

THE PYCNOGONIDS (ARTHROPODA: PYCNOGONIDA) OF SÃO MIGUEL, AZORES, WITH DESCRIPTION OF A NEW SPECIES OF *ANOPLDACTYLUS* WILSON, 1878 (PHOXICHILIDIIDAE)

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ABSTRACT

During the Third International Workshop of Malacology and Marine Biology in São Miguel, Azores, in July 2006, sampling of algae, and of the littoral and sublittoral benthos was undertaken in order to characterize the smaller marine arthropod fauna of this region, including pycnogonids. In the event, 50 specimens of Pycnogonida, representing six species and including a new species of *Anoplodactylus*, were collected. In addition, previous pycnogonid material collected around São Miguel in 1996 and 1997 was analyzed, from 112 samples of which a further 3705 pycnogonid specimens were identified, representing eight species, three additional to the above six. All of this material is described below. The zoogeography of the fifteen species now recorded from the Azores is analyzed, and the likely origins of the Azorean pycnogonid fauna are discussed.

RESUMO

Durante o 3º Workshop Internacional de Malacologia e Biologia Marinha em São Miguel, Açores, em Julho de 2006, realizaram-se amostragens de algas e o bentos do litoral e sublitoral com vista a caracterizar a fauna de artrópodes marinhos de reduzidas dimensões da região, incluindo picnogonídeos. Na ocasião foram recolhidos 50 exemplares de Pycnogonida, representando seis espécies e incluindo uma nova espécie de *Anoplodactylus*. Para além disso, analisou-se material de picnogonídeos, previamente recolhido em São Miguel em 1996 e 1997, de 112 amostragens das quais mais 3705 espécimes de picnogonídeos foram identificados, representando oito espécies, três das quais para além das seis atrás referidas. Todo este material é descrito em seguida. Analisa-se a zoogeografia das quinze espécies agora registadas para os Açores e discute-se a provável origem da fauna de picnogonídeos Açorianos.

INTRODUCTION

Pycnogonids are a group of the arthropods with minimal dispersive ability (Bamber, 1998); the larvae are not planktonic, and there are only limited examples of adults swimming, and then not as a directional migratory movement (Arnaud & Bamber, 1987). A few genera, such as the deep-water (*Bathypallenopsis*) and the generally shallow-water *Anoplodactylus*, are known to live upon medusae, and thus obtain passive dispersion in the plankton (Lebour, 1916; Arnaud &

Bamber, 1987; Bamber, 2002). Some species are known to have spread in fouling communities on ship's hulls (Krapp & Sconfiatti, 1983; Bamber, 1985).

The Azores are a group of islands somewhat isolated in the north-east Atlantic, lying adjacent to the Mid-Atlantic Ridge some 1600 km west of Portugal and 1730 km southeast of Newfoundland. The main surface water currents reaching the archipelago bring waters from two directions: the Azores drift, a diffuse southerly arm of the Gulf Stream breaking off from the North

Atlantic Drift supplies water from the Americas, while the somewhat less-significant western eddies of the Canary Current bring waters from Spain and North Africa; below these, the midwater current brings warm, hyperhaline water from the Mediterranean outflow (Morton *et al.*, 1998; Gofas, 1990). For the passively-dispersing Pycnogonida, therefore, it is of some interest to determine the suite of species which has colonized this archipelago, and their provenance.

The only previous specific study of the Pycnogonida of the Azores was that reported by Arnaud (1974), who recorded ten species from shallow waters, including the discovery of the currently Azorean-endemic *Achelia anomala*, as well as four species from waters of >500 m depth. Other previous records of pycnogonids in the Azores were noted by Loman (1912), Bouvier (1917), Arnaud (1978), Stock (1971; 1990) and Bamber (2002), although a number of these were from abyssal depths. Munilla & Sanchez (1988) reported on pycnogonids from the Canary Islands.

The twelve species recorded previously *in litt.* from the Azores, from depths shallower than 100 m, are:

Family Ammotheidae:

- Achelia anomala* Arnaud, 1974 (currently endemic);
- A. echinata* Hodge, 1864;
- Tanystylum orbiculare* Wilson, 1878.

Family Phoxichilidiidae:

- Anoplodactylus angulatus* (Dohrn 1881);
- A. maritimus* Hodgson, 1915;
- A. petiolatus* (Kroyer, 1844);
- A. pygmaeus* (Hodge, 1864).

Family Callipallenidae:

- Callipallene emaciata* (Dohrn, 1881)

Family Endeidae:

- Endeis spinosa* (Montagu, 1808);
- E. straughani* Clark, 1970 (see Stock, 1990; an Australian species, possi-

bly a misidentification, or an immigrant via ships'-hull-fouling, see Bamber, 1979 [as *E. picta*])

Family Rhynchothoracidae:

- Rhynchothorax philopsammum* Hedgpeth, 1951;
- R. monnioti* Arnaud 1974.

No members of the speciose family Nymphonidae have yet been recorded.

During the Third International Workshop of Malacology and Marine Biology at Vila Franca do Campo, on the island of São Miguel, Azores, in July 2006, sampling of the littoral and sublittoral benthos around São Miguel was undertaken in order to characterize the smaller marine arthropod fauna of this region, including pycnogonids. In the event, 50 specimens representing six species, one new to science, were collected. In addition, a previous collection from around the island was made available, from 112 samples from which a further 3705 pycnogonid specimens were identified, representing eight species, three additional to the above six. All of this material is described below.

MATERIAL AND METHODS

The present material comes from two sources. During the Workshop at Vila Franca do Campo in July 2006, a number of littoral and infralittoral habitats on the island of São Miguel were sampled for pycnogonids, including crevice habitats, macroalgae and soft sediments. The principal sampling areas were the littoral sediments, rocks and algae below the Clube Naval building (the old Vila Franca do Campo abattoir); the sediments and algae within the flooded crater of the Ilhéu de Vila Franca; and the soft sediments off Vila Franca do Campo (ca N37° 43' W 25°25'), from 12 to 200 m depth. Offshore sediments were sampled using a 0.025 m²

van Veen grab and various dredges. All samples were washed through a 0.5 mm mesh sieve, and specimens sorted alive. Some of these specimens were fixed in absolute ethanol to allow DNA analysis.

Extensive material collected in 1996 and 1997, from infralittoral rocky-substratum sites around São Miguel, was also analysed in detail. Replicate samples of algae (*Stypocaulon scoparia*, *Halopteris filicina* and *Zonaria tournefortii*) were collected by SCUBA diving at depths from between 5 and 16 m. Details of the sampling and protocols are given by Costa & Ávila (2001). The sampling sites, anti-clockwise around the Island from the north-west, were Mosteiros, Ponta da Ferraria, Santa Clara, Pesqueiro, Emissário, Sinaga, Atalhada, Ribeira da Praia, Caloura, Porto de Vila Franca do Campo, Ilhéu de Vila Franca, Ribeira Quente, Faial da Terra, Nordeste, Porto Formoso, Ladeira de Velha, Ribeirinha, Lactoaçoreana, Cofaco and São Vicente. These sites variously represented exposed and sheltered shores, undisturbed, naturally disturbed (near shallow-water vent sites or stream mouths) and polluted shores.

Voucher and type-material has been lodged in the collections of The Natural History Museum, London (NHM). The higher taxonomy is based on Arnaud & Bamber (1987). All measurements are axial, measured dorsally for the trunk and proboscis (trunk length being from the anterior margin of the cephalon to the posterior margin of the fourth lateral processes), laterally for oviger and legs.

SYSTEMATICS

Family Ammotheidae Dohrn, 1881

Achelia echinata Hodge, 1864

Figure 1A

Material: 1 male, 2 females, 1 subadult, WVF011, northeastern side of Ilhéu de Vila Franca do Campo, 16 m, scuba dive

collection by Gonçalo Calado, José Pedro Borges, Joana Xavier, Paola Rachello, Patrícia Madeira, 20 July 2006. 3 males, 4 females, 2 subadults, WVF040, off Amora, Ponta Garça, São Miguel, Azores, N37° 42' 720" W25° 21' 554", 37.8 m depth, small dredge sample, 26 July 2006, coll. António de Frias Martins & Jerry Harasewych. 1 female, 1 subadult, littoral rock scrape, Vila Franca do Campo marina, 19 July 2006, coll. Kathe Jensen. 1 male with eggs, Isl. 24.5, mid-lagoon algae, within the flooded crater of the Ilhéu de Vila Franca, 24 July 2006, coll. A. Salvador, R. Robbins & R.B.

12 specimens, Mosteiros, 8 November 1996; 139 specimens, Mosteiros, 17 June 1997; 41 specimens, Ponta da Ferraria, 17 June 1997; 53 specimens, Santa Clara, 7 November 1996; 201 specimens, Santa Clara, 12 June 1997; 20 specimens, Pesqueiro, 7 November 1997; 21 specimens, Emissário, 2 November 1996; 237 specimens, Emissário, 12 June 1997; 37 specimens, Sinaga, 30 May 1997; 1 specimen, Atalhada, 25 October 1996; 246 specimens, Atalhada, 30 May 1997; 32 specimens, Ribeira da Praia, 25 October 1996; 70 specimens, Ribeira da Praia, 16 June 1997; 61 specimens, Caloura, 14 October 1996; 119 specimens, Caloura, 26 June 1997; 48 specimens, Porto de Vila Franca do Campo, 9 May 1997; 8 specimens, Ilhéu de Vila Franca do Campo, 24 October 1996; 47 specimens, Ilhéu de Vila Franca do Campo, 16 June 1997; 44 specimens, Ribeira Quente, 18 June 1997; 5 specimens, Faial da Terra, 17 October 1996; 59 specimens, Faial da Terra, 30 May 1997; 19 specimens, Nordeste, 21 November 1966; 143 specimens, Nordeste, 2 May 1997; 36 specimens, Porto Formoso, 30 October 1996; 140 specimens, Porto Formoso, 19 June 1997; 13 specimens, Ladeira da Velha, 19 June 1997; 16 specimens, Ribeirinha, 8 October 1996; 140

specimens, Ribeirinha, 25 June 1997; 10 specimens, Lactoaçoreana, 14 October 1996; 76 specimens, Lactoaçoreana, 25 June 1997; 5 specimens, Cofaco, 25 June 1997; 13 specimens, São Vicente, 7 October 1996; 18 specimens, São Vicente, 6 May 1997; all coll. João Brum & A.C.C.

Remarks: with a total of 2146 specimens from 110 samples listed above, *Achelia echinata* is easily the commonest shallow-water pycnogonid in the Azores (occurring, for example, at every sampling site in 1996 and 1997). In the light of the potential for cryptic sibling species in this taxon, specimens collected in alcohol were analysed for their 16s DNA to compare with specimens from England which had already been analysed as part of a larger project (Bamber *et al.*, in prep.) and showed 100% agreement. All the Azorean material was collected in association with algae, on which, *inter alia*, this species is known to feed (Bamber & Davis, 1982).

Ammothella longipes (Hodge, 1864)

Figure 1B

Ammothoa longipes Hodge, 1864

Achelia longipes sens. auctt.;

Achelia magnirostris (Dohrn, 1881)

Material: 1 specimen, Atalhada, 30 May 1997; 1 specimen, Ribeira da Praia, 16 June 1997; 16 specimens, Porto de Vila Franca do Campo, 9 May 1997; 6 specimens, Ribeira Quente, 18 June 1997; 31 specimens, Lactoaçoreana, 25 June 1997; all coll. João Brum & A.C.C.

Remarks: This species has been recorded from the Atlantic coasts of Europe (England being the type-locality), the Mediterranean and North Africa, as well as the Canaries (Sanchez & Munilla, 1989), but had not been recorded previously from the Azores. It is readily distinguished from sympatric *Achelia echina-*

ta by the fleshy, glabrous dorsodistal tubercles on the lateral processes, the lack of spinose tubercles on the lateral processes and coxae, and in having nine palp articles (*A. echinata* having eight).

Family Phoxichilidiidae Sars, 1891

Anoplodactylus amora sp. nov.

Figure 2.

Material: 1 male, holotype (NHM.2007.416), 1 male, 1 subadult female, paratypes (NHM.2007.417-418), VWF040, off Amora, Ponta Garça, São Miguel, Azores, N37° 42' 720" W25° 21' 554", 37.8 m depth, small dredge sample, 26 July 2006, coll. António de Frias Martins & Jerry Harasewych; 1 subadult male, Vila Franca do Campo marina, São Miguel, Azores, littoral rock scraping, 19 July 2006, coll. Kathe Jensen.

2 males, paratypes (NHM.2007.419-420), Caloura, 26 June 1997; 1 male, paratype (NHM.2007.421), Ilhéu de Vila Franca do Campo, 16 June 1997; 1 subadult male, 1 female, paratypes (NHM.2007.422-423), Faial da Terra, 30 May 1997; all coll. João Brum & A.C.C.

Description of male: habitus typical of the *A. petiolatus* form, trunk (Figure 2A, B) almost glabrous, with segment articulations between cephalon, trunk segment two and trunk segment three. Cephalon overhanging proboscis base to half proboscis length, lateral anterior margin with slight shoulders bearing short seta; dome-shaped ocular tubercle slightly taller than wide, without distal tubercle, with four pigmented eyes and laterodistal sensory pit; oviger attachment on mid-ventral surface of first lateral process. Lateral processes shorter than segment width, separated by less than their own diameter, with simple anterodistal seta and very small dorsodistal tubercle (little more than a swelling). Abdomen simple, sub-clavate, angled upward at about 45°, exceeding distal edge of coxa 1 of leg 4, sub-

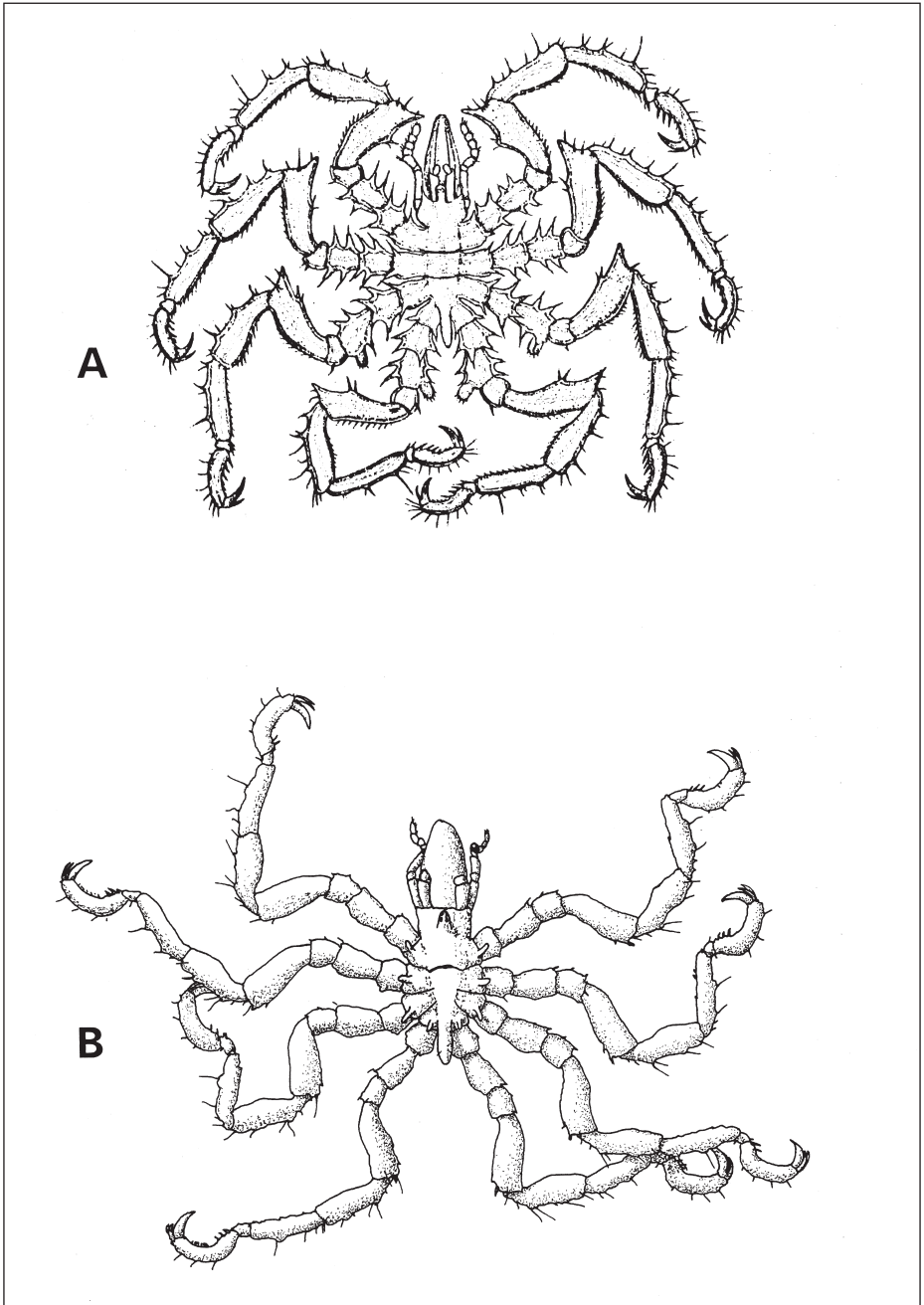


FIGURE 1. A, *Achelia echinata*, entire, dorsal (modified after Sars, 1893); B, *Ammothoella longipes*, entire, dorsal.

distally bearing pair of lateroventral spines and single mid-dorsal spine.

Proboscis stout, parallel-sided, one-third as long as trunk.

Chelifere (Figure 2C) scape of one arti-
cle, slender, with sparse dorsal and distal

setae; chela compact, fingers just shorter than palm, palm and moveable finger setose, cutting edges naked. Palp absent.

Oviger (Figure 2D) of six articles, proximal article short, compact; article 2 (O2) three times as long as wide, with single dor-

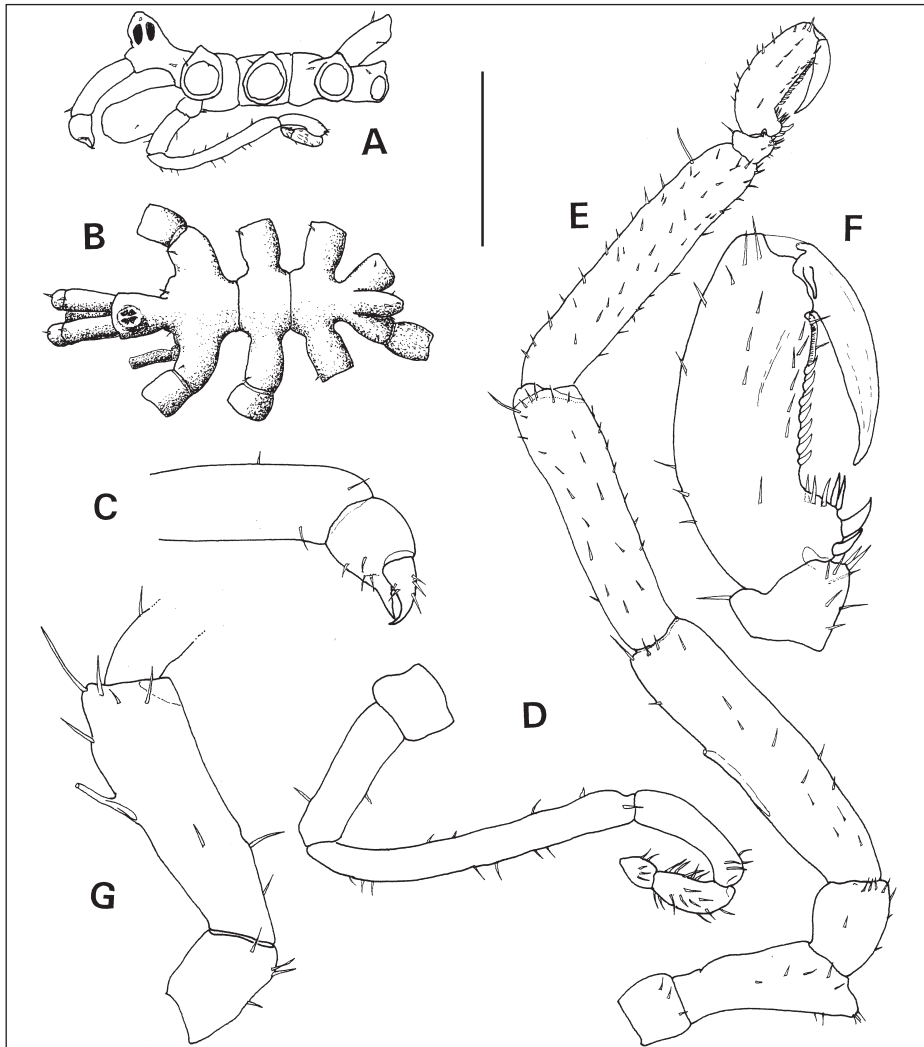


FIGURE 2. *Anoplodactylus amora* sp. nov., male holotype, A, lateral and B, dorsal; C, right chelifere; D, left oviger; E, third left leg; F, detail of distal articles of third leg; G, coxa 2 and femur of male *A. petiolatus*. Scale line = 1 mm for A and B, 0.4 mm for C and D, 0.8 mm for E, 0.3 mm for F, 0.5 mm for G.

sal and ventral setae; O3 longest, 2.3 times length of O2, slender, with sparse dorsal and ventral setae; O4 just shorter than O2, curved, with dorsodistal setae; O5 0.6 times as long as O4, with numerous setae pointing proximally; O6 compact, acorn-shaped, half length of O5, with outer and ventral setae pointing proximally.

Third leg (Figure 2E) elongate, not slender. Coxa 1 compact, with sparse distal setae, without dorsal tubercle; coxa 2 almost three-times as long as coxa 1, 2.5 times as long as wide, with pronounced ventrodistal genital spur; coxa 3 just more than half length of coxa 2. Femur stout, less than four times as long as wide, twice as long as coxa 2, setose, without conspicuous dorsodistal spur; cement-gland tube externally very short, arising at 0.6 the length of the femur, extending subcutaneously half way to proximal end of femur. Tibia 1 shorter than femur (0.9 times femur length), setose as figured; tibia 2 five times as long as wide, as long as femur, more densely setose, longest dorsodistal seta not on a spur. Tarsus small, triangular, with numerous ventral and single dorsal setae. Propodus (Figure 2F) with distinct heel, with two large proximal and five slender distal heel spines; sole with row of seven simple submarginal setae in distal two-thirds, seven short, recurved marginal spines and distal lamina for 30% of sole length. Main claw two-thirds as long as propodus, auxiliary claws small, lateral, slender, 0.15 times length of main claw.

Description of female: generally as male, but ovigerous legs absent, femur swollen; no ventral tubercles on proboscis.

Measurements of holotype male (mm). – Trunk length: 1.91; trunk segment 2 length: 0.29; width across 2nd lateral processes: 0.99; abdomen length: 0.42; proboscis length: 0.53.

Lengths of oviger articles 1 to 6 respectively: 0.13; 0.31; 0.73; 0.27; 0.17; 0.09.

Fourth leg, lengths of coxa 1: 0.24; coxa 2: 0.69; coxa 3: 0.38; femur: 1.40 (width 0.36); tibia 1: 1.23; tibia 2: 1.40 (width 0.28); tarsus: 0.12; propodus: 0.55; main claw: 0.37; auxiliary claw: 0.06.

Etymology: named after the location on São Miguel off which the type-locality lies.

Remarks: there are two previously described species of *Anoplodactylus* which have a subcutaneous proximal extension of the cement gland tube, viz. *A. erectus* Cole, 1904 from the Pacific (the Americas from Chile to British Columbia, Hawaii, Polynesia, Japan, Korea and Hong Kong) at depths of 0 to 90 m, and *A. amoybios* Bamber, 2004 from Atlantic Equatorial Africa (Gabon and Equatorial Guinea) at depths of 36 to 63 m (see Stock, 1955; Müller, 1990; Bamber, 2004). Both of these species also share the characters of a six-articled ovigerous leg, the ocular tubercle overhanging the proboscis, small auxiliary claws and a propodal lamina. *A. amoybios*, the only other Atlantic species, is immediately distinct in having dorsodistal tubercles on coxa 1 of all legs. *A. erectus* normally has conspicuous dorsodistal tubercles on the lateral processes, unlike the present species. In addition, *A. erectus* is conspicuously more slender than *A. amora* sp. nov, femur and tibia 2 length:width ratios being 5.3 and 7.7 respectively (3.9 and 5 respectively in *A. amora*), and the width across trunk segment 2 is four times the length of the segment (<3.5 times in *A. amora*); further, *A. erectus* has only simple spines on the propodal sole, and a shorter lamina. All three of these “*erectus*-group” species are clearly similar and closely related.

Arnaud (1974) recorded *A. petiolatus*

(Krøyer, 1844) from the Azores, at depths between 1 and 30 m; that species is readily distinguished from *A. amora* by its cement gland configuration (without subcutaneous extension, see Figure 2G).

Anoplodactylus angulatus (Dohrn, 1881)

Figure 3A to C

Material: 1 female, WVF011, northeastern side of Ilhéu de Vila Franca do Campo, 16 m, scuba dive collection by Gonçalo Calado, José Pedro Borges, Joana Xavier, Paola Rachello, Patrícia Madeira, 20 July 2006. 1 male, 3 females, 1 subadult, Isl. 24.4, attached littoral algae, south wall within the flooded crater of the Ilhéu de Vila Franca, 24 July 2006, coll. A. Salvador, R. Robbins & R.B.; 2 males with eggs, 1 male, 4 females, 2 subadults, Isl. 24.5, mid-lagoon algae, within the flooded crater of the Ilhéu de Vila Franca, 24 July 2006, coll. A. Salvador, R. Robbins & R.B.

1 specimen, Mosteiros, 8 November 1996; 2 specimens, Mosteiros, 17 June 1997; 1 specimen, Santa Clara, 7 November 1996; 3 specimens, Santa Clara, 12 June 1997; 12 specimens, Pesqueiro, 7 November 1997; 2 specimens, Emissário, 2 November 1996; 24 specimens, Emissário, 12 June 1997; 4 specimens, Sinaga, 30 May 1997; 25 specimens, Atalhada, 30 May 1997; 1 specimen, Ribeira da Praia, 25 October 1996; 5 specimens, Ribeira da Praia, 16 June 1997; 7 specimens, Caloura, 26 June 1997; 6 specimens, Porto de Vila Franca do Campo, 9 May 1997; 2 specimens, Ribeira Quente, 18 June 1997; 10 specimens, Nordeste, 2 May 1997; 1 specimen, Porto Formoso, 30 October 1996; 3 specimens, Porto Formoso, 19 June 1997; 4 specimens, Ladeira da Velha, 19 June 1997; 10 specimens, Ribeirinha, 25 June 1997; 1 specimen, Cofaco, 25 June 1997; 2 specimens, São Vicente, 6 May 1997; all coll. João Brum & A.C.C.

Remarks: the commonest species of *Anoplodactylus* in the Azores, *A. angulatus* is also known from the Mediterranean, the Atlantic coasts of Northern Europe and North Africa (Morocco), as well as the Canary Islands. It is an algal-associated species without a conspicuous overhang of the anterior of the cephalon, and distinguished from sympatric specimens of *A. virescens* (also occurring in algae) by the marked angular distal corners of the proboscis (Figure 3B).

Anoplodactylus maritimus Hodgson, 1915

Figure 3D

Incl. *A. parvus* Giltay, 1934; non-*A. parvum* (Hilton, 1942) = *A. hokkaidoensis* (Utinomi, 1954).

Material: 1 specimen, Emissário, 12 June 1997; 2 specimens, Caloura, 26 June 1997; 15 specimens, Porto de Vila Franca do Campo, 9 May 1997; 1 specimen, Ilhéu de Vila Franca do Campo, 24 October 1996; 2 specimens, Ilhéu de Vila Franca do Campo, 16 June 1997; 10 specimens, Lactoaçoreana, 25 June 1997; all coll. João Brum & A.C.C.

Remarks: *Anoplodactylus maritimus* has been recorded previously throughout Macaronesia, other than which it is a species of the Atlantic coast of the Americas (see discussion below) but has not been recorded from the Atlantic coasts of mainland Europe, North Africa or the Mediterranean.

Anoplodactylus pygmaeus (Hodge, 1864)

Figure 3E, F

Material: 1 female, Isl. 24.4, attached low-littoral algae, south wall within the flooded crater of the Ilhéu de Vila Franca; 1 female, Isl. 24.5, mid-lagoon algae, within the flooded crater of the Ilhéu de Vila Franca; both 24 July 2006, coll. A. Salvador, R. Robbins & R.B.

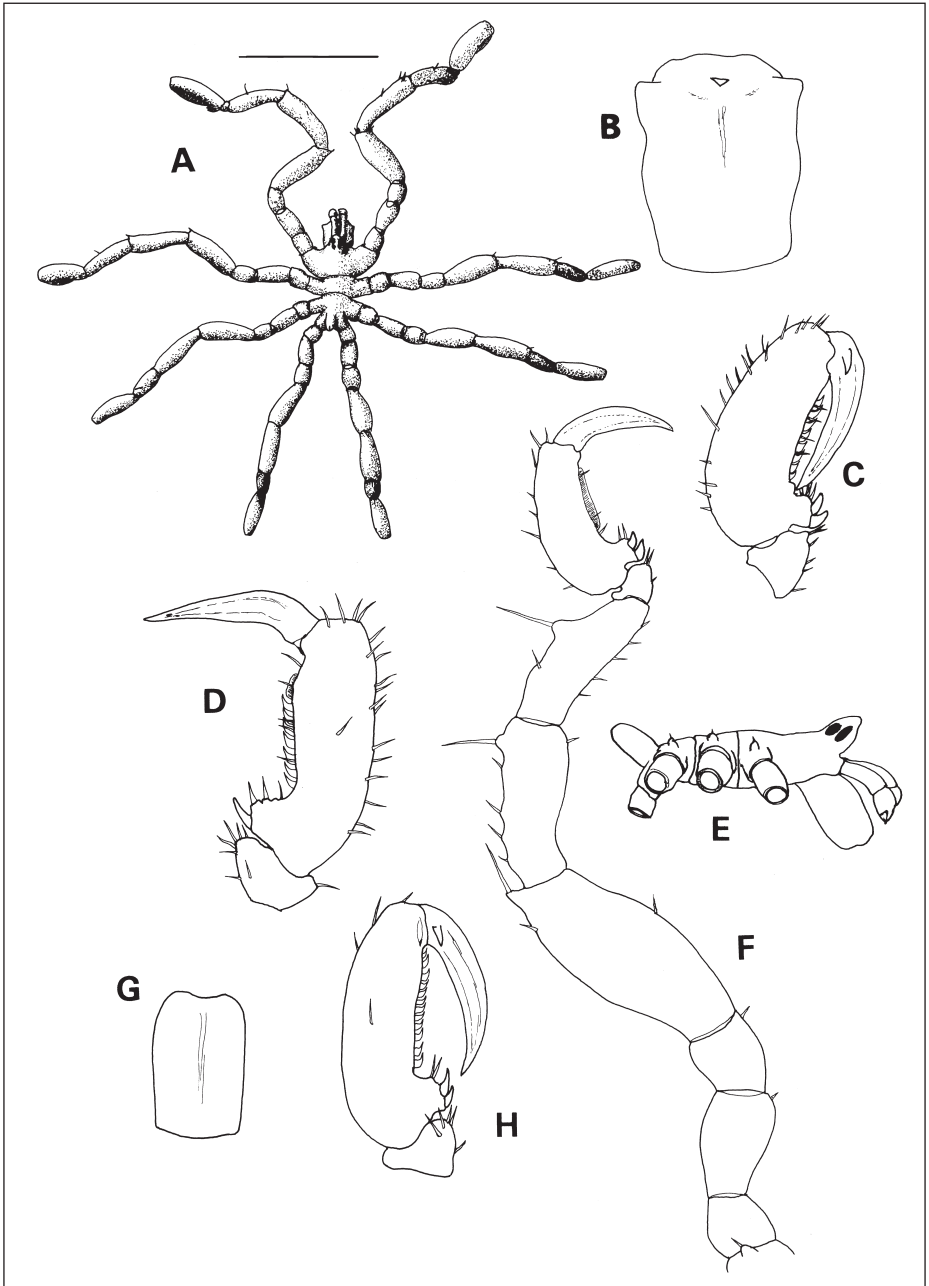


FIGURE 3. A to C, *Anoplodactylus angulatus*: A, entire, dorsal; B, proboscis, ventral; C, distal leg articles (lam = lamina); D, *A. maritimus*, distal leg articles; E and F, *A. pygmaeus*: E, body, lateral; F, third leg, entire; G to H, *A. virescens*: G, proboscis, ventral; H, distal leg articles.

1 specimen, Pesqueiro, 7 November 1997; 4 specimens, Porto de Vila Franca do Campo, 9 May 1997; 1 specimen, Faial da Terra, 30 May 1997; 1 specimen, Ribeirinha, 25 June 1997; all coll. João Brum & A.C.C.

Remarks: *Anoplodactylus pygmaeus* is a small species (as its name suggests), similar to *A. petiolatus* but with a less-marked anterior cephalic overhang and with distinct distal spines on the dorsodistal tubercles of the lateral processes; auxiliary claws are absent. It has been recorded throughout the North Atlantic and Mediterranean, including the Canaries and the Azores, in shallow water (the record from 3850 m depth on the Cape Verde Slope by Bamber & Thurston, 1993, is presumed to be a result of sampling-gear contamination from the fouling community on the ship's hull).

Anoplodactylus virescens (Hodge, 1864)

Figure 3G, H

Material: 1 female, WVF040, off Amora, Ponta Garça, São Miguel, Azores, N37° 42' 720" W25° 21' 554", 37.8 m depth, small dredge sample, 26 July 2006, coll. António de Frias Martins & Jerry Harasewych.

Remarks: while isolated females of this genus can be difficult to identify to species, *Anoplodactylus virescens*, with its trunk segmentation only between somites 1, 2 and 3, its presence of small auxiliary claws, its lack of propodal lamina, of dorsodistal lateral-process tubercles, of ventral proboscis tubercles and of chela teeth, is only confusable with *A. robustus* (Dohrn, 1881), but the latter species has angulate corners to its proboscis, unlike the present species. *A. virescens* is known from the north-east Atlantic from the United Kingdom to Morocco and throughout the Mediterranean. This is the

first record of this species for the Azores.

Family Callipallenidae Hilton, 1942

Callipallene emaciata (Dohrn, 1881)

Figure 4A

Material: 1 male, 3 females, 1 juvenile, Isl. 24.4, attached low-littoral algae, south wall within the flooded crater of the Ilhéu de Vila Franca; 5 females, 1 male, Isl. 24.5, mid-lagoon algae, within the flooded crater of the Ilhéu de Vila Franca; both 24 July 2006, coll. A. Salvador, R. Robbins & R.B.

4 specimens, Mosteiros, 8 November 1996; 118 specimens, Mosteiros, 17 June 1997; 12 specimens, Ponta da Ferraria, 17 June 1997; 24 specimens, Santa Clara, 7 November 1996; 61 specimens, Santa Clara, 12 June 1997; 17 specimens, Pesqueiro, 7 November 1997; 27 specimens, Emissario, 2 November 1996; 179 specimens, Emissario, 12 June 1997; 26 specimens, Sinaga, 30 May 1997; 1 specimen, Atalhada, 25 October 1996; 222 specimens, Atalhada, 30 May 1997; 35 specimens, Ribeira da Praia, 25 October 1996; 29 specimens, Ribeira da Praia, 16 June 1997; 18 specimens, Caloura, 14 October 1996; 133 specimens, Caloura, 26 June 1997; 24 specimens, Porto de Vila Franca do Campo, 9 May 1997; 29 specimens, Ilhéu de Vila Franca do Campo, 16 June 1997; 13 specimens, Ribeira Quente, 18 June 1997; 4 specimens, Faial da Terra, 17 October 1996; 21 specimens, Faial da Terra, 30 May 1997; 4 specimens, Nordeste, 21 November 1966; 51 specimens, Nordeste, 2 May 1997; 25 specimens, Porto Formoso, 30 October 1996; 69 specimens, Porto Formoso, 19 June 1997; 5 specimens, Ladeira da Velha, 19 June 1997; 29 specimens, Ribeirinha, 8 October 1996; 67 specimens, Ribeirinha, 25 June 1997; 14 specimens, Lactoaçoreana, 14 October 1996; 26 specimens, Lactoaçoreana, 25 June 1997; 4 specimens, Cofaco, 25 June

1997; 17 specimens, São Vicente, 7 October 1996; 1 specimen, São Vicente, 6 May 1997; all coll. João Brum & A.C.C.

Remarks: the European shallow-water species of the genus *Callipallene* are small,

cryptic species normally associated with epizoan turfs of bryozoans and hydroids. The distinction of these taxa was analysed by Stock (1952), since when his subspecies have been raised to full specific rank (*C. brevisrostris* (Johnston, 1837), *C. emaciata*, *C.*

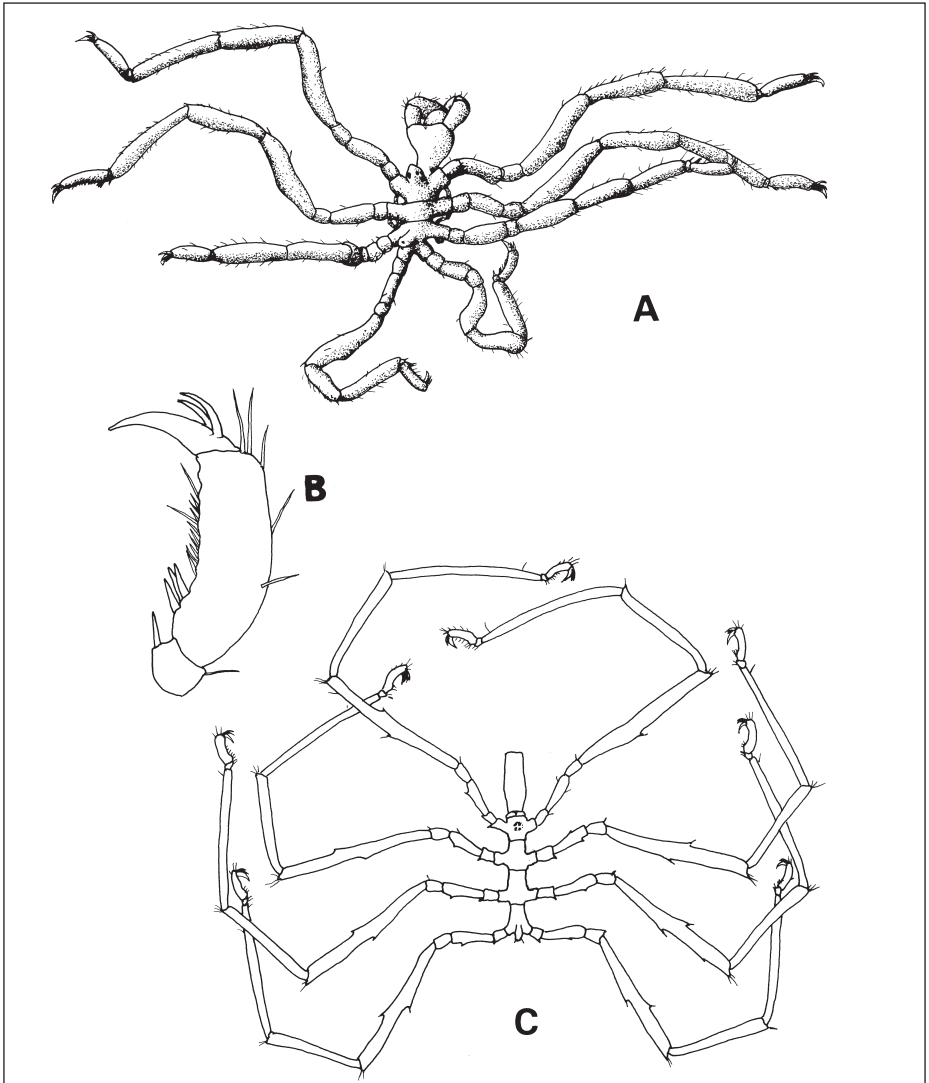


FIGURE 4. A to B, *Callipallene emaciata*: A, entire, dorsal; B, distal; leg articles; C, *Endeis spinosa*, entire, dorsal (after Bamber, 1983).

tiberi (Dohrn, 1881), *C. phantoma* (Dohrn, 1881)). While *C. breviostris* is the commonest species on the Atlantic coasts of North Europe, the present species is the only *Callipallene* recorded from the shallow waters of the Azores (the deeper-water *C. producta* Sars, 1888 has been recorded off the Azores (Bouvier, 1917; Arnaud, 1974) at depths >800 m), and is more commonly associated with algae than are the other species listed above. All the Azorean specimens were collected from algae, the species being the second commonest recorded (occurring, for example, at every sampling site in 1996 and 1997).

Family Endeidae Norman, 1908

Endeis spinosa (Montagu, 1808)

Figure 4B

Material: 3 specimens, Mosteiros, 8 November 1996; 3 specimens, Santa Clara, 12 June 1997; 1 specimen, Sinaga, 30 May 1997; 5 specimens, Atalhada, 30 May 1997; 9 specimens, Ribeira da Praia, 16 June 1997; 1 specimen, Caloura, 14 October 1996; 4 specimens, Caloura, 26 June 1997; 1 specimen, Porto de Vila Franca do Campo, 9 May 1997; 2 specimens, Ilhéu de Vila Franca do Campo, 16 June 1997; 1 specimen, Ribeira Quente, 18 June 1997; 2 specimens, Faial da Terra, 30 May 1997; 1 specimen, Nordeste, 2 May 1997; 2 specimens, Porto Formoso, 19 June 1997; 1 specimen, Lactoaçoreana, 14 October 1996; 1 specimen, Lactoaçoreana, 25 June 1997; 1 specimen, São Vicente, 6 May 1997; all coll. João Brum & A.C.C.

Remarks: a widespread North Atlantic species, where its only native congener is *Endeis charybdaea* (Dohrn, 1881) on European coasts. Stock's (1990) record of *E. meridionalis* (Böhm, 1879) from Cape Verde is highly suspect. *E. mollis* (Carpenter, 1904) may be a Lessepsian

immigrant to the Mediterranean. While the larval biology of this species is unknown, there is evidence of its waterborne transport, perhaps by association with hydromedusae.

DISCUSSION

There are now fifteen species of shallow-water pycnogonids recorded from the Azores: *Ammothoella longipes*, *Anoplodactylus virescens* and *A. amora* sp. nov. are newly recorded for the islands from the present study. *Achelia echinata*, *Anoplodactylus angulatus* and *Callipallene emaciata* are common.

Analysis of the provenance of these species is somewhat challenged by the presence of species which have in the past been misidentified, early records worldwide depending on what was at the time a limited literature, and a limited understanding of specific characters.

For example, *Achelia echinata*, a species with a type locality in the United Kingdom, has been recorded in the literature not only throughout the north-east Atlantic and Mediterranean (an accepted distribution), but also from China and Japan (as subspecies), from California and Alaska. Recent molecular work (Bamber *et al.* in prep.) has shown not only that the material from the Azores is fully conspecific with material from the United Kingdom, but also that the Chinese-Japanese "subspecies" is in fact a distinct species. The North- and East-Pacific material is highly suspect, and is not accepted herein.

Rhynchothorax anophthalmus Arnaud, 1972, recorded as such from the Azores by Arnaud (1974), was synonymized with *R. philopsammum* Hedgpeth, 1951 by Arnaud & Krapp (1990), when comparing specimens from the Mediterranean and from California: *R. philopsammum* is a Californian species, also recorded from

the Subantarctic, Pacific Mexico, Magellanic Chile, a number of Pacific Islands and Belize. Other than the Pacific material, the species is recorded (as *R. anophthalmus*) from Azores and the Mediterranean. *Rhynchothorax* is an interstitial genus which would not be expected to be transported by ships'-hull fouling or by floating weed. With this disparity in zoogeography, closer examination may yet show these two taxa to be distinct. Records of *R. monnioti* (type-locality the Azores) from Brazil and Trinidad (Arnaud & Krapp, 1990; Child, 1988) are dubious, and not accepted herein.

In the light of the above, the species currently known from the Azores show a number of zoogeographies:

- two currently endemic species – *Achelia anomala* (not recorded since the original discovery and description: Arnaud, 1974), and *Anoplodactylus amora* (recorded herein for the first time); Morton & Britton (2000) point out that endemism is low in these islands owing to their “youthfulness” (earliest emergence about 8 My ago), and such species are likely to be found elsewhere in the future;
- two species from Macaronesia and the Mediterranean – *Rhynchothorax anophthalmus* from the Mediterranean; *R. monnioti* from the Mediterranean and the Canary Islands;
- three species from the North-east Atlantic, the Mediterranean and North Africa (Morocco) – *Ammothoella longipes*, *Anoplodactylus angulatus*, *Anoplodactylus virescens* (the first two also recorded elsewhere in the Macaronesian system);
- five species found in the Mediterranean and throughout the North Atlantic, including the Americas – *Achelia echinata*, *Anoplodactylus petiolatus*, *Anoplodactylus pygmaeus*, *Callipallene emaciata* and

Endeis spinosa: closer study may yet distinguish cryptic species within these data;

- a species found throughout the southern North Atlantic – *Tanystylum orbiculare* (distribution as the previous group 4, but not including the European Atlantic coasts);
- a species from Macaronesia and the West Atlantic only – *Anoplodactylus maritimus*, recorded from Madeira, Cape Verde Islands, the Canaries and the Americas from Chesapeake Bay through the Gulf of Mexico and the Caribbean to Brazil;
- an immigrant species – *Endeis straughani* (if a valid record), a species native to Australia but since recorded in ship's-hull-fouling from Ghana (Bamber, 1979, as *E. picta*; Staples, 1982).

Apart from the presently endemic species and the anthropogenic immigrant, all but one of these species are also found in the Mediterranean, and of these all but the two *Rhynchothorax* species are recorded from Morocco. Five of these twelve species have not been found in the Western Atlantic. These data give a strong indication that the pycnogonid fauna of the Azores is largely of an easterly origin, from the Mediterranean, North Africa or Atlantic Europe.

The notable exception is *Anoplodactylus maritimus*, recorded from the Azores, the Canary Islands, Cape Verde and Madeira (see Fage & Stock, 1966; Stock, 1990; Child, 1992), and found in nine of the samples from 1996 and 1997. This species is also found in the Americas (see above), including in the Sargasso Sea, and is commonly recorded amongst floating *Sargassum* (Bourdouillon, 1955; Stock, 1954; Stock, 1957; McCloskey, 1973; Stock, 1992; Child, 1992); indeed, Hodgson (1915) found it in floating *Sargassum* south of the Azores. In

addition, Stock (1994) recorded “>500 specimens” of *A. maritimus* associated with surface-floating hydroids in the mid-Atlantic, at 24.75°N 44 to 53°W.

Drift dispersal in algae as a viable means of passive migration by pycnogonids was analyzed by Bamber (1998). Perhaps significantly, other species recorded amongst *Sargassum* are *Endeis spinosa*, *Anoplodactylus petiolatus* and *Tanystylum orbiculare* (see Timmermann, 1932; Hedgpeth, 1948), and the first two of these have been recorded on *Sargassum* in the vicinity of the Azores (Hedgpeth, 1948: Figure 7).

Finally, it is notable that the most diverse genus recorded, *Anoplodactylus*, includes species which are known to live upon medusae, and thus obtain passive dispersion in the plankton (see Introduction, above); the comparatively widespread distribution of *Anoplodactylus* species is commonly attributed to this process (see Bamber, 1998 for discussion).

Thus, the proximity and known distributions of most species would favour colonization by species from the east (Mediterranean, North Africa, Atlantic Southern Europe), and as far as we know this can be the only source of five of the species discussed above; Morton & Britton (2000) found that most components of the Azorean marine fauna show affiliation with the Mediterranean and southern Europe. However, the incidence of species recorded in the Americas in floating algae gives a mechanism for transport, which would argue for colonization from the west. In reality, pycnogonid colonization of the shallow water habitats of the Azores may be attributed to both processes. However, the mechanism of immigration from the east remains purely speculative.

For the species occurring in the 1996 and 1997 data in sufficient numbers for interpretation, no trends were detected in

relation to disturbance or exposure, although *Anoplodactylus amora* only occurred at non-polluted sites.

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