Zootaxa 2925: 1–18 (2011)
www.mapress.com/zootaxa/

Article

ISSN 1175-5326 (print edition)
ZOOTAXA
ISSN 1175-5334 (online edition)

Asterocherids (Copepoda: Siphonostomatoida) associated with marine invertebrates in the Strait of Gibraltar

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Abstract

Six years ago, an ongoing sampling programme to seek symbiont copepods was initiated in the Strait of Gibraltar. Most of the copepod species reported in this area (48%) belonged to the families Notodelphyidae and Botryllophilidae and nearly 30% of them were new to science. This paper describes a new species of *Asterocheres* (Asterocheridae, Siphonostomatoida) and redescribes two poorly known species of this genus. *Asterocheres tarifensis* n. sp. was found living in association with *Astroides calycularis*, a coral that hosts a variety of symbiotic copepods. This new species differs from its congeners by the possession of the following combined characters: body cyclopiform, 21-segmented antennule in female, 2-segmented mandibular palp, siphon reaching the insertion of maxilliped, maxilla without aesthetasc, maxilliped 5-segmented, armature of the antennary exopod consisting of two setae, inner lobe and outer lobe of maxillule each armed with four setae, genital area armed with two setae, fifth leg exopod with three setae, and caudal rami about as long as wide. Furthermore, two poorly known *Asterocheres* species are redescribed revealing some discrepancies with their previous descriptions. *Asterocheres minutus* is characterized by having a 21-segmented antennule, a very short oral siphon, a 1-segmented mandibular palp, and the two lobes of the maxillule with a similar length. The cladistic model of budding hypothesis is proposed for the origin of the two sibling *Asterocheres* species: *A. minutus* and *A. echinicola*. *Asterocheres siphonatus* is distinguished by a combination of characters that include a 21-segmented antennule, an oral siphon extending to the intercoxal plate of leg 4 and the 1-segmented mandibular palp. The controversy concerning the name of this species is also studied.

Key words: symbiosis, Copepoda, Siphonostomatoida, *Asterocheres*, Strait of Gibraltar

Introduction

The Strait of Gibraltar, limited by the meridians of 7ºW and 4ºE, lying between southernmost Spain and northwesternmost Africa, is the only natural channel connecting the Mediterranean Sea with the Atlantic Ocean. This strait, of approximately 300 metres in depth, is 58 km long and narrows to 13 km between Point Marroquí (Spain) and Point Cires (Morocco). The study of the Strait of Gibraltar is of great zoogeographical interest since the faunas of the Mediterranean and the Atlantic, along one axis, and of Europe and Africa along the other overlap (Medel & López-González 1996).

As a result of this great zoogeographical interest, different groups of marine invertebrates from this area were intensively sampled over a period of six years in order to collect symbiotic copepods. Collections were made from intertidal areas to a depth of 30 metres by snorkelling and SCUBA diving. Hitherto, a total of 45 copepod species have been listed from this region, 13 of which were new to science (Bandera & Conradi 2009; Bandera & Huys 2008; Conradi & López-González 1994; 1996; Conradi, *et al*. 1992; 1993; 1994; 2004; 2006; Ho *et al*. 1998; López-González & Conradi 1995; 1996; López-González *et al*. 1992a; 1992b; 1993; 1997; 1998; 1999a; 1999b). Furthermore, three new genera were described, and a new family, Fratiidae Ho, Conradi and López-González 1998, was erected for the new genus *Fratia* Ho, Conradi and López-González 1998 (Bandera & Huys 2008; Ho *et al.* 1998; López-González *et al*. 1998). Since the majority of the marine invertebrates studied to date in search for symbiont copepods were solitary and compound ascidians, most of the copepod species reported in this area (48%)

Accepted by S. Dippenaar: 7 Jun. 2011; published: 21 Jun. 2011

belonged to the families Notodelphyidae Dana, 1853 and Botryllophilidae Sars, 1921 (order Cyclopoida), both families being typical parasites of this group of invertebrates. Nevertheless, some specimens of the family Asterocheridae Giesbrecht, 1899 (order Siphonostomatoida) from this area have been very helpful to: (1) relocate the species *Asterocheres mucronipes* to a new asterocherid genus (Bandera & Huys 2008), (2) reveal the conspecifity of *Asterocheres echinicola* (Norman, 1868) and *A. violaceus* (Claus, 1889), (3) re-establish the valid species *A. kervillei* Canu, 1898 (Bandera & Conradi 2009), (4) describe a new species *Asterocheres astroidicola* Conradi *et al*., 2006 and (5) enlarge the distribution of *Acontiophorus scuttatus* (Brady & Robertson, 1873) (Conradi *et al*. 2006). The present paper reports three further *Asterocheres* species found in the Strait of Gibraltar: one of these, associated with a scleractinian coral, turned out to be a new species while the other two species, one associated with an ascidian and the other with a sea urchin, serve to redescribe two *Asterocheres* species poorly or incompletely described: *A. minutus* (Claus, 1889) and *A. siphonatus* Giesbrecht, 1897. Furthermore, this study contributes to the ongoing taxonomical revision of the genus *Asterocheres* (family Asterocheridae) in order to clarify the rather confused state of its systematics.

Material and methods

The hosts were individually collected, each one being isolated in a plastic bag, by SCUBA diving at Algeciras Bay and Tarifa Island (Southern Iberian Peninsula). Later, the samples were fixed by adding Formalin progressively to make a concentration of approximately 4% in sea water. The fixative sea water was passed through a 100 m net. The copepods were finally recovered from the sediment retained and preserved in 70% ethanol.

Selected specimens were dissected in lactic acid and examined as temporary mounts in lactophenol. All figures were drawn with the aid of a camera lucida on a Leica DMLB differential interference microscope and photographed in a Phillips XL 30 SEM. All appendage segments and setation elements were named and numbered using the terminology introduced by Huys and Boxshall (1991). Mean body length of the copepod was measured from the anterior margin of the rostrum to the posterior margin of the caudal rami.

Furthermore, we have examined material collected by Sars in Norway in 1915 and deposited in The Natural History Museum of the University of Oslo (ZMO). Material studied in the present paper is deposited in the Museo Nacional de Ciencias Naturales, Madrid (MNCN) and in the collection of Biodiversidad y Ecología de Invertebrados Marinos research group of the University of Seville (BEIM).

Results

Order Siphonostomatida Thorell, 1859

Family Asterocheridae Giesbrecht, 1899

Asterocheres Boeck, 1859

Asterocheres tarifensis, n. sp.

(Figs. 1–4)

Material examined. (a) holotype female (MNCN 20.04/8570) and one paratype female (MNCN 20.04/8571) associated with the scleractinian coral *Astroides calycularis* (Pallas) from Tarifa Island (southern Spain, 36º 01N, 5º 36W) at 12 m depth collected in 1999; (b) 2 females and 2 males with the same sampling data as the holotype deposited in BEIM (COP–513).

Description. Adult female: Body (Fig. 1A) cyclopiform, slender with an oval cephalothorax and a cylindrical urosome. Mean body length 558 µm (510–625 µm) and greatest width 266 µm (240–310 µm), based on 3 specimens. Ratio of length to width of prosome 1.36:1. Ratio of length of prosome to that of urosome 2.18:1. Prosome comprising cephalothorax, fully incorporating first pedigerous somite, and 3 free pedigerous somites. Somite bearing leg 4 with posterolateral angles rounded (Fig. 1A).

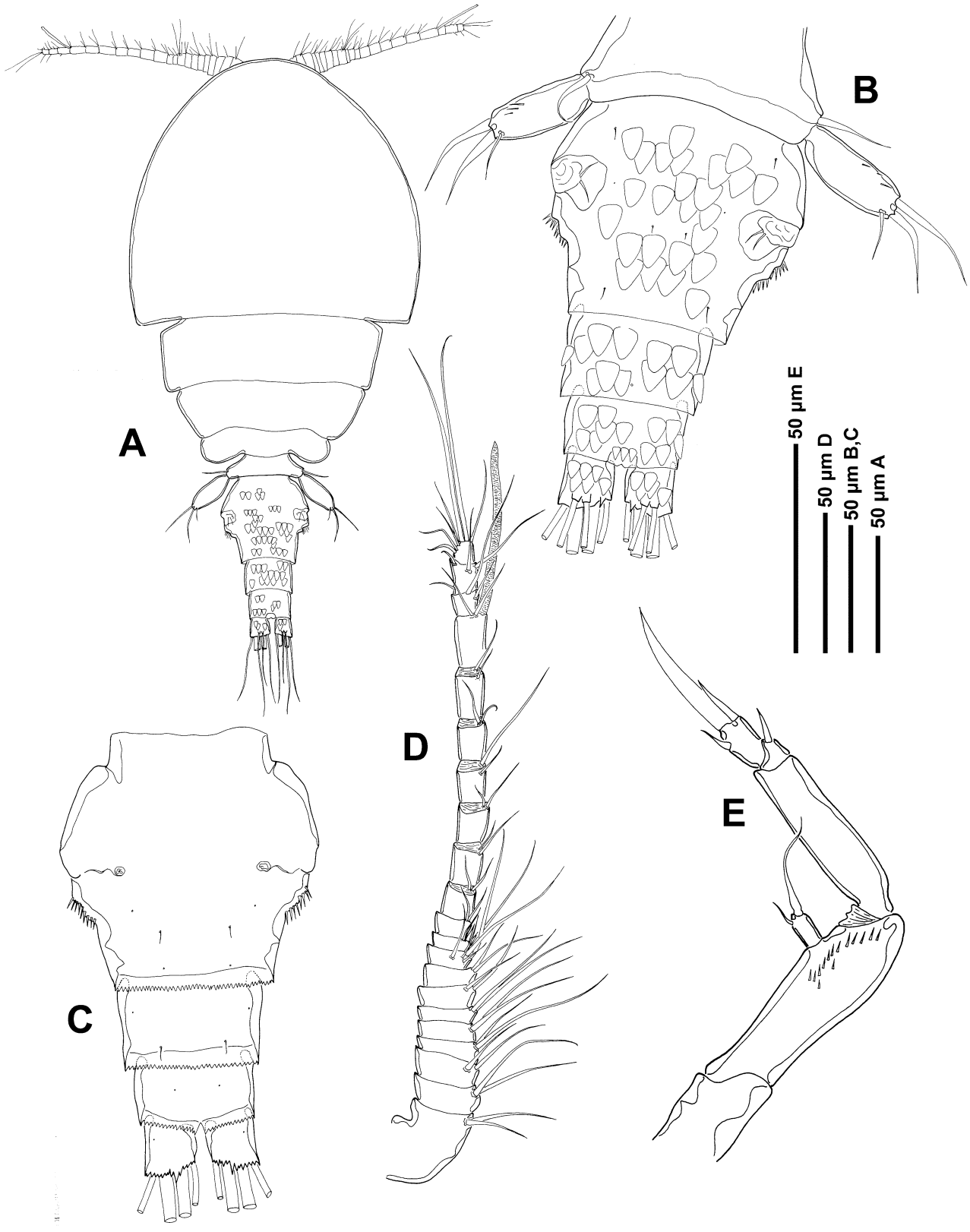

FIGURE 1. *Asterocheres tarifensis* **n. sp.**, female. A, dorsal view. B, urosome, dorsal view. C, urosome, ventral view. D, antenna. E, antennule.

Urosome 4-segmented, comprising leg 5-bearing somite, genital double-somite and 2 free abdominal somites. Genital double-somite and following somites provided with large epicuticular scales arranged in overlapping pat-

tern all around (Figs. 1B, 4A). Posteroventral margins of urosomites ornamented with hyaline frills with more or less serrated margins (Fig. 1C). Genital double-somite (95x98 µm) slightly wider than long; paired genital apertures bipartite, comprising lateroventral copulatory pore and dorsolateral gonopore (oviduct opening); lateral margins with a spinule row (about 9–10 spinules) in distal third (posterior to genital apertures) (Figs. 1B–C, 4A). Genital area armed with two setae (Figs. 1B, 4B). Integumental pores and sensilla present on urosomites.

Caudal rami (Fig. 1B–C) about 25x20 µm (length measured along outer margin); covered by overlapping epicuticular scales; armed with 6 setae, seta I absent, setae II and VII slightly offset onto dorsal surface.

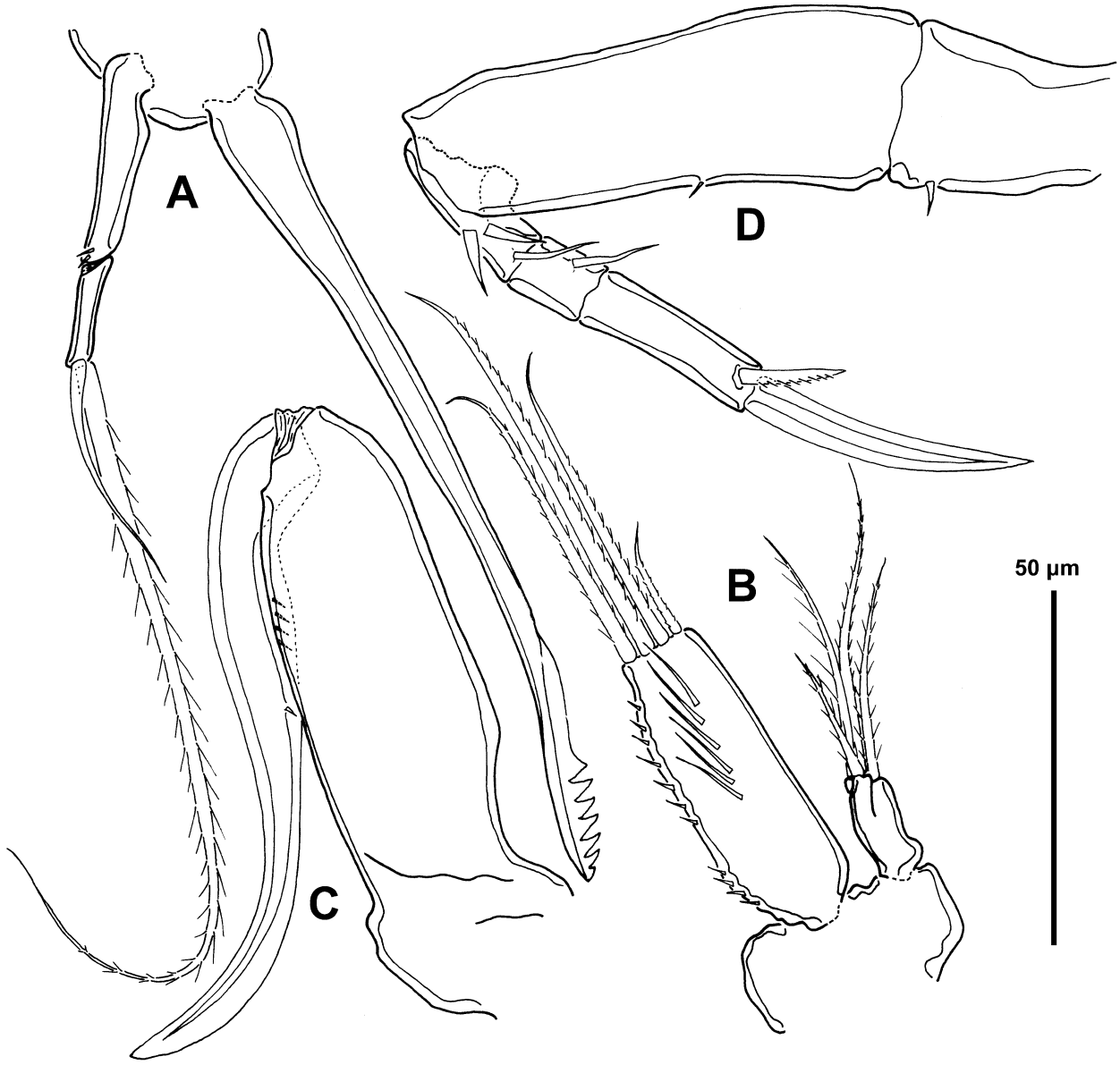

FIGURE 2. *Asterocheres tarifensis* **n. sp.**, female. A, mandible. B, maxillule C, maxilla. D, maxilliped.

Antennule (Fig. 1D) 21-segmented, about 230 µm long. Segmental homologies (expressed segment given first followed by ancestral segments in brackets) and setation 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+spine, 11 (XIV)-2, 12 (XV)-2, 13 (XVI)-2, 14 (XVII)-2, 15 (XIII)-2, 16 (XIX)-2, 17 (XX)-2, 18 (XXI)-2+ae, 19 (XXII)-2, 20 (XXIII-XXIV)-4, 21(XXV-XXVIII)-7. All setae smooth.

Antenna (Fig. 1E) biramous, 170µm long, including terminal claw. Coxa and basis unarmed; basis ornamented with fine spinule rows. Exopod 1-segmented, with one small subterminal seta and one long terminal seta. Endopod 3-segmented; proximal segment elongated; middle segment protruded distally on medial side but articulating with

distal segment proximally on lateral side, bearing one distal seta; distal segment with distal claw (35 µm long), one subterminal and one terminal seta, all setae smooth.

Siphon, about 120 µm long, reaching to insertion of maxillipeds.

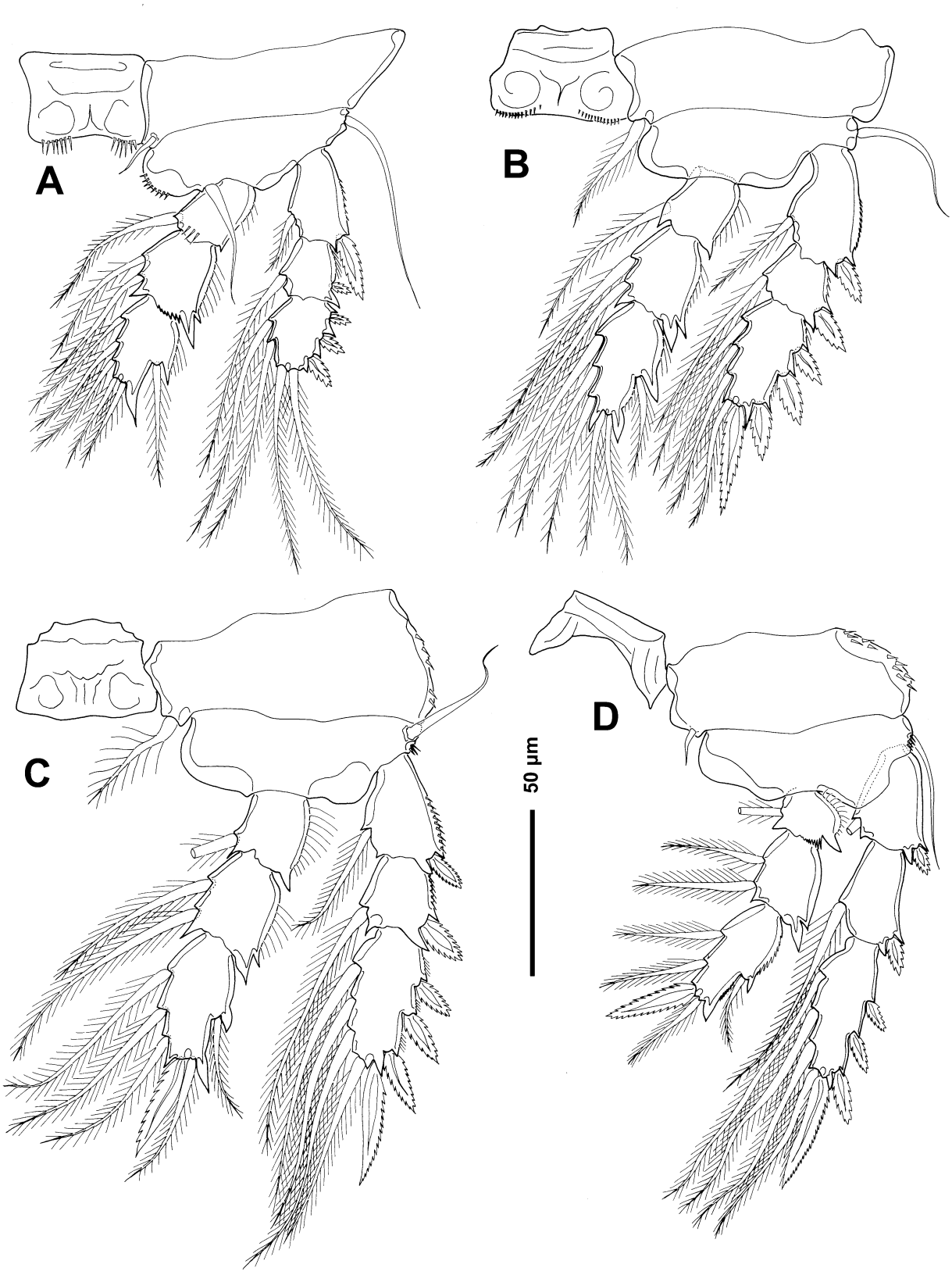

FIGURE 3. *Asterocheres tarifensis* **n. sp.**, female. A, leg 1. B, leg 2. C, leg 3. D, leg 4.

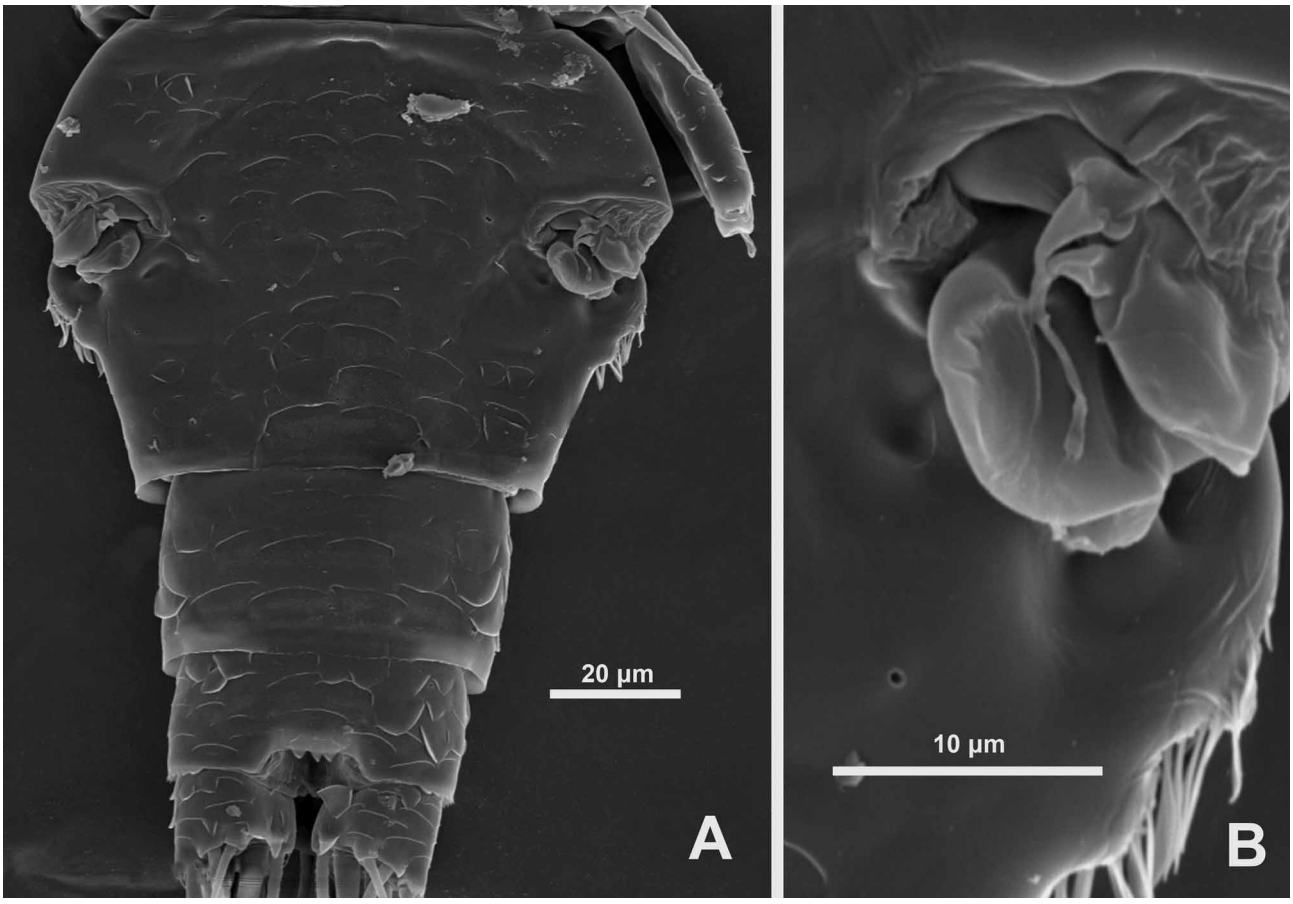

FIGURE 4. *Asterocheres tarifensis* **n. sp.**, female. A, urosome, ventral view. B, genital area.

Mandible (Fig. 2A) comprising stylet-like gnathobase and slender 2-segmented palp. Stylet located in oral cone formed by anterior labrum and posterior labium, with 5 large teeth subapically. First segment of palp ornamented with distal spinules; second segment armed with 2 apical setae, the shorter smooth and the longer pinnate.

Maxillule (Fig. 2B) bilobed; praecoxal endite (inner lobe, 45x15 µm) larger than palp (outer lobe, 16x7 µm). Praecoxal endite armed with 4 barbed distal setae, ornamented with spinules on lateral margin and a row of long setules medially. Palp armed with 4 barbed, distal setae.

Maxilla (Fig. 2C) 2-segmented; with unarmed coxa. Claw-like basis recurved in its end; armed with a few setules on the proximal inner lateral margin.

Maxilliped (Fig. 2D) 5-segmented, comprising short syncoxa, long basis and distal subchela consisting of 3 free endopodal segments armed with distal claw-like element. Syncoxa with one short seta distally. Basis with a spinule on medial inner margin. First endopodal segment bearing two short medial setae and one distal seta; second endopodal segment with one medial seta and third endopodal segment bearing curved terminal claw (45 µm long) plus additional apical barbed seta.

Swimming legs 1–4 (Figs. 3A–D) biramous, with 3-segmented rami. Intercoxal sclerite present in legs 1–4, ornamented with patches of spinules in legs 1 and 2. Spine and seta formula as follows:

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

Coxae ornamented with spinule rows laterally in legs 3 and 4. Outer spines of exopodal segments in legs 1–4 bilaterally serrated. Lateral margins of exopodal segments in legs 1–3 with minute serrations; lateral margins of

endopodal segments with rows of setules (Fig. 3A–D). Second and third endopodal segments in legs 1–4 with a small beak-shaped spiniform process distally.

Fifth leg (Fig. 1B) with protopod incorporated into somite and one outer seta displaced to dorsal surface. Free segment slender (50x20 µm), armed with one subterminal and two terminal smooth setae and ornamented with few spinules.

Sixth leg represented by paired opercular plates closing off gonopores on genital double somite; each armed with two smooth setae (Figs. 1B; 4B).

Adult male: Unknown.

Etymology. The specific name *tarifensis* refers to Tarifa Island where the species was collected.

Remarks. With regards to the antennule, the species of the genus *Asterocheres* fall into two groups: females having a 18 to 20-segmented antennule and females with a 21-segmented antennule. The latter group contains a total of 20 species (Bandera & Conradi 2009) and can be subdivided into two subgroups: (1) species with a 1-segmented mandibular palp and (2) species with a 2-segmented mandibular palp. The new species described above belongs to the second subgroup. Together with *Asterocheres tarifensis* **n.sp.**, 16 asterocherid species have a 21-segmented antennule in females and a 2-segmented mandibular palp: *A. astroidicola* Conradi *et al.*, 2006; *A. ellisi* Hamond, 1968; A. *flustrae* Ivanenko & Smurov, 1997; *A. hirsutus* Bandera *et al.*, 2005; *A. jeanyeatmanae* Yeatman, 1970; *A. kervillei* Canu, 1898; *A. latus* (Brady, 1872); *A. lilljeborgi* Boeck, 1859; *A. lunatus* Johnsson, 1998; *A. reginae* Boxshall & Huys, 1994; *A. simulans* (Scott T, 1898); *A. suberitis* Giesbrecht, 1899; *A. tenerus* (Hansen, 1923); *A. tenuicornis* Brady, 1910; *A. uncinatus* (Kritchagin, 1873) and *A. urabensis* Kim, 2004. However, *A. intermedius* (Hansen, 1923) also has to be included since there is no available information about its mandibular palp.
Asterocheres tarifensis **n.sp.** can be separated from *A. ellisi*, *A. jeanyeatmanae*, *A. lilljeborgi*, *A. lunatus*; *A. simulans*, and *A. reginae* by its body shape. While these species have a dorsoventrally flattened prosome (Marcus & Por 1960; Hamond 1968; Yeatman 1970; Ivanenko & Ferrari 2003; Johnsson 1998; Ivanenko 1997; Boxshall & Huys 1994), *A. tarifensis* shows an oval cephalothorax and a cylindrical urosome (Fig. 1A). Like the majority of *Asterocheres* species, the new species possesses three terminal setae in the free segment of the fifth leg (Fig. 1B). However, *A. uncinatus* and *A. latus* differ from this species by the possession of only two terminal setae (for *A. uncinatus*, see Marcus & Por 1960) or two terminal seta and one hyaline setule (not a genuine seta) in the exopod of this leg (for *A. latus*, see Bandera & Conradi 2009b). *Asterocheres tarifensis* **n.sp.** has a siphon which reaches up to the insertion of the maxillipeds, whereas *A. astroidicola*, *A. hirsutus*, *A. intermedius* and *A. urabensis* possess siphons which exceed this length (Kim 2004; Bandera *et al*. 2005; Conradi *et al*. 2006; Bandera & Conradi 2009a). The new species is easily separated from *A. tenuicornis*, *A. kervillei*, *A. suberitis* and *A. tenerus* by the length of the caudal rami which is, almost 6 times longer than wide in *A. tenuicornis*, twice longer than wide in *A. kervillei*, slightly more than 1.5 times longer than wide in *A. suberitis* and only just longer than it is wide in *A. tenerus*, in comparison with that of *A. tarifensis* **n. sp.**, in which the caudal rami is as long as it is wide (Bandera & Conradi 2009a; b).

Although *A. flustrae* also possesses caudal rami as long as its width, some characteristics such as the two setae of the antennary exopod (Fig. 1E), the inner lobe of the maxillule with four setae (Fig. 2B), the absence of an aesthetasc on the maxilla (Fig. 2C), the 5-segmented maxilliped (Fig. 2D) and the two setae of the genital area separate *A. tarifensis* **n.sp.** from *A. flustrae*, since, *A. flustrae* has three setae on the antennary exopod; the inner lobe of the maxillule has five setae; the maxilla bears an aesthetasc on syncoxa; each genital area is armed with two elements, one seta and one spine and the maxilliped is 6-segmented (according to the illustrations of Ivanenko & Smurov 1997).

Host. *Astroides calycularis* is an azooxanthellate dendrophylliid colonial coral, typically inhabiting shallow waters down to a depth of about 30 m, and preferring shaded places and strong water movement (Zibrowius 1980; 1995). This coral, protected by the Convention on International Trade in Endangered species of Wild Fauna and Flora (CITES), is essentially endemic to the south-western Mediterranean, with a few outliers beyond the Strait of Gibraltar in the west and the Straits of Sicily in the east.

The colonies of *A. calycularis* harbour an abundant associated fauna, including both mobile and sedentary species. At least two uncommon gastropods are now known to live and feed on this coral: *Epitonium dendrophylliae* Bouchet and Warén and the coralliophilid *Babelomurex cariniferus* (Sowerby) (Richter & Luque 2004). Various isopod species such as *Carpias stebbingi* (Monod); *Cymodoce emarginata* Leach; *C. truncata* Leach, *Dynamene edwardsi* (Lucas); *Gnathia illepida* (Wagner); *G. inopinata* Monod; *G. venusta* Monod, and *G. vorax* (Lucas) have

also been recorded living on this coral (Castellanos *et al*. 2003). Recently two copepod species have been described living in association with *A. calycularis*: the cyclopoid *Doridicola helmuti* Conradi, *et al*., 2006; and the siphonostomatoid *Asterocheres astroidicola* Conradi *et al*., 2006. These species were found together with the siphonostomatoid *Acontiophorus scutatus* (Brady & Robertson, 1873) and an undetermined harpacticoid species (Conradi *et al*. 2006). Furthermore, the collection of some specimens of *Asterocheres mucronipes* in association with this coral serves to redescribe the species and accommodate it into a new genus, *Stockmyzon* Bandera and Huys, 2008 (Bandera & Huys 2008).

Distribution. Known only from the type locality (southern Spain, 36º 01N, 5º 36W).

Asterocheres minutus (Claus, 1889)

(Fig. 5)

Echinocheres minutus Claus, 1889
Asterocheres minutus sensu Giesbrecht, 1987

Material examined. 2 females (BEIM (COP-562) associated with the sea urchin *Paracentrotus lividus* (Lamarck) from Tarifa Island (southern Spain) at 12 m depth in 1991.

Description. Adult female: Body (Fig. 5A) cyclopiform, slender with cephalothorax oval and cylindrical urosome. Mean body length 470 µm (460–480 µm) and maximum width 265 µm (260–270 µm), based on 2 specimens. Ratio of length to width of prosome 1.29:1. Ratio of length of prosome to that of urosome 2.2:1. Prosome comprising cephalothorax fully incorporating first pedigerous somite and 3 free pedigerous somites.

Antenna (Fig. 5C) biramous, 125 µm long including terminal claw. Coxa and basis unarmed. Basis ornamented with spinule row medially. Exopod 1-segmented, slightly longer than wide; with one smooth subterminal seta and two pinnate terminal setae. Endopod 3-segmented; proximal segment elongated with row of spinules laterally; middle segment protruded distally on medial side but articulating with distal segment proximally on lateral side, bearing one distal seta; distal segment with smooth distal seta and distal claw (20 µm long) ornamented with minute spinules on lateral margin.

Oral cone very short, about 90 µm long, reaching to the insertion of maxilliped (Fig. 5B), with membranous lateral flanges.

Mandible (Fig. 5D) comprising stylet-like gnathobase and slender 1-segmented palp. Palp ornamented with rows of setules laterally and armed with two unequal distal densely plumose setae, the longer ornamented with three spinules apically.

Maxillule (Fig. 5E) bilobed; inner lobe (25x15 µm) as long as outer lobe (25x5 µm). Inner lobe armed with five distal setae, one setulose very long seta, one shorter smooth seta, two median setae ornamented with setules on distal part and one short smooth seta. Outer lobe armed with three terminal and one subterminal smooth setae.

Maxilla (Fig. 5F) 2-segmented but with partial transverse suture on syncoxa possibly marking plane of praecoxa-coxa fusion; praecoxal part bearing flaccid aesthetasc-like element medially, representing tubular extension of external opening of maxillary gland; coxal part unarmed. Basis claw-like recurved, distally armed with one naked, small seta at mid length and minute spinules in distal portion.

Remaining appendages as described by Bocquet *et al*. (1963).

Adult male: As described by Bocquet *et al*. (1963).

Remarks. *Asterocheres minutus* was poorly described and illustrated as *Echinocheres minutus* by Claus in 1889 and as *Asterocheres minutus* by Giesbrecht in 1899. Later on, it was described and illustrated by Bocquet *et al*. (1963) who also made a comparative study of *A. minutus* and *A. echinicola* (=*A. violaceous*, see Bandera & Conradi 2009b). The population of this species found in Tarifa Island (Southern Spain) shows some discrepancies from the previous descriptions. (1) The antennary exopod has not two but three elements (Bocquet *et al*. (1963) missed one lateral seta); (2) The armature of the third segment of the antennal endopod consists of one apical seta, claw and lateral row of setules, and not two setae and one claw as illustrated by Bocquet *et al*. (1963); (3) The palp of the mandible possess two distal setae as illustrated by Bocquet *et al*. (1963) but the longer one is thicker and has three spinules apically in addition to the setules of the distal part. (4) The inner lobe of the maxillule bears 5 distal setae but the length and ornamentation differ from those described by Bocquet *et al*. 1963 (5) The maxilla has a flaccid element medially, representing a tubular extension of the external opening of the maxillary gland on the

proximal part of the syncoxa, and the claw-like basis is armed with a small seta and ornamented with setules on the distal part which were not illustrated or mentioned by previous descriptions.

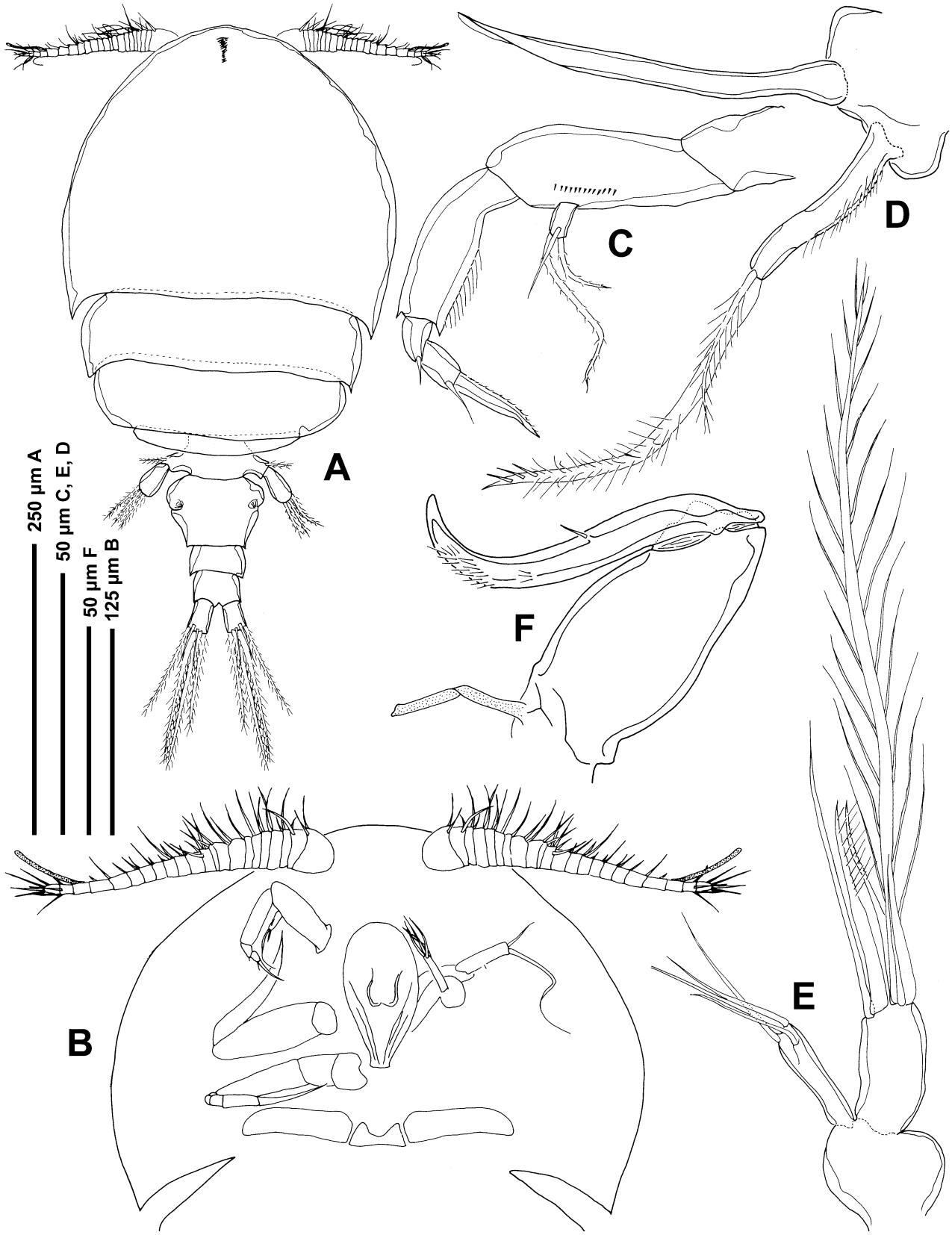

FIGURE 5. *Asterocheres minutus* (Claus, 1889), female. A, dorsal view. B, cephalic appendages C, antenna. D, mandible, E, maxillule. F, maxilla.

This species belongs to a group of *Asterocheres* species characterized by possessing a 21-segmented antennule in females and a 1-segmented mandibular palp. This group is composed of only three species: *A. bacescui* (Marcus, 1965), *A. madeirensis* Bandera *et al*., 2007, and *A. echinicola* (Norman, 1868). As commented above, we also have to include *A. intermedius*, since there is no available information about its mandibular palp. *Asterocheres minutus* can be separated from *A. bacescui*, *A. intermedius* and *A. madeirensis* by the length of the siphon which is shorter than those of the other three species (Bandera *et al*. 2007; Marcus & Por 1960, Bandera & Conradi 2009a). Furthermore, the inner lobe of the maxillule is longer than the outer lobe in *A. bacescui* and *A. madeirensis*, while the two lobes of *A. minutus* are more or less of equal length.

Asterocheres minutus is most similar to *A. echinicola*, and these two species provide a classic example of sibling species from regular echinoids on the western European coastlines (Bocquet & Stock 1963; Bocquet *et al.* 1963; Gotto 1979; Bandera & Conradi 2009b). The two copepods overlap in their distribution in the Mediterranean and may be found together on the same sea-urchin without displaying any territorial preference. Bocquet *et al* (1963) considered *A. minutus* to be derived from *A. echinicola* and believed that the present situation can be interpreted as a consequence of allopatric speciation. In this case, therefore, a single ancestral species of *Asterocheres* is envisaged, which parasitized sea-urchins over a wide geographical range, but became divided into "western" (Atlantic) and "eastern" (Mediterranean) components by a land barrier. The Atlantic population remained relatively unchanged due to a stable oceanic environment. The Mediterranean group, however, trapped in a relatively small sea subject to considerable fluctuations throughout its history, accumulated sufficient mutations to transform it into the species *A. minutus*. By the time the Strait of Gibraltar had opened to re-establish the communication, specific separation was complete. The new sea link allowed the euryplastic *A. echinicola* to recolonize the Mediterranean, but did not permit range-extension westward by *A. minutus*, a species by now stenoplastically adaptated to the conditions peculiar to an island sea (Bocquet & Stock 1963). Therefore, the most likely cladistic model of the origin of these two *Asterocheres* species is the budding hypothesis described by Queiroz (1998) since one of the *Asterocheres* species is the origin of the other, and both species (original and new) coexist in the time, naturally isolated on their respective hosts. Such demonstrations of the important role played by geographical isolation in the speciation of parasitic copepods makes information on the existence of geographic races or subspecies very desirable but such information is very scanty.

Paired species of copepods associated with echinoid hosts have also been recorded in the genera *Paramolgus*, *Plesiomolgus* and *Metaxymolgus* (Humes 1975). It may be presumed that their evolution has followed a similar course to that suggested for *Asterocheres*. Other examples of speciation which occur in the Strait of Gibraltar are the twin species *Astericola clausi* Rosoll, 1889 and *A. asterinae* (Bocquet, 1952), lichomolgid symbionts of asteroids, and *Doridicola botulosus* (Stock & Kleeton, 1963) and *D. comai* Conradi *et al*., 2004 rynchomolgid symbionts of gorgonaceans which are likely to be derived from a common ancestor (Bocquet *et al*. 1970; Conradi *et al*. 1993, 2004).

Host. This tiny copepod is restricted to Echinoidea and it has been recorded in association with three species *Paracentrotus lividus*, *Psammechinus microtuberculatus* (Blainville) and *Sphaerechinus granularis* (Lamarck) (Bocquet *et al*. 1963; Claus 1889; Giesbrecht 1987; present record).

Distribution. Mediterranean endemic: France (Bocquet *et al*. 1963), Italy (Claus 1889; Giesbrecht 1897), and Spain (present record).

Asterocheres siphonatus Giesbrecht, 1897
(Figs. 6–9)

Ascomyzon lilljeborgi Thorell, 1859, Sars, 1915
Artrotogus boeckii Brady, 1880
Asterocheres thorelli Bresciani and Lützen, 1962

Material examined. (a) One female (ZMO-F7645, 1 slide) collected in Norway by G.O. Sars. (b) One female (ZMO-F7646, 1 slide) collected in Norway by G.O. Sars. (c) 97 females (ZMO-F21603, in alcohol) collected in association with *Corella parallelogramma* (Müller) in Norway by G.O. Sars. (d) 11 females (BEIM (COP-548) associated with the ascidian *Synoicum argus* (Milne Edwards) from Las Lajas, Algeciras Bay (southern Spain) at 5 m depth in 1991.

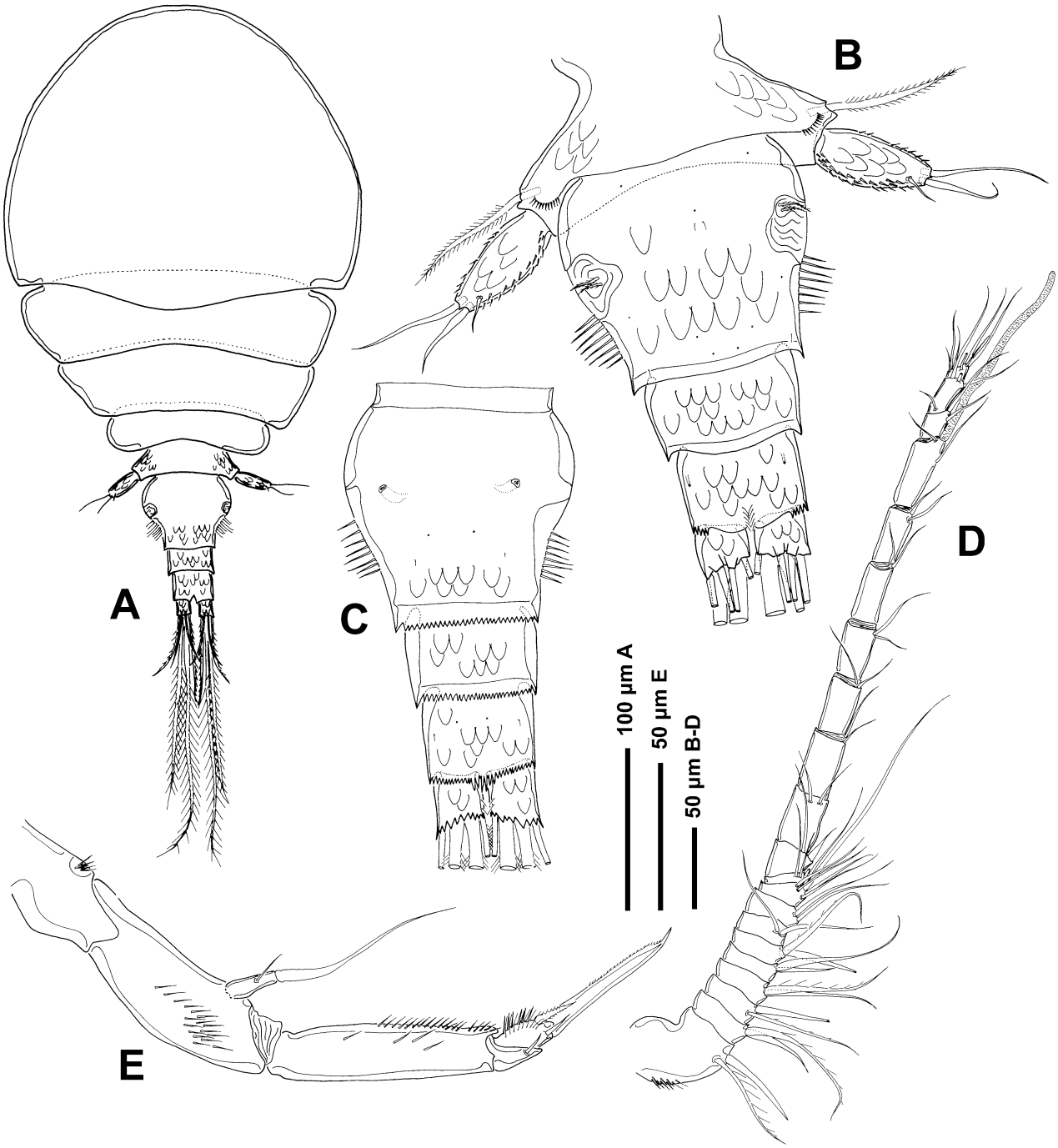

FIGURE 6. *Asterocheres siphonatus* Giesbrecht, 1897, female. A, dorsal view. B, urosome, dorsal view. C, urosome,ventral-view. D, antenna. E, antennule.

Description. Adult female. Body (Fig. 6A) cyclopiform, with moderately broad prosome and cyclindrical urosome. Mean body length 910 µm (880–960 µm) and maximum width 510 µm (450–540 µm), based on 5 specimens. Ratio of length to width of prosome 1.7:1. Ratio of length of prosome to that of urosome 2.45:1. Prosome comprising cephalothorax fully incorporating first pedigerous somite and 3 free pedigerous somites.

Urosome 4-segmented comprising leg 5-bearing somite, genital double-somite and 2 free abdominal somites. Dorsal and ventral surfaces of free abdominal somites and genital double-somite ornamented with large, flattened epicuticular scales arranged in overlapping rows (Fig. 6B, C). Posteroventral margins of abdominal somites ornamented with hyaline frills with serrated margins (Fig. 6C). Integumental pores and sensilla present on urosomal somites. Leg 5-bearing somite wider than long with some epicuticular scales on dorsal surface (Fig 6B, 9A). Geni-

tal double-somite slightly wider than long (150x145 µm), bearing paired genital apertures bipartite, each comprising lateroventral copulatory pore and dorsolateral gonopore; lateral margin with row of long spinules (about 8 spinules) in distal third (posterior to genital apertures) (Fig. 6B, C). Genital area armed with two plumose seta (Fig. 6B).

Caudal rami (Fig. 6B,C) as long as wide (30x30 µm), covered by overlapping epicuticular scales; armed with 6 setae. Seta I absent; setae II and VII smooth, slightly offset onto dorsal surface; setae III, IV, V and VI plumose.

Antennule (Fig. 6D) 21-segmented, about 470 µm long. Segmental homologies (expressed segment given first followed by ancestral segments in brackets) and setation 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)-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+ae, 19(XXII)-2, 20(XXIII-XXIV)-4, 21(XXV-XXVIII)-7. Segment 10 (XIII) reduced, partly overlapped by distal expansion of compound segment 9 (IX-XII). Three first segments with one seta with a circlet of cuticular denticles at each tip (Fig. 9C).

Antenna (Fig. 6E) biramous, 215 µm long including terminal claw. Small unarmed coxa with tuft of spinules on inner margin. Elongated unarmed basis ornamented with fine spinule rows. Exopod one-segmented, slender, bearing one medial and one terminal naked setae. Endopod three-segmented; proximal segment elongated, unarmed but ornamented with rows of spinules; middle segment small, protruded distally on medial side but articulating with third segment on lateral side and armed with smooth, distal seta; distal segment with rows of fine setules and spinules laterally, and armed with one smooth and one barbed setae, and distal claw, 55 µm long, with minute spinules on lateral margin.

Oral cone very long and slender, 620 µm long, reaching almost to posterior margin of intercoxal sclerite of leg 4.

Mandible (Fig. 7A) comprising stylet-like gnathobase and slender one-segmented palp. Stylet located in oral cone, very long and slender but expanded at the apex as illustrated. Palp slender, one-segmented with spinules arranged like a fan in middle third and some spinules on lateral margin; armed with 2 equal apical setae, one of them with spinules.

Maxillule (Fig. 7B) bilobed; praecoxal gnathobase 1.7 times longer than palp. Praecoxal endite (70x30 µm) ornamented with tufts of setules at base and distally and a row of spinules on lateral margin; armed with 5 distal setae different in length, one of them very short and naked. Palp (40x10 µm) with spinules on lateral margin; armed with 2 subterminal and 2 terminal barbed setae.

Maxilla (Fig. 7C) 2-segmented but with partial transverse suture on syncoxa (proximal segment) possibly marking plane of praecoxa-coxa fusion; coxal portion unarmed. Basis claw-like armed with small seta in distal third. Claw margins smooth.

Maxilliped (Fig. 7D) 5-segmented, comprising short syncoxa, long basis and three-segmented endopod. Syncoxa with inner seta distally. Basis elongated with short seta on lateral inner margin in middle third. First endopodal segment short, bearing 3 naked setae; second endopodal segment armed with naked seta; third endopodal segment bearing recurved terminal claw plus additional subapical seta. Claw 62 µm long, with minute spinules on lateral margin.

Swimming legs 1–4 (Fig. 8A–D) biramous, with three-segmented rami. Intercoxal sclerite present in legs 1–4, ornamented with rows of spinules in legs 1 and 2. Spine and seta formula as follows:

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

Coxae ornamented with spinule rows laterally, as illustrated. Inner coxal seta pinnate in legs 1–3 and absent in leg 4. Basis ornamented with spinule rows laterally; outer seta naked in all legs; longer than first exopodal segment in legs 1 and 2 and shorter than first exopodal segment in legs 3 and 4. Surface of legs 1–4 ornamented with flattened epicuticular scales arranged in irregular pattern (Fig. 8A–D). Lateral margins of exopodal segments with spinular rows; those of endopodal segments with rows of setules. Outer spines of exopodal segments bilaterally serrated in legs 1 and 4 and serrated only in external side in legs 2 and 3.

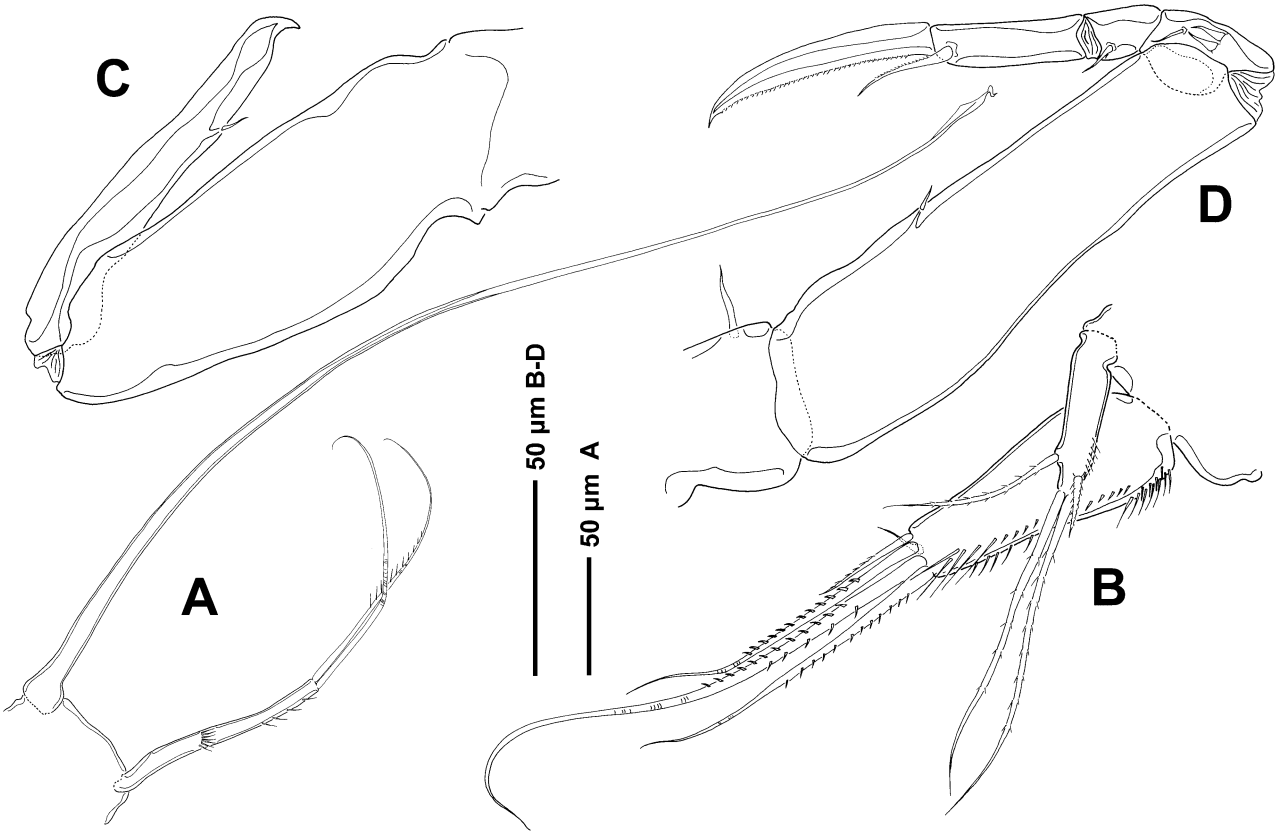

FIGURE 7. *Asterocheres siphonatus* Giesbrecht, 1897, female. A, mandible. B, maxillule C, maxilla. D, maxilliped.

Fifth leg (Fig. 6B) with protopod incorporated into somite; outer seta displaced laterally, with spinule row at base. Free segment (75x33 µm) elongated oval, 2.3 times longer than wide; ornamented with spinules and epicuticular scales and armed with one subterminal and 2 terminal naked setae (Fig. 9B).

Sixth leg (Fig. 6B) represented by paired opercular plates closing off gonopores on genital double somite; armed with two plumose setae.

Colour of living specimens reddish.

Adult male: scarcely described by Thorell (1859) and Sars (1915).

Remarks. Thorell described this species as the type species of his new genus *Ascomyzon, A. lilljeborgi*, in 1859. The specific name *lilljeborgi*, however, had already been preoccupied by *Asterocheres lilljeborgi* Boeck, 1859. This was pointed out by Brady (1880) although he also considered *Artotrogus* Boeck 1859 as synonymous to these genera. While these three genera were described at the same year, there was no doubt about the priority of Boeck's names since Thorell cited Boeck's work in his monograph. Between Boeck's two names, Brady favoured *Artotrogus,* considering it "less objectionable than the term *Asterocheres"*. Therefore, he proposed the name of *Artotrogus boeckii* for Thorell's species and *Artotrogus lilljeborgii* for Boeck's. Brady's suggestion was emended by Giesbrecht (1897) when he pointed out the certain synonymity of *Asterocheres* and *Ascomyzon* (and also *Cyclopicera* Brady, 1872), the validity of the genus *Artotrogus* and the difference between the species described by Thorell as *Ascomyzon lilljeborgi* and that described by Brady as *Artotrogus boeckii*. Hence, Giesbrecht proposed the name of *Asterocheres siphonatus* for Thorell's species (*Ascomyzon lilljeborgi)* since the specific name of *lilljeborgi* was preoccupied by *Asterocheres lilljeborgi* Boeck, 1859, and considered Brady's species as *Asterocheres boecki* (Brady, 1880).

Although Sars (1915) accepted the synonymy of *Asterocheres* and *Ascomyzon* and the priority of the first, he favoured the name of *Ascomyzon* to *Asterocheres* because "*the species of this genus are by no means exclusively parasites of asterids, but are found to infest many other invertebrate animals*". He returned Thorell`s species to the name *Ascomyzon lilljeborgi* , and considered *Asterocheres siphonatus* Giesbrecht, 1897 as a junior synonym of *Ascomyzon lilljeborgi* and changed the specific name of Boeck's to *Ascomyzon asterocheres*. Sars' erroneous suggestion was followed by Gurney (1927), Van Oorde-de lint *et al.* (1936), Bocquet (1952) and Lang (1949). Ten

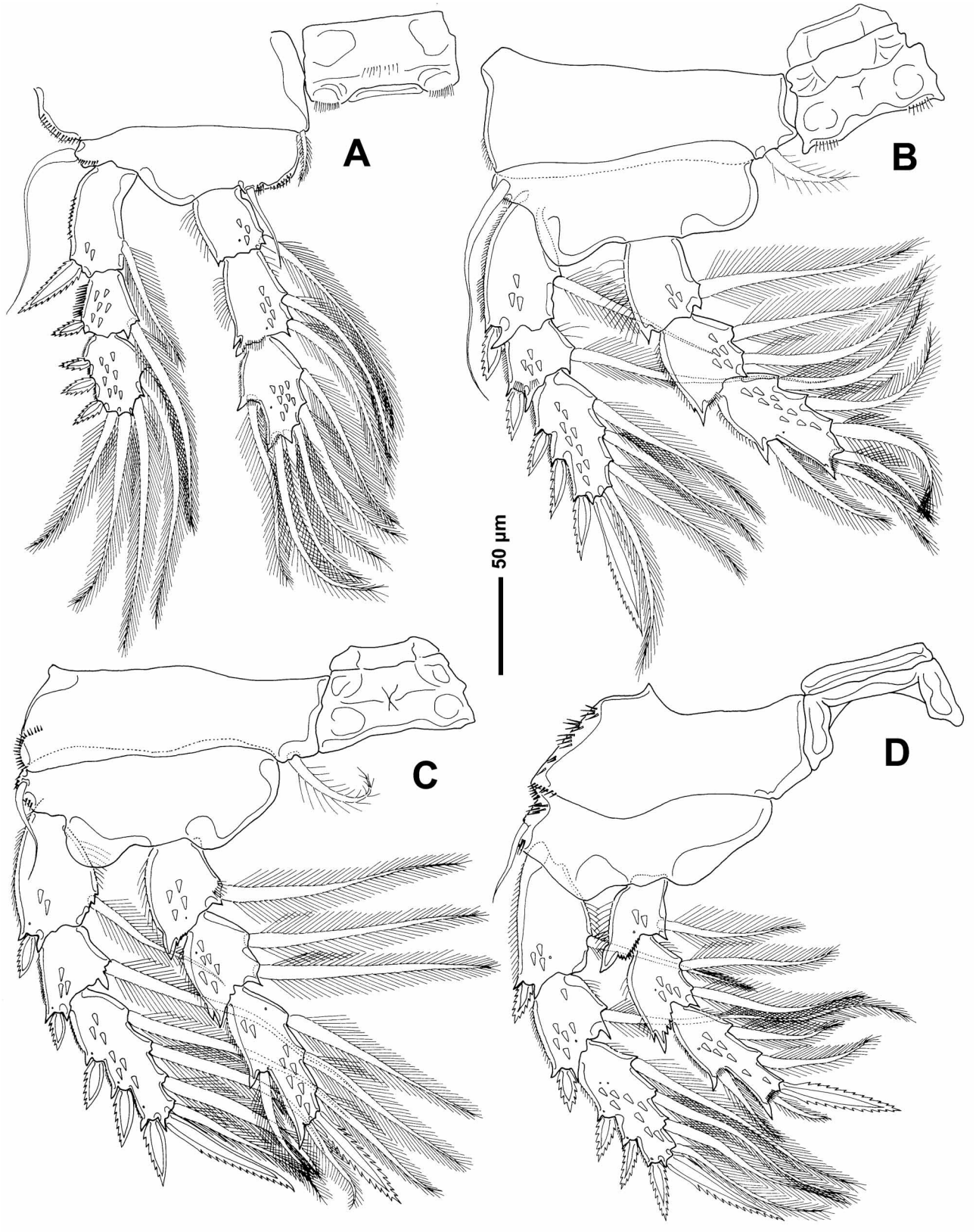

FIGURE 8. *Asterocheres siphonatus* Giesbrecht, 1897, female. A, leg 1. B, leg 2. C, leg 3. D, leg 4.

years later, Bresciani and Lützen (1962) re-established the priority of *Asterocheres* and proposed the specific name of *thorelli* for Thorell's species without considering that this species had already been named by Giesbrecht. Since then, this species has been erroneously named as *A. thorelli* (Sars G.O., 1879) (Brun 1976; Barel & Kramers 1977;

Humes 1986), until Gotto's excellent monograph (1993) where, following the International Code of Zoological (article 60.3), he cited this species as *A. siphonatus* Giesbrecht, 1897. Except for Walter (2009), most authors identify this species as such these days.

This species is easily recognized by its very long siphon and this may be the reason why it has only been illustrated by Thorell in 1859 and Sars in 1915 under the name of *Ascomyzon lilljeborgi*. Our study of *Asterocheres siphonatus* has revealed some important differences with respect to these previous descriptions: (1) For example, this species is commonly described as possessing 19–20 segments in the antennules of females, but in fact the antennule has 21 segments, (2) The antennary exopod has 2 elements, a medial and a terminal setae instead of a single element, and the last segment of the antennary endopod bears a stouter claw and one seta more than those previously illustrated. (3) The mandibular stylet was omitted, and the palp has two terminal setae equal in length as illustrated by Thorell, and not unequal as drawn by Sars. (4) The inner lobe of the maxillule has five setae instead of four, and the outer lobe has four setae, 2 subterminal and 2 terminal, in contrast with the three setae described by Thorell and the 1 subterminal and 3 terminal illustrated by Sars. (6) The basis of the maxilliped has one seta and the first endopodal bears 3 setae which were overlooked in the previous descriptions. (7) The subterminal seta of the free segment of leg 5 and the two plumose setae of leg 6 were also unobserved. (8) The flattened epicuticular scales on the urosomite and legs 1–4 were omitted.

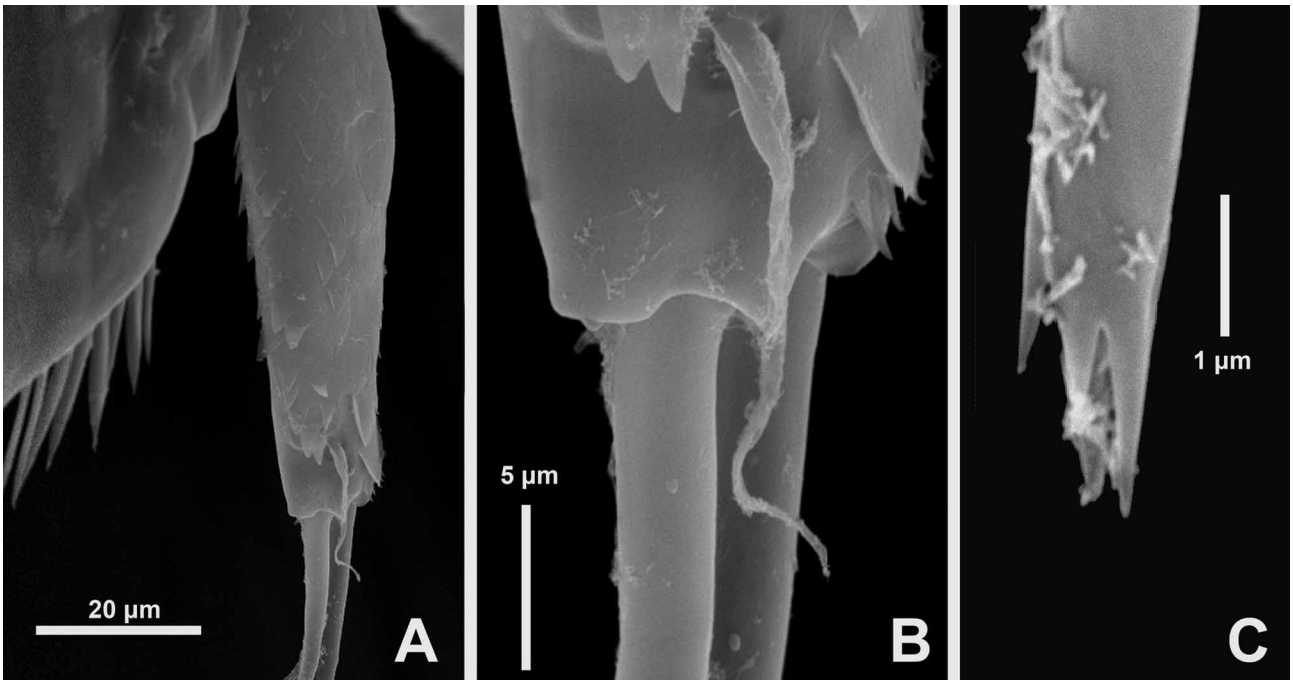

FIGURE 9. *Asterocheres siphonatus* Giesbrecht, 1897, female. A, leg 5. B, leg 5, detail of the subterminal seta. C, antennule, seta with a circlet of cuticular denticles at its tip.

From now on, *A. siphonatus* belongs to the group of species with a 21-segmented antennule in the females and a 1-segmented mandibular palp which includes only four species (*A. bacescui*, *A. madeirensis*, *A. echinicola* and *A. minutus)* together with the additional *A. intermedius* which has an undetermined mandibular palp. The very short siphon and the equal length of both maxillular lobes of *A. echinicola* and *A. minutus* separate them from *A. siphonatus*. The siphons of *A. bacescui* and *A. madeirensis* reach the insertion of the maxillipeds and that of *A. intermedius* extends to the intercoxal plate of leg 1 while that of *A. siphonatus* reaches the intercoxal plate of leg 4 (Bandera *et al*. 2007; Bandera & Conradi 2009a; Marcus & Por 1960).

Host. Although this copepod was initially recorded in association with ascidians, it has also been recorded associated with starfishes, free or among dredged material. The host ascidian species are: *Corella parallelograma* (Müller) (as *Ascidia parallelograma* in Thorell 1859; Sars 1915) and *Ascidia virginia* Müller (as *Phallusia virginia*, Aurivillus 1882).

Our specimens were found associated with the polyclinidae ascidian *Synoicum argus* (Milne Edwards) which has an Atlantic-Mediterranean distribution and generally lives in photophilic communities (Naranjo 1996). How-

ever, in Algeciras Bay, this compound ascidian is very common in harbour areas and it has been considered as an indicator of areas which have been subjected to intense stress over a long period (Naranjo *et al*. 1996). Up to now, the only fauna reported to be associated with *S. argus* has been the cyclopoid copepod *Doroixys uncinata* Kershner, 1879 (López-González *et al*. 1997).

Distribution. Sweden (Thorell 1859; Aurivillus 1882), Norway (Sars 1918); France (Van oorde-de Lint *et al*. 1936; Bocquet 1952); Suez Channel (Gurney 1927); Spain (present record).

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