

Shallow water marine gammaridean amphipods of Pulau Tioman, Malaysia, with the description of a new species

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Abstract

Eleven taxa including one new species of gammaridean amphipods are reported from the waters of Pulau Tioman. The presence of *Tethygeneia sunda* **sp. n.** represents the first record of the genus from the South China Sea. Additional material of *Ampelisca brevicornis* (Costa, 1853); *Cymadusa vadosa* Imbach, 1967; *Paradexamine setigera* Hirayama, 1984; *Erichthonius pugnax* (Dana, 1853); *Leucothoe furina* (Savigny, 1816); *Microlysias xenokeras* (Stebbing, 1918); *Monoculodes muwoni* Jo, 1990 are identified from the South China Sea, supporting previous records by Lowry (2000), Huang (1994), Imbach (1967), Margulis (1968) and Nagata (1959). Three additional species, *Gitanopsis pusilla* K.H. Barnard, 1916, *Liljeborgia japonica* Nagata, 1965b and *Latigammaropsis atlantica* (Stebbing, 1888), whilst previously reported from the neighbouring waters, comprise new records for the South China Sea.

Keywords

South China Sea, Amphipoda, Gammaridea, taxonomy, new species, *Tethygeneia sunda*

Introduction

According to Lim et al. (2010), taxonomic knowledge on the gammaridean amphipods from the waters of Peninsular Malaysia has been poorly studied in the past. Whilst there have been several revisions of species or even genera around Malaysia, most of the studies have been of a sporadic nature, with miscellaneous small papers on various taxa (e.g Muller 1993; Othman and Morino 1996, 2006; Othman and Azman 2007; Tomikawa et al. 2007; Azman and Melvin 2011, and Azman and Othman 2012). All these indicate the regional gammaridean taxa are largely poorly known but likely to be diverse and potential diversity of species still waiting for our investigation.

Particular efforts in conducting more regional based studies should be emphasized to further advance the biodiversity knowledge of these numerically abundant and taxonomically diverse taxa. Hence, the result of this work should in addition to documenting the amphipod fauna, provide new insights into the diversity and distribution patterns of the South China Sea amphipods.

Located 2°35' north of the equator and in the South China Sea, Pulau Tioman (*pu-lau* = island) is an island of approximately 100 km² in area, lying 20 km off the south-eastern coast of the Malay Peninsular. Apart from its beautiful beaches and marine ecosystems, the marine areas around Pulau Tioman and eight other nearby islands (Pulau Tulai, Pulau Sepoi, Pulau Chebeh, Pulau Tokong Bahara, Pulau Sembilang, Pulau Sri Bulat, Pulau Labas and Pulau Gut) have also been gazzeted as marine parks and marine reserves under the Fisheries Act (1985). The establishment of the marine parks and marine reserves is to conserve, protect marine fauna and flora such as fishes, coral reefs and aquatic floras from being destroyed by fishing and other human activities.

In the framework of research on taxonomic revision and ecology of selected families of gammaridean amphipods conducted at Pulau Tioman, several qualitative benthic samples from different habitats and substrate types have been analysed. In some of these samples, specimens of gammaridean amphipods were found, one of which belongs to new species herein described, and for those species already known, the morphology of populations from Pulau Tioman are compared with other populations described in the literature. Due to the high importance of Pulau Tioman to maintain inventories for scientific marine studies in the Marine Protected Areas of Malaysia, we consider it important to include these species in this report, together with the description of the new taxa.

Material and methods

The material for the present study came from the following locations in the waters of Pulau Tioman, Pahang (2°48'22"N 104°10'13"E): Kampung Tekek, Renggis, Monkey Bay, Tulai, Tomok and Genting (Fig. 1). Samples of sea grasses, macroalgae, coral rubble, live corals and intertidal rocks were mainly obtained by SCUBA; amphipod specimens were collected by formalin-wash method (Myers 1985).

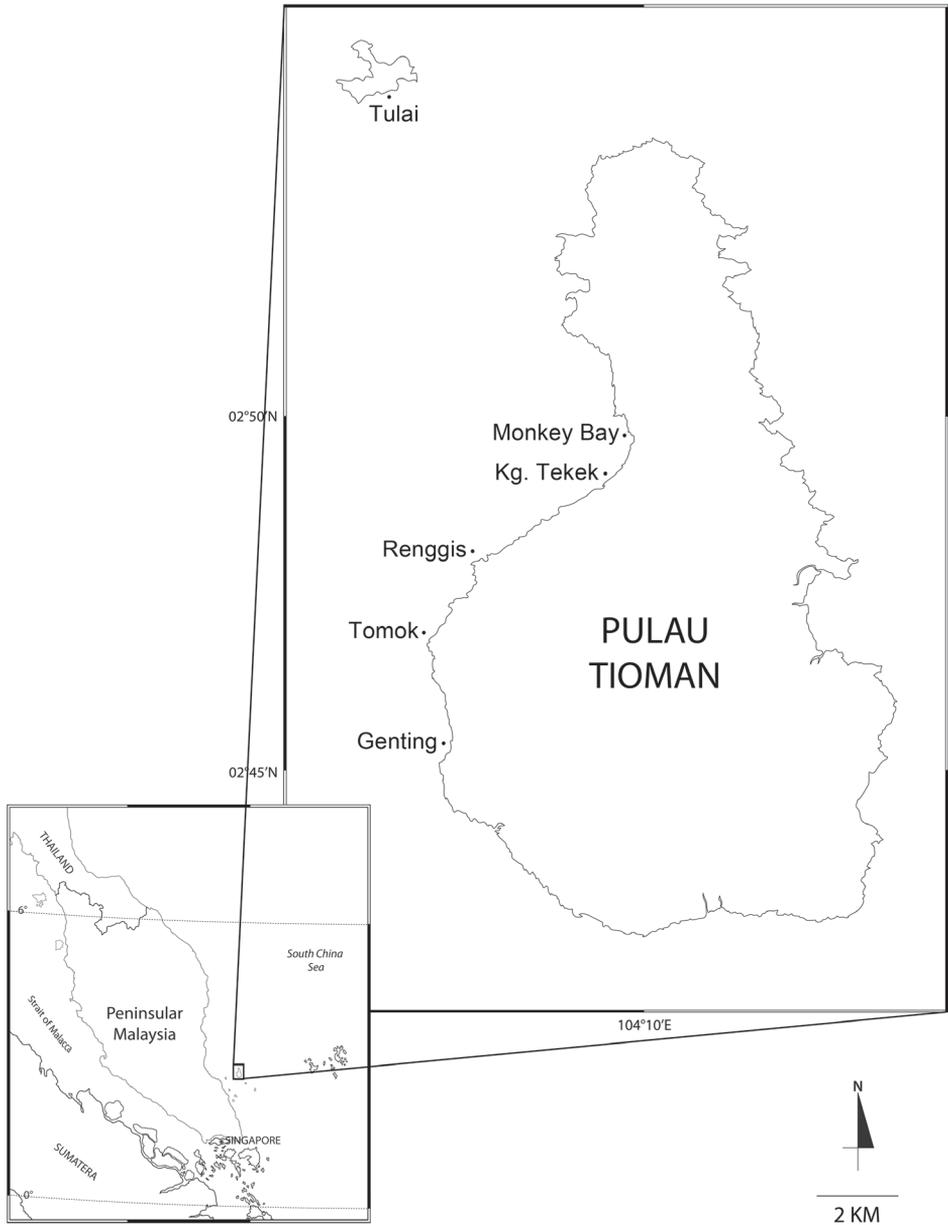


Figure 1. Study area with localities of sampling stations.

Whole animals were transferred into glycerol and drawn with a camera lucida on an Olympus SZX9 dissecting microscope. The specimens were dissected and appendages and mouthparts mounted onto slides in glycerol and drawn under a Leica DMLB light microscope using a camera lucida. Types have been deposited at Universiti Kebangsaan Malaysia Muzium Zoologi (UKMMZ); and the Australian Museum,

Sydney (AM). The following abbreviations are used in the figures. A, antenna; ABD, abdomen; EPIM, epimeron; G, gnathopod; HD, head; L, left; LL, lower lip; LM, lacinia mobilis; MD, mandible; MX, maxilla; MP, maxilliped; P, pereopod; PL, pleopod; PLN, pleonite; R, right; T, telson; U, uropod; UL, upper lip; ♂, male; ♀, female.

Results

Ampeliscidae Costa, 1857

Ampelisca brevicornis (Costa, 1853)

http://species-id.net/wiki/Ampelisca_brevicornis

Figure 2

Synonymy: *Araneops brevicornis* Costa, 1853: 171.

Ampelisca brevicornis (Costa, 1853): Chevreux and Fage 1925: 77–79; Schellenberg 1925: 130–133; Pirlot 1936: 277–278; Schellenberg 1942: 146–147; Reid 1951: 204–210; Nagata 1959: 265–266; Nagata 1965a: 150–151; Imbach 1967: 55–57, pl. 3; Kaim-Malka 1969: 928–932, 934, 953–958; Karaman 1975: 7–12; Rabindranath 1975: 257–261; Lincoln 1979: 112–113; Ledoyer 1982b: 56, 58–59; Hirayama 1991: 86. *Ampelisca* sp. cf. *brevicornis* (Costa, 1853).

Ampelisca laevigata Liljeborg, 1856: Sars 1895: 169–170, pl. 59.

Material. 5 specimens, TIO-15, Renggis, Pulau Tioman, 2°48'35"N, 104°8'6"E, washing mix sea grasses, Azman, B.A.R., Rayida, J., 15 July 1999.

Remarks. *Ampelisca brevicornis* is known to be a cosmopolitan species and has been collected from the soft substrata and water column from the littoral zone to the continental shelf from the waters of the world except for boreal areas (Rabindranath 1975; Lincoln 1979; Hirayama 1983). *A. brevicornis* was first recorded from the Mediterranean Sea (Costa 1853) by the name *Araneops brevicornis*; it occurs in waters of variable temperatures from north east Atlantic (Schellenberg 1925), south and west Norway (Sars 1895), Atlantic coast of Europe (Lincoln 1979), north Africa (Kaim-Malka 1969; Reid 1951), Indian Ocean (Rabindranath 1975), Japan (Nagata 1965a; Hirayama 1991), Indonesian archipelago (Pirlot 1936) as well as the neighbouring waters of Vietnam (Imbach 1967). Although several morphological variations in antennae, pleonal epimera and urosome are reported between European (Schellenberg 1925) and African specimens (Reid 1951), the present specimens agree in detail with descriptions by Imbach (1967) and Nagata (1959). Imbach (1967) discussed some of the variations concerning this particular species and refuted the idea of naming the existing ecophenotypes reported by Schellenberg (1925), Reid (1951), Dahl (1945) and Pirlot (1936) as a subspecies due to their insignificant distinctions.

Taking into consideration that *A. brevicornis* is one of the most popular inhabitants on a littoral sea bottom and widely distributed on the sea floor of the east coast (South China

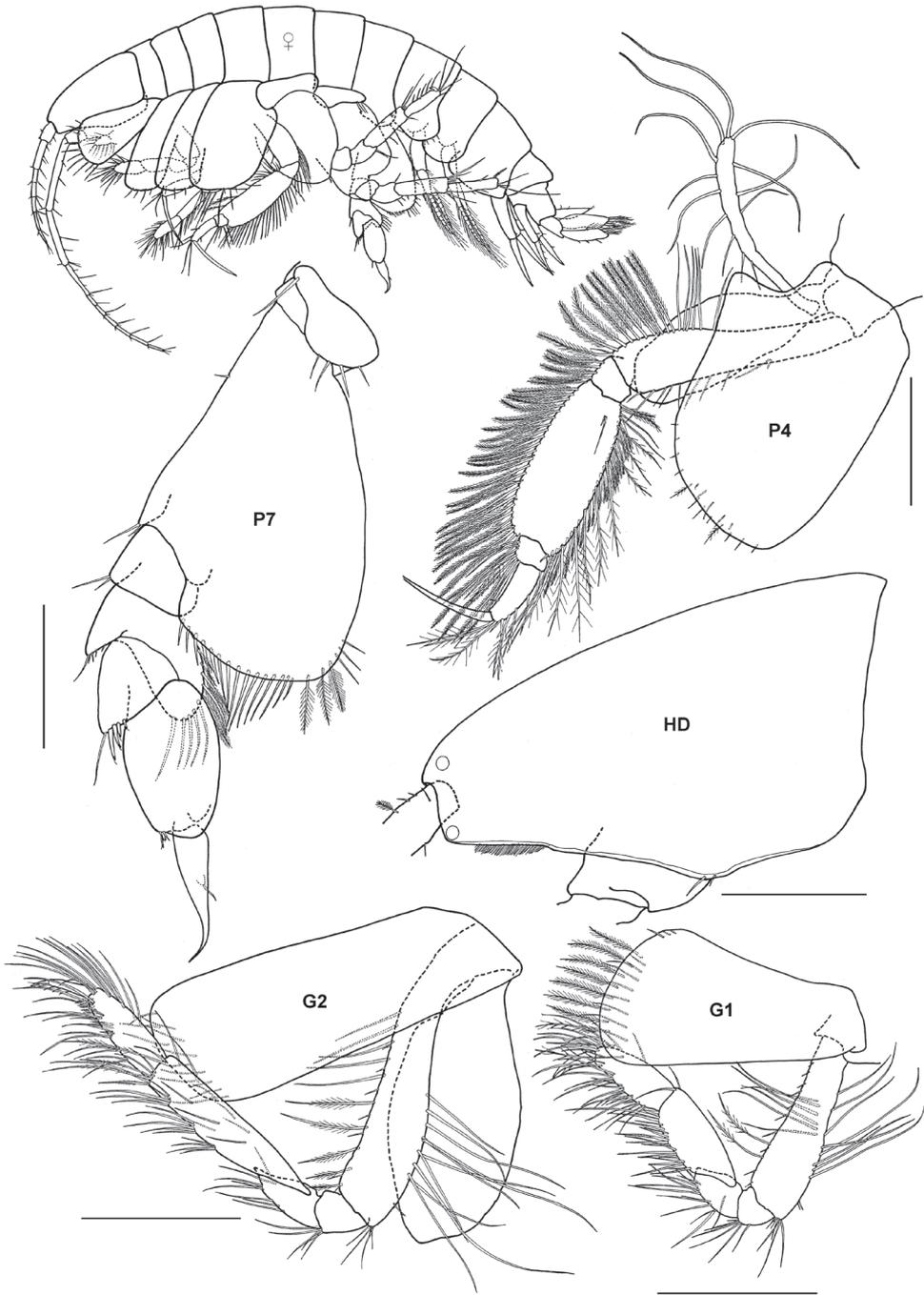


Figure 2. *Ampelisca brevicornis* (Costa), female (UKMMZ-1454), 4.8 mm. Renggis, Pulau Tioman. Scales for **G1**, **G2**, **P4**, **P7** represent 0.5 mm; **HD** scale = 0.2 mm.

Sea) and the west coast (Straits of Malacca) of Peninsular Malaysia, and numerous specimens have been meticulously examined, misidentification can be confidently ruled out. The specimens at hand show only minor disparities from Imbach's by having a broader propodus of pereopod 7, so it is clearly satisfactory to identify the specimens as *A. brevicornis*.

Amphilochidae Boeck, 1871

Gitanopsis pusilla K.H. Barnard, 1916

http://species-id.net/wiki/Gitanopsis_pusilla

Figure 3

Synonymy: *Gitanopsis pusilla* K.H. Barnard, 1916: 144, pl. 26 (11–12); Griffiths 1973a: 277; Griffiths 1974a: 178; Griffiths 1974b: 224; Griffiths 1974c: 273; Griffiths 1975: 105; Ledoyer 1979a: 17, fig. 3; Ledoyer 1982b: 104–105, fig. 33; Ortiz and Lalana 1997: 106.

Material. 5 specimens, TIO-12, Kampung Tekek, Pulau Tioman, 2°49'11"N, 104°9'32"E, macroalgae, Azman, B.A.R., Josim, J.J., 11 November 1997; 5 specimens, TIO-15, Renggis, Pulau Tioman, 2°48'35"N, 104°8'6"E, seagrass, Azman, B.A.R., Rayida, J., 15 July 1999.

Remarks. The specimens seem referable to the *G. pusilla* without much doubt. In amphiloichid amphipods, most species descriptions are based only on females, since the collection of males is rare. The female gnathopods are typical among amphiloichids in having a distally dilated propodus, an evenly convex palm and an elongate carpus. The specimens at hand are clearly related to the eastern Pacific species (K.H. Barnard 1916) in bearing the accessory flagellum of antenna 1. Ortiz and Lalana (1997) have reported *G. pusilla* and *G. antipai* from the neighbouring waters of Bunaken, Indonesia. In their illustration of *G. antipai*, the species is set apart from *G. pusilla* by the lack of an accessory flagellum, the relatively slender basis of pereopod 7 and the less spinose uropods 1–2.

Ampithoidae Stebbing, 1899

Cymadusa vadosa Imbach, 1967

http://species-id.net/wiki/Cymadusa_vadosa

Figure 4

Synonymy: *Cymadusa vadosa* Imbach, 1967: 89, pl. 32.

Material. 3 specimens, TIO 10, Kampung Tekek, Pulau Tioman, 2°49'11"N, 104°9'32"E, washing mix macroalgae, Azman, B.A.R., Josim, J.J., 11 November

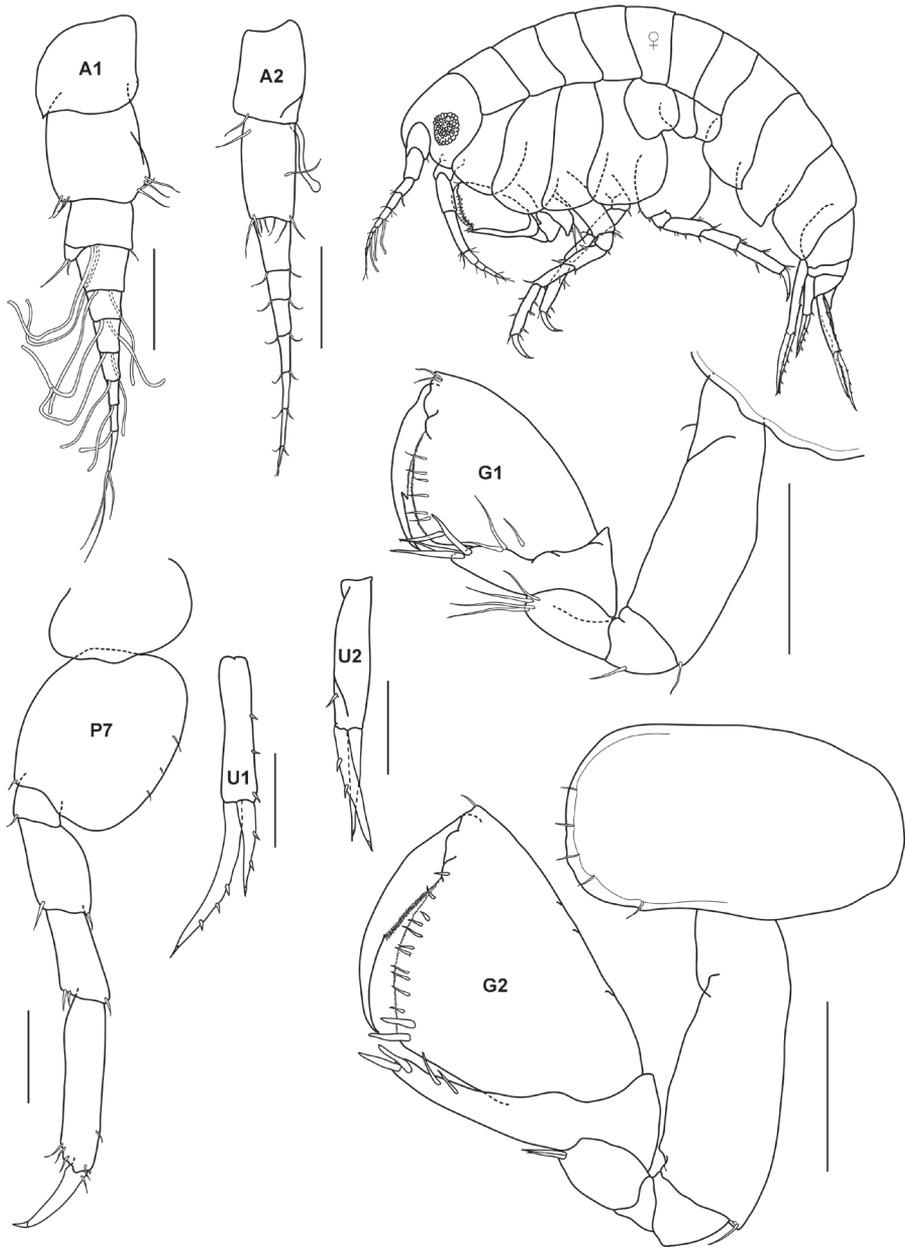


Figure 3. *Gitanopsis pusilla* K.H. Barnard, 1916, female (UKMMZ-1315), 1.7 mm. Kampung Tekek, Pulau Tioman. Scales for A1, A2, G1, G2, P7, U1, U2 represent 0.1 mm.

1997; 4 specimens, TIO 28, Tulai, Pulau Tioman, 2°54'44"N, 104°6'18"E, washing coral rubble, Azman, B.A.R, Kee, A.A., 19 October 2003; 13 specimens, TIO 29, Genting, Pulau Tioman, 2°45'42"N, 104°7'34"E, washing mix macroalgae, Azman,

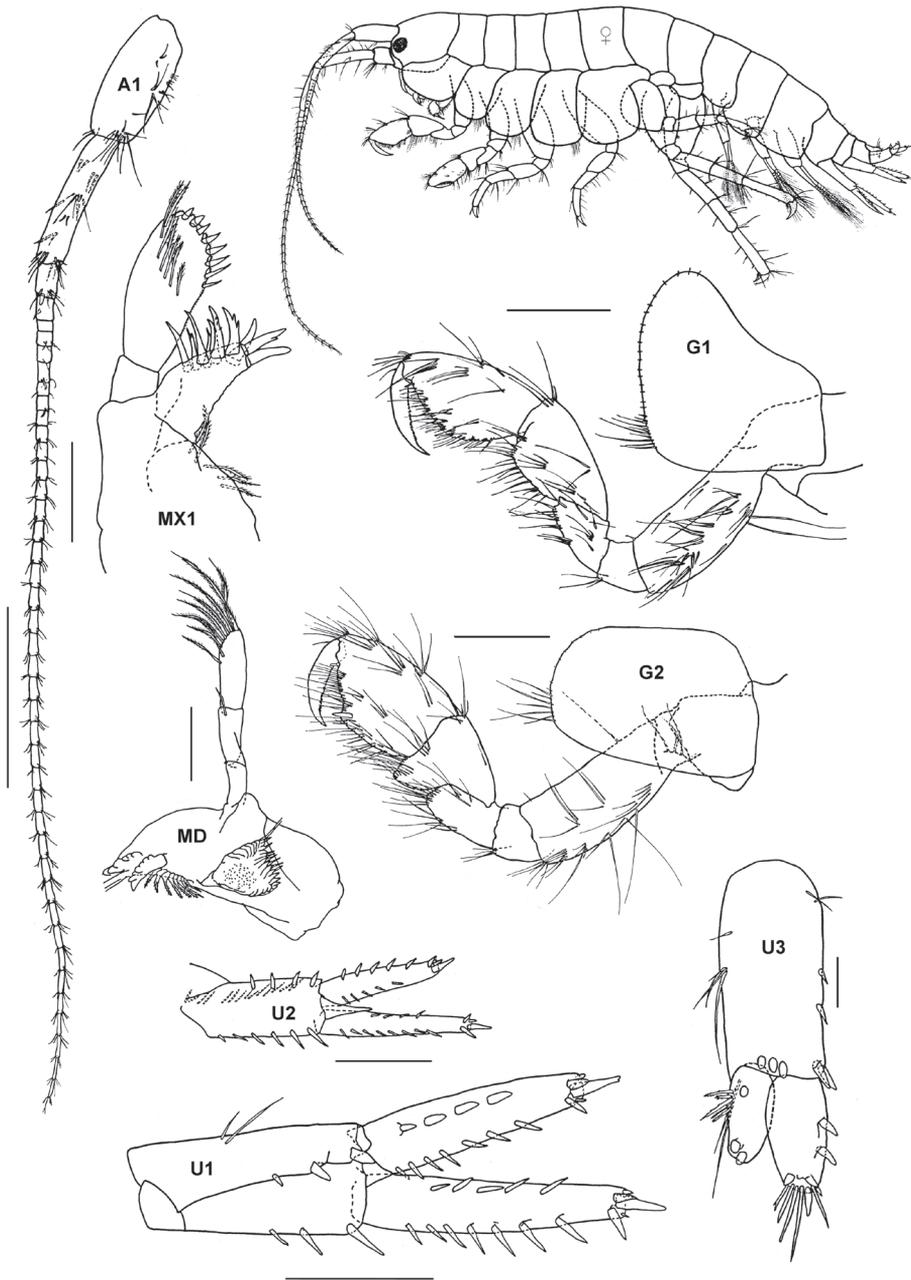


Figure 4. *Cymadusa vadosa* Imbach, 1967, female (UKMMZ-1266), 8.8 mm. Kampung Tekek, Pulau Tioman. Scale for A1, G1, G2 represents 0.5 mm; MX1, MX2 scale = 0.25 mm; U1–U3 scale = 0.2 mm.

B.A.R., Kee, A.A., 19 October 2003; 5 specimens, TIO 30, Genting, Pulau Tioman, 2°45'42"N, 104°7'34"E, washing mix macroalgae, Azman, B.A.R., Kee, A.A., 20 October 2003.

Remarks. The well-developed sharp spur on the peduncle of uropod 1 distinguishes the present specimens from the genera *Ampithoe* Leach, 1814; *Macropisthopous* K.H. Barnard, 1916; *Amphitholina* Ruffo, 1953; *Pseudopleonexes* Conlan, 1982; *Pseudoamphitoides* Ortiz, 1976; *Exampithoe* K.H. Barnard, 1926 and *Melanesius* Ledoyer, 1984. Moreover, the expanded propodus of gnathopod 1 with an oblique palm was found to be a sound character in *Peramphithoe* Conlan & Bousfield, 1982 used in separating *Cymadusa* from *Peramphithoe* (Barnard & Karaman, 1991). *Cymadusa* differs from *Amphithoides* Kossmann, 1880 by having narrow rami of uropod 3 and the absence of telsonic lobes. Moreover *Paragrubia* Chevreux, 1901 differ from *Cymadusa* by having gnathopod 1 larger than gnathopod 2 and in having a multi-articulate accessory flagellum (Poore and Lowry 1997). *Sunamphitoe* Bate, 1857 varies from *Cymadusa* by the absence of a mandibular palp.

Barnard and Karaman (1991) have listed fourteen species of *Cymadusa*, mainly marine and throughout the tropics. Since then another species, *C. munnu* (Poore & Lowry, 1997) was described from Port Jackson, New South Wales, Australia. Imbach (1967) illustrated *Cymadusa vadosa* on the basis of specimens from south-east Asia region, which he identified with *C. filosa* (Savigny, 1935), *C. hawaiiensis* (Schellenberg, 1938), *C. australis* (K.H. Barnard, 1916), *C. sardenta* (Oliveira, 1953), *C. brevidactyla* (Chevreux, 1908), *C. variata* (Sheard, 1936), *C. oceanica* (J.L. Barnard, 1955) and *C. crassicornis* (Costa, 1853), noting some minor differences between them. *C. vadosa* differs from *C. filosa*, *C. hawaiiensis*, *C. australis*, *C. compta*, and *C. microphthalma* by gnathopod 1 with article 5 shorter than article 6.

The Pulau Tioman specimens also appear to be very close to *C. filosa* in having; (1) accessory flagellum with 1 articulate; (2) peduncle of uropod 1 with strong, acute, distoventral interramal process; (3) uropod 2 with short triangular inter-ramal process.

In all probability, this material from Pulau Tioman is very similar to Imbach's illustrations in having; (1) article 2 of mandibular palp three fourths as long as article 3; (2) maxilliped extends beyond palp article 2; (3) accessory flagellum with 1 articulate; (4) article 5 shorter than article 6 of gnathopod 1; (5) rami of uropod 3 two thirds as long as peduncle; (6) peduncle of uropod 1 with strong, acute, distoventral interramal process; (7) uropod 2 with short triangular interramal process.

Dexaminidae Leach, 1814

Paradexamine setigera Hirayama, 1984

http://species-id.net/wiki/Paradexamine_setigera

Figure 5

Synonymy: *Paradexamine setigera* Hirayama, 1984: 225–230; Hirayama 1986: 488.

Material. 24 specimens, TIO 10, Kampung Tekek, Pulau Tioman, 2°49'11"N, 104°9'32"E, washing mix species of macroalgae, Azman, B.A.R., Josim, J.J., 11 November 1997, UKM I.D. 4891-4898.

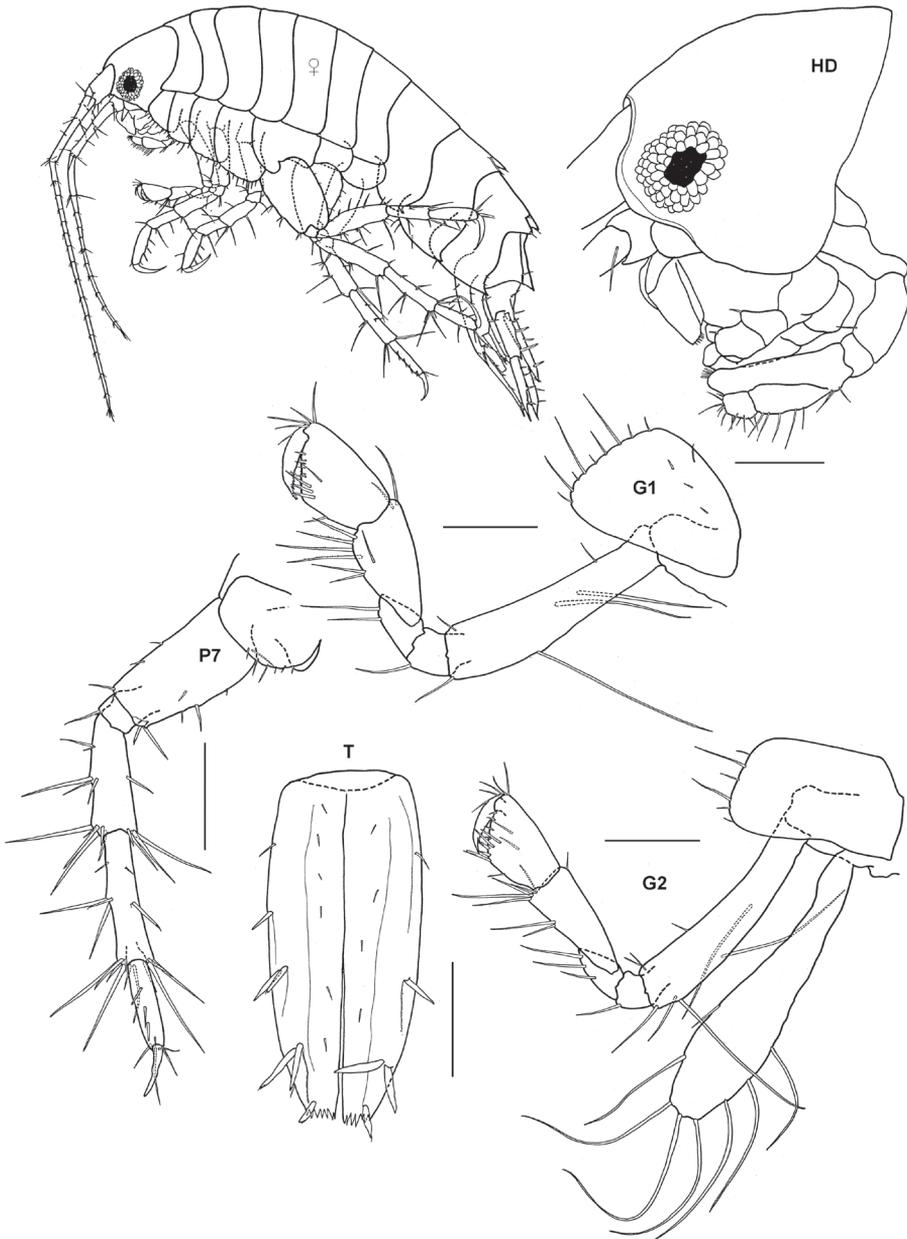


Figure 5. *Paradexamine setigera* Hirayama, 1984, male, (UKMMZ-1259), 2.1 mm. Kampung Tekek, Pulau Tioman. Scales for **G1**, **G2**, **HD**, **T** represent 0.1 mm; **P7** scale = 0.2 mm.

Remarks. The Malaysian specimens differ from those described from the waters of Japan only by the lack of the accessory setae of the mandible. At present, this seems inadequate for subspecific distinction due to the enormous resemblance of other char-

acters shared between them. Even though Hirayama (1984) mentioned the closely related *P. micronesica*, it also lacks the accessory setae of the mandible. Furthermore, the Pulau Tioman specimens show several differences from *P. micronesica* by having; 1) slenderer basis of pereopod 7; 2) several robust setae on dorsal surface of telson; 3) shorter carpus of male gnathopod 2.

Ischyroceridae Stebbing, 1899

Erichthonius pugnax (Dana, 1853)

http://species-id.net/wiki/Erichthonius_pugnax

Figure 6

Synonymy: *Pyctilus macrodactylus* Dana, 1853: 974.

Erichthonius macrodactylus Stebbing, 1906: 672; Walker 1904: 292, fig. 48.

Erichthonius pugnax Stebbing, 1906: 672; Pirlot 1938: 352; Hurley 1954: 445, figs 40–61; Nagata 1960: 179, pl. 179, figs 99–102; Nagata 1965b: 320, fig. 40; Nayar 1967: 162; Ledoyer 1969: 179, fig. 1; Hirayama 1985: 52, Ledoyer 1982a: 628, fig. 239; Moore 1988: 727–730, fig. 14; Kim and Kim 1991: 246–247, figs 13–14.

Material. 2 specimens, TIO 5, Monkey Bay, Pulau Tioman, 2°49'33"N, 104°9'45"E, coral rubble, Azman, Josim, 22 August 1996; 86 specimens, TIO 15, Renggis, Pulau Tioman, 2°48'35"N, 104°8'6"E, seagrass, Azman, Rayida, 15 July 1999, UKM I.D. 5712–5719; 2 specimens, TIO 33, Tomok, Pulau Tioman, 2°47'38"N, 104°7'16"E, live corals (*Porites* sp., *Montipora* sp., *Acropora* sp.), Azman, B.A.R, Kee, A.A., Zuhaimi, S., Maekawa, T., Okashita, T., 22 March 2004.

Remarks. The Pulau Tioman specimens agree well with figures of *E. pugnax* from Walker (1904), Nagata (1960, 1965c), Ledoyer (1982c) and Moore (1988). This species seems to have a wide-ranging distribution as far as the Arabian Sea. From closer examination of the specimens, the males not only have distally bidentate carpal spur of gnathopod 2 but also a mixture of single dentate carpal spur (see also Nagata 1960; Ledoyer 1969, 1986). As mentioned by Moore (1988) the carpal bidentate spur of gnathopod 2 will eventually be lost in hyperadult males. Unfortunately the stipulation over hyper adult morphological changes has brought several descriptions of new species that actually represented a single species (i.e. *E. macrodactylus*). Prior to this, Ledoyer (1969) synonymized *E. macrodactylus* as a hyperadult form of *E. pugnax*. Examination of the Pulau Tioman specimens confirms the presence of this hyper adult morphology: that the basis of pereopod 5 possesses a strongly developed posterodistal lobe. The Pulau Tioman specimens are undoubtedly assigned to *E. pugnax* and constitute the first record of this species for Peninsular Malaysia.

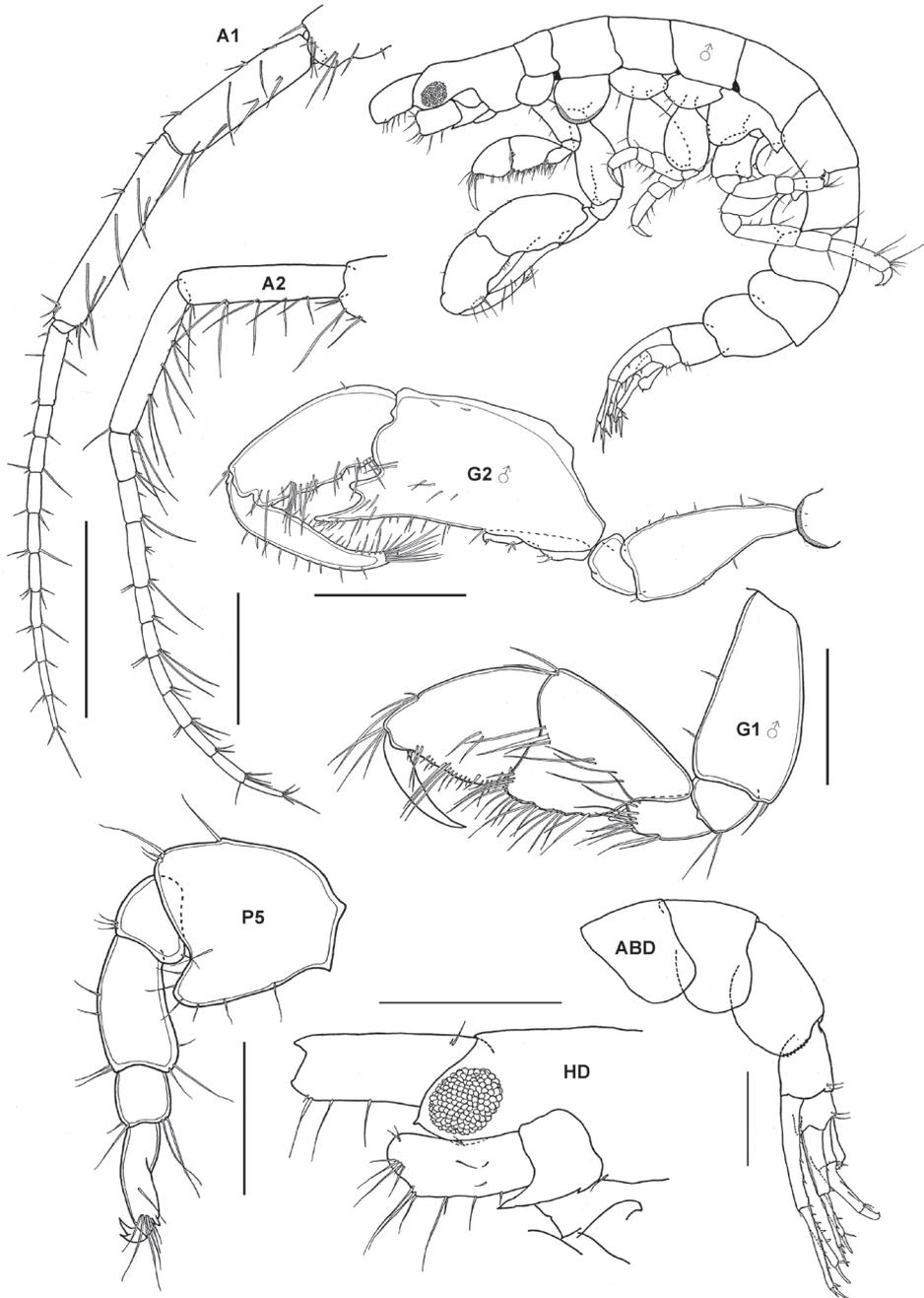


Figure 6. *Erichthonius pugnax* (Dana, 1853), male, (UKMMZ-1136), 3.8 mm. Pulau Tioman, South China Sea. Scale for **G2** ♂ represents 0.6 mm; **A1**, **A2** HD and **ABD** scales = 0.5 mm, **G1** ♂ scale = 0.25 mm; **P5** scale = 0.2 mm.

Leucothoidae Dana, 1852***Leucothoe furina* (Savigny, 1816)**

http://species-id.net/wiki/Leucothoe_furina

Figure 7

Synonymy: *Leucothoe hornelli* Walker, 1904: 258–259, pl. 3, fig. 17.

Leucothoe furina (Savigny). Cecchini 1929: 771–773; K.H. Barnard 1931: 120; K.H. Barnard 1937: 152; Pirlot 1936; Ruffo 1938: 156; Nayar 1967: 142, fig. 5d; Imbach 1967: 79, pl. 21; Rabindranath 1967: 387–388, fig. 3; Bussarawich et al. 1984: 4.

Material. 4 specimens, TIO 28, Tulai, Pulau Tioman, 2°54'44"N, 104°6'18"E, coral rubble, Azman, B.A.R., Kee, A.A., 19 October 2003; 1 specimen, TIO 31, Tomok, Pulau Tioman, 2°47'38"N, 104°7'16"E, live corals (*Porites* sp., *Montipora* sp., *Acropora* sp.), Azman, B.A.R., Kee, A.A., Zuhaimi, S., Maekawa, T., Okashita, T., 22 March 2004.

Remarks. Referred to many times in the literature from Thailand, this is the first record of *L. furina* from the intertidal area of the Peninsular Malaysia. The synonymy of this circumtropical species was discussed by Rabindranath (1967). The Pulau Tioman material agrees with the earlier descriptions of Nayar (1967), Imbach (1967) and Rabindranath (1967) with a few variations. The minute accessory flagellum, stouter palp of the mandible, and spinose uropod 1 agrees well with Imbach's specimen. The gnathopod 2 is unlike Imbach's illustration, however the nearly smooth palm is also observed in Nayar's illustration.

Liljeborgiidae Stebbing, 1899***Liljeborgia japonica* Nagata, 1965b**

http://species-id.net/wiki/Liljeborgia_japonica

Figure 8

Synonymy: Nagata 1965b: 160–164, figs 11–12.

Material. 2 specimens, TIO 34, Tomok, Pulau Tioman, 2°47'38"N, 104°7'16"E, live corals (*Porites* sp., *Montipora* sp., *Acropora* sp.), Azman, B.A.R., Kee, A.A., 22 March 2004.

Remarks. The Pulau Tioman material accords well with the description and figures of Nagata (1965b). This is the first record of the species outside Japan.

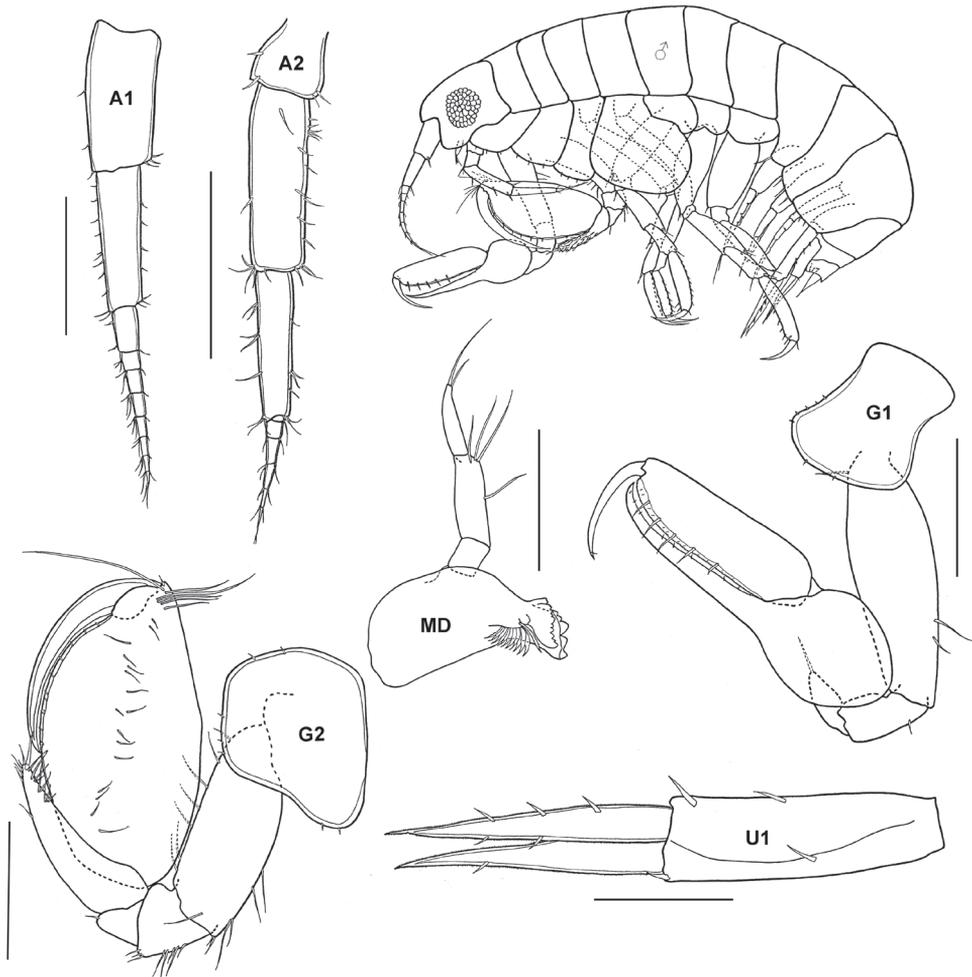


Figure 7. *Leucothoe furina* (Savigny, 1816), male, (UKMMZ-1459), 3.7 mm, Tulai, Pulau Tioman. Scales for MD and U1 represent 0.25 mm; G1, G2, A1 and A2 scales = 0.5 mm.

Lysianassidae Dana, 1849

Microlysias xenokeras (Stebbing, 1918)

http://species-id.net/wiki/Microlysias_xenokeras

Figure 9

Synonymy. *Microlysias xenokeras* (Stebbing), 1918: 64, pl. 10; K.H. Barnard 1937: 144; Griffiths 1973b: 293–294, fig. 9; Griffiths 1975: 148 – 149.

Material. 3 specimens, TIO 28, Tulai, Pulau Tioman, 2°54'44"N, 104°6'18"E, coral rubble, Azman, B.A.R., Kee, A.A., 19 October 2003.

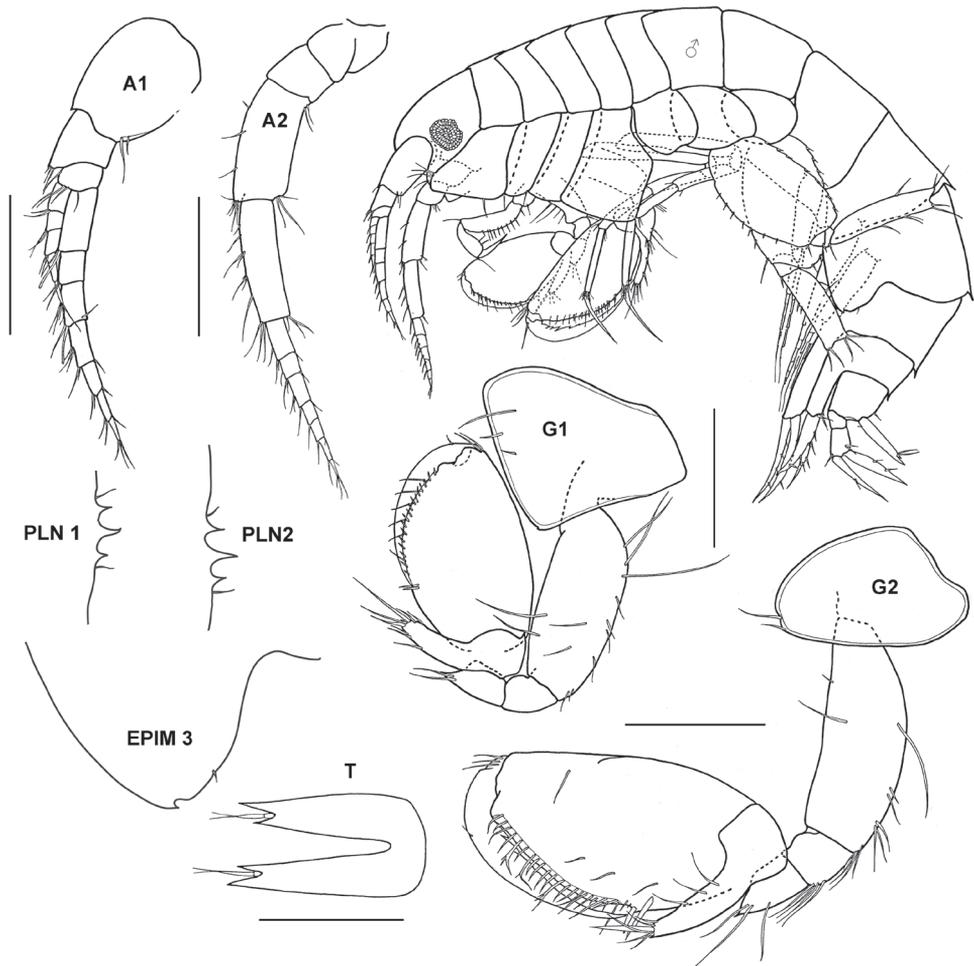


Figure 8. *Liljeborgia japonica* Nagata, 1965, male, (UKMMZ-1224), 3.2 mm. Tomok, Pulau Tioman. Scales for A1, A2, G1 and G2 represent 0.25 mm; T scale = 0.1 mm.

Remarks. Griffiths (1975) re-examined this species after discovering an erroneous identification in his earlier publication (see Griffiths 1973a) was based on Barnard's (1937) *M. indica*. Specimens from Durban Bay, described by Stebbing were the same as Griffiths's *M. xenokeras*. *M. xenokeras* is the only species in the genus known thus far, and has only been recorded in from the waters of South Africa and Mozambique. It has quite distinctive characters: 1) antenna 1 short and stout, 2) gnathopod 2 minutely chelate, 3) uropod 3 outer ramus 2-articulate, 4) telson with short robust setae dorsally and apically.

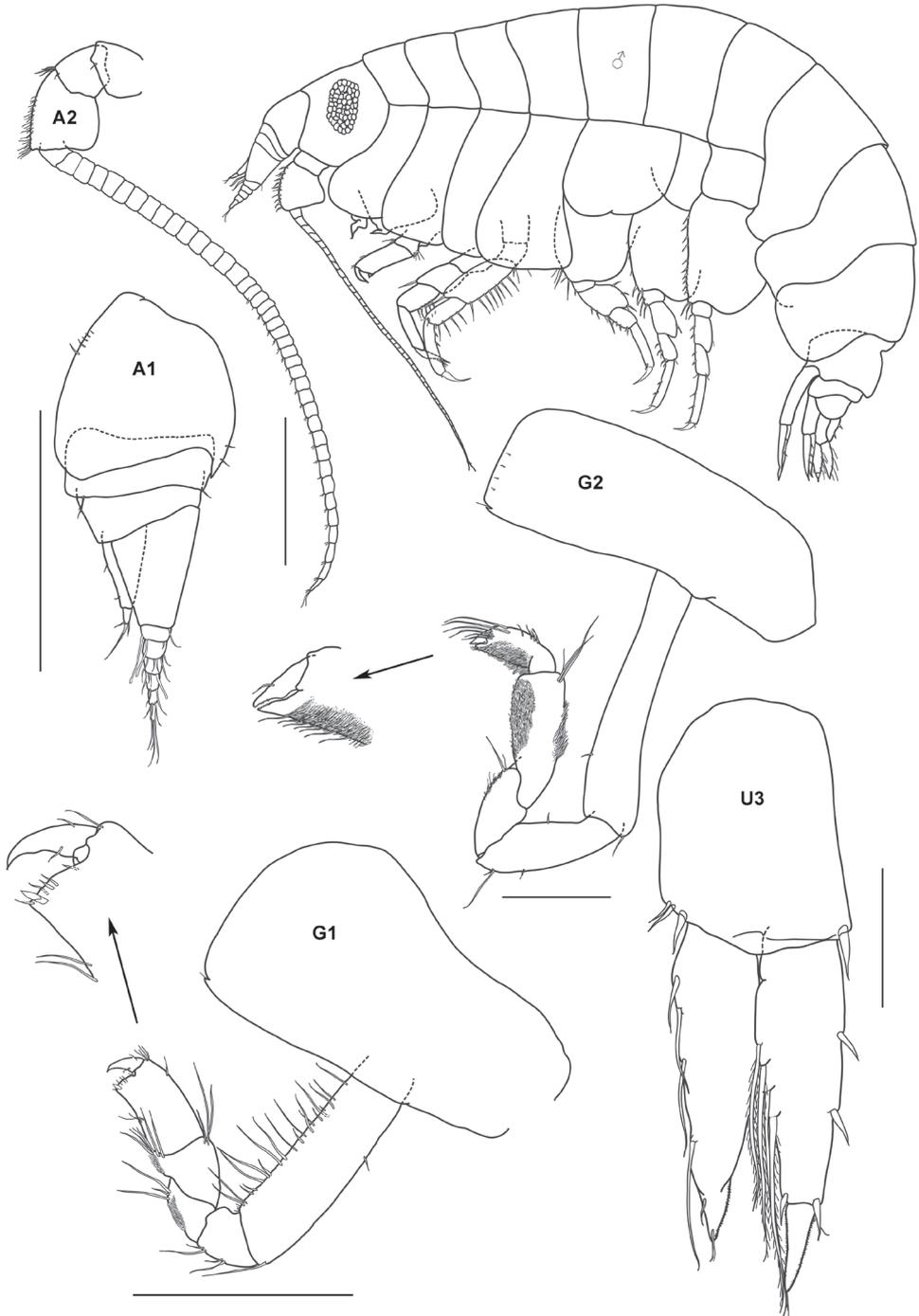


Figure 9. *Microlysias xenokeras* Stebbing, male (UKMMZ-1464), 4.2 mm. Tulai, Pulau Tioman. Scales for A1, A2, G1 and G2 represent 0.5 mm; U3 scale = 0.1 mm.

Oedicerotidae Liljeborg, 1865***Monoculodes muwoni* Jo, 1990**

http://species-id.net/wiki/Monoculodes_muwoni

Figure 10

Synonymy: *Monoculodes muwoni* Jo, 1990: 164–168, figs 5–7.

Material. 10 specimens, TIO 3, Monkey Bay, Pulau Tioman, 2°49'33"N, 104°9'45"E, coral rubble, Azman, B.A.R., Josim, J.J., 22 August 1996; 1 specimen, TIO 21, Renggis, Pulau Tioman, 2°48'35"N, 104°8'6"E, seagrass, Azman, B.A.R., Rayida, J., 15 July 1999.

Remarks. The Pulau Tioman specimens closely resemble Jo's (1990) figures described from the Korean peninsula; since then it has not been recorded anywhere else. The short and rather stout rostrum, propodus length of gnathopod 2, parallel sided telson and poorly produced posterodistal corner of coxal plate 4 are several characters unique to this species. However, the identification is not fully satisfactory in the following respects: the long carpal lobes of gnathopods and the double spine rows of the inner ramus of uropod 2. Otherwise, all specimens agree with *M. muwoni*.

Photidae Boeck, 1871***Latigammaropsis atlantica* (Stebbing, 1888)**

http://species-id.net/wiki/Latigammaropsis_atlantica

Figure 11

Synonymy: *Gammaropsis atlantica* Stebbing, 1888: 1101, pl. 114; Ruffo 1969: 43, fig. 13; J.L. Barnard 1970: 174, figs 111–113; Ledoyer 1972: 239, pl. 51–53; Griffiths 1973a: 228; Ledoyer 1979b: 33, figs 13–15; Bussarawich et al. 1984: 4; Myers 1985b: 80, fig. 60; Myers 1995: 52–52, fig. 20; Ortiz and Lalana 1997: 107.

Gammaropsis zeylanicus Walker, 1904: 282, pl. 6 fig. 41; Walker 1909: 339.

Gammaropsis gardineri Walker, 1905: 929, pl. 88 figs 11–14, 16–17.

Gammaropsis atlanticus Stebbing, 1906: 611; Stebbing 1908: 86, pl. 40b; Stebbing 1910: 614, 648; Chilton 1921: 81; Tattersall 1922: 10, pl. 1 figs 17–20; Schellenberg 1926: 375; Hale 1927: 315; Chevreux 1927: 110; Hale 1929: 223, fig. 220. Chevreux 1935: 126; K.H. Barnard 1937: 164; Pirlot 1938: 346; Reid 1951: 258; Pillai 1957: 56, fig. 14; Ruffo 1959: 19; Nayar 1967: 157–158, fig. 13.

Material. 5 specimens, TIO 12, Kampung Tekek, Pulau Tioman, 2°49'11"N, 104°9'32"E, macroalgae, Azman, B.A.R., Josim, J.J., 11 November 1997.

Remarks. Recently Myers (2009) established the genus *Latigammaropsis* to address J.L. Barnard's (1970) trepidation on the confusion surrounding the tropical members

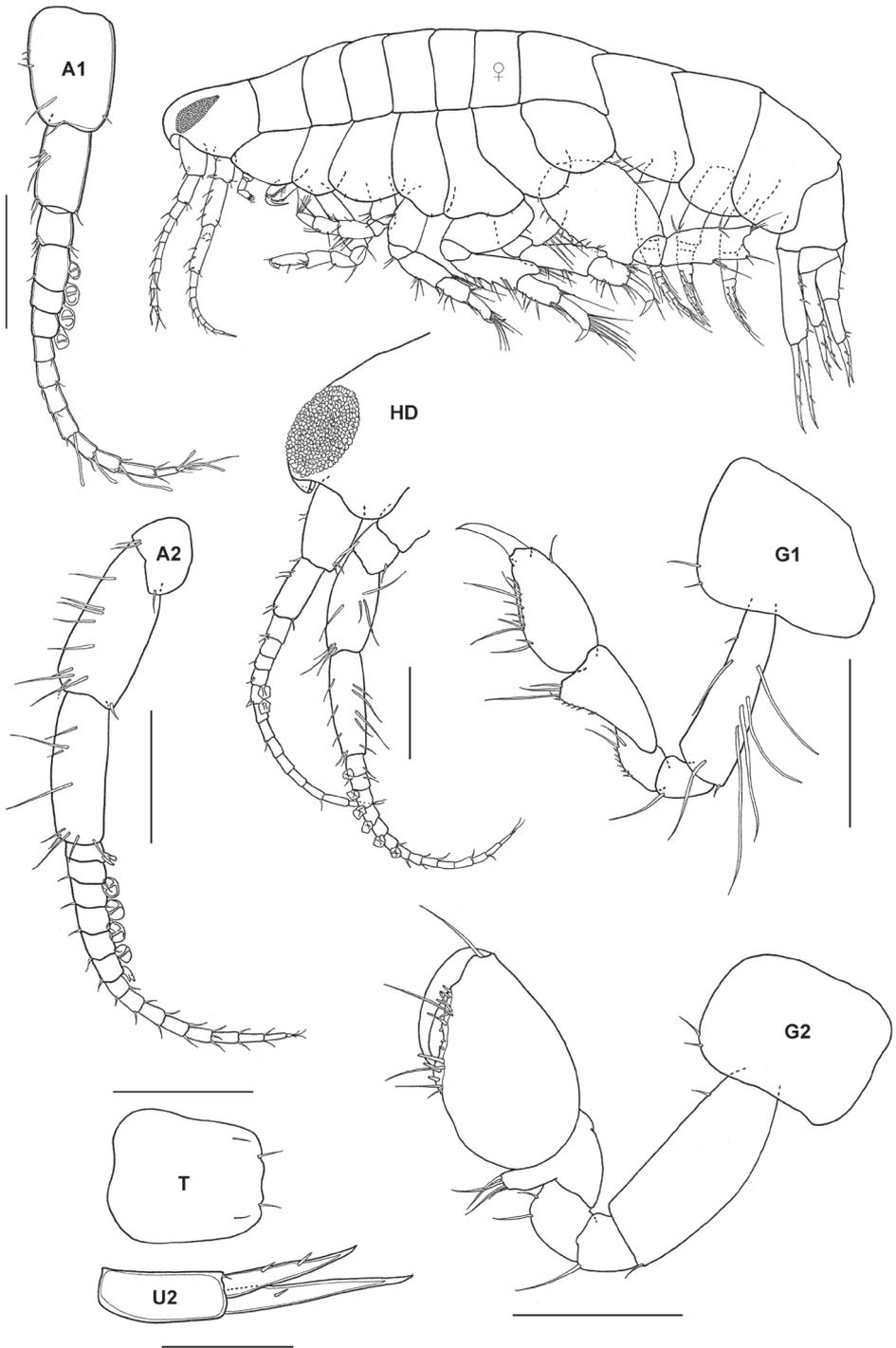


Figure 10. *Monoculodes muwoni* Jo, 1990, female (UKMMZ-1469), 3.3 mm. Monkey Bay, Pulau Tioman. Scales for A1, A2, HD, G1, G2, U2 and T represent 0.25 mm.

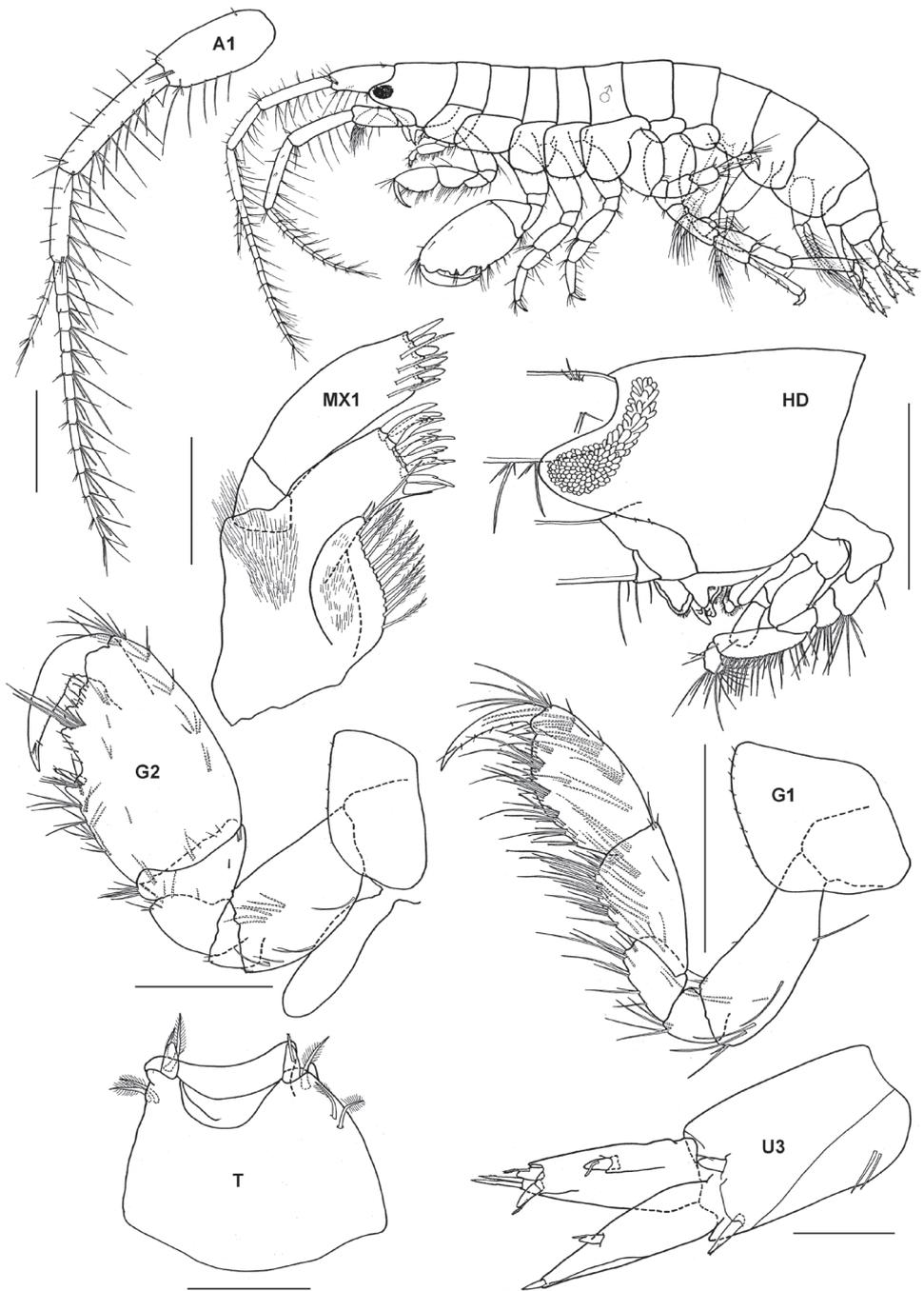


Figure 11. *Latigammaropsis atlantica* (Stebbing), male (UKMMZ-1161), 5.1 mm. Kampung Tekek, Pulau Tioman. Scales for A1, G1, G2 and HD represent 0.5 mm; T and U3 scales = 0.1 mm.

of the *afra-atlantica* complex, in relation to *Latigammaropsis atlantica* (Stebbing, 1888) and *L. afra* (Stebbing, 1888). The newly proposed *Latigammaropsis* is characterised by the strongly recessed anterodistal margin of the head; lateral cephalic lobes rounded; labrum lacking acute epistome; mandible palp article 3 spatulate; coxae 1–2 without serrations on distal margin; pleon segments lacking spines; uropod 3 peduncle short and broad, rami short and stout; outer ramus blunt-ended with a small second article bearing two fine setae and inner ramus subequal with or shorter than outer ramus, narrowing distally. Which include 16 species namely *Latigammaropsis abbotti* (J.L. Barnard, 1965), *L. afra*, *L. athenae* Myers, 2009, *L. atlantica*, *L. christensenii* (Myers, 1995), *L. dionysus* Myers, 2009, *L. gemina* (Myers, 1995), *L. grandimana* (Ledoyer, 1978), *L. hermes* Myers, 2009, *L. hestia* Myers, 2009, *L. kaumaka* (J.L. Barnard, 1970), *L. pacifica* (Schellenberg, 1938), *L. pali* (J.L. Barnard, 1970), *L. photisimilis* (Ruffo, 1969), *L. planodentata* (Myers, 1995) and *L. togoensis* (Schellenberg, 1925).

The Pulau Tioman specimens undoubtedly represent the tropical members (*afra-atlantica* group) by having an article 2 on the outer ramus of uropod 3 and the inner plate of maxilla 1 has at least 3, often 5+ setae lining the medial margin (Barnard 1970). The presence of the lageniform eye links the specimens at hand with, *L. afra*, *L. athenae* Myers, 2009, *L. atlantica*, *L. photisimilis* (Ruffo, 1969) and *L. hestia* Myers, 2009.

Although the Pulau Tioman specimens are more closely related to *L. gemina*, with the accessory flagellum with 4 articles, inner plate of maxilla 1 with 5+ setae lining the medial margin and occurrence of nobs on the urosomal margin. *L. gemina* still does not agree with the specimens at hand in having oval eyes and the telson lacking medial setae.

Nevertheless the specimens at hand are apparently very close to *L. atlantica* in having 1) ocular lobes strongly produced with lageniform eye in hyperadults; 2) antenna 2 shorter than antenna 1; 3) male gnathopod 2 with propodus a little longer than carpus; 4) uropod 1 with strong interramal process, two-thirds length of peduncle; 5) uropod 3, peduncle and outer ramus subequal in length with outer ramus stouter than inner with a small second article and 6) telsonic crests with spines and setae. In addition, the Pulau Tioman specimen appears to be referable to the other known *L. atlantica* that have been recorded from Japan, Bunaken Island, Indonesia, Madras and South Africa.

Family Pontogeniidae Stebbing, 1906

Genus *Tethygeneia* J.L. Barnard, 1972

Tethygeneia sunda sp. n.

<http://zoobank.org/51D2394A-BF87-49C5-BB06-8F743D836B8A>

http://species-id.net/wiki/Tethygeneia_sunda

Figures 12; 13; 14

Type material. Holotype, male, body length 4.5 mm (from tip of rostrum to apex of telson) (Ref: UKMMZ-1252).

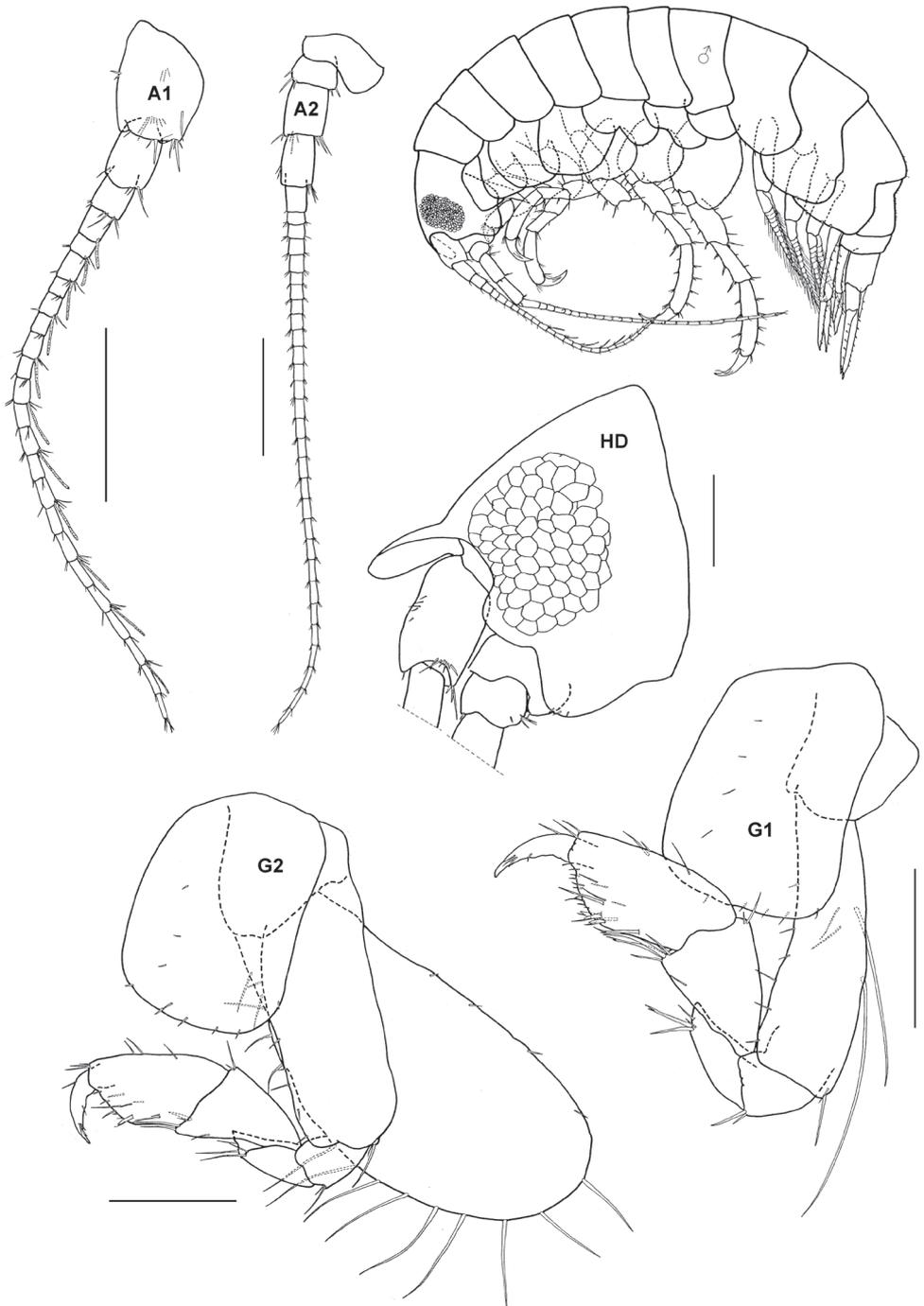


Figure 12. *Tethygeneia sunda* sp. n., holotype, male (UKMMZ-1252), 4.5 mm. Marine Park, Pulau Tioman. Scales for A1 and A2 represent 0.5 mm; G1, G2 and HD scales = 0.25 mm.

Type locality. Marine Park, Pulau Tioman, (2°49'48"N, 104°9'48"E) Peninsular Malaysia; intertidal rocks; coll. Azman, B.A.R., Jusim, J.J., 23 August 2001, UKM I.D. 6687.

Additional material examined. 32 specimens, TIO 22, Marine Park, Pulau Tioman, 2°49'48"N, 104°9'48"E, intertidal rocks, Azman, B.A.R., Jusim, J.J., 23 August 2001.

Diagnosis. Rostrum long and linguiform. Accessory flagellum absent. Maxilla 1, palp article 2 stout armed with several short teeth apically. Maxilla 2, outer plate broader than inner plate, both with plumose setae along margin. Lower lip lacking inner lobes. Mandible palp article 2 long. Gnathopod 2 lacking carpal lobe, more slender articles of carpus and propodus. Pereopods 3-4 with pair of stout locking spines. Telson cleft, lacking large spines on apices.

Description. Male: 4.5 mm. Head, rostrum large, long, curved down, apically blunt, lateral cephalic lobe broad, shallow, quadriform, defined below by weak but sharp incision; antero-ventral margin bulbous, rounded. Eye large, occupying more than half of head area.

Antenna 1 only about 70 percent as long as antenna 2; flagellum with about 21-articulate, ornamented with aesthetascs ventrally; accessory flagellum absent. Antenna 2 about half as long as body; gland cone of peduncular article 2 broad, extending beyond of peduncle article 3; flagellum long and thin with about 28 articles.

Mandible, molar triturrative, each with ragged seta; lacinia mobilis serrate and clearly distinct; palp with article 2 about twice as broad as article 3, latter slightly falcate. Lower lip lacking inner lobes, mandibular lobes subtruncate and apically fringed with small setae. Maxilliped inner plate with apicolateral spine separated from 2 medioapical spines by gap and hollow; outer plate with facial setules in 1 row and a few scattered; palp article 2 broad. Maxilla 1, palp article 2 stout armed with several short teeth apically. Maxilla 2, outer plate broader than inner plate, both with plumose setae along margin.

Gnathopod 1-2 small, subequal in size to each other, basis scarcely setose posteroventrally; propodus long, thin, sub-rectangular, palm evenly oblique.

Gnathopod 1 carpus sub-triangular, posterior margin short, lobe extended; dactylus not serrate on grasping margin. Gnathopod 2 similar to gnathopod 1. Pereopods 1-7 elongate. Pereopods 3-4 homopodous; merus slightly expanded posterodistally; carpus about ½ the length of propodus. Pereopods 5-7 homopodous; basis expanded roundly. Pereopod 7 similar but longer than pereopod 6; basis more elongate than pereopod 6.

Uropod 1 peduncle spinose on lateral margin, almost 2 times as long as outer ramus, one medium sized robust seta at distal part; outer ramus about 0.7 times as long as inner ramus, apex bifid, armed with several apical spines, one elongate. Uropod 2 extending beyond telson; peduncle subequal in length to inner ramus, spinose, and with one long robust seta at distal end; outer ramus almost 0.6 times as long as inner ramus with several apical robust setae; inner ramus apically bifid with several robust setae along margin. Uropod 3 peduncle short; rami foliaceous, subequal in length, marginally spinose and setose. Telson flat, broad, cleft more than halfway, apices slightly rounded, broad, smooth, lateral margins of lobes with 2 pairs of partial sets of fine short setae.

Remarks. J.L. Barnard (1972) proposed the genus *Tethygeneia* to group the existing eusiriid amphipods that are limited to a Tethyan distribution, referring to the

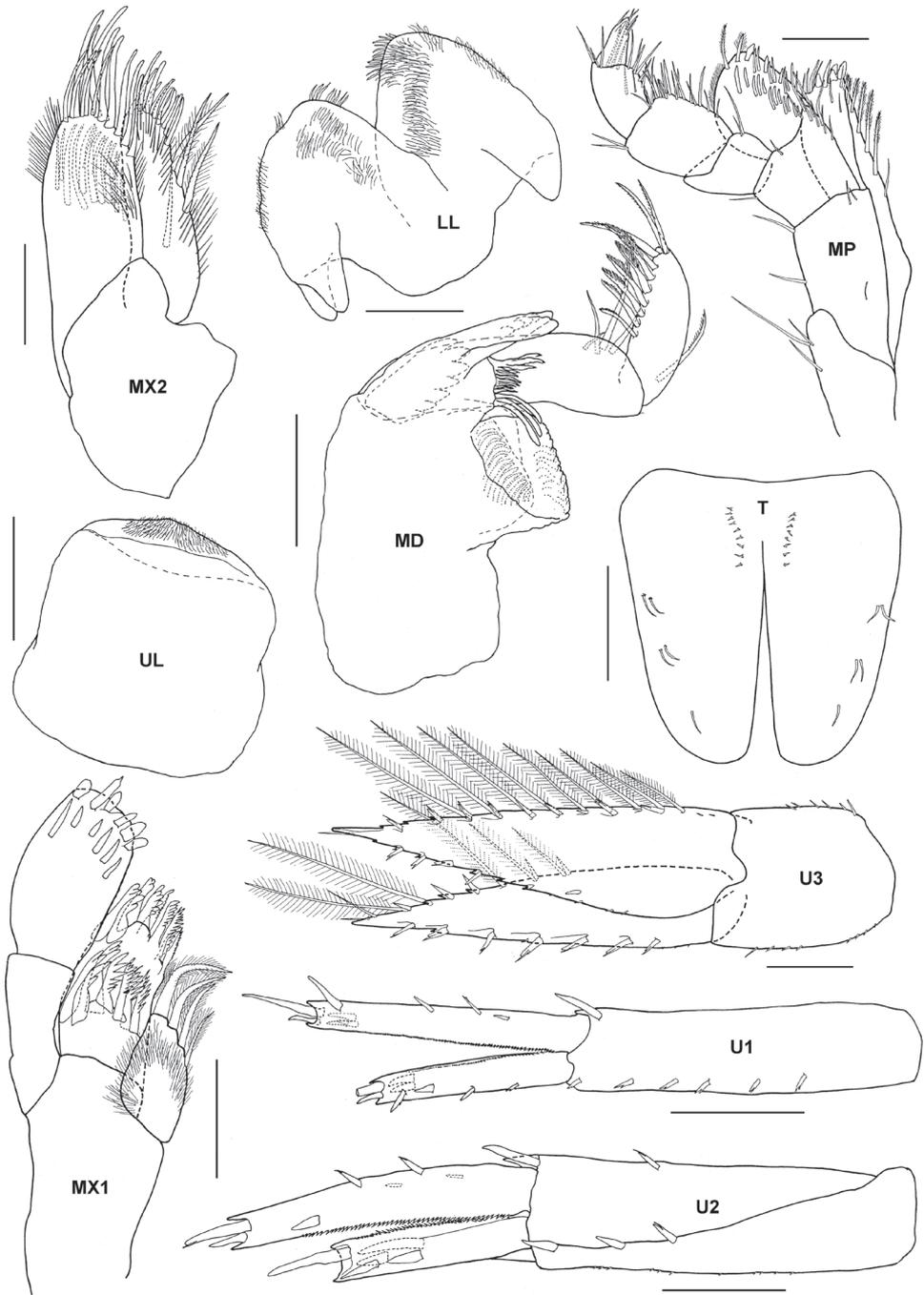


Figure 13. *Tethygenia sunda* sp. n., holotype, male (UKMMZ-1252), 4.5 mm. Marine Park, Pulau Tioman. Scales for MX1, MX2, UL, LL, MP, MD, U1–U3 and T represent 0.1 mm.

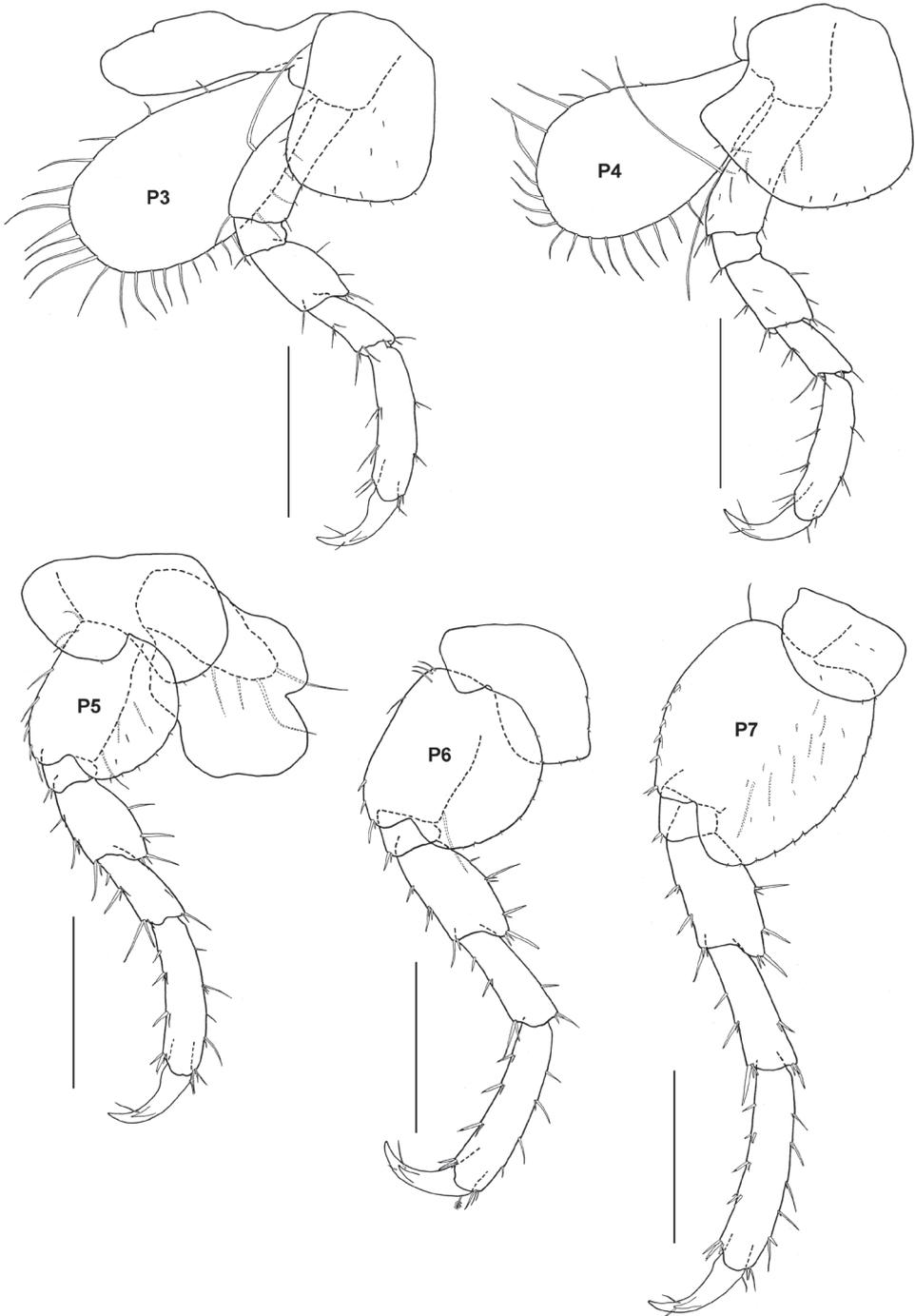


Figure 14. *Tethygeniea sunda* sp. n., holotype, male (UKMMZ-1252), 4.5 mm. Marine Park, Pulau Tioman. Scales for P3–P7 represent 0.5 mm.

Table 1. Checklist of the recorded amphipods.

Family/ Subfamily	Genus	Species
Ampeliscidae Costa, 1857	<i>Ampelisca</i> Kröyer, 1842	1. <i>Ampelisca brevicornis</i> (Costa, 1853)
Amphilochidae Boeck, 1871	<i>Gitanopsis</i> Sars, 1895	2. <i>Gitanopsis pusilla</i> Barnard, 1916
Amphithoidae Stebbing, 1899	<i>Cymadusa</i> Savigny, 1816	3. <i>Cymadusa vadosa</i> Imbach, 1967
Dexaminidae Leach, 1814	<i>Paradexamine</i> Stebbing, 1899	4. <i>Paradexamine setigera</i> Hirayama, 1984
Ischyroceridae Stebbing, 1899	<i>Erichthonius</i> Milne-Edwards, 1830	5. <i>Erichthonius pugnax</i> (Dana, 1853)
Leucothoidae Dana, 1852	<i>Leucothoe</i> Leach, 1814	6. <i>Leucothoe furina</i> (Savigny, 1816)
Liljeborgiidae Stebbing, 1899	<i>Liljeborgia</i> Bate, 1862	7. <i>Liljeborgia japonica</i> Nagata, 1965a
Lysianassidae Dana, 1849		
Tryphosinae Lowry & Stoddart, 1997	<i>Microlysias</i> Stebbing, 1918	8. <i>Microlysias xenokeras</i> (Stebbing, 1918)
Oedicerotidae Liljeborg, 1865	<i>Monoculodes</i> Stimpson, 1853	9. <i>Monoculodes muwoni</i> Jo, 1990
Photidae Boeck, 1871	<i>Latigammaropsis</i> Myers, 2009	10. <i>Latigammaropsis atlantica</i> (Stebbing, 1888)
Pontogeneiidae Stebbing, 1906	<i>Tethygeneia</i> J.L. Barnard, 1972	11. <i>Tethygeneia sunda</i> sp. n.

warm temperate waters of both hemispheres. The key character that clearly differentiates the genus from the other known eusiriids is the long and linguiform rostrum. Although this linguiform nature of the rostrum is also observed in some genera within the family (e.g. *Pontogenia*, *Gondogeneia*), *Tethygeneia* relatively exhibits a stronger form of prolonged rostrum. Since 1991, Barnard and Karaman listed 10 species of *Tethygeneia* that are mostly described from the warm-temperate waters of Australia. *T. sunda* sp. n. falls undoubtedly into the genus according to J.L. Barnard's eusiriid revisional framework (1972). It resembles *T. intermedia* (Gurjanova) in lacking a carpal lobe on gnathopod 2, but is rather closely related to *T. rostrata* (Gurjanova) and *T. longleyi* (Shoemaker) in the other characters. Differing from *T. rostrata* in the more slender articles of carpus and propodus of gnathopod 2, in the slightly more produced article 3 of antenna 1, and the more spinose rami of uropod 3. *Tethygeneia longleyi* shares the same form of head, gnathopods and uropods as in *T. sunda* sp. n. However some noteworthy differences are observed in the mouthparts, especially the mandible. The length and structure of article 2 of the mandible palp clearly distinguish *T. longleyi* from *T. sunda* sp. n.

Etymology. The specific designation is derived from the name of the Sunda shelf, which was part of the south-east Asian continent during the Pleistocene.

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Stenosternus Karsch, a possible link between Neotropical and Afrotropical Orphninae (Coleoptera, Scarabaeidae)

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Abstract

The monotypical orphnine genus *Stenosternus* Karsch is known from a single specimen of *S. costatus* collected on the São Tomé island (Gulf of Guinea). The holotype of *S. costatus* Karsch is re-examined and its characters are discussed and illustrated. Although the genus was implicitly placed by Paulian (1984) in the Old World tribe Orphnini Erichson, re-examination of the holotype of *S. costatus* shows that it has characters similar to those of the members of the New World tribe Aegidiini Paulian. Placement of *Stenosternus* in the Aegidiini is supported by the metepisternum widened posteriorly (forming posterior metepisternal lock for closed elytra) and a keel separating basal and anterolateral parts of propleurae. Relationships of *Stenosternus* with other orphnine taxa and possible ways of origin of São Toméan orphnine fauna are discussed.

Keywords

Trans-Atlantic dispersal, Africa–America disjunction, biogeography, scarab beetles, orphnines, Orphnini, Aegidiini, São Tomé, Gulf of Guinea, Cameroon line

Introduction

Orphninae Erichson is a group of predominantly tropical scarab beetles. To date, 15 genera and 195 species of Orphninae are known (Frolov 2012) and they are classed into two tribes, Aegidiini Paulian comprising four Neotropical genera and Orphnini Erichson comprising the rest of the genera distributed in the Old World (Paulian 1984). The subfamily includes the monotypical genus *Stenosternus* Karsch which was originally described as the “Copridae” (Karsch 1881) but later placed in the “Orphnidae” (Karsch 1887). According to Paulian’s (1984) classification, the genus should be considered in the tribe Orphnini because it originates from the Old World. However Paulian did not discuss characters of the genus and how they fit diagnoses of the tribes and apparently he never saw the type specimen of *S. costatus* Karsch, 1881. In his earlier work Paulian (1948) wrote that *Stenosternus* was unknown to him.

S. costatus, the only described species of the genus, has a puzzling combination of unique characters with those similar to the members of the Aegidiini. The original description of the genus and another work clarifying its position (Karsch 1887) do not include many characters of potential phylogenetic importance. Except for peculiar middle and hind tarsi, no characters were illustrated and the genus has not been compared with other genera of the Orphninae except for preliminary phylogenetic analysis which showed possible relationships with Neotropical taxa rather than Afrotropical (Frolov 2012). However, at that stage it was not possible to examine the taxon in more detail. The present work is aimed at filling this gap. Below the redescription of the holotype is given and its characters are discussed and illustrated. Relationships of *Stenosternus* with other orphnine taxa and possible ways of origin of the São Toméan orphnine fauna are also discussed.

Material and methods

Material used in this work is deposited in or borrowed from the following organizations: Institut royal des Sciences naturelles de Belgique, Bruxelles (IRSNB), Muséum d’Histoire Naturelle, Geneva (MHNG), Museum für Naturkunde, Humboldt-Universität, Berlin (MHUB), Muséum national d’Histoire naturelle, Paris (MNHN), Natural History Museum, London (NHML), Zoological Institute RAS, Saint-Petersburg (ZIN).

Preparation of genitalia follows the common technique used in entomological research. Photographs were taken with a Leica MZ9.5 stereo microscope and a Leica DFC290 digital camera from dry specimens. Partially focused serial images were combined in Helicon Focus software (Helicon Soft Ltd.) to produce completely focused images. Photographs were not altered except for digital enhancing with Adobe Photoshop (Adobe Inc.): levels and tone correction, background elimination. Outline figures were made by tracing features on digital photographs with Adobe Illustrator (Adobe Inc.).

For modeling the distribution of *Aegidium* Westwood, MaxEnt software (Elith et al. 2011) was used with the following settings: maximum number of background points

– 10000, replicates – 1, replicated run type – crossvalidate, output format – logistic. The distribution model was based on 31 localities of *Aegidium* specimens derived from the literature (Cartwright and Chalumeau 1978; Morón 1991; Paulian 1984) and from the labels of the collection specimens. Country or province records without more precise localities and doubtful data were not used. Two sets of environmental layers were used: 18 bioclimatic variables (Hijmans et al. 2005; available from <http://www.worldclim.org>) and 17 soil property variables derived from ISRIC World Soil Information database (available from <http://www.isric.org>). Preparation of environmental layers and visualization of the Maxent distribution model was done with ArcGIS software (ESRI Inc.).

Redescription

Genus *Stenosternus* Karsch, 1881.

Type species. *Stenosternus costatus* Karsch, 1881, by monotypy.

Stenosternus costatus Karsch, 1881

http://species-id.net/wiki/Stenosternus_costatus

Male, holotype (MHUB). Body length (from anterior margin of clypeus to apices of elytra) 16.1 mm, pronotal width 7.3 mm, elytral width 7.6 mm. Body (Fig. 1) uniformly dark-brown with slight bronze tint. Surface densely punctate, almost rugose. Head and most part of pronotum punctate with oval deep punctures separated by 0.5 to 0.2 their diameters, sometimes almost adjacent. Each puncture has shagreened microsculpture with 1 short (only slightly protruding above surface of pronotum) seta. Intervals between punctures look smooth.

Clypeus emarginate anteriorly, with crenate margin, without tubercles. Genal and frontoclypeal sutures absent. Genae not protruding past eyes, indistinct. Frons feebly convex medially. Labrum feebly protruding past clypeus. Eyes relatively small, eye width 1.5 times smaller than distance between eye margin and gula (in ventral view).

Antenna 10-segmented, with 3-segmented club.

Pronotum trapezoidal, elongated (1.25 times wider than long) while in other Orphninae it is normally wider and shorter (about 1.6 times wider than long, Fig. 2, 3). Pronotum with distinct longitudinal middle depression from base to almost anterior margin. Lateral margin crenulate, base not bordered. Punctuation of pronotum is similar to that of head. Propleurae with fine carinae separating anterolateral areas from basal area adjacent to bases of elytra (Fig. 34, arrowed).

Anterior tibiae relatively slender, almost parallel-sided, with 2 short lateral teeth and a smaller medial tooth (Fig. 15). Anterior tarsi absent. Anterior coxa with relatively deep longitudinal fossa on ventral side. Middle and hind legs similar in shape. Middle and hind femora relatively slender, almost parallel-sided, punctate with elongate punc-



Figures 1–10. 1–3 Habitus of males 4 punctation of elytral disc 5 aedeagus in lateral view and parameres in dorsal view 6 serration of medial margins of parameres 7–10 aedeagus in ventral view 1, 4–7 *Stenos-ternus costatus* Karsch, holotype 2 *Aegidium colombianum* Westwood 3 *Orphnus macleayi* Laporte de Castelnau 8 *Hybalus cornifrons* (Brullé) 9 *Aegidium parvulum* Westwood 10 *Orphnus compactus* Petrovitz.

tures. Middle and hind tibiae without ridges on outer sides, rugosely punctate. Middle tibiae have 2 apical spurs, outer spur about twice as long as inner one. Hind tibiae with 2 spurs (outer spur about 1.5 times longer than inner one) and with modified spur-like basal tarsomere (Fig. 13). Tarsi of middle tibiae are absent but according to the picture provided by Karsch (1887) the specimen had middle tarsi modified to spurs similar to those of hind legs. Stridulatory area on hind coxae present.

Elytra somewhat oblong, 1.2 times longer than width. Humeral umbones small but distinct. Elytra without striae but each elytron with low longitudinal ridge from base to about 5/6 its length. Elytra densely punctate with characteristic semicircular

punctures each bearing a short setae (Fig. 4). Because of rugose punctation, lateral margin of elytra appear crenulate in dorsal view. Epipleuron with concavity receiving hind margin of metepisternum.

Wings vestigial, about 1/2 length of elytra.

Scutellum 1/20 length of elytra, narrow, rounded apically.

Metepisternum narrow, almost parallel-sided, with rounded distal part which somewhat overlaps epipleuron (Fig. 24). Orifice between mesocoxal cavities absent. Abdominal sternites with irregularly shaped punctures, some punctures V-shaped. Abdominal sternite 8 longer than others, without concavity or tubercle in the middle. Plectrum trapezoidal, with minute seta in the middle near apical margin.

Aedeagus with heavily sclerotized parameres about 2 times shorter than phallobase (Fig. 5, 7). Phallobase symmetrical, with sclerotized ventral plate separated by weakly sclerotized membranous areas (Fig. 7). Apices of parameres with tooth-like rounded processes directed anterolaterally and relatively long and dense pale setae. Lateral sides of parameres with short, sparse, mostly abraded setae. Medial sides of each paramere without membrane in apical 2/3 but with dense, scale-like teeth directed apically (Fig. 6). Basal 1/3 of inner margin of parameres overlapping. Endophallus with about 15 small, tooth-like spinules, without larger sclerites.

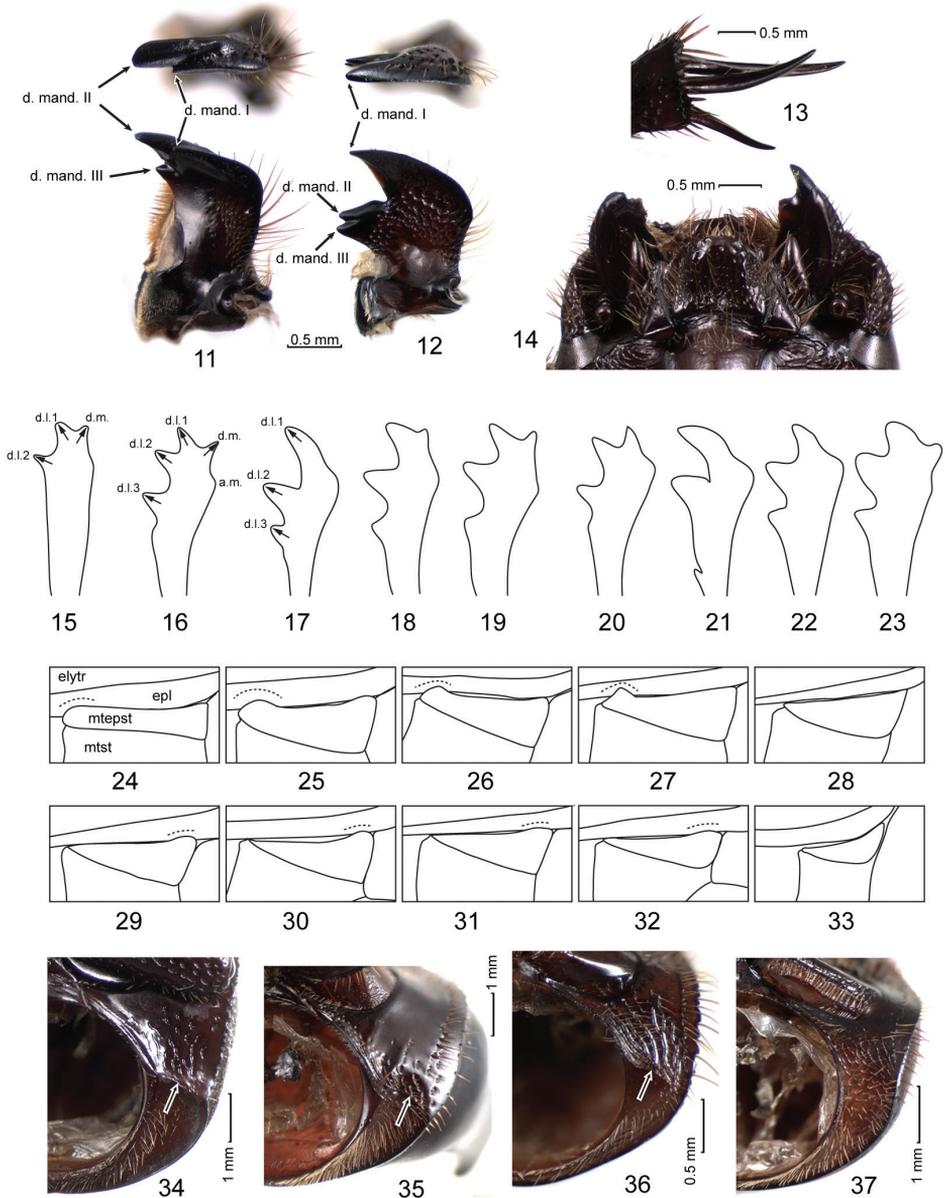
Diagnosis. *Stenosternus* can be easily distinguished from other Orphninae by the combination of uniquely modified legs and sculpture of pronotum and elytra. However, this diagnosis is based on a single male specimen and may include characters of sexual dimorphism. Aedeagus with serrated medial sides of parameres, setose apices of parameres, and separate ventral sclerite of phallobase is also highly distinctive.

Discussion

Morphological traits of *Stenosternus*

Mouthparts

Paulian (1984) separated Aegidiini from Orphnini largely on the basis of their distribution and the shape of the mouthparts, especially the mandibles. Aegidiini were described as having simplified mandibles with reduced teeth on the inner side as opposed to having well developed inner teeth in the Orphnini. However, mandibles of American taxa cannot be considered simplified in comparison to the Old World taxa. For example, right mandibles of *Ae. colombianum* Westwood (Fig. 11) and *O. declivis* (Fig. 12) both have 3 inner teeth but the shape of the incisor part is different: in *Aegidium* the teeth are somewhat clustered distally and the mandibular tooth II is the largest and actually apical while in *Orphnus* incisor part is larger and the tooth I is apical. Mandibles of *Aegidiellus alatus* (Laporte de Castelnau), *Paraegidium costalimai* Vulcano et al. and *Aegidinus guianensis* (Westwood) are similar to those of *Aegidium*, although *Aegidinus* has large lateral processes. In the Orphnini, the diversity of mandible shapes is greater which probably reflects a wider spectrum of food types utilized by the beetles.



Figures 11–37. 11, 12 Right mandible in dorsal and apical view 13 apex of metafemur 14 head in ventral view 15–23 protibia of males (arrows in figures 15–17 indicate approximate teeth direction) 24–33 metepisternum 34–37 base of prothorax (arrows in figures 34–36 indicate keel separating basal and anterolateral parts of propleurae) 11, 16, 35 *Aegidium colombianum* Westwood 12, 37 *Orphnus declivis* Schmidt 13–15, 24, 34 *Stenosternus costatus* Karsch, holotype 17, 29 *Orphnus macleayi* Laporte de Castelnau 18, 36 *Aegidinus guianensis* (Westwood) 19, 27 *Aegidiellus alatus* (Laporte de Castelnau) 20, 26 *Paraegidium costalimai* Vulcano et al. 21, 31 *Pseudorphnus hiboni* Paulian 22, 30 *Triodontus iremoi* Paulian 23 *Chaetonyx robustus* Schaum 25 *Aegidium parvulum* Westwood 28 *Orphnus giganteus* Paulian 32 *Renorphnus clementi* (Petrovitz) 33 *Hybalus cornifrons* (Brullé).

In the type specimen of *S. costatus*, right mandibular apex is worn and probably broken (Fig. 14) but the mandible shape is more similar to that of *Aegidium* than of *Orphnus*. It can be seen that the bristled incisor comb occupies a large part of the inner margin of the mandible.

Although the mandible morphology is probably species-specific in some orphnine genera, mandibular characters should be attributed low weight in reconstructing phylogeny of the groups above genus level. The morphology of the mandibles and other mouthparts depends heavily on the type of food utilized by the species. Adaptive radiation might result in parallel modification of the mouthparts in different lineages. Using mandibles in phylogenetic reconstructions is further complicated by their manifold variability not normally found in other structures: interspecific variability, asymmetry, sexual dimorphism, allometric variability in males (i.e. *Madecorphnus* Paulian), and variability caused by wearing during adult individual life. It is also important that mouthparts be studied as an interdependent complex of structures with strong morpho-functional relationships with each other. Adaptation to a particular food type results in regular and interrelated modifications in all mouthparts including labrum. Undesired redundancy can be introduced in a dataset if these characters are coded separately and, if not weighted, they can overcontribute to the most parsimonious tree topology.

Legs

The fore legs of *S. costatus* lack tarsi. The absence of protarsi is often found in Coleoptera including Scarabaeoidea; sometimes only males lack protarsi. However, in the Orphninae well developed protarsi are present in all groups except for *Stenosternus*. The shape of the *Stenosternus* protibiae is also unusual for the Orphninae: they are narrow, almost parallel-sided, with three short teeth (Fig. 15). These teeth can be interpreted as the three common scarabeoid lateral teeth with the tooth I being offset medially. However, in all Old World taxa these teeth are directed laterad of the imaginable midline of a protibia (Fig. 17, 21–23; approximate teeth direction are arrowed). In the males of the New World genera (except possibly for *Paraegidium*, Fig. 20) there is an additional, mostly shorter, medial tooth directed mediad of the protibia midline (Fig. 16, 18, 19). A similar medial tooth can be found in *Chaetonyx robustus* (Fig. 23), although it is less distinct and apparently subject to a reasonable interspecific variability. Although such medial teeth in male protibiae are known in other scarabeoid groups (i. e. in scarabeine genera *Macroderes* Westwood, *Xinidium* Harold and *Metacatharsius* Paulian), within the Orphninae they may be homologous.

One of the most prominent characters of *Stenosternus* is the modification of middle and hind tarsi which are reduced to only basal tarsomeres similar to spurs in length and shape (Fig. 13). Tarsal origin of these “spurs” can be seen from their setation and was discussed by Karsch (1887). In scarab beetles, spurs can be pectinate apically but never bear setae on their sides while tarsomeres normally do. Such modification is unique not only among orphnines but also among other scarab beetles. The middle and hind legs of *Stenosternus*, including the apical spurs, are otherwise of normal shape, symmetrical, and do not look malformed.

The shape of the legs of *S. costatus* suggests that the beetles are poorly adapted to digging in soil. Slender tibiae with short lateral teeth (in protibiae) and without transverse keels (in meso- and metatibiae) are typical for Passalidae and Lucanidae which have apparently ancestral habit as rotten wood dwellers. No information is available about biology of *S. costatus* but morphology of the specimen suggests that it too may be a rotten wood dweller. This also agrees with available data about *Aegidium cribratum* Bates which, at least in Mexico, is found only in rotten logs of a few species of tree (Morón 1991), whereas no Afrotropical, Madagascar, or Palearctic species were recorded from rotten wood.

The adaptive significance of the absence of tarsi is not always clear. It can be speculated that the tarsi are lost when there is no need for them, for example when a beetle does not clamber onto plants. Apparently a large number of Orphninae species, especially flightless ones, do not leave upper soil layer and litter and have no need in clambering. However all taxa, except for *Stenosternus*, have well developed tarsi in all legs. The absence of tarsi in *Stenosternus* might be an adaptation for defense from predators like ants or soldier termites.

Pronotum

The pronotum of *Stenosternus* is distinctive in being longer than in other Orphninae. Its width is almost equal to length (and it looks longitudinal in dorsal view) while in other taxa it is 1.5 times or more wider than long. It lacks ridges or tubercles which are found in males of most Orphninae taxa. A shallow but distinct longitudinal middle depression is found only in *Stenosternus*. The pleural areas of the pronotum have a feature which is not found in other Old World Orphninae. The propleura have fine but distinct carinae separating anterolateral areas from basal area adjacent to bases of elytra. This area is similar to that in all American genera which have basal area of pronotum adjacent to elytra separated from the rest of propleuron (Fig. 35, 36). Old World taxa have the propleura smoothly convex without any signs of carinae (Fig. 37). The shape of the pronotum of *Stenosternus* and American genera apparently allows for tighter joining of the pronotum and mesonotum which might be an antipredator adaptation.

Integument and punctuation

S. costatus has a characteristic sculpture of the dorsal body surface. Its head and pronotum are densely and rugosely punctate with relatively large, mostly adjacent punctures. In other Orphninae, the punctuation of the head and especially pronotum is normally finer and sparser. More distinctive is the punctuation of the elytra which are densely covered by U-shaped punctures directed caudally (Fig. 4). Orphninae show reasonable variability of elytral punctuation but in most taxa punctures are more or less round. Somewhat similar U-shaped punctures are known in *Paraegidium* but they are directed apically and their homology is unlikely. The elytra of *S. costatus* also have characteristic longitudinal ridges. Similar ridges are found in *Aegidium* but in this genus each elytron has 2 ridges (Fig. 2). Other taxa do not feature such elytral ridges.

Brachyptery

The type specimen of *S. costatus* has vestigial wings about 1/2 the length of elytron. Flightlessness is quite common in the Orphninae and the total number of flightless species may be up to 20 per cent (Frolov, unpubl.). *Hybalus* Brullé and *Chaetonyx* Schaum comprise completely apterous species with no visible wing rudiments whereas a number of *Orphnus* MacLeay species have vestigial wings similar to those of *Stenosternus*. Flightless species are also known among *Aegidium* (i.e. *Ae. parvulus* Westwood from Guadeloupe).

Metepisternum

The metepisternum shows reasonable variability among orphnine genera (Fig. 24–33). In most taxa it is more or less triangular and tapering caudally (in this paper only the part of metepisternum not covered by elytron is discussed and illustrated) (Fig. 28–33). In most of these groups the metepisternum has a slightly widened antero-dorsal angle slightly overlapping epipleuron which is somewhat concave in this place (Fig. 29–32). This structure, anterior metepisternal lock, apparently serves to hold the closed elytra more securely. It is absent in *Hybalus* (Fig. 33) which might be a secondary loss due to aptery, but it is also indistinct in *O. giganteus* Paulian (Fig. 28) which has fully developed wings. In the New World taxa, the anterior metepisternal lock is less developed and sometimes indistinct but there is a similar structure in posterior angle of metepisternum which is rounded to triangular and is situated in the distinct concavity of epipleuron (Fig. 25–27). Such a posterior metepisternal lock is not found in the Old World genera except for *Stenosternus*. The metepisternum of *Stenosternus* is dissimilar to that in other orphnines in being narrow, almost parallel-sided in most part, but its posterior angle is rounded and overlaps slightly the epipleuron (Fig. 24). A shallow but distinct concavity can be seen on the epipleuron. It is possible that the posterior metepisternal lock is reduced in *S. costatus* due to brachyptery and it was more developed in its flying ancestors. In the preliminary phylogenetic analysis of the Orphninae (Frolov 2012) the posterior metepisternal lock was interpreted as a synapomorphy of *Stenosternus* and American genera.

Aedeagus

The aedeagus of *S. costatus* has a few distinctive features. Scale-like serration on medial sides of each paramere in apical 2/3 is unique at least among Orphninae. The phallobase of *S. costatus* can be classed as one of the four types of phallobase found in the Orphninae. It has a ventral sclerite about 2 times shorter than dorsal sclerite. The two sclerites are separated ventrolaterally by thinner, feebly sclerotized membranes (Fig. 7). This type of phallobase is similar to that of *Hybalus* where ventral sclerite is also distinct, but in *Hybalus* it has a complex shape (Fig. 8). In the four American genera, the phallobase is tube-shaped with strongly sclerotized ventral side but without differentiation of ventral and dorsal sclerites (Fig. 9). The majority of other Orphninae genera have a phallobase of the forth type which is strongly sclerotized dorsally and with a thin membrane ventrally (Fig. 10). Apices of parameres of *S. costatus* are densely setose.

Similar setation can be found also in the monotypical American genus *Aegidiellus*, and Mediterranean genus *Hybalus*. Apparently in the Orphninae, setation of parameres is genus-specific, but its homology and phylogenetic value is not clear due to high variability of paramere shape which is, in general, species-specific.

Distribution and possible habitat of *S. costatus*

The only known specimen of *S. costatus* was collected by Richard Greeff on the São Tomé island in the Gulf of Guinea. São Tomé is the largest island of the oceanic sector of the Cameroon Line of volcano-capped swells. It lies 240 km offshore and has never been connected to mainland Africa. The age of São Tomé is estimated as 13 MY (Lee et al. 1994) although it is a minimum estimate based on the age of the oldest exposed volcanic rocks. São Tomé, Príncipe, and Annobon are classed as one of the WWF 200 ecoregions with exceptional richness of biodiversity. The original vegetation of São Tomé comprises forests of various types, including lowland and montane forests. São Tomé along with the other islands of Gulf of Guinea is considered a rain forest refuge since the mid-Miocene.

Precise collecting locality of the holotype of *S. costatus* is unknown. Krauss (1890) mentioned one locality in the island where Greeff had collected insects: Roça Rio d'Ouro. This is a plantation (roça) in the northern part of the island at elevation of about 180 m, surrounded by a forest. It is possible that *S. costatus* was collected in this locality or elsewhere in the north-eastern foothills of the escarpment.

Biogeography of the Orphninae and possible origin of São Tomé orphnine fauna

The six recent regional faunas of the Orphninae (Frolov 2012) are separated by different dispersal barriers. Of them, fauna of São Tomé is the smallest one comprising only one species of the genus *Stenosternus*. However it is quite distinctive because the genus is endemic to the island and has putative relations to the New World taxa.

The core fauna of the islands of the Gulf of Guinea is of African origin. Bioko (Fernando Po) is the largest island with the most diverse biota though it is of continental origin and was connected to mainland Africa during the last glaciation maximum. Consequently its fauna differs slightly from the fauna of the mainland Cross-Sanaga-Bioko coastal forests. Of the true oceanic islands, São Tomé is the largest (850 km²), separated from mainland Africa by 250 km, has a few climatic regions, complex terrain profile, and supports rich biota. Príncipe, although much older than São Tomé (originated in early Oligocene) has six times smaller area and two times smaller altitude range. Annobon is a small island (17 km²) lying 340 km off African shore and having relatively poor biota. Because the islands were apparently a target for colonization for a long time (since the Miocene in case of São Tomé), adaptive radiation resulted in high endemism at specific and generic levels. The islands contain some of the highest percentage of endemism in the world (Jones 1994).

Atlantic currents might facilitate dispersal of African biota to the oceanic islands of Gulf of Guinea (Renner 2004). John Measey et al. (2007) showed that favorable oceanic currents with reduction in salinity of surface waters might facilitate rafting from the Congo and Niger basins to the islands. Dispersal with rafts seems the only sound hypothesis to explain occurrence on São Tomé of such poor oceanic dispersers as shrews, as well as a high proportion of subterranean taxa amongst the herpetofaunal endemics (Drewes 2002; John Measey et al. 2007).

Of the all Gulf of Guinea islands, Orphninae have so far been recorded only from São Tomé. It is possible that some *Orphnus* species (e.g. *O. gilleti* Benderitter) known from the neighboring mainland region will be found in Bioko. Annobon is unlikely to have any Orphninae due to its small size and apparently unsuitable habitats. However few studies are available on the insects of the Gulf of Guinea and scarab beetles of the islands were not surveyed.

Available data do not allow to soundly hypothesize about the way of separation of the New World and Old world Orphninae faunas. Of the all barriers between regional orphnine faunas, the Atlantic barrier was apparently the least permeable for the members of the group. South America–Africa disjunctions are commonly explained by either vicariance or long distance dispersal. Vicariance of the previously Gondwanan group due to the continent breakup seems the least probable hypothesis in the case of the orphnines. Distribution of the extant taxa shows no pattern of Gondwanan groups: they are absent from regions where Gondwanan relicts are commonly found including Notogea (Australasia) and Patagonian Province of Neotropical Realm. Afrotropical region is the contemporary center of diversity and possible center of origin and diversification of the group. In Africa, Orphninae are mainly distributed in the central part of the continent in savannah and forest–savannah mosaic regions. Few species were recorded south of 25°S.

It is possible that orphnines dispersed from Western Africa to north-eastern South America via the Atlantic ocean. Zoogeographical relationships of Gulf of Guinea islands with South America have been discussed in a few works and modern disjunctive ranges of a number of plant (Renner 2004) and animal (Carranza and Arnold 2006) taxa are explained by long distance dispersal. The islands of the Gulf of Guinea lie on this putative migration path since the early Miocene. Migrants might have ecize on the islands and *Stenosternus* might be the only survived descendant of these migrants. Putative habit of *Stenosternus* and its ancestors as rotten wood dwellers might facilitate dispersal over the ocean inside wood logs. Such dispersal seems less probable in case of geophilous taxa like *Hybalus* and *Chaetonyx*, as well as litter and upper soil layer dwellers to which most of Afrotropical, Madagascar, and South-East Asian taxa apparently belong.

To analyze distribution pattern of the Orphninae, MaxEnt distribution models were created for a number of genera including *Aegidium* (Fig. 38). It is beyond the scope of the present work to analyze *Aegidium* model in detail but one aspect of it is relevant here: the model predicts high probability of environmentally suitable biotopes in the islands of Cameroon line including São Tomé. The model is based on current climatic conditions but despite reasonable fluctuation of climate in the Northern

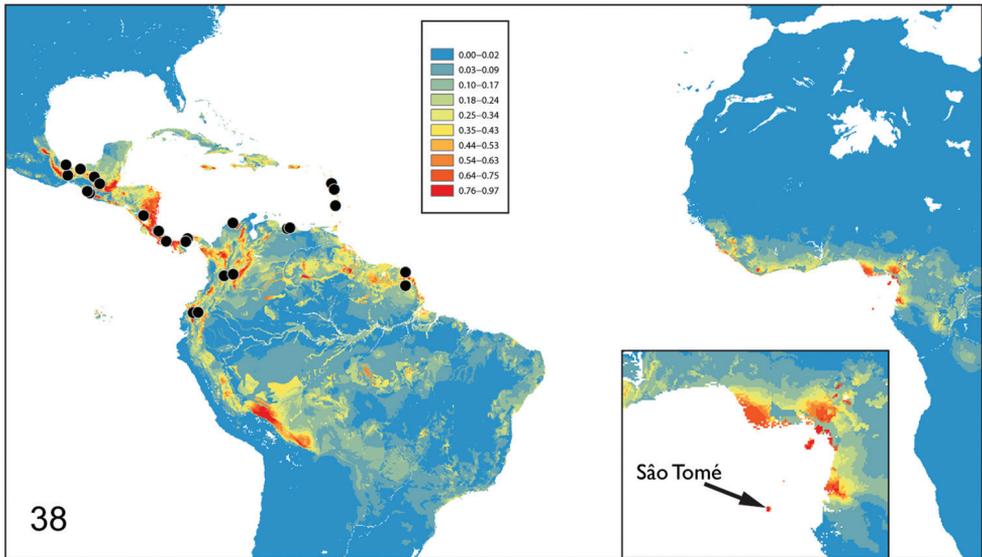


Figure 38. Representation of the MaxEnt distribution model for *Aegidium* Westwood. Warmer colors show areas with better predicted conditions. Black dots indicate known collecting localities of *Aegidium* used for the model. Insert shows the Gulf of Guinea and the São Tomé island. Other explanations are in text.

Hemisphere, especially in the Pleistocene, and fluctuation of the size of equatorial rain forests in Africa and South America, climatic conditions are thought to be relatively stable in the Gulf of Guinea and the islands are considered a rain forest refuge since the Miocene. The distribution model suggests that *Aegidium* and *Stenosternus* share similar type of habitat. This can be an additional argument for considering the two genera phylogenetically related rather than superficially similar.

Taxonomic position of *Stenosternus* and phylogeny of the Orphniinae

The data available to date do not allow *Stenosternus* to be definitely classified as a member of either Orphnini or Aegidiini. Paulian (1984) assumed it was a member of the Orphnini but he did not discuss it. Colby (2009) apparently followed Paulian. I provisionally moved *Stenosternus* to the tribe Aegidiini (Frolov 2012). The placement in the Aegidiini seems better justified as it is supported by a few putative synapomorphies: metepisternum widened posteriorly (forming posterior metepisternal lock for closed elytra) and a keel separating basal and anterolateral parts of propleura. The shape of the mandibles of *Stenosternus* is more similar to that of New World genera as is the fore tibia with a medial tooth. The two later characters however need confirmation on a larger material which is currently not available. In general appearance, *Stenosternus* resembles *Aegidium* which was also noticed by Kolbe (cited by Karsch 1887). On the other hand, *Stenosternus* lacks a hole connecting middle coxal cavities. This character was interpreted as a synapomorphy of the New World orphnine genera (tribe Aegidiini

sensu Paulian: Frolov 2012) but the presence of the hole in *Aegidinus* requires confirmation because my observation was based on a single specimen and might be a preparation artifact. The phallobase of *Stenosternus* is not similar to that of the New World genera which all have rather uniform tube-shaped phallobase.

Phylogenetic relationships of *Stenosternus* require further research because the material currently available is limited to a single specimen. The study of a female would reveal sexual dimorphism of this taxon. Especially important would be the study of premature stages because the larvae of the New World taxa, at least the genus *Aegidium*, differ significantly from those of the Old World taxa (Barbero and Palestini 1993; Morón 1991; Paulian and Lumaret 1982; Randriamanantsoa et al. 2010).

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First record of *Clausidium* (Copepoda, Clausidiidae) from Brazil: a new species associated with ghost shrimps *Neocallichirus grandimana* (Gibbes, 1850) (Decapoda, Callianassidae)

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Abstract

A new clausidiid copepod was found living in galleries of ghost shrimps *Neocallichirus grandimana* (Gibbes, 1850) in Natal, Brazil. The new species resembles to *Clausidium senegalense* Humes, 1957 and *C. vancouverense* (Haddon, 1912) in the armature of P2–P5 of the female, and shares with *C. senegalense* similar segmentation and armature of the antenna and maxilla of the female. Nevertheless, it can be easily distinguished from its congeners by the unique characteristics observed in the antenna, maxilliped and first leg of males, as well as by the anal somite, maxillule and maxilliped of the females. This new species extends the group distribution to the Southwest Atlantic and represents the first record of the genus in Brazil. A key for the identification of the species based on females of *Clausidium* is provided.

Keywords

Biodiversity, CLSM, Crustacea, Poecilostomatoida, taxonomy, identification key

Introduction

Clausidiids characterized by the presence of sucking discs on endopods of legs 1 to 4, the genus *Clausidium* Kossmann, 1874 was established to accommodate *C. apodiforme* (Philippi, 1839). During the revision by Light and Hartman (1937), *C. californiense* Wilson, 1935 was considered a synonym of *C. vancouverense*, and at present this genus contains 10 species found in the Atlantic, Pacific and Indian oceans (Table 1). Wilson (1921) and Humes (1949) provided keys to species.

The representatives of *Clausidium* are typically external associates of marine decapods. They can be found inhabiting the burrows of ghost or mud shrimps of the families Callinassidae Dana, 1852 and Upogebiidae Borradaile, 1903 (Table 1).

Although *Clausidium* is reported in population studies of the ghost shrimp *Callichirus seilacheri* (Bott, 1955) from Chilean coast (Marin and George-Nascimento 1993; Hernáez and Wehrmann 2007), these species remain unidentified. *Clausidium searsi* Wilson, 1937 and *C. vancouverense* (Haddon, 1912), collected along the Peruvian coast, are the only described species in South America.

A new clausidiid copepod, which can not be reconciled to any of the 10 species of *Clausidium* that have been described so far, was found living in galleries of ghost shrimps *Neocallichirus grandimana* (Gibbes, 1850) in the intertidal zone of a beach in Natal, state of Rio Grande do Norte (N.E. of Brazil). This is the first record of genus *Clausidium* in Brazil.

Methods

The copepods were recovered from water drawn from the burrows and collected from pleopods of the ghost shrimp *Neocallichirus grandimana* in the intertidal zone of a beach in Natal, state of Rio Grande do Norte, Brazil (5°45'S, 35°11'W).

Whole specimens were examined in temporary lactic acid mounts. Chips of cover slip were used to support the cover glass of the preparation. After examination, material was returned to and preserved in 70% ethanol. Dissections were made in glycerine and the dissected parts were placed on slides and sealed with Glyceel.

A Leitz Laborlux D⁺ phase-contrast microscope and a Zeiss Axioskop 2 Plus⁺ compound microscope equipped with differential interference contrast, digital camera Nikon Coolpix 995⁺ and camera lucida were used to examine and prepare illustrations of the specimens.

Two females and two males were prepared for scanning electron microscopy (SEM). Specimens were dehydrated through a series of graded acetone; critical-point dried, mounted on stubs, sputter-coated with palladium and observed using a Philips XL 30 Field Emission Scanning Electron microscope (Philips, Eindhoven, Netherlands).

For confocal laser scanning microscopy (CLSM), a female was stained with Congo Red and mounted on slide following the procedure described by Michels and Büntzow

Table 1. A list of species of *Clausidium* including known distributional records, hosts and references.

Species	Distribution	Hosts	References
<i>Clausidium apodiforme</i> (Phillippi, 1839)	North Atlantic Ocean	<i>Calianassa subterranea</i> (Montagu, 1808)	Phillipi 1839
Syn: <i>Hersilia apodiformis</i> Phillipi, 1839	(Adriatic and Mediterranean sea)	<i>Calianassa</i> sp.	Kossmann 1874
<i>Clausidium testudo</i> Kossmann, 1874		<i>Pestarella candida</i> (Olivi, 1792)	Humes 1949
			Manning and Stevcic 1982
<i>Clausidium caudatum</i> (Say, 1818)	North Atlantic Ocean	<i>Callichirus major</i> (Say, 1818)	Say 1818
			Wilson C.B. 1921
			Pearse 1947
			Humes 1949
<i>Clausidium chelatum</i> Pillai, 1959	Indian Ocean	<i>Calianassa</i> sp.	Pillai 1959
<i>Clausidium dissimile</i> Wilson C. B., 1921	North Atlantic Ocean	<i>Calianassa</i> sp.	Wilson C.B. 1921
		<i>Gilvossius setimanus</i> (De Kay, 1844)	Wilson C.B. 1932
		<i>Lepidophthalmus louisianensis</i> (Schmitt, 1935)	Humes 1949
		<i>Sergio trilobata</i> (Biffar, 1970)	Corsetti and Strasser 2003
<i>Clausidium saldanhae</i> Kensley, 1974	South Atlantic Ocean	<i>Pestarella rotundicaudata</i> (Stebbing, 1902)	Kensley 1974
<i>Clausidium searsi</i> Wilson C. B., 1937	South Pacific Ocean	<i>Calianassa</i> sp.	Wilson C.B. 1937
			Humes 1949
<i>Clausidium senegalense</i> Humes, 1957	South Atlantic Ocean	<i>Calianassa</i> sp.	Humes 1957
<i>Clausidium tenax</i> Humes, 1949	North Atlantic Ocean	<i>Callichirus islagrande</i> (Schmitt, 1935)	Humes 1949
<i>Clausidium travancorensis</i> Pillai, 1959	Indian Ocean	<i>Neocallichirus maxima</i> (A. Milne-Edwards, 1870)	Pillai 1959
<i>Clausidium vancouverense</i> (Haddon, 1912)	North Pacific Ocean	<i>Callichirus seilacheri</i> (Bott, 1955)	Haddon 1912
Syn: <i>Hersilia</i> (<i>Clausidium</i>) <i>vancouverensis</i>	South Pacific Ocean	<i>Neotrypaea californiensis</i> (Dana, 1854)	Humes 1949
Haddon, 1912		<i>Neotrypaea gigas</i> (Dana, 1852)	Light and Hartman 1937
<i>Clausidium californiense</i> Wilson C. B., 1935		<i>Upogebia pugettensis</i> (Dana, 1852)	Campos et al. 2009
			Iannacone et al. 2008
<i>Clausidium</i> sp.	South Pacific Ocean	<i>Callichirus seilacheri</i> (Bott, 1955)	Marin and George-Nascimento 1993
	South Atlantic Ocean	<i>Neocallichirus grandimana</i> (Gibbes, 1850)	Hernández and Wehrmann 2007

(2010). The material was scanned using a Leica TCS SP5 (Leica, Wetzlar, Germany) equipped with a Leica DM5000 B upright microscope (Leica, Wetzlar, Germany) and 3 visible-light lasers (DPSS 10 mW 561 nm; HeNe 10 mW 633 nm; Ar 100 mW 458 nm, 476 nm, 488 nm and 514 nm), combined with the software LAS AF 2.2.1. - Leica Application Suite Advanced Fluorescence (Leica, Wetzlar, Germany).

Series of stacks were obtained, collecting overlapping optical sections throughout the whole preparation; the optimal number of scans and the imaging settings according to the software, are given in Table 2. Final images were obtained by maximum projection, and CLSM illustrations were composed and adjusted for contrast and brightness using the software Adobe Photoshop CS4 (Adobe Systems, San José, U.S.A.).

Total body length was measured from the anterior margin of the rostrum to the posterior margin of the caudal rami. The descriptive terminology follows Huys and Boxshall (1991) and Huys et al. (1996). Abbreviations used in the text are: ae, aesthetasc; P1–P6, legs 1–6; exp and enp, exopod and endopod respectively; exp (enp)-1 (-2, -3), proximal (middle, distal) segments of a ramus.

The type material is deposited in the collection of the Museu de Zoologia, Universidade de São Paulo, São Paulo, Brazil.

Table 2. Microscope lens and confocal laser scanning microscopy (CLSM) settings used for the observation of the specimens; Ch1 and Ch2 = detection channels 1 and 2.

Lens	HC PL APO CS (High-grade colour-corrected Plan Achromat lens for confocal)
Objective	20×
Numerical aperture	0.7
Immersion	Oil
Excitation wavelength	488 and 633 nm
Laser intensity	50% and 33%, respectively
Excitation beam splitter	TD 488/561/633
Detected emission wavelength	Ch1: 493 – 600 nm
	Ch2: 650 – 750 nm
Detector gain	833.8 and 791.6 V
Amplitude offset	-0.9 and -1.0 %
Electronic zoom	3X
Pinhole aperture	54.6 μm
Image format	2048 × 2048 dpi

Results

Order Poecilostomatoida Burmeister, 1835

Family Clausidiidae Embleton, 1910

Genus *Clausidium* Kossmann, 1874

Clausidium rodriguesi sp. n.

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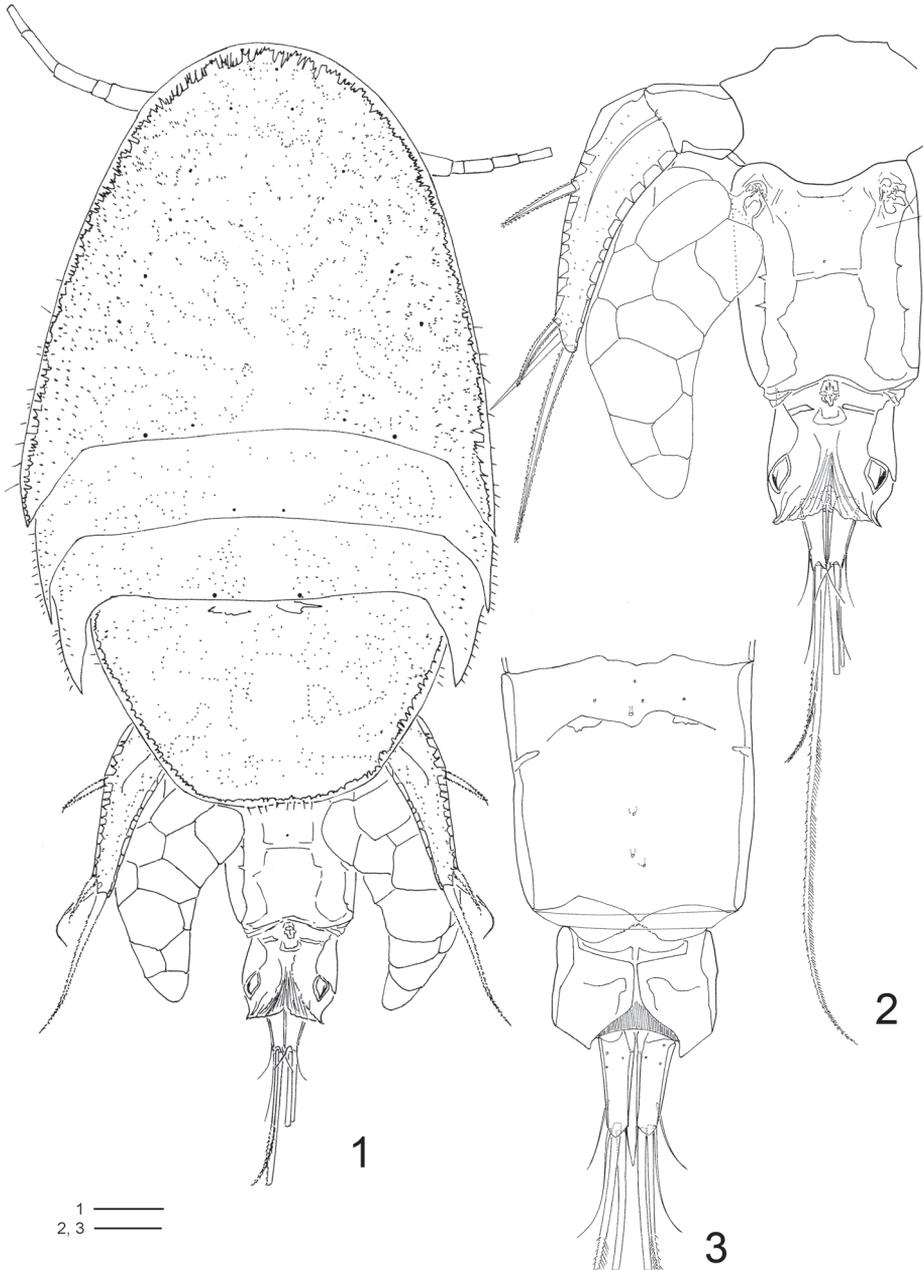
http://species-id.net/wiki/Clausidium_rodriguesi

Figs 1–11

Type material. Holotype female (reg. no. MZUSP 16464) in ethanol, dissected paratypes consist of 2 females and 2 males (reg. no. MZUSP 19628–19631) undissected paratype consist of 1 female (reg. no. MZUSP 19632) deposited in the collection of the Museu de Zoologia, Universidade de São Paulo, São Paulo, Brazil. All material collected in 02/1984 from the type locality by Prof. Dr. G. Shimizu.

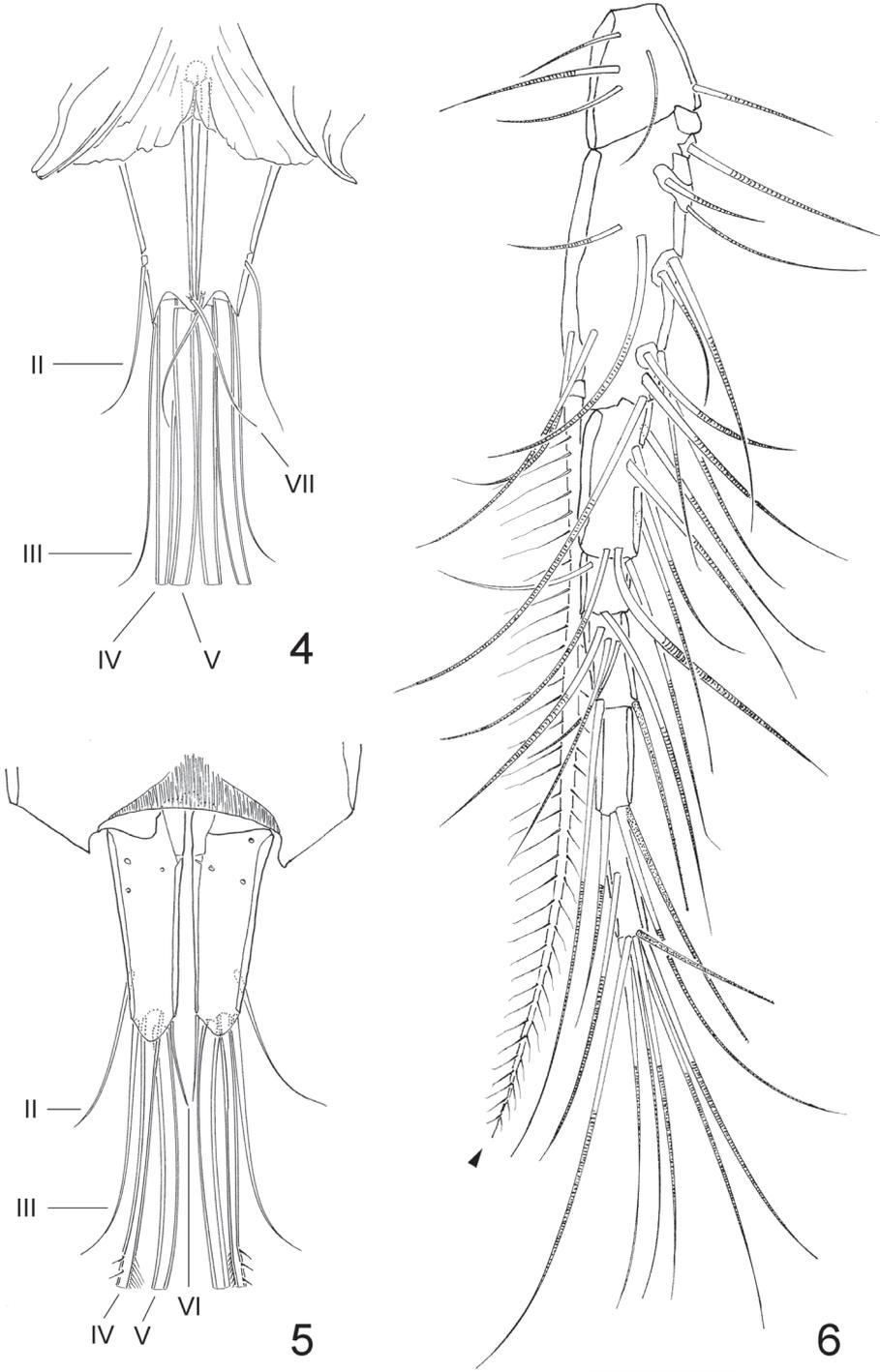
Type locality. Rio Grande do Norte, Natal, margin of Potengi river (5°45'S, 35°11'W). All specimens from water drawn from the burrows and pleopods of the ghost shrimp *Neocallichirus grandimana*.

Description. FEMALE (Figs 1–19, 32–38, 42, 45, 47, 48): Total length, excluding setae on caudal rami, 1.36–1.40mm (N=6). Body cycloform (Figs 1, 32–33), maximum width measured at posterior margin of cephalic shield. Prosome twice longer than urosome. First pedigerous somite fused with cephalosome. Body prosomites with minute integumental pits, sensilla and numerous pores distributed as illustrated in Fig. 1. Somites bearing P2–P3 subequal, both with latero-posterior margin sharply drawn out and posterior margin smooth. Somite bearing P4 trapezoid in form, longer than the two anterior somites combined, posterior margin with row of sensilla. Urosome (Figs 1–3, 32–35) 3-segmented, distinctly narrower than prosome. Urosome comprising fifth pedigerous somite, genital double-somite, and anal somite. Somite bearing P5 (Figs 1–2, 32–33) 1.4 times broader than long in dorsal view and with P5 arising ventrolaterally. Genital double-somite (Figs 1–3, 32–33) 1.3 times longer than broad, dorsal and ventro-lateral cuticular ridges marking plane of fusion between genital and first abdominal somite. Genital apertures (Fig. 2) located dorsolaterally on each side, near posterior margin of fifth pedigerous somite. Presence of pairs of pores near genital apertures and medial pore on dorsal view. Ventral surface with pores along medial region (Fig. 3). Egg sacs dorsolaterally located on each side, reaching posterior edge of anal somite and containing 13–15 eggs each. Anal somite (Figs 1–3, 32–33) well developed, formed by second to fourth abdominal somites fused in single somite; dorsal surface with well sclerotized leaf-like areas laterally displaced and intricate folders as illustrated in figures 2 and 34, clearly incised medially, posterior borders with pointed curved extensions on outer corners; almost quadrate in ventral view, with pointed posterior inner corners and fringed with membrane medially.



Figures 1–3. *Clausidium rodriguessi* sp. n. Female: **1** habitus, dorsal **2** urosome, dorsal **3** urosome lacking somite bearing P5, ventral. Scale bars: **1** = 100 μm ; **2, 3** = 50 μm .

Caudal ramus (Figs 2–5) about 3.5 times longer than wide, and armed with 6 setae. Seta I absent, setae II and III slender and naked; setae IV and V strongly developed and bipinnate, plumose on inner edge and spinulose on outer edge (seta V, 2.5 times



Figures 4–6. *Clausidium rodriguesi* sp. n. Female: **4** caudal rami, dorsal **5** caudal rami, ventral **6** antennule (arrow head indicating bipinnate seta). Scale bar = 50 μ m.

longer than seta IV); seta VI the shortest; seta VII triarticulate and located at inner posterior corner, both naked. Caudal ramus with rounded lappet on posterior margin of ventral surface covering basal portion of setae III–V.

Rostrum (Fig. 33) incorporated into cephalothorax, demarcated by sclerotized areas laterally; with pair of sensilla ventrally and pattern of pores as illustrated.

Antennule (Fig. 6) 7-segmented. Segment 2 longest, with well-developed pinnate seta inserted on inner distal corner and extending over tip of antennule (arrowed in Fig. 6). Aesthasc inconspicuous, very similar to other setae. Segment 6 with aesthasc fused basally to seta. Armature formula: I-[5], II-[14 + 1 bipinnate], III-[6], IV-[3], V-[4 + ae], VI-[2 + ae], VII-[7 + ae].

Antenna (Figs 7, 36) 4-segmented. Coxobasis elongated, with row of spinules along inner margin, with single seta on inner distal corner. Endopod 3-segmented; segment 1 with seta along inner margin; segment 2 with 4 setae (2 pinnate and 2 naked); segment 3 with row of spinules along distal margin, 7 apical setae, 2 of them with setules and 2 with spinules.

Labrum (Figs 8, 36, 39–40) twice wider than long; lateral projections with row of denticles. Metastomal area ornamented as in figures 40 and 41.

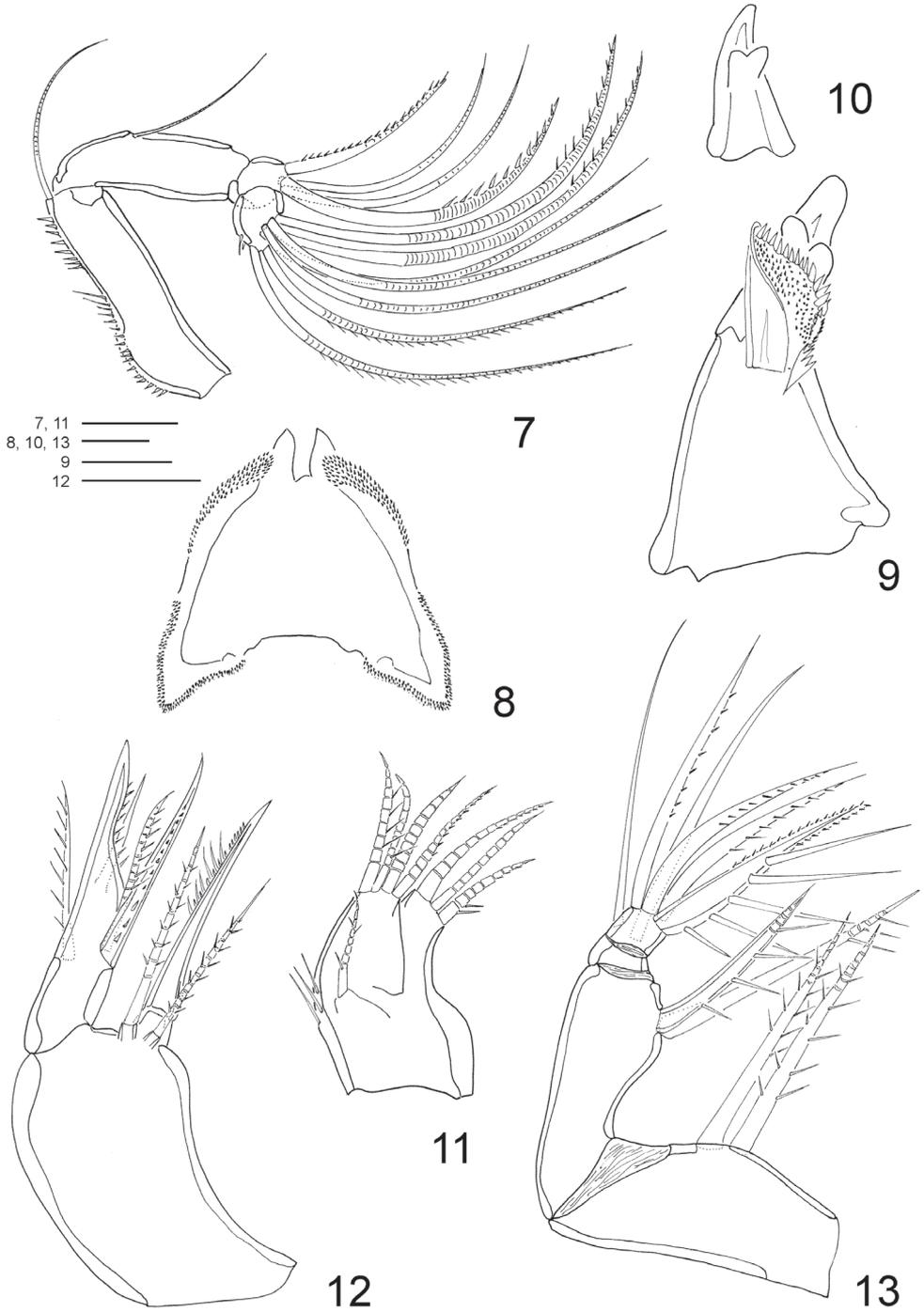
Mandible (Figs 9–10, 36) well developed. Armed with 3 elements, 1 toothed projection, 1 small seta, and 1 conical structure covered with minute spinules covering inner surface and spines along distal margin.

Maxillule (Figs 11, 36) bilobed, with 1 lateral seta pinnate. Outer lobe with row of spinules along outer margin and 4 setae (2 pinnate and 2 naked). Inner lobe with 3 setae (2 pinnate and 1 naked).

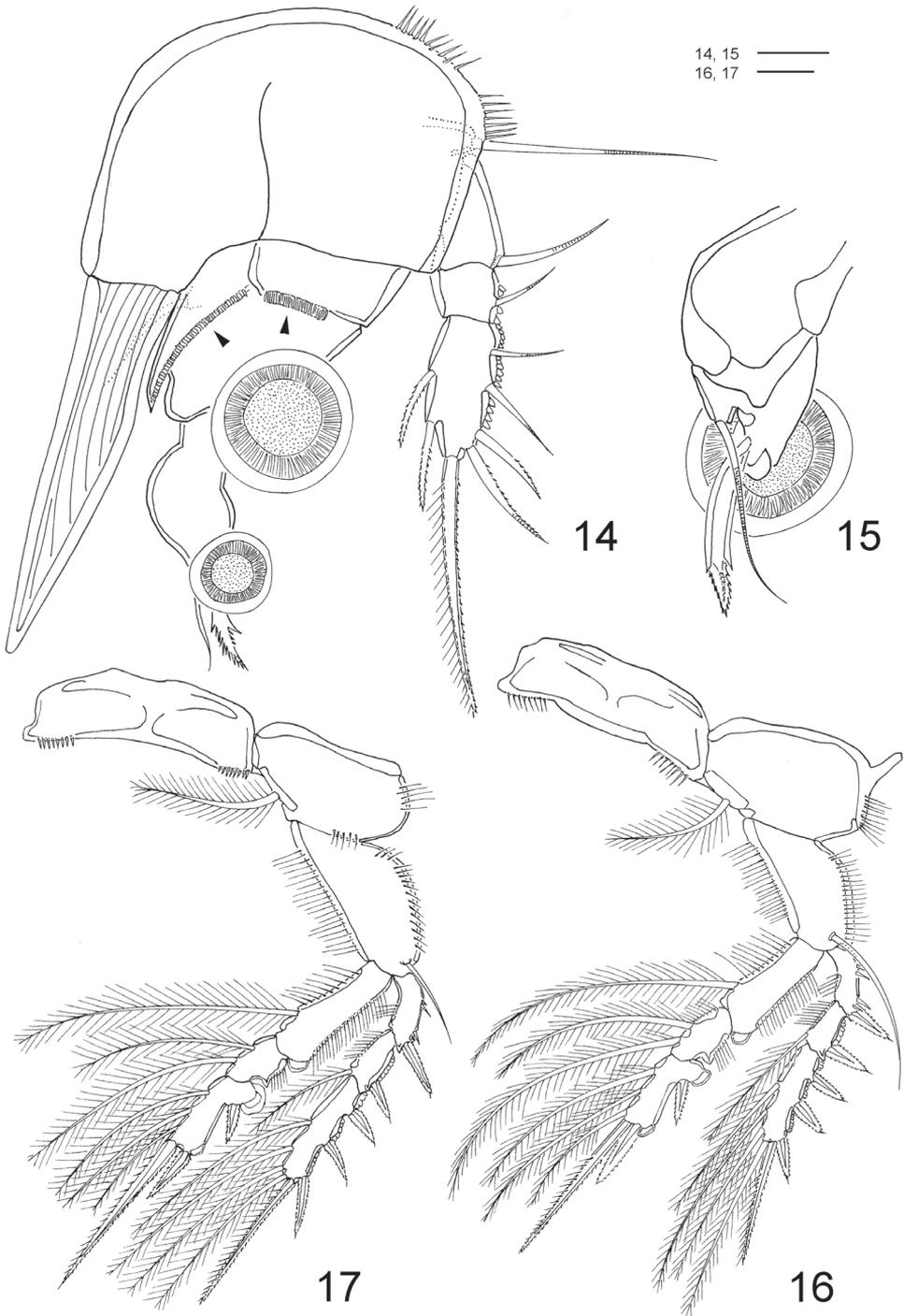
Maxilla (Figs 12, 36) 2-segmented. Syncoxa with 2 bipinnate setae and one stout spine with spinules on distal edge. Basis with large spinous process with spinules along concave margin, bearing 3 setae (2 pinnate and 1 naked) and 1 pinnate spine.

Maxilliped (Figs 13, 36) 4-segmented. Syncoxa with 2 bipinnate setae along inner margin. Basis with 1 pinnate seta and 1 spine with long spinules. Endopod 2-segmented; first segment unarmed; second segment bearing 2 naked lateral setae, 3 pinnate distal setae and stout distal spine with long and slender spinules along inner margin; minute spinules on opposite margin.

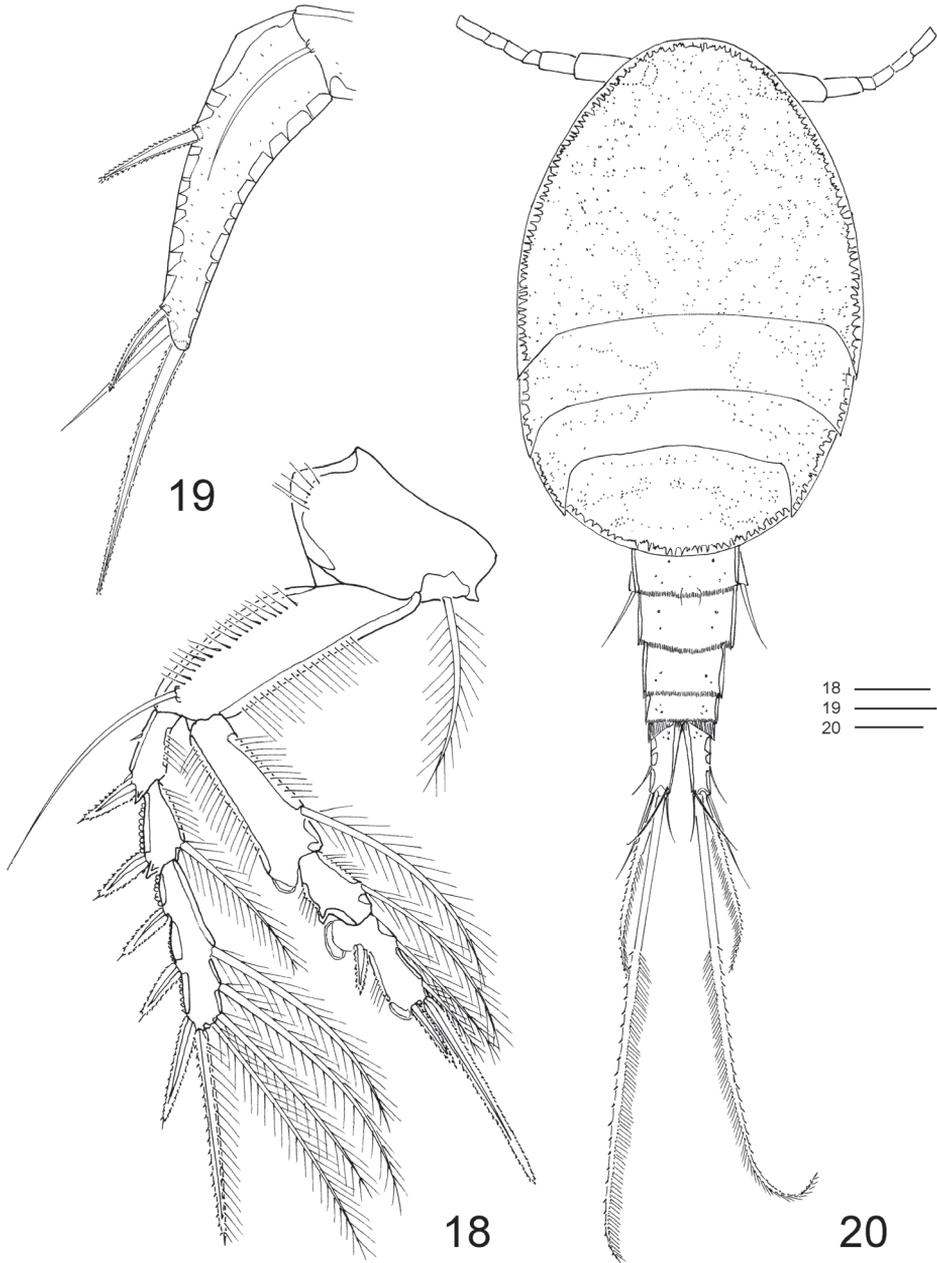
P1 (Figs 14–15, 33, 37, 42) biramous, both rami 3-segmented, and highly modified for prehension. Coxa and basis fused forming well-developed segment with row of spines along proximal margin, plumose seta on outer proximal corner; large blade-like seta with acute apex and concentric lines on inner distal corner. Exp-1 and -2 with 1 outer seta each; exp-2 with row of denticles along outer margin. Exp-3 with row of denticles along outer margin, 3 outer setae (2 naked and 1 pinnate), 2 apical setae (outer one pinnate, inner one longest and bipinnate) and 2 inner bipinnate setae. Enp-1 with 1 stout curved process with an adhesive fringe (arrowed in Fig. 14). Enp-2 with pinnate seta. Enp-3 elongated, irregular segment ending in a lobe with serrate margin and armed with 1 seta and 2 sucking discs (Fig. 15); proximal sucking disc 1.6 larger than distal one.



Figures 7–13. *Clausidium rodriguessi* sp. n. Female: **7** antenna **8** labrum **9** mandible **10** Detail of mandible tooth **11** maxillule **12** maxilla **13** maxilliped. Scale bars: 7 = 50 μ m; 8 = 10 μ m; 9, 10 = 25 μ m; 11–13 = 20 μ m.

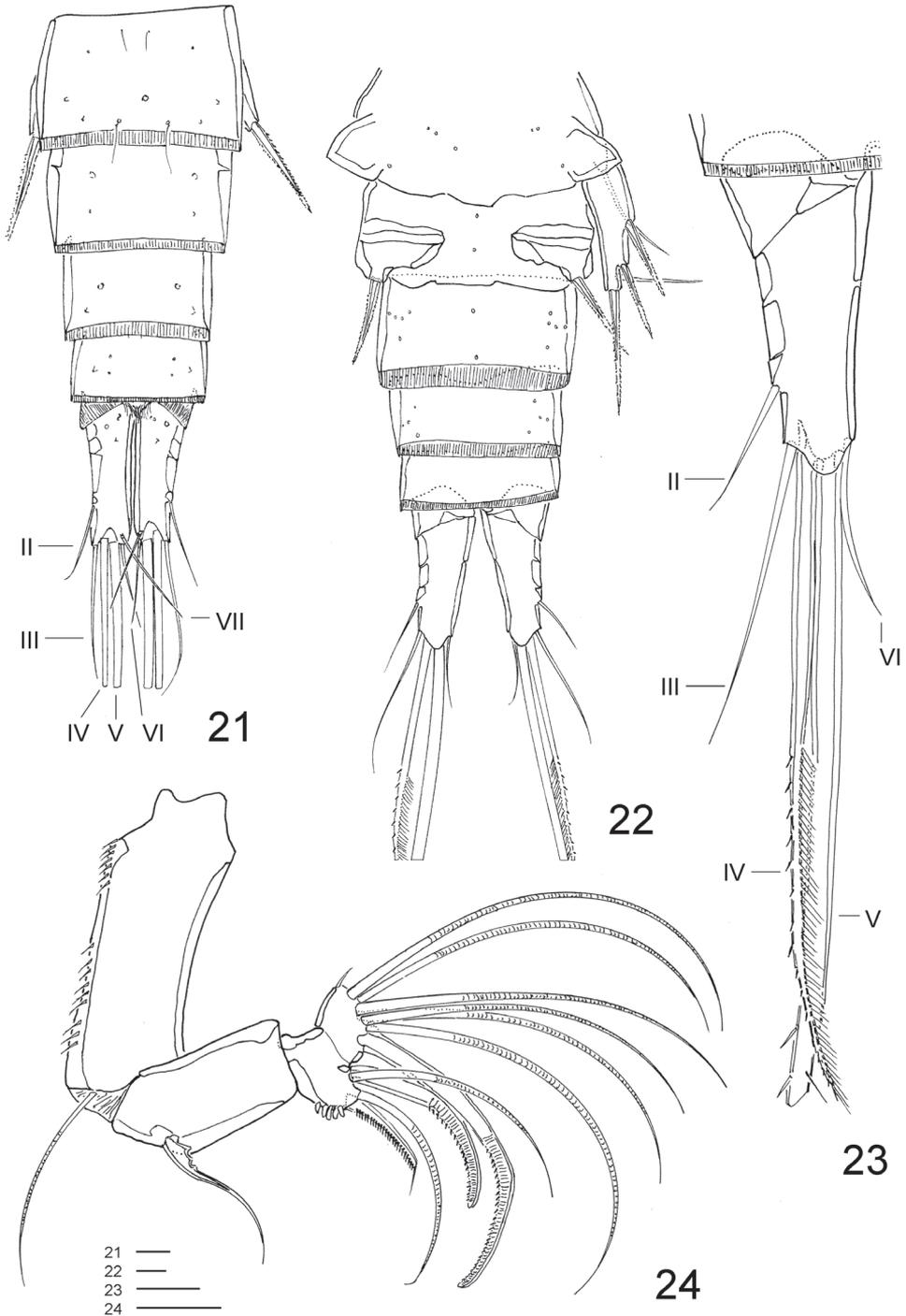


Figures 14–17. *Clausidium rodriguesi* sp. n. Female: **14** P1, anterior (arrows indicating adhesive fringe) **15** detail of distal area of P1 endopod, posterior **16** P2, anterior **17** P3, anterior. Scale bars: **14** =20 μm ; **15** =10 μm ; **16**, **17** =50 μm .

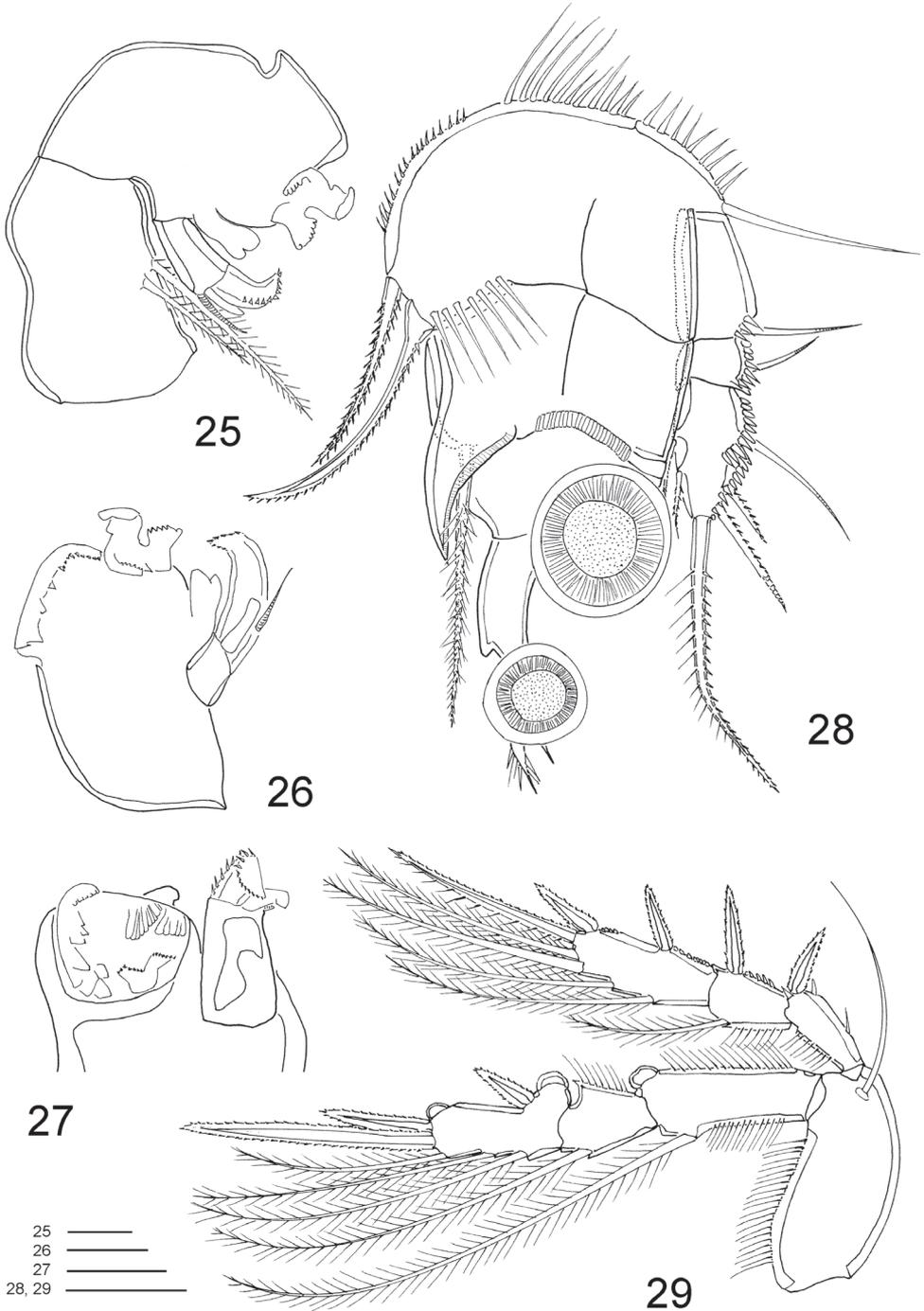


Figures 18–20. *Clausidium rodriguessi* sp. n. Female: **18** P4, anterior **19** P5, anterior. Male: **20** habitus, dorsal. Scale bars: **18** = 20 μm ; **19** = 50 μm ; **20** = 100 μm .

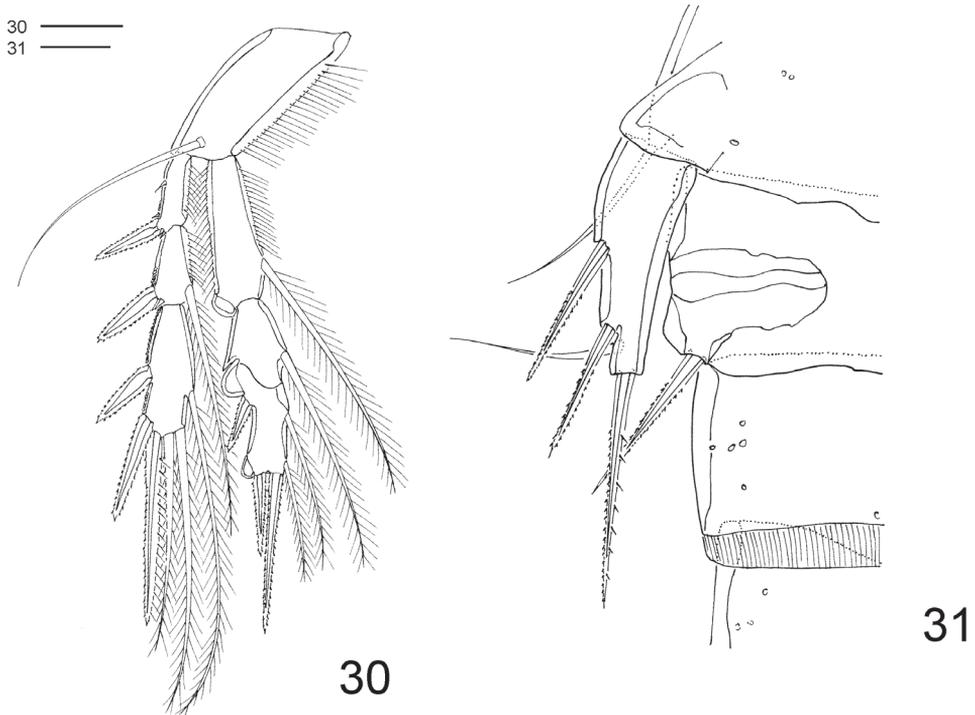
P2–P4 (Figs 16–18, 33, 38, 47) biramous, with both rami 3-segmented. Coxae with inner plumose seta, row of sparse setules along outer margin and row of spinules along distal margin (P3). Basis of P2–4 longitudinally elongate, with naked seta on outer distal



Figures 21–24. *Clausidium rodriguezi* sp. n. Male: **21** urosome lacking somite bearing P5, dorsal **22** urosome, ventral **23** caudal ramus, dorsal **24** antenna. Scale bars: **21–23** =20 µm; **24** =25 µm.



Figures 25–29. *Clausidium rodriguessi* sp. n. Male: **25** mandible **26** mandible, detail, ventral **27** mandible, detail, dorsal **28** P1, anterior **29** P2, anterior. Scale bars: **25–27** = 10 μm ; **28, 29** = 20 μm .



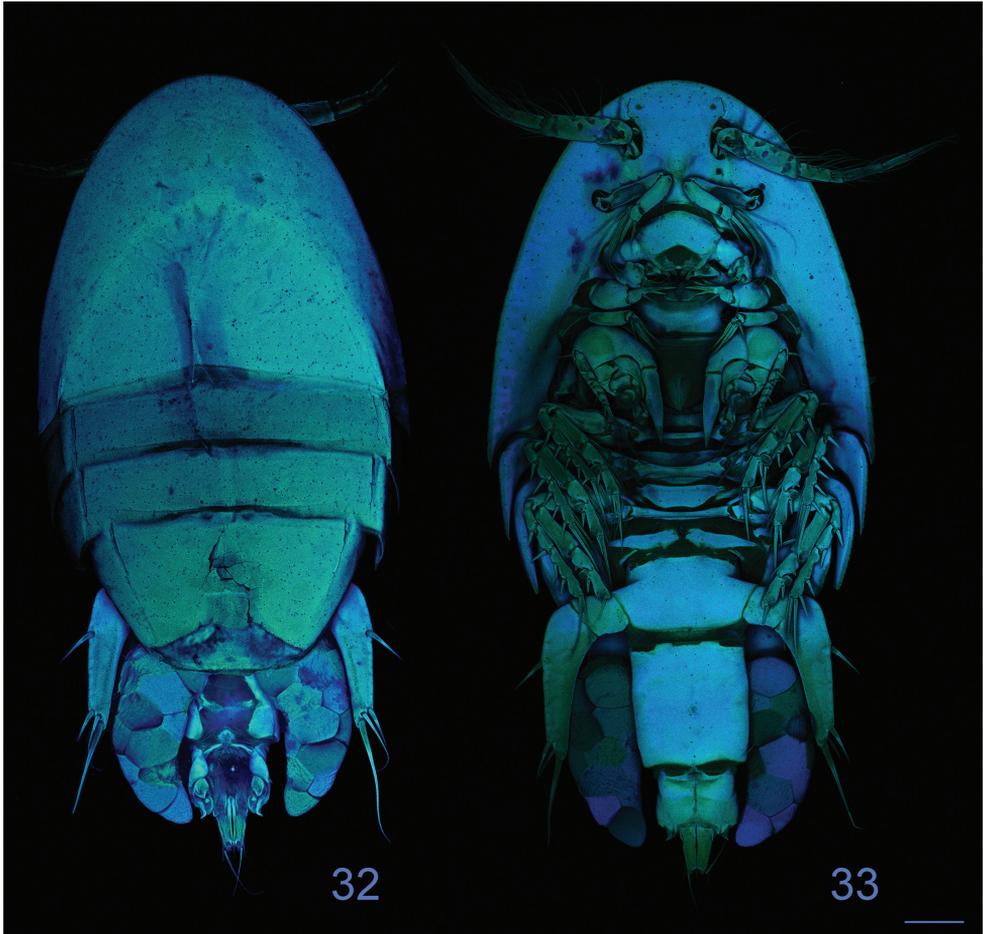
Figures 30–31. *Clausidium rodriguezsi* sp. n. Male: **30** P4, anterior **31** P5 and P6. Scale bar: 20 μ m.

corner, row of spinules along outer margin and row of setules along inner margin. Exp-1 and Exp-2 with row of setules along inner margin and row of spinules (exp-1) or denticles (exp-2) along outer margin, but exp-3 with denticles along outer margin; exopod outer spines serrate and with terminal flagellum (Fig. 48), apical spine with serrate outer margin and spinulose inner margin. Enp-1 and Enp-2 with row of setules along both margins; endopod outer and apical spines serrate and with terminal flagellum, inner apical spines with serrate outer margin and spinulose inner margin (P2–P3) (Figs 16, 17) or both margins serrate (P4) (Fig. 18); sucking discs (Fig. 47, detail in Fig. 49) on distal inner edge of enp-1 and proximal and subterminal inner edges of enp-3.

Armature formula of P2–P4 (Figs 13–16) as follows (Roman numerals representing spines, Arabic numerals representing setae):

	Coxa	Basis	Exopod	Endopod
P2	0-1	1-0	I-0; I-1; III,I,4	0-1; 0-2; I,II,3
P3	0-1	1-0	I-0; I-1; III,I,4	0-1; 0-2; I,II,3
P4	0-1	1-0	I-0; I-1; III,I,4	0-1; 0-1; I,II,2

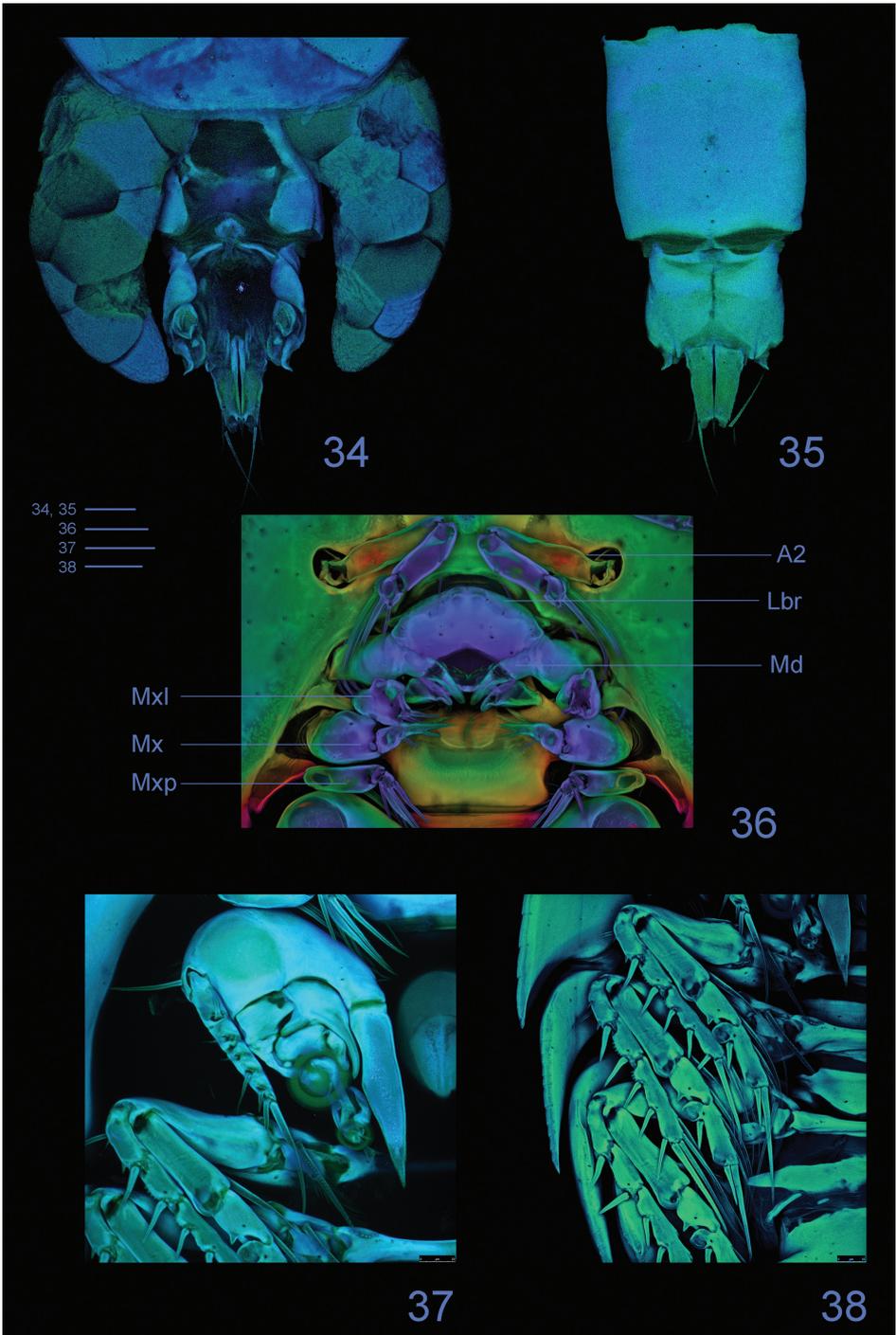
P5 (Figs 2, 19, 33) uniramous, 2-segmented and located laterally on somite. Proto-pod with 1 outer seta; free exopodal segment elongated with 2 serrate spines, 1 naked seta along outer margin and serrate spine apically; dorsal punctuations as in figures 19 and 33.



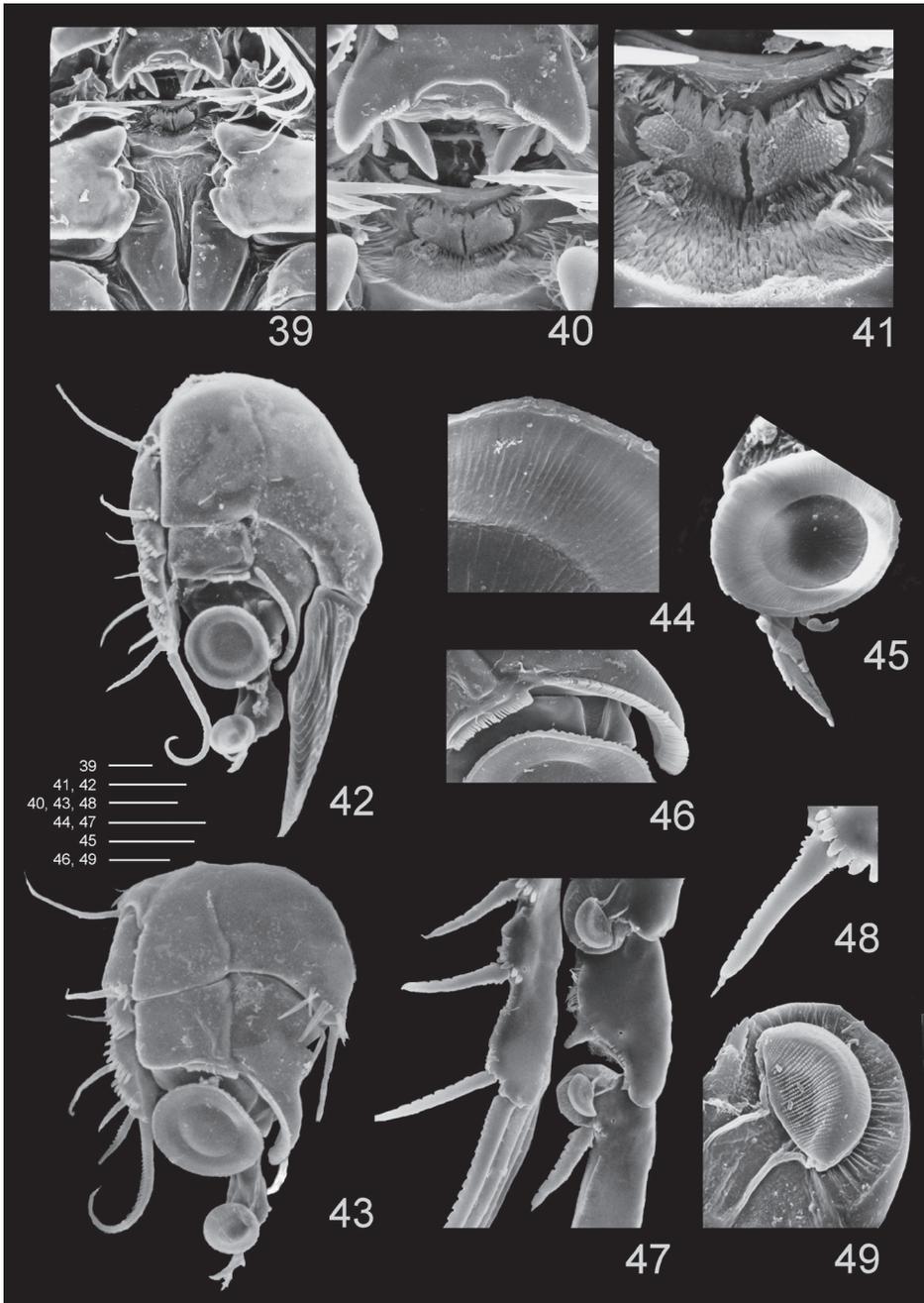
Figures 32–33. *Clausidium rodriguessi* sp. n. Female: Confocal laser scanning microscopy maximum projections **32** habitus, dorsal **33** habitus, ventral. Scale bars: 100 μ m.

P6 (Fig. 2) consisting of 3 small setae.

MALE (Figs 20–31, 39–41, 43, 44, 46): Total length, excluding setae on caudal rami, 0.75–0.79mm (N=4). Body cyclopiform (Fig. 20). Prosome longer than urosome (1.5:1). First pedigerous somite fused with cephalosome. Body prosomites with minute integumental pits, sensilla and numerous pores distributed as illustrated in figure 20. Cephalosome and 3 free prosomites with posterior borders smooth; somites bearing P2–P3 subequal; somite bearing P4 with distal margin rounder than in female. Urosome (Figs 21–22) 6-segmented, distinctly narrower than prosome. Somite bearing P5 (Fig. 22) 1.5 times broader than long in ventral view and with P5 arising ventrolaterally. Pores and sensilla as illustrated in Figures 21–22. Hyaline frills of first to third abdominal somites finely striated. Anal somite (Figs 21–22) extremely reduced and deeply incised medially, with hyaline frill on dorsal posterior margin.



Figures 34–38. *Clausidium rodriguessi* sp. n. Female: Confocal laser scanning microscopy maximum projections **34** urosome, dorsal **35** urosome lacking somite bearing P5, ventral **36** antenna and oral region **37** P1, anterior **38** P2-P4, anterior. Scale bars: 50 μm.



Figures 39–49. *Clausidium rodriguesi* sp. n.: Scanning electron microscopy photos **39** metastomal area, male **40** detail of metastomal area, male **41** detail of metastomal area, male **42** P1, anterior, female **43** P1, anterior, male **44** detail of sucking disc of P1, male **45** detail of lobe with serrate margin and distal sucking disc of enp-3 of P1, female **46** detail of P1 enp-1 adhesive fringe, male **47** suckling discs of P2, female **48** detail of serrate spine with apical flagellum of P2, female **49** detail of sucking disc of P2, female. Scale bars: **39, 40, 47** =25 μm; **41, 44–46** =10 μm; **42** =35 μm; **43** =20 μm; **48** =12.5 μm; **49** =4 μm.

Caudal ramus (Figs 21–23), antennule, mandible, maxillule and maxilla resembling those of female.

Antenna (Fig. 24) 4-segmented. Coxobasis elongated, with row of spinules along inner margin, with single seta on inner distal corner. Endopod 3-segmented; seta on segment 1 with proximal third enlarged and irregular, inserted along inner margin; segment 2 with row of denticles, 2 naked setae, spinulose spine with terminal flagellum and curved spine with serration along distal inner margin; segment 3 with row of spinules along distal margin, 6 naked setae and 1 curved spine with serration along distal inner margin.

Maxilliped (Figs 25–27, 39) well developed, strongly modified. Syncoxa with 2 pinnate setae. Basis with unequal denticulate projections and distal half of border curved and with irregular margin. Endopod 1-segmented; with strong serrate claw implanted near curved projection, and 1 small seta.

P1 (Figs 28, 43) similar to female. Coxa and basis fused, with rows of stout spinules along proximal margin, row of long spinules near inner distal corner, long naked seta on outer edge and 2 pinnate setae on inner distal corner. Exp-1 and Exp-2 with 1 outer seta each, and row of spinules along outer margin. Exp-3 with row of denticles along outer margin, 3 outer setae (2 pinnate and 1 naked), 1 apical bipinnate seta and 2 inner bipinnate setae. Enp-1 with adhesive fringe along distal margin, stout curved process with adhesive fringe (Fig. 46) and long pinnate seta on inner distal corner. Enp-2 and Enp-3 as in female.

P2–P4 (Figs 29–30) lacking outer spine on Exp-3. P4 (Fig. 30) without inner seta on Exp-3. Armature formula of P2–P4 as follows (Roman numerals representing spines, Arabic numerals representing setae):

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

P5 (Fig. 31) smaller than in female.

P6 (Fig. 31) represented by membranous flaps with bipinnate seta.

Variability. One female paratype showed left P3 endopod modified - enp-2 with only 1 seta and enp-3 with 8 elements in total (I,II, I+4).

Etymology. The new species is named in honor of Prof. Dr. Sérgio de A. Rodrigues (Universidade de São Paulo) in recognition of his significant contributions to the taxonomy of Callianassidae and who kindly made available the studied material.

Discussion

Although the new species *C. rodriguesi* resembles *C. senegalense* and *C. vancouverense* in the armature of P2–P5 of the female, and shares with *C. senegalense* similar segmentation and

armature of the female antenna and maxilla, it can be easily distinguished from its congeners by the unique characteristics observed in the males, = i. e., antenna with modified elements (enlarged seta on endopod-1 and spines on endopod-2 and endopod-3); maxilliped with distinct denticulate projections; and P1 coxobasis with 1 outer and 2 inner setae.

Other differential features refer to the morphology of the anal somite with sclerotized leaf-like areas and intricated folders dorso-laterally, posterior borders with pointed curved extensions on outer corners and clearly incised medially; maxillule with apical outer lobe bearing 2 pinnate and 2 naked setae, as well as maxillular inner lobe bearing 2 pinnate and 1 naked setae; and female maxilliped with 1 pinnate seta and 1 pinnate spine on basis, and endopod-2 bearing 2 naked lateral setae and 4 pinnate apical elements (3 setae and 1 spine).

This new species, the first record of *Clausidium* in Brazil, not only extends the group distribution to the Southwest Atlantic but also enlarges the host list for the genus by adding *N. grandimana* (Gibbes, 1850).

A dichotomous key to the 11 valid species of *Clausidium* based exclusively on females is given below. Males differ from females by shape and size of the body, as well as by small differences in the segmentation and armature of antenna, setal formulae of legs, maxilliped strongly modified - adapted to grasp the female. In addition, many records of males are not well detailed. Thus, any identification of males must be verified against the best available description of the species.

1	Antenna 3-segmented	2
–	Antenna 4-segmented	3
2	Antennary distal segment with 5 setae .. <i>Clausidium caudatum</i> (Say, 1818)	
–	Antennary distal segment with 7 setae ... <i>Clausidium searsi</i> C. B. Wilson, 1937	
3	P2 and P3 enp-2 with 1 seta	4
–	P2 and P3 enp-2 with 2 setae.....	5
4	P1 exp-3 with 5 elements in total..... <i>Clausidium saldanhae</i> Kensley, 1974	
–	P1 exp-3 with 7 elements in total..... <i>Clausidium tenax</i> Humes, 1949	
5	P4 enp-2 with 1 seta	6
–	P4 enp-2 with 2 setae.....	7
6	Maxilliped enp-2 with 5 elements in total; antenna enp-2 with 3 setae	
 <i>Clausidium vancouverense</i> (Haddon, 1912)	
–	Maxilliped enp-2 with 6 elements in total; antenna enp-2 with 4 setae	
 <i>Clausidium rodriguessi</i> sp. n.	
7	P2 and P3 enp-3 with 5 elements in total	
 <i>Clausidium apodiforme</i> (Philippi, 1839)	
–	P2 and P3 enp-3 with 6 elements in total	8
8	P4 exp-3 with 9 elements in total... <i>Clausidium travancoreense</i> Pillai, 1959	
–	P4 exp-3 with 8 elements in total.....	9
9	P1 exp-3 with 4 elements in total <i>Clausidium dissimile</i> C. B. Wilson, 1921	
–	P1 exp-3 with 5 elements in total..... <i>Clausidium chelatum</i> Pillai, 1959	
–	P1 exp-3 with 7 elements in total..... <i>Clausidium senegalense</i> Humes, 1957	

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An introduction to Iranian Collembola (Hexapoda): an update to the species list

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Abstract

The Collembola fauna of Iran is little known and no comprehensive examination of this group of Hexapoda is available for this region. The only notable work on Collembola was carried out by Cox (1982). Recently, studies on the Collembola fauna have started in several regions. In this paper, publications by different researchers are documented and the species that have been found in different regions of Iran until January 2013 are listed. At present, 112 species, belonging to 18 families and 57 genera are known from Iran.

Keywords

Springtails, taxonomy, Iran, checklist

Introduction

Worldwide about 8,000 species of Collembola have been described (Bellinger et al. 1996–2012). Most Collembola species have been reported from Europe or North America but little literature or taxonomic keys are available from Asian countries especially from those of the Middle East.

Iran is a country in southwest Asia with an area of 1,648,195 km². It spans several different climatic zones and biomes, therefore the diversity of animals is high and this presumably also applies to those living in soil. According to biogeographic zonation, Iran has been considered part of the Palearctic region by most authors. However, some parts in the southern Iran, such as Khuzestan Plain and Persian Gulf coast, have been considered as Ethiopian (Cox 1982). The study of Collembola fauna of Iran is poor and most attention has been paid to crop pest species, which are few.

Farrahbakhsh (1961) was the first to provide information on Iranian Collembola. He reported *Sminthurus viridis* Linnaeus, 1758 from wheat and alfalfa fields in Khuzestan (Southern Iran). The most comprehensive study on Collembola was carried out by Cox (1982) who travelled to Northern, West and Central provinces in Iran and collected and identified 70 species of 30 genera and five families. The scientific names of some species recorded by Cox were changed later and their modern names are used in Appendix: *Cyphoderus ambigua* was changed to *Oncopodura ambigua* according to Christiansen (1957); the genus *Cryptopygus* Willem, 1902 was changed to *Hemisotoma* Börner, 1903 according to Rusek (2000). The species *Folsomia litsteri* Bagnall, 1939 was changed to *F. candida* (Willem, 1902); *F. multiseta* Stach, 1947 was changed to *F. penicula* Bagnall, 1939; *Neanura echinata* (Kos, 1940) was changed to *Thaumanura echinata* (Kos, 1940); the genus *Xenyllodes* Axelson, 1903 was changed to *Axenyllodes* Stach, 1949; *Xenyllodes lamellifera* was changed to *Superodontella lamellifera* (Axelson, 1903); *Onychiurus pseudogranulosus* Gisin, 1951 was changed to *Onychiuroides pseudogranulosus* (Gisin, 1951); *Onychiurus rectopapillatus* Stach, 1933 was changed to *Orthonychiurus rectopapillatus* (Stach, 1933). Also *Sminthurus marginatus* Schött, 1893 which is recorded by Kahrarian et al. (2012) was changed to *Caprainea marginata* (Schoett, 1893). Recently, some master and doctoral students started to work on the Collembola fauna of several regions of Iran and therefore the list of species certainly will increase.

Here we provide an update to the list of Iranian Collembola published from 1961 to 2013 mainly from the northern Iran. Obviously, the fauna of large parts of Iran is unknown and there is a need for additional research on the distribution of species but also on other aspects of these animals such as ecology, biology and their role in ecological processes in different ecosystems. It is the intention of the paper to encourage young entomologists to become aware of these gaps of knowledge and direct their interest towards Collembola fauna of this country.

Methods

The updated Iranian Collembola list was provided from two resources. First, it is based on bibliographic references and unpublished records from different regions (taxa not ascribed to species are not included in the total number of species). Second, results of sampling campaigns of Collembola by authors from different regions in Iran during 2009–2012 years are included. In the latter studies, soil and litter samples were collected from various habitats in Sari, Gorgan (Northern Iran) and Kermanshah



Figure 1. Extractor system for soil animals.

(Western Iran). The samples were placed in dark polythene bags. Collembola were extracted from soil and leaf litter by Berlese funnels (Figure 1). Animals were collected in water and separated under a dissecting microscope. The extracted specimens were preserved in 75% ethanol. Permanent microscopic slides were prepared using Hoyer medium; for immediate identification, a mixture of lactic acid and glycerin (5:1) was used. For observing detailed structures of specimens, a 100×oil immersion objective was used. The specimens were identified by taxonomic keys such as Gisin (1960), Fjellberg (1980, 1998, and 2007), Bretfeld (1999) and Potapov (2001). Identification of species was confirmed by Collembola experts such as Dr. Mikhail Potapov (Russia), Dr. Hans-Uergen Schulz (Germany), Dr. Ulrich Burkhart (Germany) and Dr. Louis Deharveng (France).

Result and discussion

The number of Iranian Collembola species recorded until March 2012 is 112, belonging to 18 families and 57 genera. A systematic list of species according to the modern classification for the class Collembola (Deharveng, 2004) and details of species collection are shown in Appendix. The distribution of the species in the different provinces is shown in Figure 2. Most recorded species belong to Isotomidae (24%) and Entomobryidae (21%) (Figure 3). Collembola taxa for which species were not identified and which were reported as sp. was not included in this checklist. In addition to the genera shown in Appendix, some specimens from the genera, *Pachyotoma* (Bagnall, 1949), *Prodrepanura* (Stach, 1963), *Isotomodes* (Linnaniemi, 1907), *Gnathofolsomia* (Deharveng & Christian, 1984) *Protaphorura* (Absolon, 1901) (distributed in Kermanshah) by Kahrarian et al. (2012), *Orchesella* Templeton, 1835 (distributed in Kermanshah and Golestan) by Falahati et al. (2011), *Stenacidia* Reuter, 1881, (distributed in Gilan) by Daghighi (2012) were reported for Iran fauna but the species were not identified. Some species belonging to Symphypleona were recorded by Falahati et al. (2013b) with dubious identification, for example the photo illustrated the species *Sminthurinus reticulatus* seems to be belonging to Arrhopalitidae. The species listed in this paper include *Dicyrtomina ornate*, *Smin-*

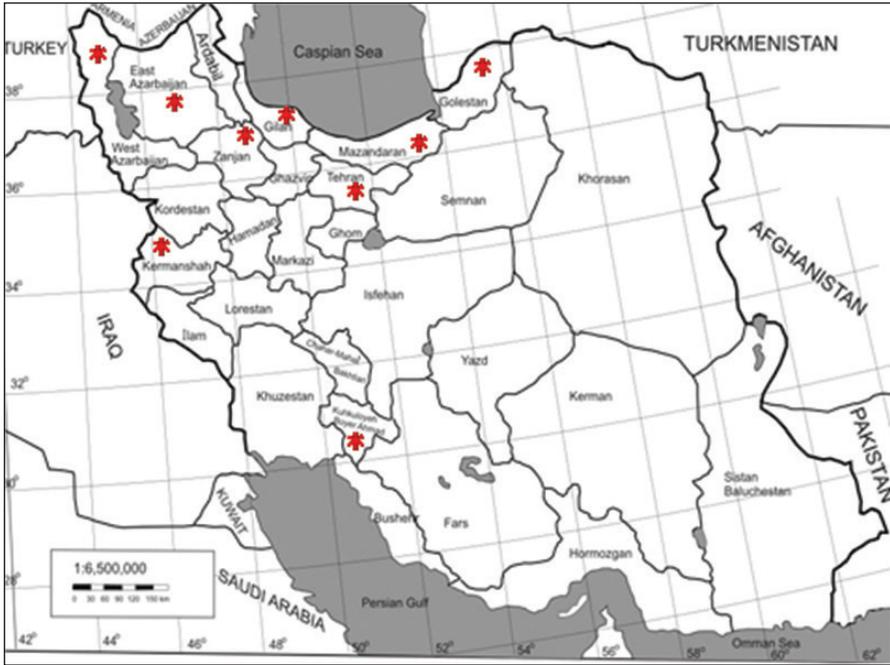


Figure 2. Map of Iran showing the provinces (*) from which Collembola have been collected.

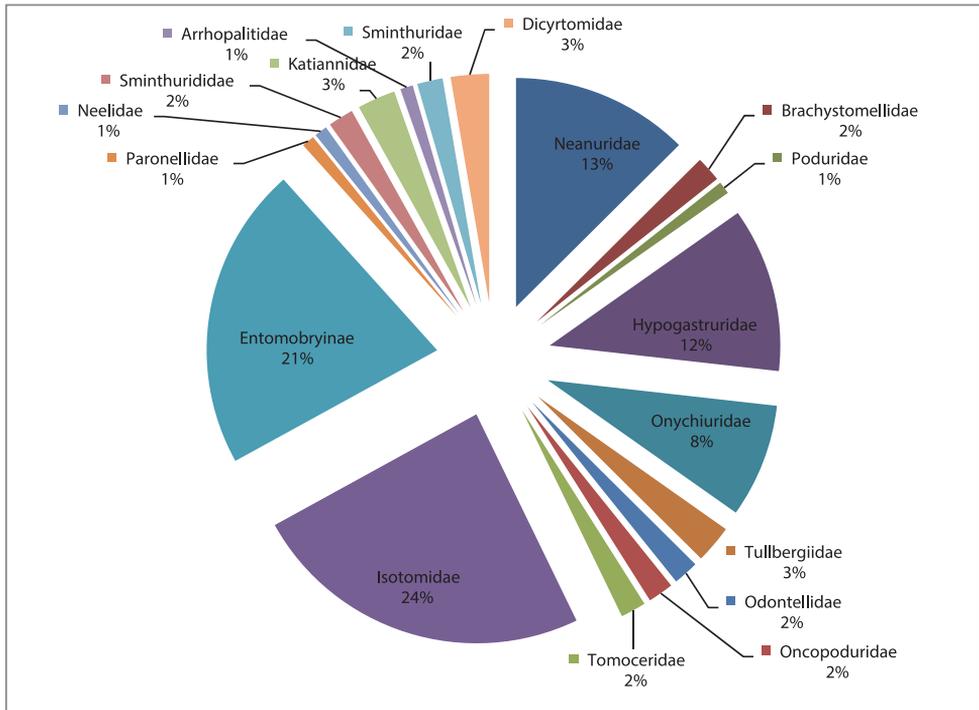


Figure 3. Percentage of Iranian Collembola species from different families.

thurides aquaticus, *Smynthurinus signatus*, *Smynthurinus transversalis*, *Smynthurinus reticulatus* and *Smynthurinus elegans*. Additionally Dr. Bretfeld didn't confirm the identifications. For these reasons the species recorded in this paper are excluded from present checklist.

The results of this paper indicate that study of Collembola is at an early stage in Iran but recently interest in the group is increasing.

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Appendix

Checklist of Iranian Collembola species. Species marked by * were recorded for the first time from Iran.

Taxonomy Class/Order/Family/Subfamily/ Species	Reference	Distribution in Iran Province/Location	Habitat
Class Collembola			
Order Poduromorpha			
Family Neanuridae			
Subfamily Pseudachorutinae			
Genus Anurida Laboulbne, 1865			
<i>Anurida ellipsoides</i> Stach, 1949	Cox (1982)	E. Azarbaijan, W. Azarbaijan	Soil, Leaf litter
<i>Anurida sensillata</i> Gisin, 1953	Cox (1982)	Gilan	Soil, Leaf litter
<i>Anurida thalassophila</i> (Bagnall, 1939)	Cox (1982)	Gilan, E. Azarbaijan	Soil, Leaf litter
Genus Pseudachorutes Tullberg, 1871			
<i>Pseudachorutes dubius</i> Krausbauer, 1898	Cox (1982)	Central, Gilan	Soil, Leaf litter
<i>Pseudachorutes parvulus</i> Börner, 1901	Cox (1982)	Central, Gilan	Soil, Leaf litter
<i>Pseudachorutes subcrassus</i> Tullberg, 1871	Cox (1982)	Central, Gilan	Soil, Leaf litter
Subfamily Frieseinae			
Genus Friesea Dalla Torre, 1895			
<i>Friesea mirabilis</i> (Tullberg, 1871)	Cox (1982)	Central, Gilan, E. Azarbaijan	Soil, Leaf litter
Subfamily Morulininae			
Genus Morulina Börner, 1906			
<i>Morulina verrucosa</i> Börner, 1903*	Daghighi (2012)	Gilan/Rasht	Soil (<i>Ulmus</i> sp.)
Subfamily Neanurinae			
Genus Bilobella Caroli, 1912			
<i>Bilobella aurantiaca</i> (Caroli, 1912)	Cox (1982)	Central, Mazandaran, Gilan, E. Azarbaijan	Soil, Leaf litter
Genus Cryptonura Cassagnau, 1979			
<i>Cryptonura persica</i> sp. n.*	Smolis et al. (2012)		
<i>Cryptonura maxima</i> sp. n.*	Smolis et al. (2012)		
Genus Deutonura Cassagnau, 1979			
<i>Deutonura decolorata</i> (Gama & Gisin, 1964)	Cox (1982)	Mazandaran	Soil, Leaf litter
Genus Neanura MacGillivray, 1893			
<i>Thaumanura echinata</i> (Kos, 1940)	Cox (1982)	unknown	Soil, Leaf litter
<i>Neanura muscorum</i> (Templeton, 1835)	Cox (1982) Yahyapour (2012)	Mazandaran, Gilan, Zanjan Mazandaran/ Sari	Leaf litter
Family Brachystomellidae			
Genus Brachystomella Agren, 1903			
<i>Brachystomella parvula</i> (Schäffer, 1896)	Cox (1982)	Gilan, E. Azarbaijan, Zanjan	Soil, Leaf litter
<i>Brachystomella nubila</i> Gisin, 1957	Cox (1982)	Gilan, E. Azarbaijan, Zanjan	Soil, Leaf litter
Family Poduridae			
Genus Podura Linnaeus, 1758			
<i>Podura aquatica</i> Linnaeus, 1758	Cox (1982)	Central	Soil, Leaf litter near water
Family Hypogastruridae			
Genus Ceratophysella Börner, 1932			
<i>Ceratophysella armata</i> (Nicolet, 1841)*	Falahati et al. (2012)	Kohgiluyeh and Boyer- Ahmad, Charam	Soil

Taxonomy Class/Order/Family/Subfamily/ Species	Reference	Distribution in Iran Province/Location	Habitat
<i>Ceratophysella denticulata</i> (Bagnall, 1941)	Cox (1982) Yahyapour (2012) Ghahramanine- zhadand et al. (2012)	Central, Mazandaran, Gilan, E. Azarbaijan, W. Azarbaijan, Zanjan Mazandaran/ Sari Kermanshah	Leaf litter Soil
<i>Ceratophysella stercoraria</i> Stach, 1963*	Kahrarian et al. (2012) Falahati et al. (2012)	Kermanshah, Sahneh Kohgiluyeh and Boyer- Ahmad, Charam	Soil
Genus <i>Choreutinula</i> Paclt, 1944			
<i>Choreutinula inermis</i> Tullberg, 1871*	Daghighi (2012)	Gilan/Rasht	Soil (<i>Prunus</i> sp., <i>Ficus</i> sp., <i>Platanus</i> sp., <i>Ulmus</i> sp., <i>Alnus</i> sp.)
Genus <i>Hypogastrura</i> Bourlet, 1839			
<i>Hypogastrura assimilis</i> (Krausbauer, 1898)*	Falahati et al. (2012)	Kohgiluyeh and Boyer- Ahmad, Charam	Soil
<i>Hypogastrura manubrialis</i> (Tullberg, 1869)	Cox (1982) Falahati et al. (2012)	Central, Mazandaran, Gilan, E. Azarbaijan, W. Azarbaijan, Zanjan Kohgiluyeh and Boyer- Ahmad, Charam	Soil, Leaf litter
<i>Hypogastrura tullbergi</i> (Schäffer, 1900)	Cox (1982)	Mazandaran, Gilan	Soil, Leaf litter
<i>Hypogastrura vernalis</i> (Carl, 1901)*	Falahati et al. (2012)	Kohgiluyeh and Boyer- Ahmad, Charam	Soil
Genus <i>Xenylla</i> Tullberg, 1869			
<i>Xenylla humicola</i> (Fabricius, 1780)	Cox (1982)	Gilan, E. Azarbaijan, W. Azarbaijan	Soil, Leaf litter
<i>Xenylla maritima</i> Tullberg, 1869	Cox (1982)	Gilan, E. Azarbaijan, W. Azarbaijan	Soil, Leaf litter
<i>Xenylla welchi</i> Folsom, 1916*	Yahyapour (2012) Falahati et al. (2012)	Mazandaran/ Sari Kohgiluyeh and Boyer- Ahmad, Charam	Leaf litter Soil
Genus <i>Willemia</i> Börner, 1901			
<i>Willemia anophthalma</i> Börner, 1901	Cox (1982)	Central, E. Azarbaijan	Soil, Leaf litter
<i>Willemia aspinata</i> Stach, 1949*	Daghighi (2012)	Gilan/Rasht	Soil (<i>Pinus</i> sp.)
Family Onychiuridae			
Subfamily Onychiurinae			
Genus <i>Protaphorura</i> Absolon, 1901			
<i>Protaphorura fimata</i> (Gisin, 1952)	Cox (1982)	Central, Mazandaran, Gilan, E. Azarbaijan, W. Azarbaijan, Zanjan	Soil, Leaf litter
<i>Protaphorura bicampata</i> (Gisin, 1956)	Cox (1982)	Central, Mazandaran, Gilan, E. Azarbaijan, W. Azarbaijan, Zanjan	Soil, Leaf litter
<i>Protaphorura quadriocellata</i> (Gisin, 1947)	Cox (1982)	Central, Mazandaran, Gilan, E. Azarbaijan, W. Azarbaijan, Zanjan	Soil, Leaf litter
Genus <i>Onychiuroides</i> Bagnall, 1948			
<i>Onychiuroides granulosus</i> (Stach, 1930)	Cox (1982)	Central, Mazandaran, Gilan, E. Azarbaijan, W. Azarbaijan, Zanjan	Soil, Leaf litter
<i>Onychiuroides pseudogramulosus</i> (Gisin, 1951)	Cox (1982)	Central, Mazandaran, Gilan, E. Azarbaijan, W. Azarbaijan, Zanjan	Soil, Leaf litter

Taxonomy Class/Order/Family/Subfamily/ Species	Reference	Distribution in Iran Province/Location	Habitat
Genus <i>Hymenaphorura</i> Gervais, 1841			
<i>Hymenaphorura sibirica</i> (Tullberg, 1876)	Cox (1982)	Central, Mazandaran, Gilan, E. Azarbaijan, W. Azarbaijan, Zanjan	Soil, Leaf litter
Genus <i>Orthonychiurus</i> Stach, 1954			
<i>Orthonychiurus folsomi</i> (Schäffer, 1900)*	Yahyapour (2012)	Mazandaran/ Sari	Leaf litter
<i>Orthonychiurus rectopapillatus</i> (Stach, 1933)	Cox (1982)	Central, Mazandaran, Gilan, E. Azarbaijan, W. Azarbaijan, Zanjan	Soil, Leaf litter
Subfamily Tetrodontophorinae			
Genus <i>Tetrodontophora</i> Reuter, 1882			
<i>Tetrodontophora bielensis</i> (Waga, 1842)*	Daghighi (2012)	Gilan/Rasht	Soil (<i>Ulmus</i> sp., <i>Prunus</i> sp., <i>Alnus</i> sp., <i>Parrotia</i> <i>persica</i> , <i>Acer</i> sp., <i>Salix alba</i> , <i>Punica</i> sp., <i>Robinia</i> sp., <i>Eriobotrya</i> sp., <i>Populus</i> sp.)
Family Tullbergiidae			
Genus <i>Mesaphorura</i> Börner, 1901			
<i>Mesaphorura krausbaueri</i> (Börner, 1901)	Cox (1982)	Central, Mazandaran, Gilan, E. Azarbaijan, Zanjan	Soil, Leaf litter
Genus <i>Metaphorura</i> Stach, 1954			
<i>Metaphorura affinis</i> Börner, 1902	Cox (1982) Daghighi (2012) Ghahramaninezhad et al.(2012)	Central, Gilan, E. Azarbaijan Gilan/Rasht Kermanshah	Soil (<i>Quercus</i> sp., <i>Platanus</i> sp., <i>Alnus</i> sp., <i>Punica</i> sp., <i>Ulmus</i> sp., <i>Pinus</i> sp., <i>Cupressus</i> sp., <i>Robinia</i> sp., <i>Eriobotrya</i> sp., <i>Zelkova</i> sp.) litter
Genus <i>Paratullbergia</i> Womersley, 1930			
<i>Paratullbergia callipygos</i> (Börner,1902)	Cox (1982)	Central, Zanjan	Soil, Leaf litter
Family Odontellidae			
Genus <i>Axenyllodes</i> Stach, 1949			
<i>Axenyllodes bayeri</i> Kseneman, 1935	Cox (1982)	Gilan, E. Azarbaijan	Soil, Leaf litter
Genus <i>Superodontella</i> Stach, 1949			
<i>Superodontella lamellifera</i> (Axelson, 1903)	Cox (1982)	E. Azarbaijan	Soil, Leaf litter
Order Entomobryomorpha			
Family Oncopoduridae			
Genus <i>Oncopodura</i> Carl & Lebedinsky, 1905			
<i>Oncopodura ambigua</i> Christiansen, 1957	Cox (1982)	Mazandaran, Gilan	Soil, leaf litter
<i>Oncopodura hamata</i> Carl & Lebedinsky, 1905*	Daghighi (2012)	Gilan/Rasht	Soil (<i>Ulmus</i> sp., <i>Prunus</i> sp.)

Taxonomy Class/Order/Family/Subfamily/ Species	Reference	Distribution in Iran Province/Location	Habitat
Family Tomoceridae			
Genus <i>Tomocerus</i> Nocolet, 1842			
<i>Tomocerus minor</i> (Lubbock, 1862)	Cox (1982)	Central, Mazandaran, Gilan, E. Azarbaijan, Zanjan	Soil, Leaf litter
<i>Tomocerus vulgaris</i> (Tullberg, 1871)	Cox (1982)	Central, Mazandaran, Gilan, E. Azarbaijan, Zanjan	Soil, Leaf litter
Family Isotomidae			
Genus <i>Anurophorus</i> Nocolet, 1842			
<i>Anurophorus coiffaiti</i> Cassagnau & Delamare, 1955*	Falahati (2012) Falahati et al. (2013a) Daghighi (2012) Daghighi et al.(2013a) Daghighi et al.(2013b)	Golestan/Gorgan Gilan/Rasht	Soil (<i>Ulmus</i> sp., <i>Punica</i> sp.)
Genus <i>Ballistura</i> Börner, 1906			
<i>Ballistura schoetti</i> (Dalla Torre, 1895)	Cox (1982)	Gilan	Soil, Leaf litter
Genus <i>Hemisotoma</i> Bagnall, 1949			
<i>Hemisotoma thermophila</i> (Axelson, 1900)	Cox (1982) Daghighi (2012) Daghighi et al.(2013a) Daghighi et al.(2013b)	Central, Mazandaran, Gilan, E. Azarbaijan, W. Azarbaijan Gilan/Rasht	Soil (<i>Ulmus</i> sp., <i>Ficus</i> sp., <i>Ziziphus</i> sp., <i>Populus</i> sp.) Leaf litter
Genus <i>Desoria</i> Nicolet, 1841			
<i>Desoria tigrina</i> Nicolet, 1842*	Kahrarian et al. (2012)	Kermanshah	Soil
<i>Desoria olivacea</i> (Tullberg, 1871)	Cox (1982)	E. Azarbaijan	Soil, litter
Genus <i>Folsomia</i> Willem, 1902			
<i>Folsomia binoculata</i> (Wahlgren 1899)*	Ghahramaninezhad et al. (2012)	Kermanshah	Soil
<i>Folsomia brevifurca</i> (Bagnall, 1949)	Cox (1982)	Mazandaran	Soil, Leaf litter
<i>Folsomia candida</i> (Willem, 1902)	Cox (1982) Yahyapour (2012)	Central, Mazandaran, Gilan, E. Azarbaijan Mazandaran/Sari	Soil, Leaf litter
<i>Folsomia fimetaria</i> (Linnaeus, 1758)	Cox (1982)	Central, Mazandaran, Gilan	Soil, Leaf litter
<i>Folsomia penicula</i> Bagnall, 1939*	Cox (1982) Falahati (2012) Falahati et al. (2013a) Daghighi (2012) Daghighi et al.(2013a) Daghighi et al.(2013b) Falahati et al. (2011)	Central, Mazandaran, E. Azarbaijan Golestan/Gorgan Gilan/Rasht	Soil (<i>Quercus</i> sp.)
<i>Folsomia quadrioculata</i> (Tullberg, 1871)	Cox (1982)	Central, Mazandaran, Gilan, E. Azarbaijan, W. Azarbaijan	Soil, Leaf litter
<i>Folsomia similis</i> Bagnall, 1939*	Moravvej et al. (2007) Daghighi (2012) Daghighi et al.(2013a) Daghighi et al.(2013b)	Tehran Gilan/Rasht	Soil (<i>Ficus</i> sp., <i>Pinus</i> sp.)
Genus <i>Folsomides</i> Stach, 1922			
<i>Folsomides angularis</i> Axelson, 1905*	Daghighi (2012) Daghighi et al.(2013a) Daghighi et al.(2013b)	Gilan/Rasht	Soil (<i>Prunus</i> sp.)
<i>Folsomides marchicus</i> (Frenzel, 1941)*	Kahrarian et al. (2012)	Kermanshah/Sahneh/Harsin	Soil

Taxonomy Class/Order/Family/Subfamily/ Species	Reference	Distribution in Iran Province/Location	Habitat
<i>Folsomides parvulus</i> Stach, 1922	Cox (1982) Yahyapour (2012) Kahrarian et al. (2012) Daghighi (2012) Daghighi et al.(2013a) Daghighi et al.(2013b)	Central, Mazandaran, Gilan, E. Azarbaijan, W. Azarbaijan Mazandaran/ Sari Kermanshah/Sahneh/Harsin Gilan/Rasht	Soil (<i>Morus</i> sp.), Leaf litter
Genus <i>Isotoma</i> Bourlet, 1839			
<i>Isotoma viridis</i> Bourlet, 1839	Cox (1982) Yahyapour (2012)	Central, Mazandaran, E. Azarbaijan, W. Azarbaijan Mazandaran/ Sari	Soil, Leaf litter
Genus <i>Isotomiella</i> Bagnall, 1939			
<i>Isotomiella minor</i> (Schäffer, 1896)	Cox (1982) Moravvej et al. (2007) Yahyapour (2012) Daghighi (2012) Daghighi et al.(2013a) Daghighi et al.(2013b) Ghahramaninezhad et al. (2012)	Mazandaran, Gilan, E. Azarbaijan Tehran Mazandaran/ Sari Gilan/Rasht Kermanshah	Soil (<i>Quercus</i> sp., <i>Prunus</i> sp., <i>Pinus</i> sp.) Leaf litter
Genus <i>Isotomina</i> Börner, 1903			
<i>Hemisotoma pontica</i> Stach, 1947	Cox (1982) Moravvej et al. (2007) Kahrarian et al. (2012) Yahyapour (2012)	Central, Mazandaran, Gilan, E. Azarbaijan, W. Azarbaijan Tehran Kermanshah Mazandaran/ Sari	Soil, Leaf litter
<i>Hemisotoma orientalis</i> Stach, 1947	Cox (1982)	Central, Mazandaran, Gilan, E. Azarbaijan, W. Azarbaijan	Soil, Leaf litter
Genus <i>Isotomurus</i> Börner, 1903			
<i>Isotomurus maculatus</i> (Schäffer, 1869)*	Falahati (2012) Falahati et al. (2013a) Falahati et al. (2011)	Golestan/ Gorgan	Soil
<i>Isotomurus palustris</i> (Muller, 1776)	Cox (1982)	Central, Mazandaran, Gilan	Soil, Leaf litter
<i>Isotomurus punctiferus</i> Yosii, 1963*	Falahati (2012) Falahati et al. (2013a) Daghighi (2012) Daghighi et al.(2013a) Daghighi et al.(2013b)	Golestan/Gorgan Gilan/Rasht	Soil
Genus <i>Parisotoma</i> Bagnall, 1940			
<i>Parisotoma notabilis</i> (Schäffer, 1896)	Cox (1982) Moravvej et al. (2007) Kahrarian et al. (2012) Daghighi (2012) Daghighi et al.(2013a) Daghighi et al.(2013b)	Central, Mazandaran, Gilan, E. Azarbaijan, W. Azarbaijan, Zanjan Tehran Kermanshah Gilan/Rasht	Soil (<i>Platanus</i> sp., <i>Ulmus</i> sp., <i>Cupressus</i> sp.) Leaf litter
Genus <i>Proisotoma</i> Börner, 1901			
<i>Proisotoma minima</i> Absolon, 1901*	Yahyapour (2012)	Mazandaran/ Sari	Leaf litter
<i>Proisotoma minuta</i> (Tullberg, 1871)	Cox (1982) Nematollahi et al. (2009)	Central, Mazandaran, Gilan, E. Azarbaijan, W. Azarbaijan	Soil, Leaf litter, African violet
<i>Proisotoma subminuta</i> Denis, 1931*	Moravvej et al. (2007) Daghighi (2012) Daghighi et al.(2013a) Daghighi et al.(2013b)	Tehran Gilan/Rasht	Soil (<i>Ulmus</i> sp.)

Taxonomy Class/Order/Family/Subfamily/ Species	Reference	Distribution in Iran Province/Location	Habitat
<i>Proisotoma tenella</i> Reuter, 1895*	Daghighi (2012) Daghighi et al.(2013a) Daghighi et al.(2013b)	Gilan/Rasht	Soil (<i>Melia</i> sp.)
Family Entomobryidae			
Subfamily Entomobryinae			
Genus <i>Entomobrya</i> Rondani, 1861			
<i>Entomobrya atrocincta</i> Schött, 1886*	Yahyapour (2012) Yahyapour et al. (2011) Kahrarian et al. (2012)	Mazandaran/Sari Kermanshah/ Harsin	Leaf litter
<i>Entomobrya corticalis</i> (Nicolet, 1841)	Cox (1982)	Gilan	Soil, Leaf litter
<i>Entomobrya dollfusi</i> Denis, 1924*	Yahyapour (2012)	Mazandaran/ Sari	Leaf litter
<i>Entomobrya lindbergi</i> Stach, 1960*	Daghighi (2012) Daghighi et al.(2013b) Moravvej (2003)	Gilan/Rasht Tehran	Soil (<i>Alnus</i> sp. and <i>Ulmus</i> sp.)
<i>Entomobrya lanuginosa</i> (Nicolet, 1841)	Cox (1982)	Central, Mazandaran, Gilan, E. Azarbaijan	Soil, Leaf litter
<i>Entomobrya handschini</i> Stach, 1922*	Moravvej (2003)	Tehran	Soil
<i>Entomobrya multifasciata</i> Tullberg, 1871*	Yahyapour (2012) Yahyapour et al. (2011)	Mazandaran/ Sari	Leaf litter
<i>Entomobrya unostrigata</i> Stach, 1930*	Moravvej (2003)	Tehran	Soil
Genus <i>Mesentotoma</i> Salmon, 1942			
<i>Mesentotoma subdollfusi</i> Jacquemart, 1974*	Daghighi (2012) Daghighi et al.(2013b)	Gilan/Rasht	Soil(<i>Alnus</i> sp., <i>Ulmus</i> sp., <i>Parrotia</i> <i>persica</i> , <i>Acer</i> sp. and <i>Salix alba</i>)
Genus <i>Sinella</i> Brook, 1882			
<i>Sinella curviseta</i> Brook, 1882*	Moravvej (2003)	Tehran	Soil
<i>Sinella tenebricosa</i> Folsom, 1902*	Nematollahi et al. (2009)	Isfahan/ Isfahan	vegetables and cucumber greenhouses
Subfamily Lepidocyrtinae			
Genus <i>Lepidocyrtus</i> Bourlet, 1839			
<i>Lepidocyrtus cyaneus</i> Tullberg, 1871	Cox (1982)	Central, Mazandaran, Gilan, E. Azarbaijan, Zanjan	Soil, Leaf litter
<i>Lepidocyrtus lanuginosus</i> (Gmelin, 1788)	Cox (1982)	Central, Mazandaran, Gilan, E. Azarbaijan	Soil, Leaf litter
<i>Lepidocyrtus ruber</i> Schött, 1902	Cox (1982)	Central, Mazandaran, Gilan, E. Azarbaijan	Soil, Leaf litter
Genus <i>Pseudosinella</i> Schaefer, 1897			
<i>Pseudosinella alba</i> (Packard, 1873)*	Daghighi (2012) Daghighi et al.(2013b)	Gilan/Rasht	Soil (<i>Quercus</i> sp., <i>Ulmus</i> sp., <i>Platanus</i> sp., <i>Alnus</i> sp., <i>Parrotia persica</i> , <i>Acer</i> sp. <i>Salix</i> <i>alba</i> , <i>Punica</i> sp.)
<i>Pseudosinella duodecimpunctata</i> Denis, 1931	Cox (1982)	E. Azarbaijan	Soil, Leaf litter
<i>Pseudosinella imparipunctata</i> Gisin, 1953	Cox (1982)	Mazandaran, Gilan, Zanjan	Soil, Leaf litter

Taxonomy Class/Order/Family/Subfamily/ Species	Reference	Distribution in Iran Province/Location	Habitat
<i>Pseudosinella octopunctata</i> Böner, 1901	Cox (1982) Yahyapour et al. (2011) Yahyapour (2012)	Central, Mazandaran, Gilan, E. Azarbaijan, W. Azarbaijan, Zanjan Mazandaran/Sari	Soil, Leaf litter
<i>Pseudosinella sexoculata</i> (Schött, 1902)*	Ghahramaninezhad et al.(2012)	Kermanshah	Soil
Subfamily Scirinae			
Genus <i>Seira</i> Lubbock, 1870			
<i>Seira domestica</i> Nicolet, 1842*	Yahyapour (2012) Yahyapour et al. (2011) Kahrarian et al. (2011) Daghighi (2012) Daghighi et al.(2013b)	Mazandaran/Sari Kermanshah/ Harsin Gilan/ Rasht	Leaf litter, Soil (<i>Magnolia</i> sp., <i>Ficus</i> sp., <i>Ulmus</i> sp., <i>Prunus</i> sp.)
Subfamily Willowsiinae			
Genus <i>Willowsia</i> Shoebotam, 1917			
<i>Willowsia nigromaculata</i> Lubbock, 1873*	Daghighi (2012) Daghighi et al.(2013b)	Gilan/Rasht	Soil (<i>Platanus</i> sp., <i>Prunus</i> sp., <i>Ulmus</i> sp., <i>Ficus</i> sp., <i>Alnus</i> sp., <i>Quercus</i> sp.)
Subfamily Orchesellinae			
Genus <i>Heteromurus</i> Wankel, 1860			
<i>Heteromurus major</i> (Moniez, 1889)	Cox (1982) Yahyapour (2012) Yahyapour et al. (2011) Daghighi (2012) Daghighi et al.(2013b)	Central, Mazandaran, Gilan, E. Azarbaijan Mazandaran/Sari Gilan/ Rasht	Soil, Leaf litter
<i>Heteromurus nitidus</i> (Templeton, 1835)	Cox (1982)	Mazandaran, Gilan	Soil, Leaf litter
<i>Heteromurus sexoculatus</i> Brown, 1926	Cox (1982)	Mazandaran	Soil, Leaf litter
Family Paronellidae			
Genus <i>Cyphoderus</i> Nicolet, 182			
<i>Cyphoderus albinus</i> Nicolet, 1842*	Daghighi (2012)	Gilan/Rasht	Soil (<i>Platanus</i> sp.)
Order Neelipleona			
Family Neelidae			
Genus <i>Neelus</i> Folsom, 1896			
<i>Neelus murinus</i> Folsom, 1896	Cox (1982)	Central, Mazandaran, E. Azarbaijan	Soil, Leaf litter
Order Symphypleona			
Family Sminthurididae			
Genus <i>Sphaeridia</i> Linnaniemi, 1912			
<i>Sphaeridia pumilis</i> (Krausbauer, 1898)	Cox (1982) Kahrarian et al. (2012)	Central, Gilan Kermanshah/ Sahneh/Harsin	Soil, Leaf litter
Genus <i>Sminthurides</i> Börner, 1900			
<i>Sminthurides malmgreni</i> (Tullberg, 1876)	Cox (1982)	Central, Gilan, E. Azarbaijan	Soil, Leaf litter

Taxonomy Class/Order/Family/Subfamily/ Species	Reference	Distribution in Iran Province/Location	Habitat
Family Katiannidae			
Genus <i>Sminthurinus</i> Börner, 1901			
<i>Sminthurinus aureus</i> Lubbock, 1862*	Yahyapour (2012) Daghighi (2012) Daghighi et al.(2013b)	Mazandaran/ Sari Gilan/Rasht	Leaf litter Soil (<i>Ulmus</i> sp., <i>Prunus</i> sp., <i>Acer</i> sp., <i>Cupressus</i> sp., <i>Robinia</i> sp., <i>Populus</i> sp.)
<i>Sminthurinus bimaculatus</i> (Axelson, 1902)	Cox (1982)	Gilan	Soil, Leaf litter
<i>Sminthurinus elegans</i> Fitch, 1863	Cox (1982) Yahyapour(2012) Falahati (2012) Ghahramaninezhad et al.(2012)	unknown Mazandaran/ Sari Golestan/ Gorgan Kermanshah	Soil Leaf litter Leaf litter Leaf litter
Family Arrhopalitidae			
Genus <i>Arrhopalites</i> Börner, 1906			
<i>Arrhopalites caecus</i> (Tullberg, 1871)	Cox (1982) Ghahramaninezhad et al.(2012)	Gilan, E. Azarbaijan Kermanshah	Soil, Leaf litter
Family Sminthuridae			
Genus <i>Sminthurus</i> Latreille, 1804			
<i>Sminthurus viridis</i> Linnaeus, 1758*	Farrahbakhsh (1961)	Khuzestan	wheat and alfalfa fields
Genus <i>Capraïnea</i> Dallai 1970			
<i>Capraïnea marginata</i> (Schott, 1893)*	Kahrarian et al. (2012)	Kermanshah/Sahneh/Harsin	Soil
Family Dicyrtomidae			
Genus <i>Dicyrtomina</i> Börner, 1903			
<i>Dicyrtomina ornata</i> Nicolet, 1842*	Yahyapour (2012)	Mazandaran/ Sari	Leaf litter
Genus <i>Dicyrtoma</i> Bourlet, 1841			
<i>Dicyrtoma minuta</i> (Fabricius, 1783)	Cox (1982)	Mazandaran, Gilan	Soil, Leaf litter
<i>Dicyrtoma fusca</i> Lubbock, 1873*	Yahyapour (2012)	Mazandaran/ Sari	Leaf litter

Three new species of *Omalodes* (*Omalodes*) (Histeridae, Histerinae) from South America

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Abstract

Three new species of *Omalodes* are described from South America, including descriptions of male and female genitalia. *Omalodes* (*O.*) *mazuri* **sp. n.** is described from Peru and Bolivia; *Omalodes* (*O.*) *punctulatus* **sp. n.** from Brazil, and *Omalodes* (*O.*) *rivus* **sp. n.** from Bolivia and Brazil. This is the first paper with detailed information on the male and female genitalia of the genus, showing a great degree of variation to characterize different species. All three new species can be easily distinguished from other known *Omalodes* and from each other, on the basis of morphology and male genitalia pattern.

Keywords

Omalodini, South America, holotype, taxonomy

Introduction

The name *Omalodes* was first proposed in the Dejean Catalogue (1833), where 10 species are merely listed. Only a year later those species were properly described by Erichson (1834). Not until 1853 and the following years were new species described for the genus, mainly by Marseul in his “Essai Monographique sur la Famille des Histérides”.

In 1861, the genus already had around 35 species, and over the next few years others were described by multiple authors. In 1919, Desbordes described the last three known species of the genus.

When Kryzhanovskij (1972) proposed the tribe Omalodini, the genus had 60 species, divided into 3 subgenera, with *Omalodes sensu stricto* being the largest, with 51 species. Given the fact that *Omalodes* represent close to 70% of the entire tribe (Mazur 2011), a bigger, more complete study of the genus was important. A complete revision for the subgenus *Omalodes* is being done, and in this manuscript a few of the new species found for this subgenus are described. These species present either a unique combination of characters or are closely related to other species already described, which are broadly distributed across South America. Considering the morphology and distribution of the new species we hope to facilitate their identification.

The subgenus *Omalodes* is characterized by a marginal pronotal stria interrupted behind the head, third dorsal stria of elytra usually weak, present mostly on the anterior half, fourth and fifth dorsal striae usually absent, marginal mesoventral stria in most species widely interrupted, present only at the angles, and lateral metaventral stria continuous with recurrent stria.

Adults of *Omalodes* are collected mostly in decaying trees or other vegetal material, especially when fermenting. Some species can also be found in animal material such as rotten fish, lizards or other animals (personal observation). The genus has a neotropical distribution, with only three species being registered for the southern border of the United States, mostly Florida and Arizona, and not being found on the southern half of Argentina and Chile (Mazur 2011, author unpublished data).

Material and methods

Descriptive terminology follows Wenzel and Dybas (1941), supplemented by Ôhara (1994) and Lackner (2010). The total length is measured from the anterior margin of the pronotum to the posterior margin of the elytra (to exclude preservation variability in head and pygidial extension), and width is taken at the widest point, generally near the elytral humeri.

The following information is provided for each described species, according to the label: collection data: verbatim citation of country, province or state, locality, date of collection, collector's name; number of specimens; and collection. The data from each specimen are within double quotes (" "). Each line on the same label is separated by a (;). Each label is separated by a slash between spaces (/).

The photographs were taken with a Leica DFC500 digital camera, edited using the software Auto-montage PRO Digital imaging system (SYNCROSCOPY) and Leica MZ16 stereomicroscope.

The studied material belongs to the following institutions: Museu de Zoologia da Universidade de São Paulo, São Paulo (MZSP), Museu Nacional do Rio de Janeiro, Rio de Janeiro (MNRJ), Coleção Entomológica Padre Jesus Santiago Moure, Curitiba,

Paraná (DZUP), Museu Anchieta, Porto Alegre, Rio Grande do Sul (MAPA), Museu Paraense Emilio Goeldi, Belém, Pará (MPEG), Brazil; Snow Entomological Collection, University of Kansas Natural History Museum, Lawrence, Kansas (SMEK) and Field Museum of Natural History, Chicago, Illinois (FMNH), United States of America. The type material was deposited in the museum from which it was originally borrowed.

Taxonomy

Omalodes (*O.*) *mazuri* sp. n.

<http://zoobank.org/B4C51AD8-179C-4DC0-B44E-FCDD2CD882F4>

http://species-id.net/wiki/Omalodes_mazuri

Figs 1A, 2A, 3A, 4A, 5A–G

Type material. Holotype: Male. BOLIVIA: “Bolivia tropical; Region Chapare; I:5:50, 400m; R. Zischka leg. / regarded by Mazur as n. sp.” (FMNH). **Paratype: Male. PERU:** “PERU: Cusco, Villa Carmen Field; Stn., ~1.7 km W cafeteria, res.; trns. 12.89250°S. 71.41917°W; 555m. 22–24.v.2011. Flight; intercept. D. J. Bennett & E. Razuri; PER-11-FIT-007” (SMEK).

Diagnosis. Frons with a sulcus, little wider close to the epistoma (Fig. 3A); sutural stria present on posterior half (Fig. 1A); prosternal keel with carinal striae indicated on the posterior half, along the prosternal process; marginal mesoventral stria complete, beginning close to mesometaventral suture and continuous along the anterior and lateral margins (Fig. 2A).

Description. *Size range:* Length: 5–6.5mm, Width: 4–5mm. *Body form* (Fig. 1A): Body oval, convex, piceous, covered with micropunctures. *Head* (Fig. 3A): Frontal stria complete, anterior portion somewhat projected towards epistoma, bordering a broad sulcus, connected to supraorbital stria on each side; labrum subtrapezoidal, almost rectangular, anterior margin straight, posterior margin articulated with epistoma, about 1.5 times as wide as long; mandibles short, without subapical teeth. *Pronotum* (Figs 1A, 3A): Sides rounded, narrower anteriorly, with a pair of foveae close to lateral punctures on posterior half; marginal pronotal stria beginning at anterior angles, interrupted behind head, continuous to posterior margin; lateral pronotal stria present, indicated along lateral and anterior margins; lateral punctures of pronotum indicated close to lateral margin, except for posterior fourth, where absent or indicated by weaker punctures, almost as fine as ground punctures. *Elytra* (Fig. 1A): With depression on each side, posterad to humeral stria; marginal epipleural stria absent; epipleural stria complete; outer subhumeral stria present at posterior third, inner subhumeral stria absent; first dorsal stria just slightly shortened at posterior margin; second dorsal stria absent from anterior fifth; third dorsal stria present, strongly marked behind base, weaker close to anterior margin, with two or three punctures close to posterior margin; sutural stria indicated in posterior half; apical stria absent. *Prosternum* (Fig. 2A): Prosternal lobe rounded, slightly emarginated at middle of anterior margin, marginal

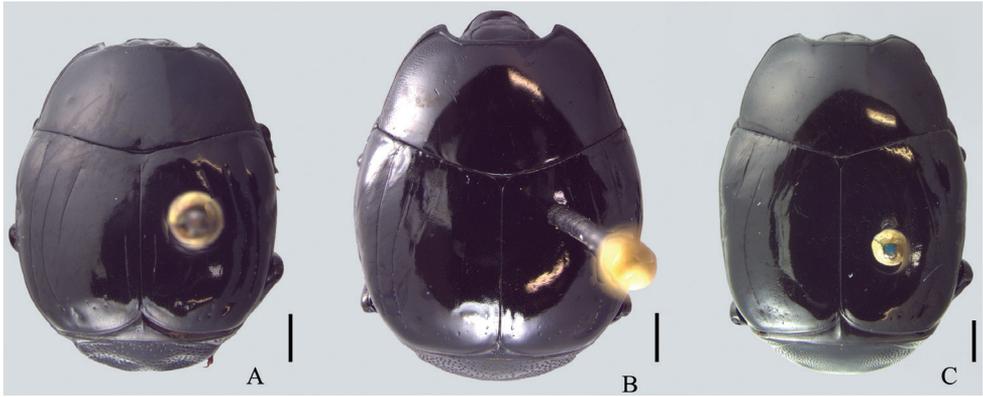


Figure 1. Dorsal view. **A** *Omalodes* (*O.*) *mazuri* sp. n. **B** *Omalodes* (*O.*) *rivus* sp. n. **C.** *Omalodes* (*O.*) *punctulatus* sp. n. Scale: 0.5 mm.

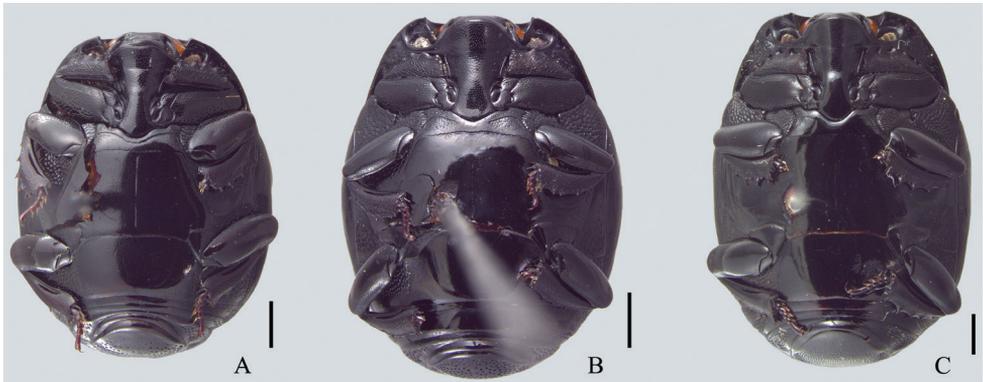


Figure 2. Ventral view. **A** *Omalodes* (*O.*) *mazuri* sp. n. **B** *Omalodes* (*O.*) *rivus* sp. n. **C.** *Omalodes* (*O.*) *punctulatus* sp. n. Scale: 0.5 mm.



Figure 3. Head and pronotum, frontal view. **A** *Omalodes* (*O.*) *mazuri* sp. n. **B** *Omalodes* (*O.*) *rivus* sp. n. **C** *Omalodes* (*O.*) *punctulatus* sp. n. Scale: 0.25 mm.

stria complete; lateral punctures of prosternal keel present; carinal striae of prosternal keel present only in posterior half; prosternal process rounded. *Mesoventrite* (Fig. 2A): Marginal mesoventral stria complete, continuous along lateral and anterior margins;



Figure 4. Propygidium and pygidium. **A** *Omalodes* (*O.*) *mazuri* sp. n. **B** *Omalodes* (*O.*) *rivus* sp. n. **C** *Omalodes* (*O.*) *punctulatus* sp. n. Scale: 0.25 mm.

mesometaventral stria somewhat crenulated medially with mesometaventral suture visible along its length. *Metaventrите* (Fig. 2A): Lateral metaventral stria continuous with recurrent stria. *Abdomen* (Figs 2A, 4A): Abdominal ventrites smooth medially, punctuated on sides, the punctures somewhat irregular; propygidium with punctures more dense and regularly distributed close to posterior half and lateral margins, sparser and more irregular close to anterior margin, with a pair of impressions on the posterior half, on each side; pygidial punctures more or less regularly distributed, although sparse, especially in the middle. *Male genitalia* (Figs 5A–G): Eighth sternite divided in two longitudinally elongate sclerites, base with shallow emargination; eighth tergite subrectangular, with a pair of anterolateral projections, one on each side, apex with small, less sclerotized area along margin, medially curved with small desclerotized point before curvature; “spiculum gastrale” elongate, sclerotized in anterior half, base slightly concave; ninth tergite divided in two elongate sclerites, wider medially, apex without emargination; tenth tergite composed of a single sclerite, widely emarginated at anterior half, somewhat concave at apex, wider at posterior half and with small desclerotized area along lateral margin; aedeagus elongate, cylindrical, basal piece about two times as long as wide, parameres just slightly fused anteriorly on the ventral side, almost completely fused dorsally, truncate at apex; basal margin with a wide “V”-shaped emargination ventrally and superficial one dorsally; parameres a little wider close to the apex and slightly dilated at basal margin in lateral view. *Female Genitalia*: Unknown.

Etymology. This species is named in honor of Dr. Slawomir Mazur, a great researcher of Histeridae.

Distribution. This species is known from Bolivia, Region Chapare and Peru, near Cusco. The holotype was probably collected close to Chapare, Cochabamba.

Remarks. The complete marginal mesosternal stria of this species is somewhat peculiar in regards to the subgenus *Omalodes*. For the already known species, only *Omalodes* (*O.*) *fortunatus* Lewis, 1898 has a similar stria. The sutural stria is longer than the usual for the subgenus, being indicated on the posterior half as a well marked, continuous stria. The only species that have the sutural stria as long as this species are *Omalodes* (*O.*) *pulvintatus* Erichson, 1834 and *Omalodes* (*O.*) *mendax* Marseul, 1861, but both have the stria indi-

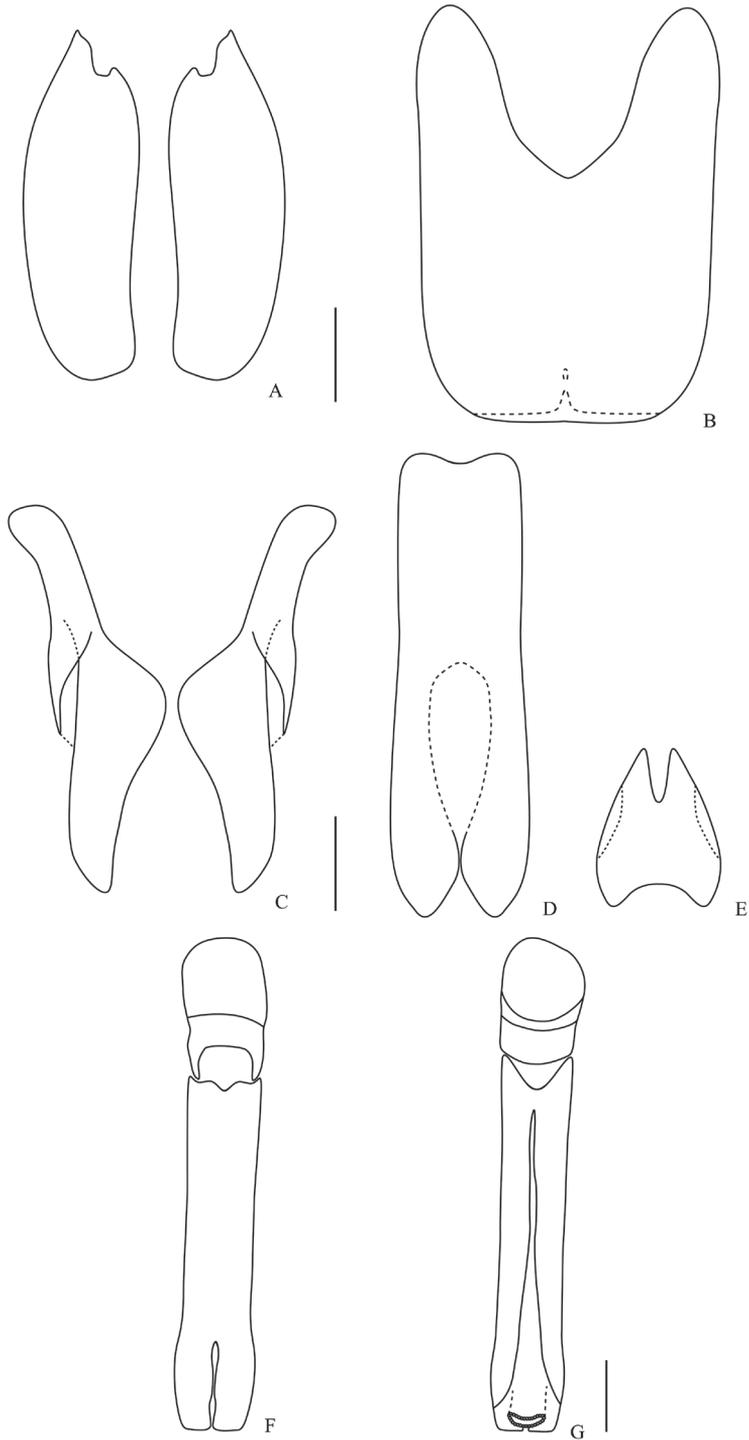


Figure 5. Male genitalia. *Omalodes (O.) mazuri* sp. n. **A** eighth sternite **B** eighth tergite **C** ninth tergite **D** “spiculum gastrale” **E** tenth tergite **F** aedeagus, dorsal view **G** aedeagus, ventral view. Scale: 0.25 mm.

cated by a series of punctures. In other species of the subgenus the stria is absent or only indicated by a few punctures close to the posterior margin of the elytra. Even though those characters are a little different from usual for the subgenus, this species can be easily placed inside *Omalodes s. str.* when a wider set of characters is taken into account.

The paratype of this species lacks the pair of pronotal foveae close to the lateral punctuation. This probably means that the character is somewhat variable or more probably that those foveae are a developmental anomaly.

***Omalodes* (*O.*) *rivus* sp. n.**

<http://zoobank.org/2BCE1143-798F-4569-81BA-0D7956B43D18>

http://species-id.net/wiki/Omalodes_rivus

Figs 1B, 2B, 3B, 4B, 6A–G, 8A–E

Type material. Holotype: Male. BRAZIL: “Brasil Pará; Serra Norte; Manganes M₂; 13/X/1986 / Armadilha; Shanon / Brasil Pará; J. Dias” (MPEG). **Paratypes: BOLIVIA:** “Bolívia; Pcia Ichilo; Buenavista XI.1950; A. Martinez leg.”, 1 specimen; (MZSP); **BRAZIL:** “Brasil, Amapá; Serra do Navio; X-1996; P. Magno leg. / Assentamento”, 1 specimen (MNRJ); “Coleção; M. Alvarenga / Colônia Rio Branco; Óbidos Pará BRASIL; 5-XII-1952; P. A. Teles col.”, 1 specimen (DZUP); “Coleção Campos Seabra / Mangabeira MOCAJUBA; Pará BRASIL; II-1953; Orlando M. Rego”, 1 specimen (MNRJ); “Coleção Campos Seabra / Óbidos; Pará BRASIL; I-1954 J. Brazilino”, 2 specimens (MNRJ); “Brasil; Santaremsinho; Mun. de Itaituba; Rio Tapajós = Pará; VI-62 Dirings”, 1 specimen (MZSP); “Itaituba, PA; XII.1963”, 1 specimen (MZSP); “Brasil, Pará; Marajó-Breves; Rio Caruacá; 22.II.1988 / Area 1; Margem–SE; Isca 1 Solo”, 5 specimens (MPEG); “Brasil, Pará; Marajó-Breves; Rio Caruacá; 22.II.1988 / Area 1; Isca 2; Coleta solo”, 1 specimen (MPEG); “Brasil, Pará; Marajó-Breves; Rio Caruacá; 22.II.1988 / Area 2; Margem W; Isca 2”, 5 specimens (MPEG); “Brasil, Pará; Marajó-Breves; Rio Caruacá; 22.II.1988 / Area 2; Isca 2; Margem W; Coletas solo”, 1 specimen (MPEG); “Brasil Pará; Marajó-Breves; Rio Caruacá; 4.VIII.1988 / Brasil PA; J. Dias / B55; L17”, 1 specimen (MPEG); “Brasil Pará; Marajó-Breves; Rio Caruacá; 6.VIII.1988 / Isca Laranja / M. Martins”, 1 specimen (MPEG); “Brasil Pará; Marajó-Breves; Rio Caruacá; B60; 6.VIII.1988 / Brasil Pará; J. Dias”, 1 specimen (MPEG); “Brasil Pará; Marajó-Breves; Rio Caruacá; 9.VIII.1988; B-66–Isca Laranja / Brasil Pará; J. Dias”, 2 specimens (MPEG); “Brasil Pará; Marajó-Breves; Rio Caruacá; 12.VIII.1988; B72; Isca abacaxi / Brasil Pará; J. Dias”, 1 specimen (MPEG); “Brasil Pará; B72; Marajó-Breves; Rio Caruacá; 12.VIII.1988; Isca laranja / Brasil Pará; J. Dias”, 1 specimen (MPEG); “Brasil Pará; Serra Norte; Pojuca; 4.VII.1985 / Brasil Pará; R. B. Neto”, 1 specimen (MPEG); “Brasil Pará; Serra Norte; M2 Mata; Isca de fruta; 24 a 26.I.1986 / Brasil Pará; M. F. Torres”, 1 specimen (MPEG); “Brasil Pará; Serra Norte; Mangans M₂; 13.X.1986 / Armadilha; Shanon / Brasil Pará; J. Dias”, 1 specimens (MPEG); “Brasil Pará; Serra Norte; Mangans; Isca 2.4; 13.X.1986 / Brasil Pará; J. Dias”, 1 specimen (MPEG); “Brasil Pará; Serra Norte; 3 Alfa; 15 a 18.X.1986 / Armadilha Shanon; J. Dias”, 1 specimen (MPEG);

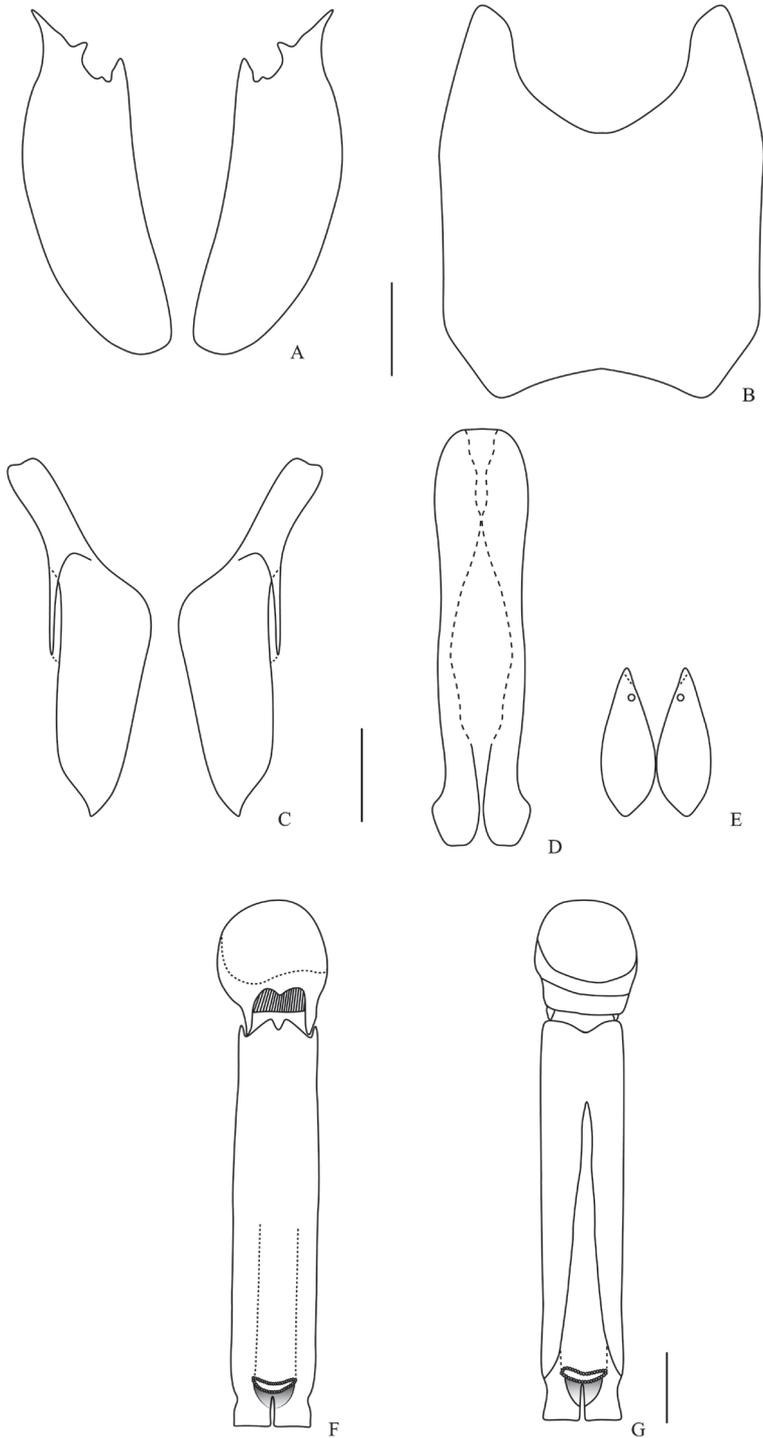


Figure 6. Male genitalia. *Omalodes (O.) rivus* sp. n. **A** eighth sternite **B** eighth tergite **C** ninth tergite **D** “spiculum gastrale” **E** tenth tergite **F** aedeagus, dorsal view **G** aedeagus, ventral view. Scale: 0.25 mm.

“Brasil Pará; Serra Norte; N2; Isca fruta; 22 a 24.I.1986 / Brasil Pará; H. Andrade”, 1 specimen (MPEG); “Brasil Pará; Serra Norte; N2; Isca fruta; 22 a 24.I.1986 / Brasil Pará; M. F. Torres”, 1 specimen (MPEG); “Brasil Pará; Paragominas; Faz. Cachoeira; do Rio Vermelho; 18 a 21.I.1991 / Brasil Pará; P. Tadeu / Armadilha Malayse”, 1 specimen (MPEG); “Brasil Pará; Paragominas; Faz. Cachoeira; do Rio Vermelho; 18.I.1991 / Brasil Pará; P. Tadeu”, 1 specimen (MPEG); “Brasil Pará; Benevides; F. Morelândia; 6.III.1987 / Brasil Pará; J. Dias”, 1 specimen (MPEG); “Coleção Campos Seabra / Guajará; Borba Amazonas; Brasil IV.1943; A. Parko”, 1 specimen (MNRJ); “Brasil: AM; Itacoatiara; V/1962 Dirings”, 1 specimen (MZSP); “Forte Príncipe da; Beira. Rondônia; 19.XI-3.XII.1967; G. R. Kloss col. / *Omalodes* sp.; N. Degallier”, 1 specimen (MZSP).

Diagnosis: Frons flat or slightly concave (Fig. 3B); outer subhumeral stria long, present at least on posterior half, usually beginning close to the end of humeral stria; propygidium punctate, little sparser at anterior half (Fig. 4B); marginal mesosternal stria interrupted, present in angles and slightly along anterior margin (Fig. 2B).

Description. *Size range:* Length: 5–6.5mm, Width: 4–5mm. *Body form* (Fig. 1B): Oval, convex, piceous, covered with micropunctures. *Head* (Fig. 3B): Frons flat or with medial longitudinal impression, slightly concave; frontal stria complete or slightly interrupted medially, joined with supraorbital stria laterally at posterior margin; labrum subrectangular with anterior margin nearly straight, posterior margin with a small semicircular smooth area; about two times as wide as long; mandibles short, without subapical teeth. *Pronotum* (Figs 1B, 3B): Sides rounded, narrower anteriorly; marginal pronotal stria beginning at angles, interrupted behind the head, continuous to posterior margin; lateral pronotal stria present, indicated along lateral and anterior margins; lateral punctures not strongly indicated, but easily visible, equally covering lateral margin. *Elytra* (Fig. 1B): Marginal epipleural stria absent, elytra with superficial impression in its place; epipleural stria complete; outer subhumeral stria present at posterior half, beginning close to humeral stria, sometimes slightly interrupted medially or anteriorly; inner subhumeral stria absent; first dorsal stria slightly shortened near posterior margin, indicated in posterior third by a series of punctures; second dorsal stria shortened in anterior margin, indicated in posterior fourth by a series of punctures; third dorsal stria weakly indicated, continuous in anterior half, with some punctures near posterior margin; a few punctures close to the posterior margin; sutural stria variable, usually present in posterior half, posterior third or indicated by series of irregularly spaced and variably intense punctures. *Prosternum* (Fig. 2B): Prosternal lobe rounded, marginal stria complete along anterior margin; lateral punctures of prosternal keel present, weakly indicated; prosternal keel without carinal striae; prosternal process rounded. *Mesoventrite* (Fig. 2B): Marginal mesoventral stria interrupted, present in lateral margin and slightly along anterior margin; mesometaventral stria present, almost straight, slightly curved towards prosternal process. *Metaventricle* (Fig. 2B): Lateral metaventral stria continuous with recurrent stria. *Abdomen* (Fig. 2B): Ventrites smooth medially, with irregular punctures on sides; propygidium almost completely punctate, weaker and more dispersed in middle of anterior half; pygidium punctate regularly distributed. *Male genitalia* (Figs 6A–G): Eighth sternite divided in two longitudinally elongate sclerites, base with irregular emargination; eighth tergite subrectangular, with

pair of anterolateral projections, apex concave; “spiculum gastrale” longitudinally elongate and with anterior margin rounded; ninth tergite divided in two longitudinally elongate sclerites, wider medially, apex without emargination; tenth tergite with two sclerotized areas, longitudinally elongate, almost parallel sided, with small anterior non-sclerotized circular area; aedeagus elongate, cylindrical, basal piece widely and deeply emarginated dorsally; parameres almost completely fused dorsally, except for posterior tenth; fused only in anterior third ventrally, basal margin with a couple of projections dorsally and a concave emargination ventrally; apex truncated, with superficial constriction on each side. *Female Genitalia* (Figs 8A–E): Eighth sternite with sides rounded, basal margin irregularly sclerotized, apex slightly curved, proximal baculi not fused to sternites; eighth tergite trapezoidal, larger at base, with non-sclerotized medial area, apex with non-sclerotized area medially and laterally; oval area in coxites covered with dense and strong punctures, with setae laterally and ventrally, gonostyle only visible ventrally, articulated with coxites, with three apical setae, two long and one short, valvifer elongate, enlarged at anterior third; spermatheca elongate, smooth in posterior third, annulated on anterior 2/3; spermathecal gland longer than spermatheca, wider in posterior half.

Etymology. The name of this species refers to its main localities of collection being close to rivers, especially in Pará, Brazil.

Distribution. Pará, Rondônia, Amapá, Amazonas (Brazil) and Ichilo (Bolivia). Mostly of the material was collected close to large rivers of those regions, especially in Pará, along the Caruaca river.

Remarks. This species resembles a few others in the subgenus; the frons and the length of the outer subhumeral stria is quite similar to *Omalodes* (*O.*) *gagatinus* Erichson, 1847 and *Omalodes* (*O.*) *anthracinus* Marseul, 1854, but this stria is a little longer on *Omalodes* (*O.*) *rivus*. The punctures of the propygidium is reminiscent of that in *Omalodes* (*O.*) *lucidus* Erichson, 1834, being completely covered by punctures which are sparser and weaker on the anterior half. The ninth tergite is more or less similar to all other species of the subgenus, but in *Omalodes* (*O.*) *rivus* it is wider in the posterior half, and has a very subtle emargination along the anterolateral margin, this emargination is not known for any other species in the subgenus.

Observations. There are few specimens with specific ecological data associated. Some labels indicate that the bait was fruit (orange or pineapple), probably rotten, since some other species of the genera are known to be attracted only by rotting vegetal or fruit material.

***Omalodes* (*O.*) *punctulatus* sp. n.**

<http://zoobank.org/82F13716-A5D8-4541-AE55-CFA548C49ABF>

http://species-id.net/wiki/Omalodes_punctulatus

Figs 1C, 2C, 3C, 4C, 7A–G

Type material. Holotype: Male. BRAZIL: “15.IX.1955; Barueri; S. Paulo; 5876 / K. Lenko Leg. (MNRJ) **Paratypes: BRAZIL:** “Itapiranga; II 55”, 2 specimens (MAPA);

“Itapiranga; II 55”, 2 specimens (DZUP); “Est. Minas; Araguay; 5.XII.1921; Melim”, 1 specimen (MNRJ); “1225; 9.IX.1954; Barueri; Leg. K. Lenko”, 1 specimen (MNRJ); “29.X.1955; Barueri; S. Paulo; 6658 / K. Lenko Leg.”, 2 specimens (MNRJ); “Serro Azul; 3.40”, 1 specimen (MAPA); “1-44; Paraná; Monjolinho / 1628 / Coleção; F. Justus Jor.”, 1 specimen (DZUP); “Pelotas; II 55”, 1 specimen (DZUP).

Diagnosis. Frons punctate with a medial fovea (Fig. 3C); dorsal elytral striae weakly indicated (Fig. 1C); propygidium almost completely covered with punctures, except for a semicircular area on anterior margin and with a pair of superficial impressions, one on each side at posterior half (Fig. 4C).

Description. *Size range:* Length: 7–8mm, Width: 5–6mm. *Body form* (Fig. 1C): Oval, convex, piceous, covered with micropunctures. *Head* (Fig. 3C): Frons impressed medially, with a well delimited fovea, punctate; frontal stria complete, slightly curved close to antennal insertion, continuous to epistoma, curved reaching the medial fovea, joined with supraorbital stria laterally at posterior margin; labrum subrectangular with anterior margin nearly straight, about two and a half times as wide as long; mandibles short, without subapical teeth. *Pronotum* (Figs 1C, 3C): Sides rounded, narrower anteriorly; marginal pronotal stria beginning at angles, interrupted behind the head, continuous to posterior margin; lateral pronotal stria present, indicated along lateral and anterior margin, slightly shortened near posterior margin; lateral punctures covering entire lateral margin, more visible and covering a wider area at anterior third. *Elytra* (Fig. 1C): Marginal epipleural stria absent; epipleural stria complete; outer subhumeral stria present at posterior third; inner subhumeral stria present, indicated by few weak punctures beginning at posterior third and continuous at posterior fifth; all dorsal striae weakly indicated, first stria slightly interrupted at anterior margin, with a curvature near humerus and two weak punctures near posterior margin; second dorsal stria beginning a little after the anterior margin, continuous until and indicated by two stronger wider punctures at posterior margin, third dorsal stria weakly indicated, continuous at anterior half, with some punctures near posterior margin; fourth and fifth dorsal striae absent; few punctures close to posterior margin; sutural stria indicated by few weak punctures at posterior margin. *Prosternum* (Fig. 2C): Prosternal lobe rounded, marginal stria complete along anterior margin; lateral punctures of prosternal keel present; prosternal keel without carinal striae; prosternal process rounded. *Mesoventrite* (Fig. 2C): Marginal mesoventral stria only present at angles; mesometaventral stria absent, mesometaventral suture visible and almost straight. *Metaventrite* (Fig. 2C): Lateral metaventral stria continuous with recurrent stria. *Abdomen* (Fig. 2C): Ventrites smooth medially, punctures somewhat irregular on the sides; propygidium with pair of impressions on posterior half and almost completely covered with strong punctures laterally, weaker towards the middle and a smooth semi-circular area on anterior margin; pygidium almost completely covered with punctures except for a small smooth area along lateral and posterior margin. *Male genitalia* (Figs 7A–G): Eighth sternite divided in two longitudinally elongate sclerites, base with a wide and regular emargination; eighth tergite subrectangular, with pair of anterolateral projections, a more sclerotized triangular area at apex; “spiculum gastrale” longitudinally elongate; ninth

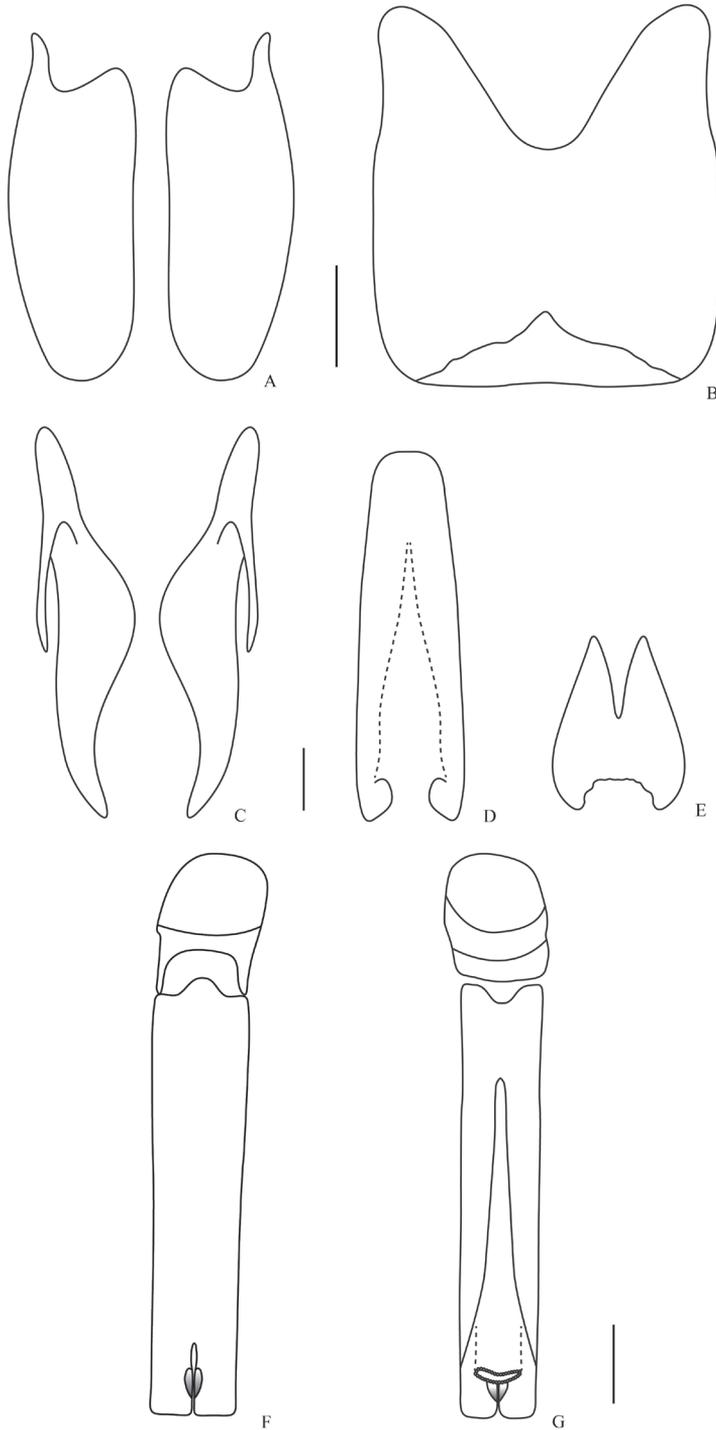


Figure 7. Male genitalia. *Omalodes (O.) punctulatus* sp. n. **A** eighth sternite **B** eighth tergite **C** ninth tergite **D** “spiculum gastrale” **E** tenth tergite **F** aedeagus, dorsal view **G** aedeagus, ventral view. Scale: 0.25 mm.

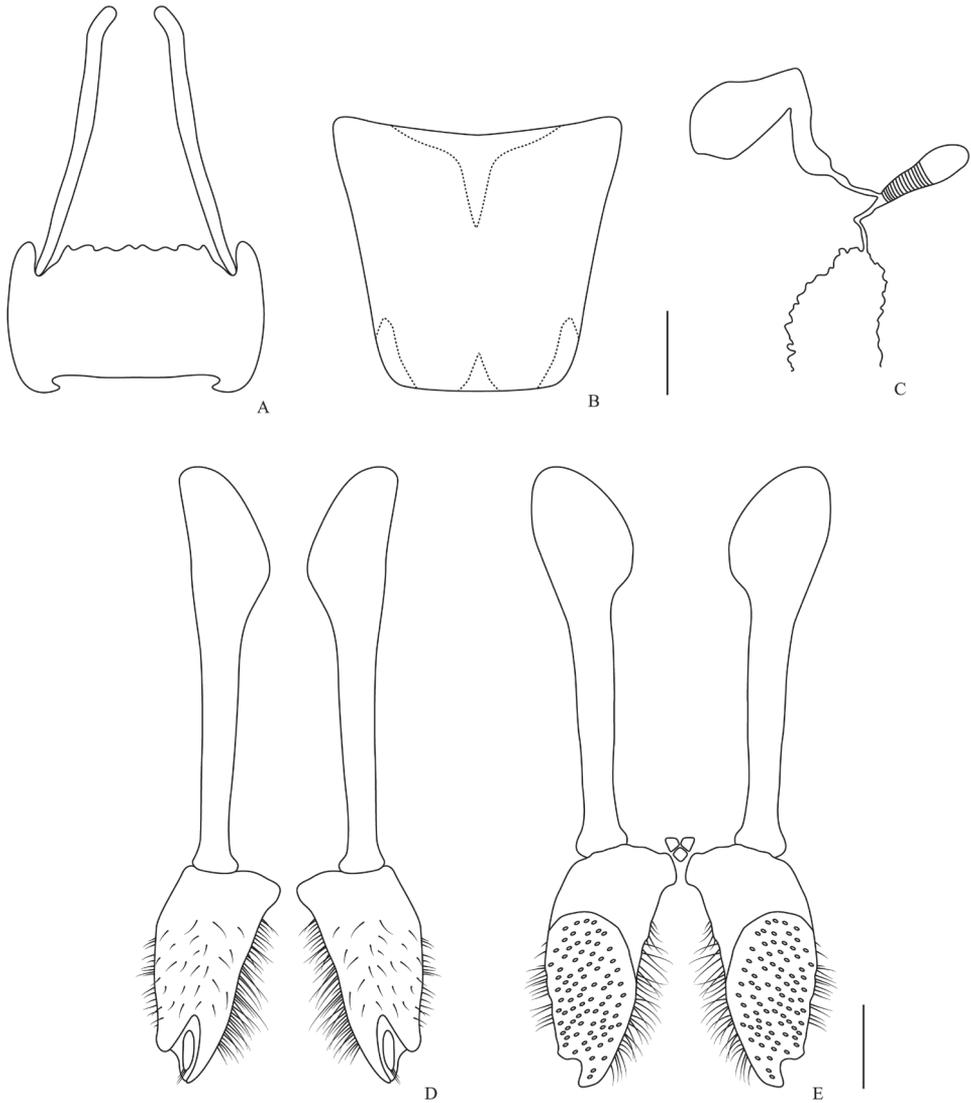


Figure 8. Female genitalia. *Omalodes* (*O.*) *rivus* sp. n. **A** eighth sternite and proximal baculi **B** eighth tergite **C** spermatheca and spermathecal gland **D** gonostyle, coxites and valvifer, ventral view **E** coxites and valvifer, dorsal view. Scale: 0.25 mm.

tergite divided in two longitudinally elongate sclerites, wider medially, apex without emargination; tenth tergite wider at posterior half, with deep emargination in anterior half and a wider, irregular one at apex; aedeagus elongate, cylindrical, parameres almost completely fused dorsally, except for posterior fifth, fused in anterior fifth ventrally, basal margin with medial emargination ventrally and projected dorsally in the middle; apex truncate. *Female genitalia*: The female genitalia of this species resemble that of

Omalodes (*O.*) *rivus*, but spermatheca and spermathecal gland were not prepared for examination in this species.

Etymology. The name of this species refers to the punctures of the pronotum, which are peculiar for the subgenus.

Distribution. The known distribution for the species is the southern and southeastern region of Brazil, ranging from Araguari, Minas Gerais; going through Barueri, São Paulo; Cerro Azul and the Monjolinho Natural Reserve, Paraná; Itapiranga, Santa Catarina until Pelotas, Rio Grande do Sul.

Remarks. *Omalodes* (*O.*) *punctulatus* has a few punctures near the posterior margin of the elytra, and because of this, appears closely related to *Omalodes* (*O.*) *lucidus*. However, its punctures are less numerous and more regular (maybe related to the 4th and 5th dorsal striae), while the punctures of *Omalodes* (*O.*) *lucidus* are more numerous and irregularly distributed over the posterior margin of the elytra. Likewise the dorsal striae are weakly indicated, as in *Omalodes* (*O.*) *gagatinus* and *Omalodes* (*O.*) *anthracinus*, but when compared to those species, its striae are not so weakly indicated nor highly interrupted or shortened. The punctures of the propygidium resembles that of *Omalodes* (*O.*) *planifrons* but it differs from this species by the punctures in the pronotum and its frons with a medial fovea. When compared to *Omalodes* (*O.*) *rivus* this species has a shorter outer subhumeral stria, present only at posterior third and the frons has a medial fovea while in *Omalodes* (*O.*) *rivus* the outer subhumeral stria is present in the posterior half and the frons is plan or only slightly concave.

The inner subhumeral stria can be present only at the posterior fifth or absent; the punctures next to the posterior margin of the elytra can vary in number and intensity; the sutural stria can be completely absent and a few specimens have the dorsal striae more strongly indicated, although never as strongly as some other species of the genus.

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The enigmatic Otway odd-clawed spider (*Progradungula otwayensis* Milledge, 1997, Gradungulidae, Araneae): Natural history, first description of the female and micro-computed tomography of the male palpal organ

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Abstract

The recently described cribellate gradungulid *Progradungula otwayensis* Milledge, 1997 is endemic to the Great Otway National Park (Victoria, Australia) and known from only one male and a few juvenile specimens. In a recent survey we recorded 47 specimens at several localities across the western part of the Great Otway National park. Our field data suggest that this species is dependant on the microclimate in the hollows of old myrtle beech trees since other hollow trees were very much less inhabited. Furthermore, we describe the female for the first time and study the male palpal organ by using X-ray microtomography. The female genitalia are characterized by eight spermathecae which are grouped in two quartets. The spermophor resembles the general organization of gradungulids, but is similar to *Kaiya* Gray, 1987 by a convoluted appearance within the embolus. The muscle 30 is located in the cymbium and resembles the organization of other non-entelegyne Araneomorphae.

Keywords

Taxonomy, micro-CT, palp, spermatheca, web, *Nothofagus*

Introduction

The family Gradungulidae consists of seven genera with 16 described species from eastern Australia and New Zealand (Platnick 2013). The genera *Macrogradungula* (*M. moonya* Gray, 1987) and *Progradungula* (*P. carraiensis* Forster and Gray, 1979 and *P. otwayensis* Milledge, 1997) can be distinguished from the remaining gradungulids by being cribellate. These spiders use a very conspicuous catching ladder for prey capture (Forster et al. 1987; Gray 1983; Figs 2B–C). The enigmatic *P. carraiensis* is known only from the Carrai Bat Cave in northern New South Wales (Forster and Gray 1979; Gray 1983) and thus it was remarkable when Milledge (1997) described a second species, *P. otwayensis*, from the Great Otway National Park in southern Victoria (Australia). Nevertheless, only a single adult male and several immatures were reported at that time. In the present paper, we describe the female for the first time and reconstruct the male palpal organ by using X-ray microtomography (micro-CT). Moreover, we provide new data on the natural history of this species.

Material and methods

We observed a total of 47 specimens (juveniles, females, one male) in the localities depicted in Fig. 1. Several individuals were collected for further analyses. The female genitalia were digested following the protocol of Álvarez-Padilla and Hormiga (2007). The material was examined and documented (extended focal range images) in 80% ethanol using a Zeiss Discovery V20 stereo microscope with a Zeiss MCr camera and a Leica M205A with a Leica 290 camera. Editing of images to adjust brightness, contrast and color was performed using Adobe Photoshop CS4. The measurements and description are based on Forster et al. (1987), the description of the spination follows Ramirez (2003).

For the micro-CT analyses of the male palp, the sample was dehydrated in graded ethanol and stained with a 1% iodine solution for 12 hours. After washing in pure ethanol, the sample was scanned in ethanol with an Xradia MicroXCT-200 X-ray imaging system (Carl Zeiss X-ray Microscopy Inc., Pleasanton, USA) at 20 kV and 4 W (10.0 scintillator-objective lens unit, 11 s exposure time, 2.18 μm pixel size). The female genitalia were digested with enzymatic cleaner for contact lenses Ultrazyme, and dried after the iodine treatment using hexamethyldisilazane (HMDS). The scan was performed using the same system at 30 kV and 6 W (20.0 scintillator-objective lens unit, 6 s exposure time, 1.18 μm pixel size). The obtained data were processed using the 3D analysis software AMIRA v. 5.4.2 (Visage Imaging, Berlin, Germany). The spermophor was reconstructed by delineation of the contours in each section and a smooth surface was computed using the surface editor. The image stack is stored in MorphDBase under creative commons attribution (ID: P_Michalik_20130802-M-5.1, https://www.morphdbase.de/?P_Michalik_20130802-M-5.1).

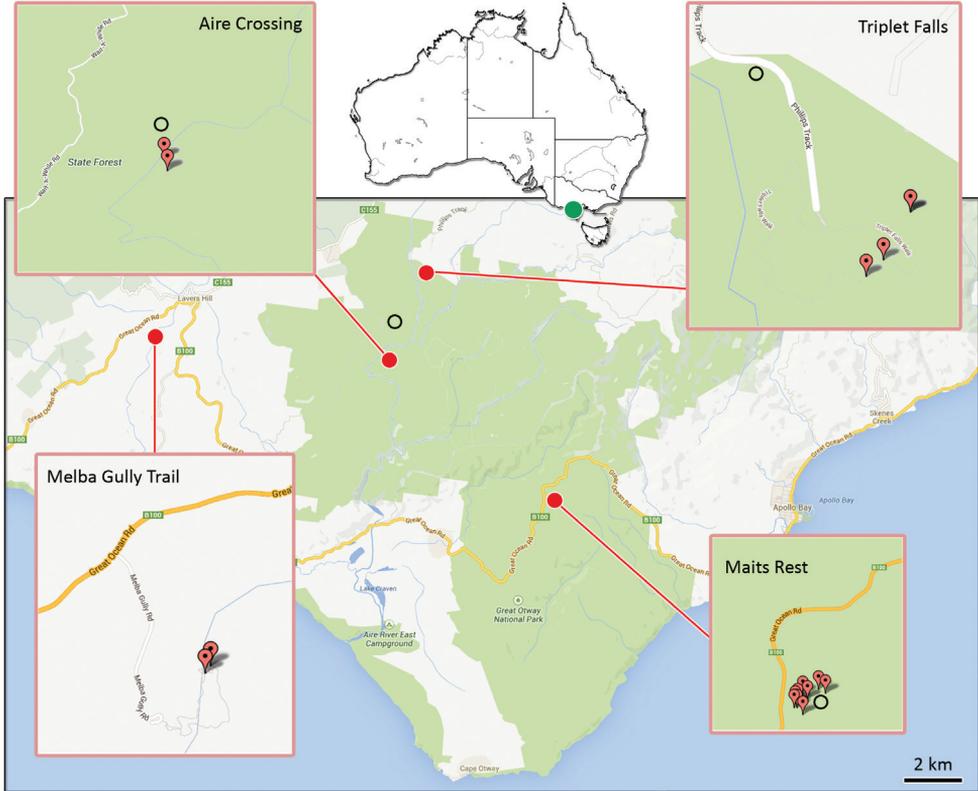


Figure 1. Distribution map of *P. otwayensis* in the Great Otway National Park, Victoria (Australia). Red marks indicate localities for the present study; black circles indicate localities given by Milledge (1997).

Abbreviations

ALE	anterior lateral eyes
AME	anterior median eyes
B	bursa
bH	basal hematodocha
Cb	cymbium
E	embolus
EF	epigastric furrow
Gl	glands
GP	genital pockets
m29	muscle 29
m30	muscle 30
mA	median apophysis
mH	median hematodocha
PE	process of embolus

PF	postepigastric fold
PLE	posterior lateral eyes
PME	posterior median eyes
S	spermophor
Sp	spermatheca
St	subtegulum
Te	tegulum
Ue	uterus externus
tm29	tendon of muscle 29
tm30	tendon of muscle 30
MACN	Museo Argentino de Ciencias Naturales (Buenos Aires, Argentina)
MV	Museum of Victoria (Melbourne, Victoria)
ZIMG	Zoologisches Institut und Museum Greifswald (Germany)

Taxonomy

Family Gradungulidae Forster, 1955

Genus *Progradungula* Forster & Gray, 1979

Progradungula otwayensis Milledge, 1997

http://species-id.net/wiki/Progradungula_otwayensis

Type material. Male holotype: AUSTRALIA: Victoria. Otway Ranges, Aire Crossing Track, 0.5 km N of Aire River crossing, 38°42'S, 143°29'E, 31 Jan 1995, G. Milledge (MV K3260, not examined).

Material examined. AUSTRALIA: VICTORIA: **Great Otway National Park:** Little Aire Cascade Trail, E of Lavers Hill, S38.67032°, E143.49810° (GPS, ±100m), elev. 330m, 11 Feb 2013, *Nothofagus*, *Eucalyptus*, tree ferns wet forest, hand collecting, P.Michalik & M.J.Ramírez (MJR-Loc-125), two females (MACN-Ar 30666); Triplet Falls Trail, E of Lavers Hill, S38.67188°, E143.49673° (GPS, ±300m), elev. 300m (GPS), 10 Feb 2013, *Nothofagus*, *Eucalyptus*, tree ferns wet forest, hand collecting, P.Michalik & M.J.Ramírez (MJR-Loc-124), three females (MACN-Ar 30667, ZIMG II/28128, ZIMG II/28129); Mait's Rest Trail, W Apollo Bay, S38.75492°, E143.55495° (GPS, ±200m), elev. 240m, 13–14 Feb 2013, *Nothofagus*, tree ferns wet forest, hand collecting, P.Michalik & M.J.Ramírez (MJR-Loc-126), one female (ZIMG II/28130); Melba Gully Trail, S38°41.726', E143°22.312' (GPS, ±200m), elev. 328m, 15 Feb 2013, *Nothofagus*, tree ferns wet forest, hand collecting, P.Michalik & M.J.Ramírez (MJR-Loc-128), one male (ZIMG II/28127).

Diagnosis. This species can be distinguished from *P. carraiensis* by the single process on the embolus of the male palpal organ and the presence of eight spermathecae in the female genitalia.



Figure 2. **A** Habitat with supporting web (blue arrow) and sturdy thread (red arrows) connecting with the retreat in the hollow of a *N. cunninghamii* tree **B** Catching ladder in front of a hollow in a large tree **C** Immature male of *P. otwayensis* holding the catching ladder.

Female (Figs 3–4).

Measurements (mm, in MV). Carapace length 6.92; carapace width 4.66; caput width 2.66; abdomen length 8.51; abdomen width 7.18. Legs: length of segments (femur + patella/tibia + metatarsus + tarsus = total length): I 11.97 + 14.10 + 11.57 + 2.66 = 40.30, II 9.31 + 10.77 + 8.25 + 2.53 = 30.86, III 7.98 + 9.18 + 7.85 + 2.13 = 27.14, IV 9.98 + 10.91 + 9.44 + 2.13 = 32.46, palp 2.93 + 2.66 + - + 2.79 = 8.38.

Colour pattern. Carapace yellowish brown, darker on cephalic area, particularly in eye region. Chelicerae, maxillae and labium reddish brown. Sternum reddish brown marginally, paler centrally. Legs yellowish brown. Abdomen fawn-coloured with dark brown dorsal pigmentation consisting of 3 chevron markings. Carapace longer than wide, widest between coxae II and III. Cephalic area elevated behind eyes (Fig. 3A). Clypeus sloping, as long as the median ocular quadrangle, with a strongly curved anterior border. Fovea pit-like.

Eyes. Frontal view (Fig. 3D): anterior row slightly recurved, posterior row slightly procurved. Dorsal view (Fig. 3B): anterior row recurved, posterior row slightly recurved. AME < PME < ALE = PLE 0.23 : 0.32 : 0.35 : 0.35. Interdistances: AME-AME 0.18, AME-ALE 0.33, ALE-PLE 0.08, PLE-PME 0.40, PME-PME 0.28. Median ocular quadrangle: length 0.58 mm, anterior width 0.55 mm, posterior width 0.87 mm. Clypeus height 0.50. AME black, remainder white.

Chelicerae. Strong, vertical, slightly divergent. Three strong prolateral teeth, evenly spaced. Five very small retromarginal teeth (or denticles) in row on basal half of groove, with a spine on the apico-dorsal side. Stridulatory ridges absent.

Maxillae. Subparallel, external margin strongly curved and ending anteriorly in a bluntly pointed apex (Fig. 3C). Serrula present.

Labium. Free. Length 0.83, width 0.87. Apical margin indented, lateral margin subparallel below, sloping in toward apex above (Fig. 3C).

Sternum. Length 3.33, width 2.20. Elongate, shield-shaped with pointed apex which extends back midway between coxae IV (Fig. 3C).

Legs. 1423. Trochanters shallowly notched. Superior claws of 1st and 2nd legs dissimilar, with raptorial proclaws long and strongly developed (Fig. 3F), retroclaws shorter. Inferior claws of legs I and II slender and strongly hooked. Superior claws of legs III and IV similar (Fig. 3G). Accessory claw setae on all tarsi. Distal half of tarsus I and II with strong ventral setae. Calamistrum short, located in second quarter of metatarsus 4 (Fig. 3H).

Pattern of spination. (Approximate, slightly asymmetrical.) Femur I d (r2p1)-r2-r1-p1-1-2-p1-2-p1-2-2-3ap v 0-p1-0-0-0; patella r 1; tibia d 2-0-2-p1-0-p1-3 v 2-0-0-2-p1-0-2-0; metatarsus d r1-p1-p1-0-0-0-0 v p1-r1-p1-p1-r1-p1-r1-2ap; II; femur d (r2p1)-r2-2-p1-2-p1-2- 2-p1-3 v 0-p1-1-0-0; patella p 1; tibia d 2-p1-1-2-2-p1-p1-1-3 v 2-0-p1-r1-p1-2-0-2ap; metatarsus d 2-p1-2-r1-p1-r1-p1-p1-2ap v p1-r1-2-2-r1-p1-3ap; III; femur d (r3p1)-1-r1-2-p1-2-2-2-r1-3 v r1-p1-2-0-0; patella p 1 d 1 r 1; tibia d 2-1-p1-3-2-2 v 2-0-p1-r1-p1-2ap; metatarsus d 2-p1-p1-r1-p1-2- 2ap v 2-p1-p1-r1-p1-p1-r1-3ap; tarsus v 0-r1-0; IV femur d

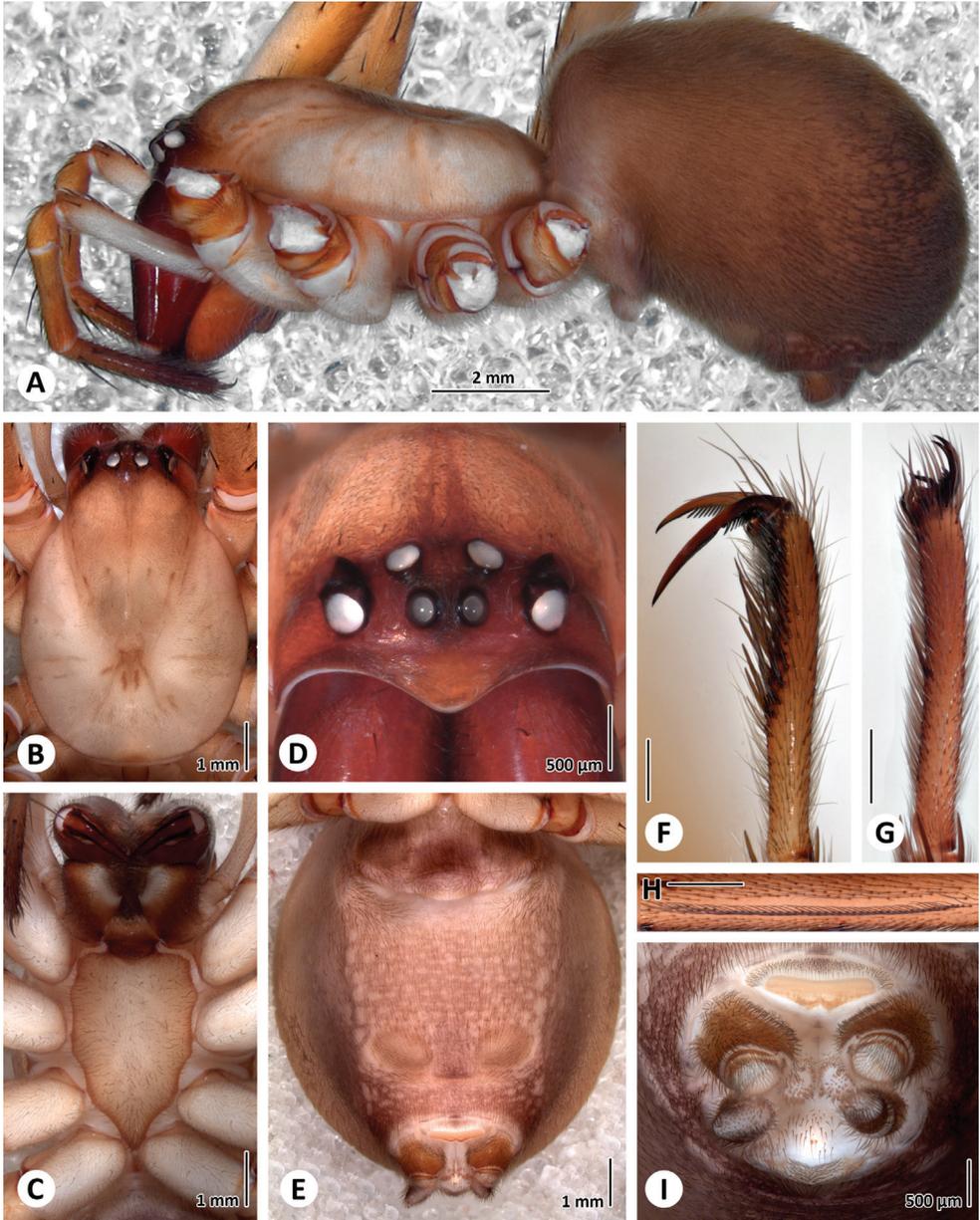


Figure 3. Somatic characters of the female of *P. otwayensis*. **A** Lateral view of prosoma and opisthosoma (ZIMG II/28128) **B** Dorsal view of prosoma (MV) **C** Ventral view of Prosoma (MV) **D** Frontal view of ocular area (ZIMG II/28128) **E** Ventral view of opisthosoma **F** Tarsus of leg I **G** Tarsus of leg IV **H** Calamistrum. **I** Ventral view of spinnerets. Scale bar in **F–H** is 500 µm.

(r4p2)-r2-1-r2-p1-2-2-2-3 v 0-p1-p1-0-0-0; patella p 1 d 1; tibia d 2-2-p1-1-3-r1 v 2-0-0-p1-p1-2ap; metatarsus d 2-p1-2-r1-2ap v p1-2-p1-p1-p1-2-r1-3ap; tarsus v 0-1-0.

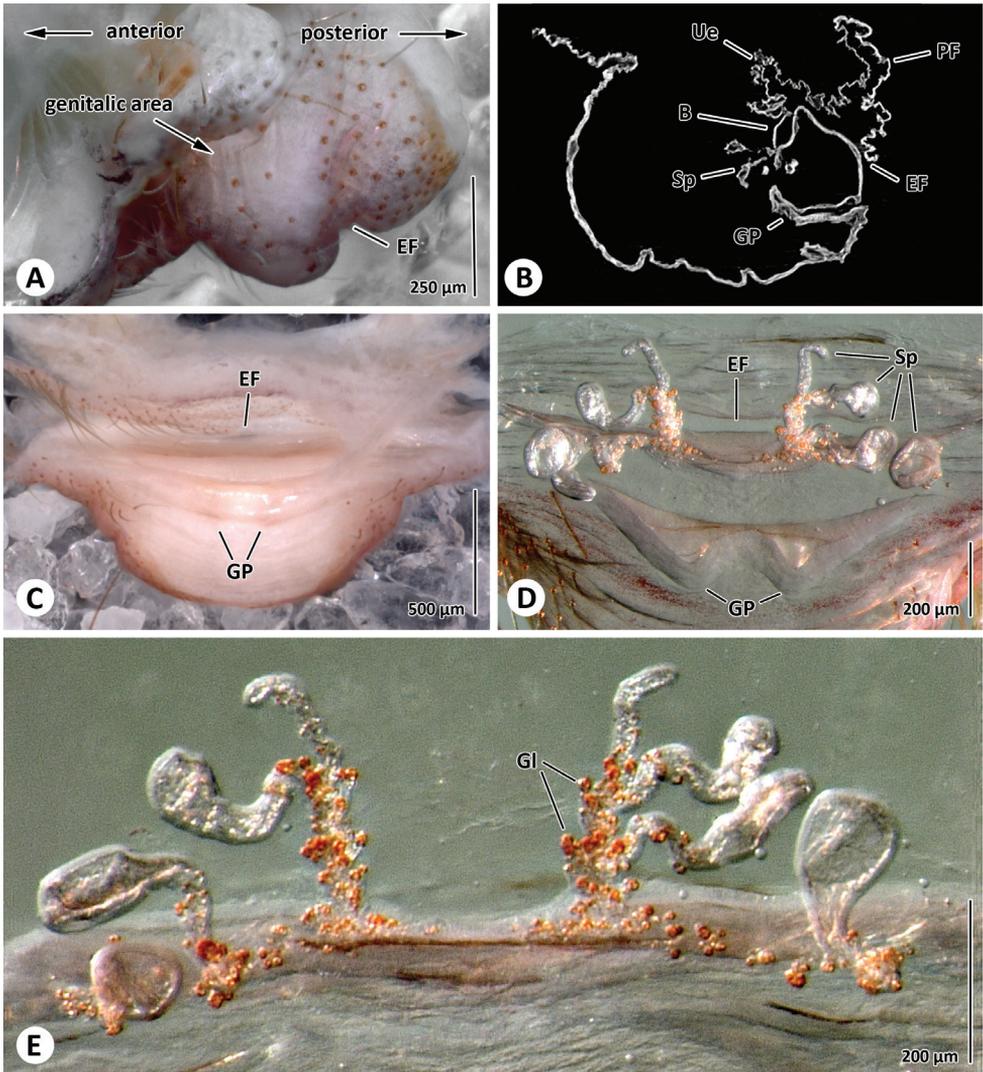


Figure 4. Female genitalia. **A** Lateral view of the dome-shaped genital area (compare also to Fig. 3A) (MACN-Ar 30667) **B** Sagittal section through genital area obtained by micro-CT (MACN-Ar 30667) **C** Posterior view of genital area (MACN-Ar 30667). Spermathecae in anterior (**D**) and ventral view (**E**) (ZIMG II/28128). Abbreviation: **B** bursa; **EF** epigastric furrow; **GP** genital pockets; **GI** glands; **PF** postepigastric fold; **Sp** spermathecae; **Ue** uterus externus.

Palp. Single claw. Spines: femur d 0-0-1-1-3ap patella p 1 d 1-1, tibia d 1-1, p 0-2-0; tarsus d 2-2-1-2-3ap v 2-2-2ap.

Abdomen. Cribellum undivided, with narrow spinning field, as wide as basal span of anterior spinnerets (Figs 3E, 3I). Spiracles of posterior lung books well separated but joined by a transverse groove. Genital area swollen and only faintly sclerotized near the epigastric furrow (Fig. 3E).

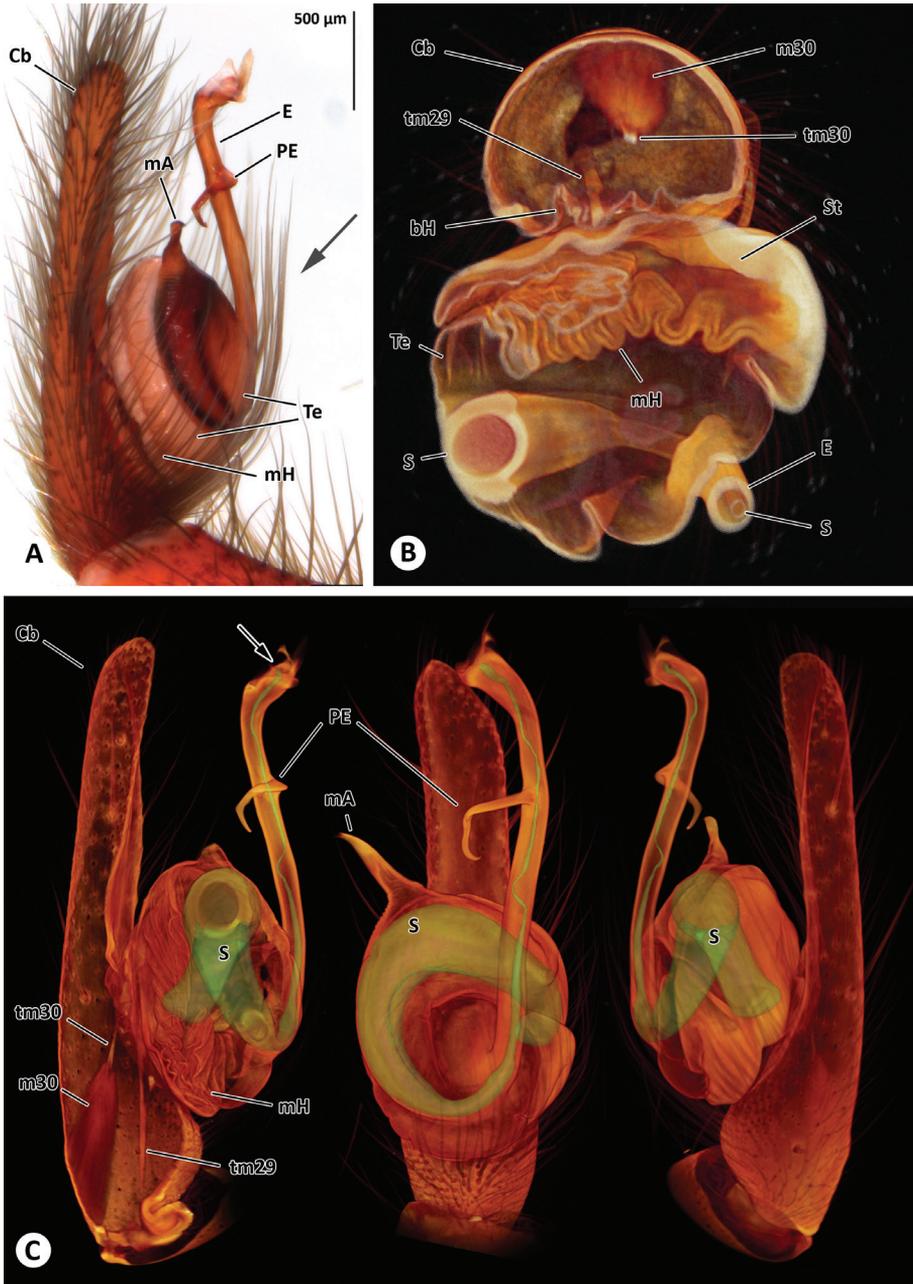


Figure 5. Right male palp of *P. otwayensis* (ZIMG II/28127). **A** Prolateral view; the arrow marks the section plane of Fig. 5B **B** Section of the volume rendered male palp **C** Surface model of the spermophor superimposed on the volume rendering of the male palp (prolateral, ventral and retrolateral views). The cymbium, subtegulum and tegulum are partly removed in the prolateral view to show tendons, muscles and hematodochae. The arrow points to the opening of the embolus. Abbreviation: **Cb** cymbium; **E** embolus; **m29** muscle 29; **m30** muscle 30; **mA** median apophysis; **mH** median hematodocha; **PE** process of embolus; **S** spermophor; **St** subtegulum; **Te** tegulum; **tm29** tendon of muscle 29; **tm30** tendon of muscle 30.

Genitalia. Genital area distinct and dome-shaped (Figs 3A, 4A). Internal genitalia simple, with eight spermathecae grouped in two quartets (Figs 4D–E). The outer spermathecae are ovoid and have a short duct. The inner spermathecae can be grouped leading into the bursa through a long, slender convoluted duct (Fig. 4). Glandular projections are mainly present on the spermathecal ducts. A fold with two distinct sclerotized pockets is situated anterior/ventral to the spermathecae. A blind-ended invagination, the postepigastric furrow, is situated immediately posterior to the epigastric furrow.

Male (ZIMG II/28127; Fig. 5).

Male palp. Tegulum with short median apophysis. Embolus tube-like with a solid single hook-shaped process; tip of the embolus widened and hyaline; fundus sac-like, spermophor with an internal band delimited by two parallel ridges (Fig. 5B), distal part of the spermophor within the embolus partly convoluted and very thin (approximately 8µm in diameter); m30 and tm30 in cymbium; m29 in tibia and attaching to the spermophor.

Natural history. The web structure is similar to *P. carraiensis* (for details see Gray 1983) and web construction is performed after sunset. The catching ladders and supporting webs (Figs 2B–C) are connected by a single sturdy thread to retreats in hollow trees Fig. 2A), often far away (up to 3 meters). As already described by Milledge (1997), we found most of the specimens in hollows of old *Nothofagus cunninghamii* trees (Fig. 2A), but also several in hollows of mountain ash (*Eucalyptus regnans*) trees, the bases of large tree ferns (Fig. 2B) and under bridges on trails. On one occasion, we had access to a large hollow mountain ash tree and found catching ladders and supporting webs of juveniles inside of it.

Distribution. Endemic to the Great Otway National Park (Victoria). In addition to the locations reported by Milledge (1997), we found several specimens (one male, several juveniles) at the Melba Gully Trail which is located at the western end of the National Park (Fig. 1).

Discussion

Our data are in accordance with the previous detailed descriptions on the distribution and natural history of *Progradungula* species (Forster and Gray 1979; Forster et al. 1987; Gray 1983; Milledge 1997). The new records of *P. otwayensis* from the Melba Gully trail might imply a wider distribution in the Great Otway National Park. Nevertheless, this species seems to be dependent on hollow trees with a suitable microclimate (Gibbons and Lindenmayer 1997; Gibbons et al. 2002), since specimens mostly occur in the oldest and extensively hollow myrtle beech trees in the humid forests in the western part of the Great Otway National Park, or in mountain ash trees, upon which the myrtle trees depend (Lindenmayer et al. 2000). Other habitats such as tree ferns were much less inhabited in areas where old hollow myrtles occur (Milledge 1997). The presence of juvenile catching ladders and supporting webs inside the hollow trees suggests that early instars live exclusively in hollows. This is also supported by the fact that we could never observe exposed juvenile catching ladders, as we abundantly found for larger immatures and adults.

The female genitalia of *P. otwayensis* are very similar to *P. carraiensis* as the number of spermathecae is reduced compared to other gradungulids and they are bilaterally arranged (Forster et al. 1987). Thus, we here confirm the generic placement suggested by Milledge (1997). Additionally, we found distinct and sclerotized pockets in a fold anteriorly to the epigastric furrow which has not been reported from any other gradungulid (Forster et al. 1987). The function of these pockets is unknown, but an interaction with the embolic process during copulation seems to be a possibility. Moreover, in contrast to Forster et al. (1987) we could not find a “median receptaculum”. Instead, the organization is mainly in accordance with the interpretation of Griswold et al. (2005) of the genitalia of gradungulids.

As revealed by micro-CT analysis of the male palpal organ of *P. otwayensis*, the spermophor has a thick wall and an internal band delimited by two parallel ridges, which in the micro-CT sections appears associated with glandular tissue. As described by Forster et al. (1987) for *Kaiya* Gray, 1987, the spermophor of *P. otwayensis* is convoluted within the embolus. The muscles (m29 and m30) and their tendons are in accordance with the description of *Gradungula sorenseni* Forster, 1955 by Huber (1994) and resemble the usual organization for non-entelegyne Araneomorphae (Huber 2004). Thus, the organization might be typical for all Gradungulidae and different to the organization found in austrochilines (Michalik and Ramírez in press).

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First records and description of metallic red females of *Euglossa (Alloglossura) gorgonensis* Cheesman, with notes on color variation within the species (Hymenoptera, Apidae)

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Abstract

Metallic coloration is one of the signatures of orchid bees of the genus *Euglossa*, with some species showing variation associated with their geographic range. *Euglossa (Alloglossura) gorgonensis* Cheesman exhibits color variation, ranging from mainly green specimens in the southern extreme of its range (Pacific slope of Colombia), to noticeably reddish specimens in parts of the northern known limits of its range (Pacific slope of southern Costa Rica). Here we present the first description of females from Costa Rica belonging to the reddish extreme of the color variation.

Keywords

Apoidea, *Euglossa*, orchid bees, Costa Rica, color variation

Introduction

Besides their interesting biology, orchid bees are morphologically attractive, among other things due to the metallic coloration of the body. Within the genus *Euglossa* Latreille in particular, with few exceptions (see Hinojosa-Díaz and Engel 2011a), species exhibit bright metallic coloration all over the body, including colors such as green, blue, bronze–reddish (see Roubik and Hanson 2004), variations of these, as well as combinations and intergradations of them. A number of species in the genus are known to be variable in the metallic coloration of the body, which can be associated with the geographic range of the particular species. Examples are discussed by Roubik (2004) for species in the subgenus *Glossura* Cockerell, and by Hinojosa-Díaz and Engel (2012) for species in the recently proposed subgenus *Alloglossura*. As part of this last assemblage, *Euglossa* (*Alloglossura*) *gorgonensis* Cheesman, exhibits integumental color variation along its distributional range, from predominantly green specimens in the southern Pacific slope of Colombia, to distinctively reddish specimens in the southern Pacific slope of Costa Rica (Hinojosa-Díaz and Engel 2012). The species was originally described based on green females from Gorgona Island in Colombia, while Dressler (1978) created a separate subspecies for the reddish males from Costa Rica. Until now females for the red extreme of the color variation were unknown. Here we present a description of females from the Pacific slope of southern Costa Rica filling this knowledge gap.

Material and methods

The female specimens used in this study were collected as part of a study of the effects of forest fragmentation on Costa Rican bee communities (Brosi et al. 2007, Brosi et al. 2008, Brosi 2009). One specimen was captured via aerial netting in a bee survey; the other was captured in a Van Someren trap baited with rotten fish. One of the specimens is housed in B. Brosi's collection at Emory University, Atlanta, Georgia, USA, the other is deposited in the Division of Entomology, University of Kansas Natural History Museum, Lawrence, Kansas, USA (SEMC).

Morphological terminology in general follows that of Engel (2001), and Michener (2007); some procedures for establishing metrics (e.g., clypeal protuberance) follow Brooks (1988). Length measurements are presented as the average of the two specimens used in the study with individual specimen measurements in parenthesis, except when both specimens had the same value. The description is based on the overall format for *Euglossa* species as presented by Hinojosa-Díaz and Engel (2007, 2011a, 2011b, 2012). Photomicrographs were prepared using a Cannon EOS 7D digital camera and an Infinity K-2 long-distance microscope lens. Multilayer images were produced by using the software CombineZP.

Results

Euglossa (*Alloglossura*) *gorgonensis* Cheesman

http://species-id.net/wiki/Euglossa_gorgonensis

Figs 1–3

Euglossa gorgonensis Cheesman, 1929: 141–154 [146].

Euglossa (*Glossura*) *gorgonensis erythrophana* Dressler, 1978: 167–185 [170].

Female red morph description. *Structure.* Total body length 10.45 mm (10.30, 10.59); labiomaxillary complex in repose slightly surpassing metasomal tip (estimation) (Figs 1–2). Head length 2.63 mm (2.56, 2.70); head width 4.23 mm (4.16, 4.30); upper interorbital distance 2.15 mm; lower interorbital distance 2.04 mm (2.01, 2.07); upper clypeal width 1.23 mm (1.19, 1.26); lower clypeal width 1.84 mm (1.83, 1.85); clypeal protuberance 0.78 mm (0.74, 0.81); medial clypeal ridge well developed, paramedial clypeal ridges well developed along their lower two thirds; labrum slightly wider than long, length 0.98 mm (0.96, 1.00), width 1.11 mm (1.10, 1.11); medial labral ridge sharp; paramedial labral ridges sharp, oblique, running on about four fifths of labral length; labral windows occupying about half of labral length; interocellar distance 0.33 mm; ocellocular distance 0.66 mm; length of first flagellomere [0.39 mm (0.37, 0.41)] comparable to combined length of second and third flagellomeres [0.39 mm (0.37, 0.41)]; length of malar area 0.05 mm. Mandible tridentate. Pronotal lateral angle characteristic of *Alloglossura* (slightly obtuse not broadened anterolaterally and with no projections); intertegular distance 3.26 mm; mesoscutal length 2.69 mm (2.59, 2.78); mesoscutellar length 1.30 mm (1.26, 1.33); posterior margin of mesoscutellum strongly convex; mesotibial length 2.04 mm (2.00, 2.07); mesobasitarsal length 1.86 mm (1.78, 1.93), maximum width 0.50 mm (0.48, 0.52); metatibia triangular (scalene triangular), metatibial anterior margin sinuate, proximally concave, length 2.78 mm (2.67, 2.89); ventral margin length 1.78 mm (1.56, 2.00); metatibial posterodorsal margin length 3.12 mm (3.04, 3.19); metabasitarsus characteristic of *Alloglossura* females (trapezoidal with narrower and straight distal margin) (Fig. 2), length 1.56 mm (1.48, 1.63), maximum width 0.72 mm (0.70, 0.74). Forewing length 8.04 mm (7.78, 8.30); hind wing with 17–20 hamuli. Maximum metasomal width 4.26 mm (4.22, 4.30).

Coloration. Head green, with noticeable golden–bronzy iridescence all over but accentuated on frontal areas (clypeal disc, and antennal depressions); some blue lights on vertex and lower paraocular areas; clypeal disc with brown coloration as in previously known specimens (i.e. restricted to contiguous areas along upper half of medial ridge) (Fig. 3); mesosoma green, with golden–bronzy iridescence all over, turning reddish on posterior half of mesoscutum, as well as on all mesoscutellar surface; legs green, with golden–bronzy iridescence; metasoma with basal green coloration overtaken by strong golden–reddish iridescence, particularly dominant on dorsal surfaces of terga (Figs 1–2).



Figures 1–3. *Euglossa (Alloglossura) gorgonensis* Cheesman, female, red specimen from the Pacific slope of southern Costa Rica. **1** Dorsal habitus **2** Lateral habitus **3** Facial aspect.

Sculpturing and vestiture. As described for the known predominantly green specimens (i.e. Hinojosa-Díaz and Engel 2012).

Material examined. Both female specimens from Costa Rica, labeled as follows: “Specimen’04 # 2251; morphosp: 94 // Tucanes [vertical writing] Costa Rica, Coto

Brus, near San Vito; 8°49'01.88"N, 82°59'31.02"W BG; elev. 1200m; Aug. 2004; aerial netting; B.Brosi, T.Shih, B. Graham IXT 8/25" (1♀) (Emory University); "Practice #94; morphosp: // Santa Clara [near San Vito de Coto Brus, Puntarenas, Costa Rica, 8°48'23.56" N, 82°58'35.02"W] 7/9; FISH Int // c.f. *Euglossa*; *gorgonensis* // Collected outside of sampling; regime; morphosp #: 94 [captured in the middle of a 3-Ha forest fragment using a Van Someren trap baited with rotten fish, on 9-July-2004]" (1♀) (SEMC).

Discussion

Cheesman (1929) originally described *Euglossa* (*Alloglossura*) *gorgonensis* based on two female specimens from Gorgona Island, off the southern Pacific coast of Colombia. The holotype specimen (and presumably the other female of the type series) exhibits a characteristic green integument with some blue–green iridescence, and very faint golden–bronzy lights. A couple of additional females, from the Canal Zone in Panama, included in the redescription of the species as part of the subgenus *Alloglossura* (Hinojosa-Díaz and Engel 2012), are similarly colored with the exception of the golden–bronzy iridescence being more noticeable, especially on the anterior section of the metasomal terga (see Hinojosa-Díaz and Engel 2012, figs 36–37). On the other hand, male specimens of *E. (A.) gorgonensis*, are known from Colombia, Panama and Costa Rica. As asserted by Hinojosa-Díaz and Engel (2012), specimens from Colombia and Panama have corresponding integumental coloration to the females as mentioned above (i.e. mainly green with weak golden–bronzy iridescence). The Costa Rican male specimens exhibit a range of integumental coloration with dominant golden–bronzy iridescence that turns intense red in specimens from some areas of the southern Pacific slope of the country. The distinctive bright red iridescent coloration of these males seemed to be compelling enough to describe a subspecies, *E. (A.) gorgonensis erythrophana* Dressler (1978), distinguishable from the predominantly green specimens. Following Hinojosa-Díaz and Engel (2012), the subspecific names within *E. (A.) gorgonensis* are seen as synonymous, as there seems to be continuous intergradation from the bright red specimens in the southern Pacific side of Costa Rica, to the rather green specimens from the southern Pacific of Colombia. Despite this intergradation, the red colored specimens are quite distinctive and females had been unknown until now. The two females used for the present work were collected in localities in which bright red males have also been collected; these localities are also in the proximity of localities cited in the original description of *E. (A.) gorgonensis erythrophana*. The discovery of these female specimens is significant from more than one point of view. They fill up a gap in terms of the knowledge of the morphological variation of the species. The females here studied are distinctively red colored, more noticeably on the posterior dorsal half of the mesosoma, and more strongly on all metasomal terga. The red coloration is not as strong as in some of the males from the region (see Hinojosa-Díaz and Engel 2012, figs 34–35), but they are distinctive from the Panamanian and Colombian previously

known female specimens. There is also variation in the coloration of the males in the area, all of them having the distinctive bright red integument, but to different degrees, some of them matching the coloration of the females here studied. It should be noted, as stated by Hinojosa-Díaz and Engel (2012), that *Alloglossura* females tend to exhibit more extended blue–green to purple coloration than the males. Another interesting aspect of the discovery of these females lies in the general scarcity or absence of female specimens in collections from the area. Despite the constant surveying of orchid bees in both Costa Rica and Panama, females are unknown for other species, like the closely related *E. (A.) oleolucens* Dressler (see Hinojosa-Díaz and Engel 2012). The bias towards the collection of males by using chemical baits could explain the paucity of female specimens, which are rarely attracted to these baits; however both authors have spent more than one season collecting bees from flowers in the region, having collected no females of *E. (A.) oleolucens*, and in the case of a longer survey by B.J. Brosi, the two females of *E. (A.) gorgonensis* here presented. One of these two females was captured in a trap baited with rotten fish, which could be an indication of the biology of the species. We encourage the use of alternative collecting methods in addition to the use of chemical baits, to sample the orchid bee fauna as a way to get a better picture of the morphological variation with respect to the female bees.

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