4 and 21(XXV-XXVIII)-7 and the setation described by Kim (2010) is different: 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)-2, 11(XIV)-2, 12(XV)-2, 13(XVI)-2, 14(XVII)-2, 15(XVIII)-2, 16(XIX)-2, 17(XX)-2, 18(XXI)-2+1 aesthetasc, 19(XXII-XXIII)-4, 20(XXIV)-2 and 21(XXV-XXVIII)-7; (2) the outer lobe of maxillule shows four plumose distal setae instead of the naked setae illustrated by Kim (2010).

After the redefinition of the genus *Asterocheres* by Kim (2010), only 60 valid species are considered as belonging to this genus. *Asterocheres genodon* belongs to the group of *Asterocheres* species with 21-segmented antennules in females, which comprises 22 species. These species are: *A. astroidicola* Conradi, Bandera and López-González, 2006, *A. echinicola* (Norman, 1868), *A. ellisi* Hamond, 1968, *A. flustrae* Ivanenko and Smurov, 1997, *A. hirsutus* Bandera, Conradi and López-González, 2005, *A. jeanyeatmanae* Yeatman, 1970, *A. kervillei* Canu, 1898, *A. latus* (Brady, 1872), *A. lilljeborgi* Boeck, 1859, *A. madeirensis* Bandera, Conradi and López-González, 2007, *A. minutus* (Claus, 1889), *A. nudicoxus* Kim, 2010, *A. peniculatus* Kim, 2010, *A. reginae* Boxshall and Huys, 1994, *A. simulans* (Scott, 1898), *A. siphonatus* Giesbrecht, 1897, *A. suberitis* Giesbrecht, 1897, *A. tarifensis* Conradi and Bandera, 2011, *A. tenerus* (Hansen, 1923), *A. tenuicornis* Brady, 1910, *A. tubiporae* Kim, 2004 and *A. urabensis* Kim, 2004.

*Asterocheres genodon* can be easily separated from five of these species, *A. echinicola*, *A. madeirensis*, *A. minutus*, *A. nudicoxus* and *A. siphonatus*, by the number of segments in the mandibular palp. Whereas these species have a one-segmented mandibular palp, *A. genodon* has two segments in the mandibular palp (Bandera et al. 2007; Bandera and Conradi 2009c; Kim 2010; Conradi and Bandera 2011).



Figure 1. *Asterocheres genodon* Stock, 1966, holotype (female). (A) Antennule; (B) maxillule.

The oral cone of *A. genodon* forms an elongate siphon, reaching slightly beyond the intercoxal plate of leg 2. However, the siphon of *A. peniculatus*, *A. hirsutus*, *A. ellisi*, *A. urabensis* and *A. latus* only reaches to the intercoxal plate of leg 1 (Kim 2004a, 2010; Bandera et al. 2005; Bandera and Conradi 2009b, 2009c); in *A. flustrae*, *A. reginae*, *A. simulans*, *A. suberitis*, *A. jeanyeatmanae*, *A. tarifensis*, *A. kervillei* and *A. tubiporae*, the siphon extends only to the insertion of maxillipeds (Yeatman 1970; Boxshall and Huys 1994; Ivanenko 1997; Ivanenko and Smurov 1997; Kim 2004b; Bandera and Conradi 2009a, 2009c; Conradi and Bandera 2011); and in *A. lilljeborgi* the siphon extends only to the maxilla (according to Ivanenko and Ferrari 2003).

Eiselt's illustration of the habitus of *A. tenuicornis* shows a caudal ramus six times longer than wide (Eiselt 1965). In contrast, *A. genodon* has a caudal ramus slightly longer than wide.

Finally, *A. genodon* can be differentiated from the remaining two species, *A. astroidicola* and *A. tenerus*, by having a ventral seta on the caudal ramus (illustrated and described by Kim 2010). As Kim mentioned, this ventral seta on the caudal ramus is also reported in *A. dysideae* Humes, 1996. This feature is very rare in the genus because it is absent in most species. However, this "seta 1" on the caudal ramus was observed by Boxshall and Huys (1994) in *A. reginae*, although in this case this seta was much shorter and lateral.

*Asterocheres halichondriae* Stock, 1966  
(Figure 2)

*Material examined*

(a) Holotype female (ZMA-Co.100.951c), allotype male (ZMA-Co.100.951a) and 23 females and one male paratype (ZMA-Co.100.951b) associated with the sponge *Halichondria symbiotica* Levi from Flic en Flacq Lagoon (Mauritius) at 1 m depth, collected 13 February 1964 by J.H. Stock; (b) 20 females (ZMA-Co.100.952) associated with *Halichondria symbiotica* Levi from Black River Bay (Mauritius) at 1.5 m depth, collected 24 January 1964 by J.H. Stock; (c) two females (ZMA-Co.100.953) associated with *Halichondria symbiotica* Levi from Pointe aux Sables (Mauritius) at 1.5 m depth, collected 26 January 1964 by J.H. Stock.

*Description*

*Female.* Body cyclopiform with oval cephalothorax and cylindrical urosome (fig. 2A; Stock 1966). Mean body length 480  $\mu\text{m}$  (455–510  $\mu\text{m}$ ) and maximum width 265  $\mu\text{m}$  (250–285  $\mu\text{m}$ ), based on five specimens. Prosome comprising cephalothorax (fully incorporating first pedigerous somite) and three free pedigerous somites. Urosome four-segmented, comprising leg-5 bearing somite, genital double-somite and two free abdominal somites (fig. 3A; Stock 1966). Dorsal surface of free abdominal somites and posterior part of genital double-somite with epicuticular spinules. Genital double-somite about as long as wide; paired genital apertures bipartite, each comprising lateroventral copulatory pore and dorsolateral gonopore; lateral margins with long spinules in distal half, posterior to genital apertures (fig. 3A; Stock 1966). Each genital area with two small naked setae.

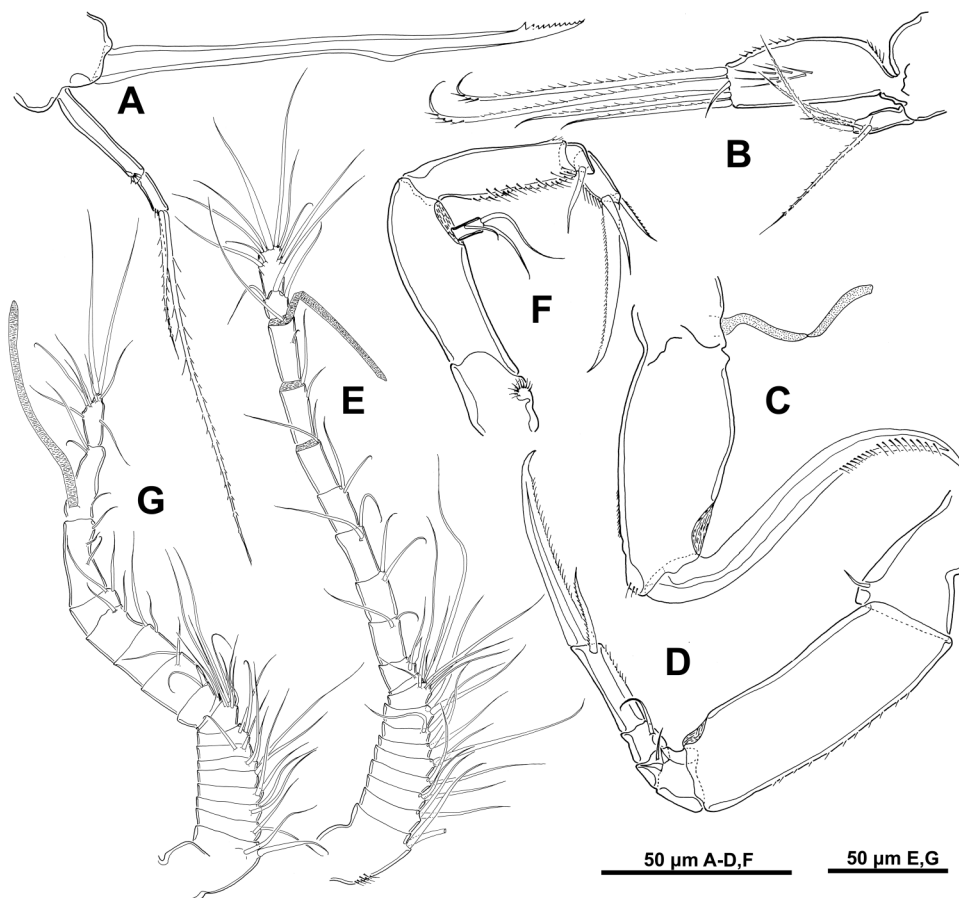


Figure 2. *Asterocheres halichondriae* Stock, 1966, holotype (female). (A) Mandible; (B) maxillule; (C) maxilla; (D) maxilliped; (E) antennule; (F) antenna. *Asterocheres halichondriae*, male. (G) Antennule.

Caudal rami about as long as wide (fig. 3A; Stock 1966), trapezoidal with inner margin shorter than outer; with six setae; seta I absent, setae III–VI plumose (middle setae very stout) and setae II and VII slightly displaced onto dorsal surface and smooth.

Antennule 20-segmented (Figure 2E), about 265 μm long. Segmental fusion pattern 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, 11(XIV)-1+1 spine, 12(XV)-2, 13(XVI)-2, 14(XVII)-2, 15(XVIII)-2, 16(XIX)-2, 17(XX)-2, 18(XXI)-2+1 aesthetasc, 19(XXII-XXIII)-3 and 20(XXIV-XXVIII)-9. Segment 10(XIII) reduced and partly overlapped by distal expansion of compound segment 9(IX-XII). All setae smooth.

Antenna biramous (Figure 2F), about 175 μm long. Coxa small with fan-like spinular tuft. Basis elongate, unarmed. Exopod one-segmented, about twice as long as wide, with two long terminal setae and one shorter and lateral seta. Endopod three-segmented; proximal segment elongated with spinules in inner margin; middle segment

produced distally on medial side but articulating with distal segment proximally on lateral side, bearing one distal smooth seta (longer than segment); distal segment with two subterminal setae, one of them plumose, and distal claw with minute spinules on inner margin.

Siphon short, about 125  $\mu\text{m}$  long, and conical. Reaching to posterior margin of maxilliped insertion.

Mandible (Figure 2A) comprising stylet-like gnathobase and slender two-segmented palp. Proximal segment of palp longer, with fan-like spinular tuft in distal part; distal segment shorter, with one distal spinule and two slightly plumose, unequal terminal setae. Stylet located in oral cone, with denticulate margin subapically.

Maxillule bilobed (Figure 2B). Inner lobe almost three times longer and wider than outer one. Praecoxal endite with five distal setae, one of them minute and naked, with tuft of long spinules medially and row of shorter spinules laterally. Palp with two terminal and two subterminal setae; all slightly plumose.

Maxilla two-segmented (Figure 2C) but with partial transverse surface suture on syncoxa (proximal segment) possibly marking plane of praecoxa-coxa fusion; praecoxal portion bearing flaccid aesthetasc-like element medially, representing tubular extension of external opening of maxillary gland. Coxal portion ornamented with spinules on outer margin being longer at apical part. Basis claw-like with spinule row in distal half as figured.

Maxilliped five-segmented (Figure 2D). First segment with one short smooth seta on inner distal margin. Second segment elongate, with small spinules on outer margin. Third segment compound, partial suture marking original separation of two ancestral segments, with (2,1) armature formula. Fourth segment short, with one smooth seta on inner medial part. Fifth segment with small spinules on inner margin, one plumose subterminal seta and a terminal claw with spinules on inner margin.

Swimming legs 1–4 biramous (fig. 4A–D; Stock 1966), with three-segmented rami and each with intercoxal sclerite. Legs 1–4 as described and illustrated by Stock (1966). Spine and seta formula as follows (Table 1):

Fifth leg (fig. 3A; Stock 1966) with protopod incorporated into somite. Exopod elongate, ornamented with small spinules on margins and armed with three terminal setae, the two longer plumose. Smooth protopodal seta on somite longer than entire exopod.

Sixth leg represented by two short smooth setae in genital area (fig. 3A; Stock 1966).

*Male.* Body cycloform, with cephalothorax oval and cylindrical urosome. Mean body length 406  $\mu\text{m}$  (380–430  $\mu\text{m}$ ), based on three specimens. Urosome five-segmented, comprising leg 5-bearing somite, genital somite, and three free abdominal

Table 1. Spine and seta formula for *Asterocheres halichondriae* Stock, 1966.

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



somites. Genital somite about as long as wide bearing genital apertures posterolaterally on ventral surface (fig. 5A; Stock 1966). Most appendages as for female except for antennules, maxillipeds, and legs 2 and 6.

Antennule 18-segmented (Figure 2G), geniculate with geniculation positioned between segments 16(XIX-XX) and 17(XXI-XXIII). Segmental fusion pattern 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, 11(XIV)-1+1 spine, 12(XV)-2, 13(XVI)-2, 14(XVII)-2, 15(XVIII)-2, 16(XIX-XX)-3, 17(XXI-XXIII)-3+1 aesthetasc and 18(XXIV-XXVIII)-9. Segment 10(XIII) reduced and partly covered by distal expansion of compound segment 9 (IX-XII). All setae smooth.

Maxilliped five-segmented (fig. 5C; Stock 1966), very similar to that of female but with tooth-like process in proximal half of second segment.

Second leg (fig. 5D; Stock 1966) showing sexual dimorphism in third endopodal segment.

Fifth leg (fig. 5A; Stock 1966) as for female but all exopodal setae smooth.

Sixth leg (fig. 5A; Stock 1966) represented by opercula closing off genital apertures; each with two smooth setae and rows of fine spinules.

### Remarks

*Asterocheres halichondriae* was collected by Stock at Flic en Flacq (Mauritius) in 1964 where it lives associated with the sponge *Halichondria symbiotica* Levi. The re-examination of the holotype and allotype has revealed some differences with the original description. (1) The antennule is 20-segmented in the female and not 19-segmented as Stock described it. (2) The antennary exopod carries one medial seta in addition to the two terminal setae described by Stock. The second endopodal segment has a subterminal seta much longer than the seta illustrated by Stock. (3) The second segment of the mandibular palp has two plumose terminal setae. (4) The inner lobe of maxillule has five terminal setae, all of them plumose except for the shorter seta, and the two longer setae have three or four stout spinules distally. (5) The maxilla bears a flaccid element medially, representing tubular extension of external opening of maxillary gland. (6) The third segment of maxilliped has three elements instead of the two elements described by Stock. (7) The antennule is 18-segmented in the male and not 17-segmented as Stock described it.

*Asterocheres halichondriae* belongs to the group of *Asterocheres* species with 20-segmented antennules in females, which comprises 21 species. These species are: *A. aesthetes* Ho, 1984, *A. boeckii* (Brady, 1880), *A. bulbosus* Malt, 1991, *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. maxillatus* Stock, 1987, *A. neptunei* Johnsson, 2001, *A. oricurvus* Kim, 2010, *A. planus* Kim, 2010, *A. sensilis* Kim, 2010, *A. simplex* Schirl, 1973, *A. stimulans* Giesbrecht, 1897, *A. stocki* Nair and Pillai, 1984, *A. tenuipes* Kim, 2010, *A. tricuspis* Kim, 2010, *A. trisetatus* Kim, 2010 and *A. ventricosus* (Brian, 1927).

*Asterocheres halichondriae* differs from eight of these 21 species (*A. planus*, *A. sensilis*, *A. indivisus*, *A. bulbosus*, *A. boeckii*, *A. corneliae*, *A. aesthetes* and *A. stocki*) in the possession of a one-segmented mandibular palp, in contrast to the two-segmented mandibular palp shown by the present species (Brady 1880; Schirl 1973; Ho 1984; Nair and Pillai 1984; Bandera and Conradi 2009b; Kim 2010).

As for the body shape, *A. halichondriae* has an oval cephalothorax and cylindrical urosome, whereas *A. tenuipes* has a very broad, almost rounded prosome, and a very small urosome and *A. galeatus* has a large, helmet-shaped cephalothorax (Kim 2010). Stock (1987) described the cephalosome of *A. maxillatus* as a rounded shield that covers metasomite 3 and urosomite 1, and *A. neptunei* has a dorsoventrally flattened prosome (Johnsson et al. 2001).

Among the remaining 10 species, *A. oricurvus* and *A. stimulans* can be easily separated from *A. halichondriae* by the length of the oral cone. The siphon reaches leg 4 in *A. oricurvus* and *A. stimulans*, whereas in *A. halichondriae* it extends only to the insertion of maxillipeds (Giesbrecht 1899; Kim 2010).

The shape of the caudal rami serves to separate *A. halichondriae* from *A. complexus* and *A. simplex*. The caudal rami in these two last species are longer than wide, in contrast *A. halichondriae* has caudal rami that are wider than long (Stock 1960; Schirl 1973).

From the point of view of the genital double-somite, *A. halichondriae* shows a regularly rounded contour, whereas *A. dentatus*, *A. ventricosus* and *A. tricuspis* have one- or four-denticulated processes at posterolateral corners of broad anterior part (Giesbrecht 1899; Kim 2010). Although the description made by Brian in 1927 for *A. ventricosus* (as *Ascomyzon ventricosum*) is incomplete, the illustration of the urosome shows a tooth-like process on the genital double-somite (Brian 1927).

Finally, the remaining two species, *A. crinoidicola* and *A. trisetatus* can be differentiated from *A. halichondriae* by the maxillule. In *A. halichondriae*, the inner lobe is almost three times longer and wider than the outer and the lobes are provided with five distal setae and two terminal and two subterminal setae, respectively. However, in *A. crinoidicola*, the inner lobe of maxillule is twice as long as wide; and *A. trisetatus* has only three distal setae on the outer lobe of the maxillule (Kim 2010).

***Asterocheres hoi* sp. nov.**

(Figures 3 and 4)

*Material examined*

Holotype female (ZMA-Co.201.521) and one paratype female (ZMA-Co.201.521) associated with *Lytechinus variegatus* (Lamarck, 1816) in Piscadera Bay (Curaçao) at 3 m depth collected 17 November 1958 by J.H. Stock.

*Description*

*Female.* Body cyclopiform with oval cephalothorax and short, cylindrical urosome (Figure 3A). Mean body length 780  $\mu\text{m}$  (750–810  $\mu\text{m}$ ) and maximum width 430  $\mu\text{m}$  (410–450  $\mu\text{m}$ ), based on two specimens. Prosome comprising cephalothorax (fully incorporating first pedigerous somite) and three free pedigerous somites. Cephalothorax and free pedigerous somites with rounded posterolateral angles. Rostrum triangular. Dorsal cephalothoracic shield and free pedigerous somites with integumental pores and sensilla. Urosome four-segmented, comprising leg-5 bearing somite, genital double-somite, and two free abdominal somites (Figure 3B). Genital double-somite slightly wider than long; paired genital apertures bipartite, each comprising lateroventral copulatory pore and dorsolateral gonopore; lateral margins with

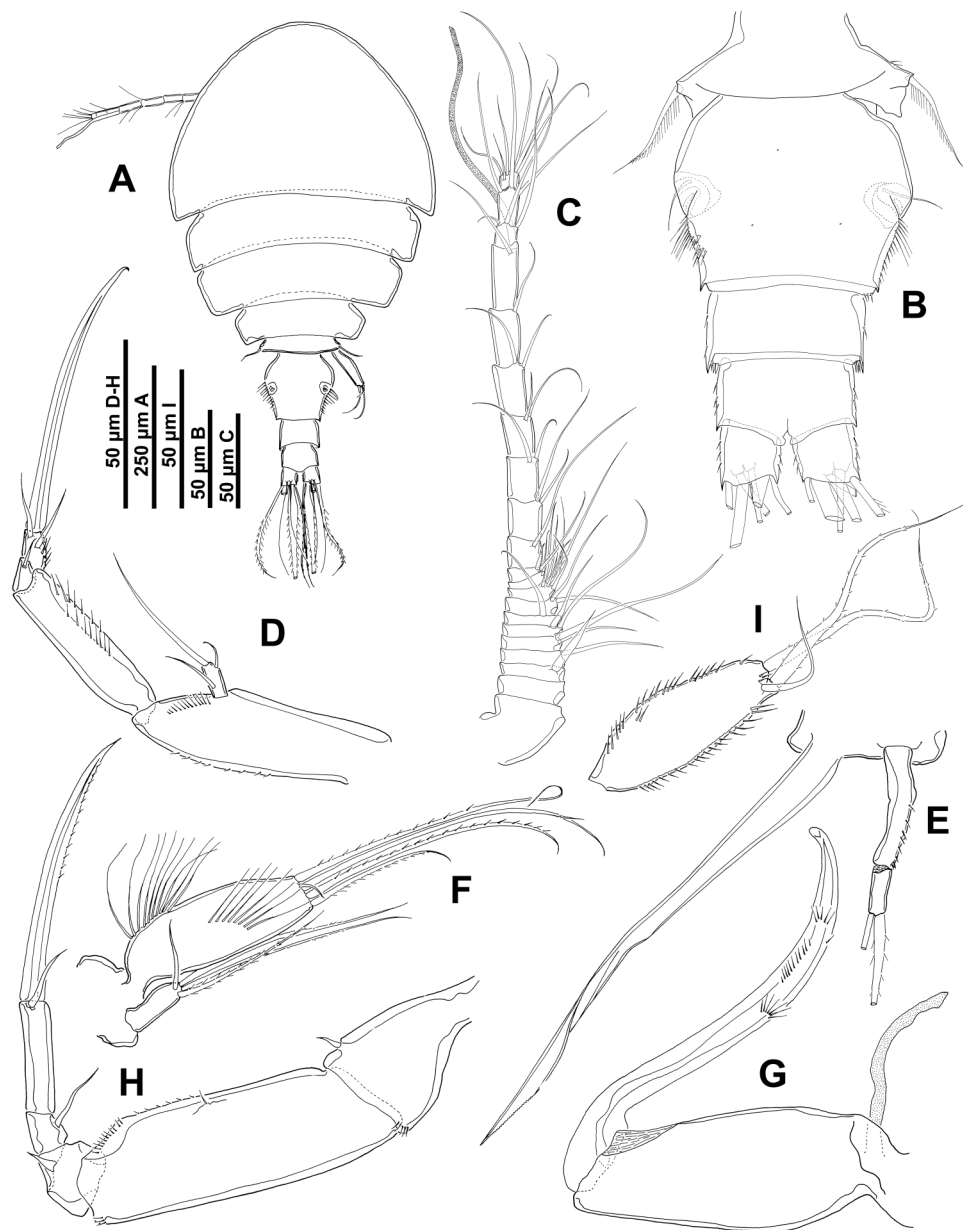


Figure 3. *Asterocheres hoi*, sp. nov. (female). (A) Dorsal view; (B) urosome, dorsal view; (C) antennule; (D) antenna; (E) mandible; (F) maxillule; (G) maxilla; (H) maxilliped; (I) leg 5.

long spinules in middle third, posterior to genital apertures (Figure 3B). Each genital area with smooth seta.

Caudal rami (Figure 3A,B) slightly longer than wide (measured along outer margin), armed with six setae; seta I absent, setae III–VI plumose and setae II and VII slightly displaced onto dorsal surface and smooth.

Antennule 21-segmented (Figure 3C), about 320  $\mu\text{m}$  long. Segmental fusion pattern as follows: 1(I), 2(II), 3(III)-1, 4(IV)-1, 5(V)-2, 6(VI)-2, 7(VII)-1, 8(VIII)-2, 9(IX-XII)-7, 10(XIII)-1, 11(XIV)-1+1 spine, 12(XV)-1, 13(XVI)-2, 14(XVII)-2, 15(XVIII)-2, 16(XIX)-2, 17(XX)-1, 18(XXI)-1+1 aesthetasc, 19(XXII)-2, 20(XXIII-XXIV)-4 and 21(XXV-XXVIII)-6. Segment 10(XIII) reduced and partly overlapped by distal expansion of compound segment 9(IX-XII).

Antenna biramous (Figure 3D), about 300  $\mu\text{m}$  long (excluding coxa and including terminal claw). Coxa lost in dissection. Basis unarmed, with fine spinule rows on margins. Exopod one-segmented, about twice as long as wide; with one lateral seta, one subterminal seta and one long terminal seta, all naked. Endopod three-segmented; proximal segment elongate with spinular rows as figured; middle segment produced distally on medial side but articulating with distal segment proximally on lateral side, bearing one subterminal smooth seta; distal segment with spinules on inner margin and two smooth subterminal setae, and distal claw.

Siphon slender, about 350  $\mu\text{m}$  long, reaching to intercoxal sclerite of leg 1.

Mandible (Figure 3E) comprising stylet-like gnathobase and two-segmented palp. Proximal segment of palp longer, with row of spinules on lateral margin; distal segment with two unequal apical setae. Stylet located in oral cone, formed by anterior labrum and posterior labium, with denticulate margin subapically.

Maxillule bilobed (Figure 3F); inner lobe 3.5 times longer than outer, with row of very long setules on lateral margin and medially, and with five terminal setae, four of them long and plumose and one minute and naked. Outer lobe with four terminal setae, three of them long and pinnate and one shorter and naked.

Maxilla (Figure 3G) two-segmented but with partial transverse surface suture on syncoxa (proximal segment) possibly marking plane of praecoxa-coxa fusion; praecoxal portion bearing flaccid aesthetasc-like element medially, representing tubular extension of external opening of maxillary gland. Coxal portion unarmed. Basis claw-like with fan-like tufts of spinules medially and distally, and rows of spinules on distal half; recurved tip.

Maxilliped five-segmented (Figure 3H), comprising short syncoxa, long basis and three-segmented endopod. Syncoxa with row of spinules and one short seta distally. Basis with rows of spinules on inner margin and distally and one minute seta medially. First endopodal segment compound, partial suture marking original separation of two ancestral segments, with (1,0) armature formula; second endopodal segment bearing one naked seta; third endopodal segment with recurved terminal claw plus additional apical seta. Inner margin of claw provided with row of minute spinules.

Swimming legs 1–4 biramous (Figure 4A–D), with three-segmented rami and each with intercoxal sclerite. Spine and seta formula (Table 2):

Table 2. Spine and seta formula for *Asterocheres hoi* sp. nov.

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

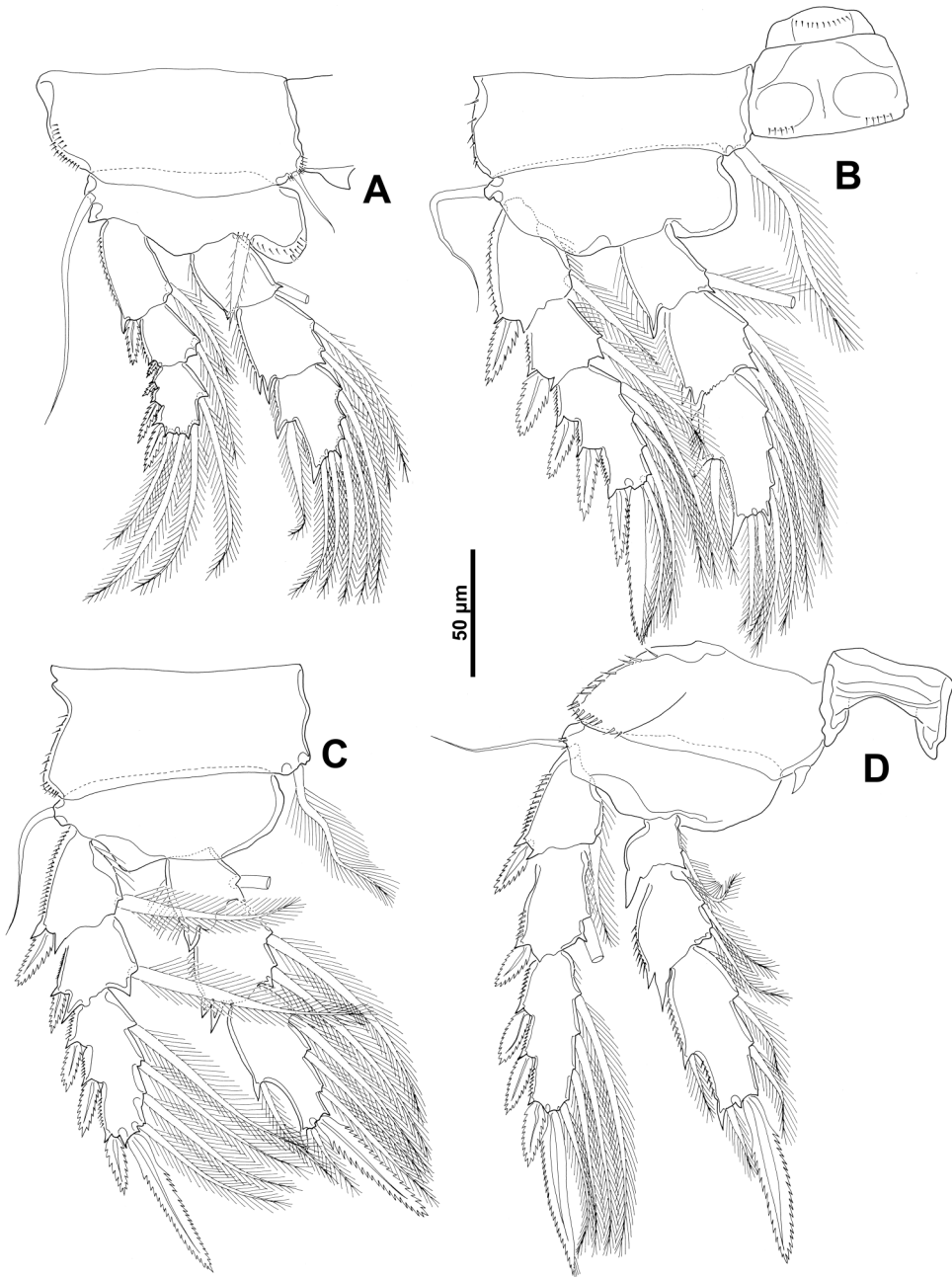


Figure 4. *Asterocheres hoi*, sp. nov. (female). (A) Leg 1; (B) leg 2; (C) leg 3; (D) leg 4.

Coxae ornamented with spinule rows around outer margin; inner coxal seta short and naked in leg 1, long and plumose in legs 2–3, and reduced in leg 4 (Figure 4A–D). Basis of leg 1 with spinules around inner margin; outer seta long and naked in legs 1–4. Outer spines of exopodal segments in legs 1–4 bilaterally serrate. Lateral margins

of exopodal segments with minute serrations or spinular rows; those of endopodal segments with rows of setules.

Fifth leg (Figure 3I) with protopod incorporated into somite. Free segment almost three times longer than wide, elongate-oval, with two long pinnate terminal setae and one shorter smooth subterminal seta; outer and inner margins with spinules.

Sixth leg (Figure 3B) represented by paired opercular plates closing off gonopores on genital double-somite; each armed with one smooth seta.

*Male.* Unknown.

### *Etymology*

The species is named in honour of Prof. Ju-shey Ho.

### *Remarks*

This species was found in a vial labelled as “*Asterocheres cf. simulans* (Th. Scott, 1898)” which turned out to contain a new species. This species was collected by Stock in Curaçao (Piscadera Bay) in 1958 and lives associated with *Lytechinus variegatus* (Lamarck, 1816). The most striking features of this species are: (1) the antennules are 21-segmented; (2) the antenna has a three-segmented endopod and a one-segmented exopod with three setae; (3) the mandible has two-segmented palp with two terminal setae and stylet with denticulate margin subapically; (4) the siphon reaches approximately to the insertion of leg 1; (5) the outer lobe of maxillule has four distal setae and the inner lobe has five distal setae (one minute and naked) and rows of long setules in the lateral margin and medially; (6) the maxilla bears a flaccid element medially, representing tubular extension of external opening of maxillary gland and claw with rows of spinules in the second half; (7) the maxilliped is five-segmented with terminal claw; (8) legs 1–4 biramous, as usual in the genus; (9) the free segment of fifth leg bears three terminal setae; (10) the caudal rami are slightly longer than wide with six terminal setae.

This species belongs to the group of species with a 21-segmented antennule in the female and a two-segmented mandibular palp. This group consists of 18 species named above.

The oral cone of *A. hoi* possesses an elongate siphon reaching to the intercoxal plate of legs 1. In contrast, the siphon of *A. genodon*, *A. astroidicola*, *A. ellisi* and *A. tenerus* reaches to the intercoxal plate of leg 2; in *A. frustrae*, *A. reginae*, *A. simulans*, *A. suberitis*, *A. jeanyeatmanae*, *A. tarifensis*, *A. kervillei* and *A. tubiporae*, the siphon reaches the insertion of maxillipeds; and in *A. lilljeborgi* the siphon extends only to the maxilla (Ivanenko and Ferrari 2003).

The shape of the caudal rami separates *A. hoi* from *A. hirsutus*, *A. tenuicornis*, (according to the illustration in Eiselt 1965) and *A. latus*, as the new species has caudal rami only slightly longer than wide, but in *A. hirsutus* the caudal rami are 2.5 times longer than wide, in *A. latus* 2.6 times longer than wide and in *A. tenuicornis* six times longer than wide.

The ornamentation of the antenna and the maxillule serve to differentiate *A. hoi* from *A. peniculatus*. The new species has the antennal claw longer than the first

endopodal segment and a row of very long setules on the lateral margin of the inner lobe of the maxillule. *Asterocheres peniculatus* has an antennal claw shorter than the first endopodal segment and the basis has a longitudinal row of bifurcate or trifurcate spinules or scales near base of the exopod; the inner lobe of the maxillule has a row of short setules, as usual in the genus (Kim 2010).

Finally, the exopod of leg 5 is 2.5 times longer than wide and the two terminal barbed setae are much longer than the entire segment in *A. hoi*. In contrast, in *A. urabensis* the exopod of leg 5 is 3.8 times longer than wide and the two terminal smooth setae are shorter than the free segment (Kim 2004a).

*Asterocheres maxillatus* Stock, 1987

(Figure 5)

*Material examined*

Holotype female (ZMA-Co.102.745c) and one paratype female (ZMA-Co.102.745a+b) associated with *Manicina areolata* (L.) f. *mayori*. In Curaçao (500 m west off Piscadera Bay) at 4 m depth, collected 7 January 1974 by J.H. Stock.

*Description*

*Female.* Body cyclopiform, consisting of dorsoventrally flattened prosome with rounded cephalothorax, and cylindrical urosome (fig. 1A; Stock 1987). Total length 610  $\mu\text{m}$  and maximum width 420  $\mu\text{m}$ . Prosome comprising cephalothorax (fully incorporating first pedigerous somite) and three free pedigerous somites. Cephalothorax and pedigerous somite 2 and 3 forming a rounded shield covering pedigerous somites 4 and 5 and even half of genital double-somite dorsally (fig. 1A; Stock 1987). Epimeral areas of cephalothorax and somite bearing leg 2 with posterolateral angles pointed backwards. Urosome four-segmented, comprising leg-5 bearing somite, genital double-somite, and two free abdominal somites (fig. 1B; Stock 1987). Genital double-somite wider than long, with paired genital apertures bipartite, each comprising lateroventral copulatory pore and dorsolateral gonopore. Each genital area with one long seta and one stout spine (fig. 1B; Stock 1987). Prosome and urosome with numerous integumental pores and sensilla.

Caudal rami longer than wide, with six terminal setae. Seta I absent; setae II and VII slightly displaced onto dorsal surface; setae III–VI arranged around posterior margin and plumose (fig. 1B; Stock 1987).

Antennule 20-segmented, as described and illustrated by Stock (fig. 1D; Stock 1987).

Antenna biramous (Figure 5A), about 220  $\mu\text{m}$  long (including terminal claw). Coxa short and basis elongate, both unarmed. Exopod one-segmented, 1.5 times longer than wide, with one proximal short seta and two terminal setae, unequal in length. Endopod three-segmented; first segment elongate, with spinules rows as figured; second segment produced distally on medial side but articulating with distal segment proximally on lateral side, with short barbed seta; and third segment with row of long setules on inner margin, two plumose subterminal setae, and terminal claw with spinule row on inner margin.

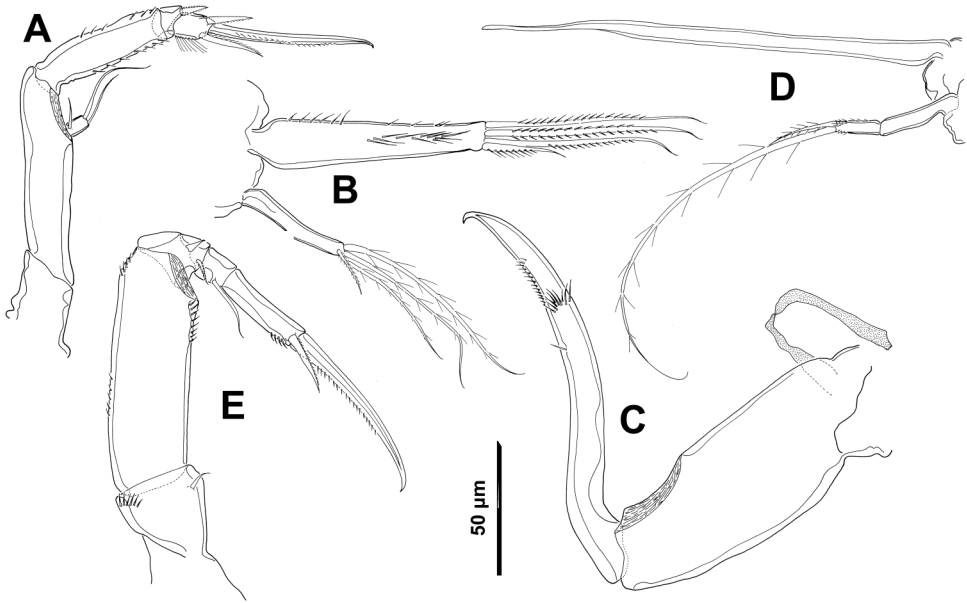


Figure 5. *Asterocheres maxillatus* Stock, 1987, holotype (female). (A) Antenna; (B) maxillule; (C) maxilla; (D) mandible; (E) maxilliped.

Siphon conical about 190  $\mu\text{m}$  long, reaching to maxilliped insertion.

Mandible (Figure 5D) comprising stylet-like gnathobase and two-segmented palp. Stylet located in oral cone, with denticulate margin subapically. First segment of palp elongate, unarmed; second segment short, with spinules in lateral margins and apically, and two plumose setae, one short.

Maxillule bilobed (Figure 5B). Both lobes very long and narrow, but inner lobe twice as long as outer. Inner lobe with spinules row in lateral margin and medially and four plumose terminal setae, unequal in length but all shorter than entire segment. Outer lobe with short barbed subterminal seta and three long plumose terminal setae.

Maxilla two-segmented (Figure 5C) but with partial transverse surface suture on syncoxa (proximal segment) possibly marking plane of praecoxa-coxa fusion; praecoxal portion bearing flaccid aesthetasc-like element medially, representing tubular extension of external opening of maxillary gland. Coxa robust and unarmed and basis claw-like with fan-like tuft of spinules and spinule rows in distal half.

Maxilliped five-segmented (Figure 5E), comprising short syncoxa, long basis and three-segmented endopod. Syncoxa with short distal seta on inner margin and spinule row on outer distal margin. Basis elongate, with spinules on margins. First endopodal segment compound, partial suture marking original separation of two ancestral segments, with (1,1) armature formula. Second endopodal segment short, with one smooth very long seta medially. Third endopodal segment with minute spinules on inner distal margin, one plumose subterminal seta, and terminal claw with spinule row on inner margin.

Swimming legs 1–4 biramous (fig. 2C–F; Stock 1987), with three-segmented rami and each with intercoxal sclerite. Spine and seta formula as follows (Table 3):



Table 3. Spine and seta formula for *Asterocheres maxillatus* Stock, 1987.

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

Fifth leg with protopod incorporated into somite (fig. 1B; Stock 1987). Free segment (exopod) three times longer than wide, with two smooth terminal setae and one subterminal seta. Somite with outer smooth basal seta displaced to laterodorsal surface and longer than entire exopod.

Sixth leg (fig. 1B; Stock 1987) represented by one long smooth seta and one spine on each genital area.

*Male.* Unknown.

#### Remarks

This species lives associated with *Manicina areolata* (L.) f. *majori*. Stock collected it in Curaçao in 1974. Comparison with Stock's text and illustration revealed a number of discrepancies: (1) the antennary exopod has two distal setae and one proximal seta, which was overlooked by Stock; (2) the second segment of the mandibular palp carries rows of spinules; (3) the inner lobe of the maxillule has long spinules medially; (4) the maxilla bears a flaccid element medially, representing tubular extension of external opening of maxillary gland; (5) the setae present on the third and fifth maxilliped segments are plumose.

This species belongs to the group of species with 20-segmented antennules in the female. This group is composed of 21 species, however *A. maxillatus* can be separated from all of them by the shape of the body. In this species the cephalosome and metasomites 1 and 2 form a rounded shield, dorsally covering metasomite 3, urosomite 1 and the anterior half of urosomite 2 (genital double-somite) (Stock 1987). No other species in this group shows this feature.

#### *Asterocheres proboscideus* Stock, 1966 (Figure 6)

#### *Material examined*

Holotype female (ZMA-Co.100.957a) and six paratype females (ZMA-Co.100.957a and ZMA-Co.100.957b) associated with the calcareous sponge *Pericharax heteroraphis* Polejaeffin Mauritius (20°22'S, 57°21' E) at 10–19 m depth collected 10 February 1964 by J.H. Stock.

#### *Description*

*Female.* Body cycloform, with cephalothorax nearly circular in outline and occupying distinctly less than half of entire body length and cylindrical urosome (fig. 9A;

Stock 1966). Mean body length 720  $\mu\text{m}$  (650–810  $\mu\text{m}$ ) and maximum width 370  $\mu\text{m}$  (330–400  $\mu\text{m}$ ), based on six specimens. Prosome comprising cephalothorax (fully incorporating first pedigerous somite) and three free pedigerous somites. Cephalothorax and free pedigerous somites with rounded posterolateral angles (fig. 9A; Stock 1966). Urosome four-segmented, comprising leg 5-bearing somite, genital double-somite and two free abdominal somites (fig. 9B; Stock 1966). Genital double-somite about as long as wide; paired genital apertures bipartite, each comprising lateroventral copulatory pore and dorsolateral gonopore; lateral margins with rows of long spinules on distal half and posterior part of somite (fig. 9B; Stock 1966). Each genital area with two smooth setae.

Caudal rami slightly wider than long; with rows of spinules on terminal part; and six setae. Seta I absent. Setae II and VII smooth and displaced onto dorsal surface. Setae III–VI plumose, arranged around posterior margin of segment, middle setae very stout.

Antennule 20-segmented (Figure 6B), about 360  $\mu\text{m}$  long. Segmental fusion pattern as follows: 1(I)-2, 2(II)-2, 3(III)-2, 4(IV)-2, 5(V)-1, 6(VI)-2, 7(VII)-1, 8(VIII)-2, 9(IX–XII)-7, 10(XIII)-1, 11(XIV)-1+1 spine, 12(XV)-2, 13(XVI)-2, 14(XVII)-2, 15(XVIII)-2, 16(XIX)-2, 17(XX)-1, 18(XXI)-2+1 aesthetasc, 19(XXII–XXIII)-3 and 20(XXIV–XXVIII)-9. Segment 10(XIII) reduced and partly overlapped by distal expansion of compound segment 9(IX–XII). All setae smooth.

Antenna biramous (Figure 6E), about 270  $\mu\text{m}$  long (including terminal claw). Coxa small, unarmed. Basis elongate with spinules on inner distal margin. Exopod

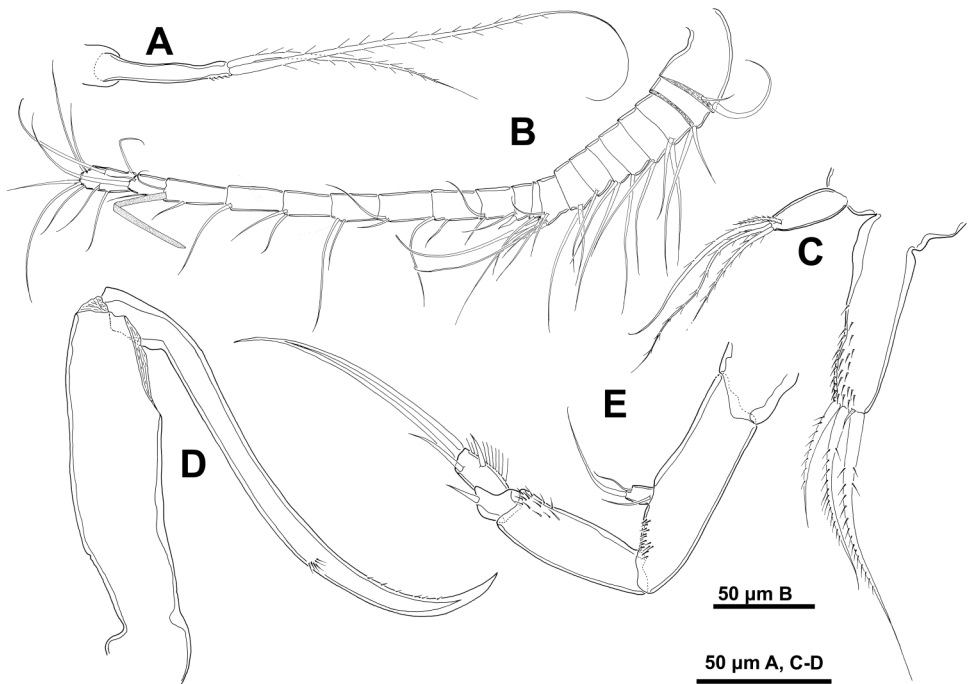


Figure 6. *Asterocheres proboscideus* Stock, 1966, holotype (female). (A) Mandibular palp; (B) antennule; (C) maxillule; (D) maxilla; (E) antenna.

one-segmented, 1.5 times longer than wide, with one proximal seta medially, one subterminal seta laterally, and one distal seta twice as long as other two; all setae smooth. Endopod three-segmented; proximal segment elongate, with spinules on inner part; middle segment produced distally on medial side but articulating with distal segment proximally on lateral side, with one smooth subterminal seta, shorter than entire segment; distal segment with row of long setules on inner margin, one smooth lateral seta, one smooth subterminal seta, and terminal claw slightly longer than entire endopod.

Siphon very long, about 600  $\mu\text{m}$  long, with tubiform distal part usually curled; reaching beyond caudal rami.

Mandible (Figure 6A) comprising stylet-like gnathobase and one-segmented palp. Palp elongate, with spinules on laterodistal margin and two plumose terminal setae unequal in length.

Maxillule bilobed (Figure 6C). Inner lobe 2.5 times longer than outer; with tuft of short spinules on distal half and four distal setae, one of them smooth and short. Outer lobe with one subterminal barbed seta and three plumose terminal setae.

Maxilla (Figure 6D) two-segmented. Coxa unarmed and basis claw-like with row of small spinules on outer margin and fan-like tuft of setules medially as figured.

Maxilliped five-segmented (fig. 10E; Stock 1966) as described and illustrated by Stock (1966).

Swimming legs 1–4 biramous, with three-segmented rami and intercoxal sclerite present in all of them. Swimming legs 1–4, fifth and sixth legs as described and illustrated by Stock (figs 9B, 10F, 11A–C; Stock 1966).

Colour ruddy-yellowish.

*Male.* Unknown.

### *Discussion*

This species, which lives associated with the sponge *Pericharax heteroraphis* Polejaeff in Mauritius, was collected by Stock in 1964. The discrepancies found in the re-examination of this species are as follows: (1) the antennule has 20 segments in contrast with the 19 segments described by Stock; (2) Stock described the antennary exopod having two terminal setae but this segment has one terminal, one subterminal and one proximal seta; (3) the only segment of the mandibular palp carries two plumose distal setae; (4) the inner lobe of the maxillule (second half) is covered with short and stout spinules; (5) the second segment of the maxilla, the claw, has a fan of spinules at middle length and a row of spinules on the distal margin.

This species belongs to the group of species with a 20-segmented antennule in the female. This group comprises 22 species, however *A. proboscideus* can be separated from all of the remaining species by the length of the oral cone. This is the only species in the group with a siphon that extends beyond the caudal rami (Stock 1966).

### *Asterocheres scutatus* Stock, 1966 (Figure 7)

### *Material examined*

Holotype female (ZMA Co. 100.974a) and one paratype female (ZMA Co. 100.9746) from near Hotel Coral Beach, Eilat (Israel); associated with the anemone

*Rhodactis rhodostoma* (Ehrenberg, 1834) and collected at 1 m depth by J.H. Stock, April 1962.

### Description

*Female.* Body cyclopiform, almost circular in outline and slightly dorsoventrally flattened (fig. 1A; Stock 1966). Total length of holotype 540  $\mu\text{m}$  and maximum width 430  $\mu\text{m}$ . Prosome comprising cephalothorax (fully incorporating first pedigerous somite) and three free pedigerous somites. Cephalothorax with posterolateral angles slightly pointed, somite bearing leg 2 with posterolateral angles very pointed, somite bearing leg 3 with posterolateral angles rounded and somite bearing leg 4 partly covered by previous somite. Urosome four-segmented, comprising leg 5-bearing somite, genital double-somite, and two free abdominal somites, which are wider than long. Leg 5-bearing somite wider than long, not visible in lateral view as completely concealed by last abdominal somite. Genital double-somite laterally expanded, 1.5 times wider than long, paired genital apertures bipartite, each comprising lateroventral copulatory pore and dorsolateral gonopore; lateral margins with rows of long spinules in distal half. Each genital area with one smooth seta (fig. 1B; Stock 1966).

Caudal rami slightly wider than long, with six terminal setae, two longest plumose (fig. 1B; Stock 1966).

Antennule 19-segmented, about 260  $\mu\text{m}$  long. All setae plumose. Described and illustrated by Stock (fig. 1C; Stock 1966).

Antenna biramous (Figure 7D), about 200  $\mu\text{m}$  long; coxa small with tuft of spinules; basis elongate. Exopod one-segmented, small, twice as long as wide; with one lateral and two terminal setae, all of them smooth. Endopod three-segmented; first segment elongate with row of long spinules; second segment produced distally on medial side but articulating with distal segment proximally on lateral side, triangular, with

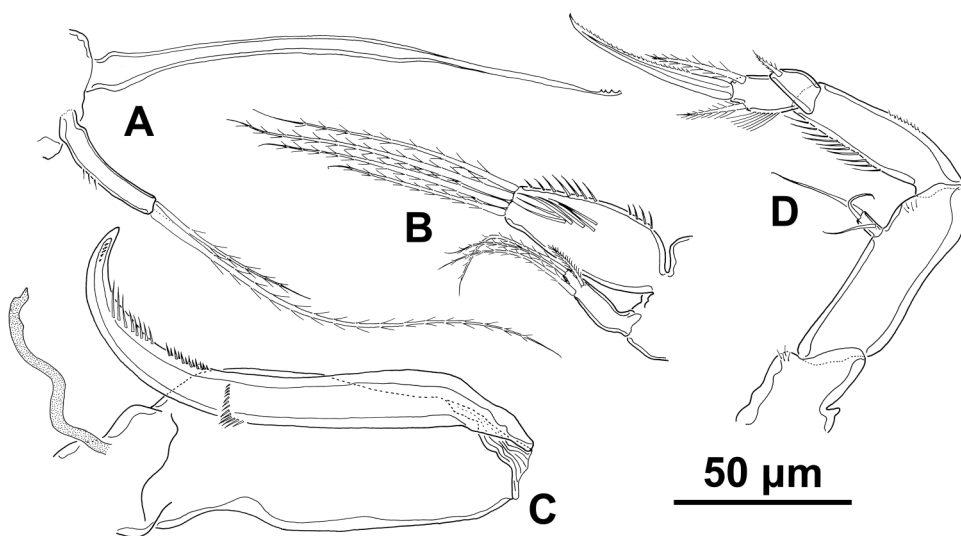


Figure 7. *Asterocheres scutatus* Stock, 1966, holotype (female). (A) Mandible; (B) maxillule; (C) maxilla; (D) antenna.

one plumose seta; third segment with row of setules on inner margin and two plumose subterminal setae plus terminal claw.

Siphon short, about 160  $\mu\text{m}$  long, conical, reaching to maxilliped insertion.

Mandible (Figure 7A) consisting of stylet-like gnathobase with four distal teeth and small one-segmented palp. Palp with few spinules on lateral margin and two plumose terminal setae, unequal in length.

Maxillule bilobed (Figure 7B); inner lobe oval and twice as long as outer one, with tuft of long spinules medially, row of shorter spinules laterally, and four plumose distal setae. Outer lobe with two terminal and two subterminal setae, one of them shorter and barbed.

Maxilla (Figure 7C) two-segmented but with partial transverse surface suture on syncoxa (proximal segment) possibly marking plane of praecoxa-coxa fusion; praecoxal portion bearing flaccid aesthetasc-like element medially, representing tubular extension of external opening of maxillary gland. Coxal portion unarmed. Basis claw-like with rows of spinules on distal half.

Maxilliped (fig. 1I; Stock 1966) five-segmented with armature formula (1,0,2,1,1+claw) as described and illustrated by Stock in 1966.

Swimming legs 1–4 biramous (fig. 2A–E; Stock 1966) with three-segmented rami and intercoxal sclerite present in all of them. Swimming legs as described by Stock (1966).

Fifth and sixth legs as described by Stock (fig. 1B; Stock 1966).

Colour light yellowish.

*Male.* Unknown.

### Remarks

This species was described by Stock from two females collected in Eilat (Israel) in 1962. *Asterocheres scutatus* lives associated with the sea anemone *Rhodactis rhodostoma* (Ehrenberg, 1834). Some oral appendages of this species are slightly different from those described by Stock: (1) the endopod of the antenna has three well-defined segments and the terminal seta of the exopod is approximately twice as long as the seta illustrated by Stock; (2) the stylet of the mandible is illustrated for the first time; (3) the setae of the inner and the outer lobes of the maxillule are plumose and the inner lobe has a patch of long spinules; (4) the maxilla bears a flaccid element medially, representing tubular extension of external opening of maxillary gland.

This species belongs to the group of species with 18- or 19-segmented antennules in females that comprises 13 species. These species are: *A. bahamensis* Kim, 2010, *A. brevisurculus* Kim, 2005, *A. canui* Giesbrecht, 1897, *A. dysideae* Humes, 1996, *A. enewetakensis* Humes, 1997, *A. fastigatus* Kim, 2010, *A. hongkongensis* Malt, 1991, *A. pilosus* Kim, 2004, *A. plumosus* Kim, 2010, *A. rotundus* Malt, 1991, *A. serrulatus* (Humes, 1996), *A. unioviger* Kim, 2010 and *A. walteri* Kim, 2004.

*Asterocheres scutatus* differs from 11 of these 13 species (*A. bahamensis*, *A. canui*, *A. dysideae*, *A. enewetakensis*, *A. fastigatus*, *A. pilosus*, *A. plumosus*, *A. rotundus*, *A. serrulatus*, *A. unioviger* and *A. walteri*) in the possession of a two-segmented mandibular palp, in contrast to the one-segmented mandibular palp shown by the present species (Giesbrecht 1899; Humes 1996b, 1997; Kim 2004a, 2010; Bandera and Conradi 2009b).

*Asterocheres hongkongensis* differs from *A. scutatus* in the extremely short caudal setae (described and illustrated by Malt 1991 as about as long as the caudal rami). In contrast, *A. scutatus* has long caudal setae, as usual for the genus.

As for the shape of the urosome, *A. scutatus* has a genital double-somite that is much wider than long, whereas *A. brevisurculus* has a genital double somite that is longer than wide (Kim 2005).

### Acknowledgements

The authors are very grateful to Dirk Platvoet, curator at the Zoological Museum of Amsterdam, for the loan of the type material. We wish to thank Dr G.A. Boxshall (The Natural History Museum, London, UK) for the English revision of the manuscript.

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