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The large carpenter bees of central Saudi Arabia, with notes on the biology of *Xylocopa sulcatipes* Maa (Hymenoptera, Apidae, Xylocopinae)

Mohammed A. Hannan[1], Abdulaziz S. Alqarni[1],
Ayman A. Owayss[1], Michael S. Engel[2]

1 *Department of Plant Protection, College of Food and Agriculture Sciences, King Saud University, Riyadh 11451, PO Box 2460, KSA* **2** *Division of Entomology, Natural History Museum, and Department of Ecology & Evolutionary Biology, 1501 Crestline Drive – Suite 140, University of Kansas, Lawrence, Kansas 66049-2811, USA*

Corresponding author: *Abdulaziz S. Alqarni* (alqarni@ksu.edu.sa)

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Abstract

The large carpenter bees (Xylocopinae, *Xylocopa* Latreille) occurring in central Saudi Arabia are reviewed. Two species are recognized in the fauna, *Xylocopa* (*Koptortosoma*) *aestuans* (Linnaeus) and *X.* (*Ctenoxylocopa*) *sulcatipes* Maa. Diagnoses for and keys to the species of these prominent components of the central Saudi Arabian bee fauna are provided to aid their identification by pollination researchers active in the region. Females and males of both species are figured and biological notes provided for *X. sulcatipes*. Notes on the nesting biology and ecology of *X. sulcatipes* are appended. As in studies for this species from elsewhere, nests were found in dried stems of *Calotropis procera* (Aiton) (Asclepiadaceae) and *Phoenix dactylifera* L. (Arecaceae).

Keywords

Apoidea, Anthophila, Xylocopini, Arabian Peninsula, systematics, biology, host plants, nesting

Introduction

The tribe Xylocopini comprises the large carpenter bees (Xylocopinae: *Xylocopa* Latreille) species of which principally nest in dead wood (including the wood of human constructions), bamboo culms, and other similar substrates (e.g., Hurd 1958,

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1978; Hurd and Moure 1960, 1963; Sakagami and Laroca 1971; Gerling et al. 1983, 1989; Maeta et al. 1985, 1996; Raju and Rao 2006; Boontop et al. 2008; Gonzalez et al. 2009; Pereira and Garófalo 2010; Prager and Hunter 2011), and Le Goff (2004) even records a species emerging from the wood of a Senegalese ceremonial mask. Owing to their conspicuousness, interesting biology and behavior, and agricultural potential (e.g., Keasar 2010), the group has received increased systematic scrutiny, although most recent work has focused on relationships among the tribes of the subfamily or those of the constituent genera and subgenera (e.g., Minckley 1998; Engel 2001, in press; Leys et al. 2002; Flores-Prado et al. 2010). Meanwhile, the number of detailed, species-level revisions has lagged over the last 15 years (although when done, there are some very nice examples: e.g., Leys 2000) despite the fact that it is at this level for which the documentation and interpretation of biological phenomena is most critical (e.g., Engel 2011). Today, the diversity of carpenter bees in many areas of the world remains largely unexplored.

As part of an on-going effort to survey the bee fauna and pollinator resources of the Kingdom of Saudi Arabia and to eliminate the taxonomic impediment for working on this diverse region, we have begun with surveys of the melittofauna from central Saudi Arabia. Herein we provide a brief contribution to this larger effort by documenting the species of the large carpenter bees occurring in this area and as an aid to studies of wild bee pollination already underway (Hannan et al. in prep.). Two species are recognized from the region, *Xylocopa* (*Koptortosoma*) *aestuans* (Linnaeus) and *X.* (*Ctenoxylocopa*) *sulcatipes* Maa, although the latter may be frequently found misidentified in some collections as *X.* (*Xylomelissa*) *hottentotta* Smith or *X.* (*C.*) *fenestrata* (Fabricius) (e.g., Al-Ahmadi and Salem 1999). *Xylocopa hottentotta* is an entirely unrelated species of African distribution (Eardley 1983, 1993), while *X. fenestrata* is certainly very closely allied to *X. sulcatipes* but occurs more easterly and southerly (Maa 1970). The latter species is quite similar but can be readily distinguished on the basis of the male terminalia (Maa 1970, and figures herein, *vide infra*). In total five nominal species have been recorded from throughout the Arabian Peninsula [e.g., Al-Ahmadi and Salem 1999: recorded as *X. aestuans*, *X. hottentotta*, *X. caffra* (Linnaeus), and *X. valga*?], but many of these seem to be misidentifications (e.g., *X. hottentotta*) and thorough collecting and new identifications, particularly with comparisons to holotypes, is desperately needed. Diagnoses, figures (particularly the male terminalia), and keys are provided so as to aid regional entomologists in the identification of their material. In addition, we append observations on the biology and ecology of *X. sulcatipes*.

Material and methods

Material examined herein is deposited in the King Saud University Museum of Arthropods, Plant Protection Department, College of Food and Agriculture Sciences, King Saud University, Riyadh, Kingdom of Saudi Arabia (KSMA) and Division of Entomology (Snow Entomological Collections), University of Kansas Natural History

Museum, Lawrence, Kansas, USA (SEMC). Photomicrographs were prepared using a Nikon D1x digital camera attached to an Infinity K-2 long-distance microscope lens. Morphological terminology in the diagnoses follows that of Engel (2001) and Michener (2007). Herein we follow the supraspecific classification of Xylocopini advocated by Minckley (1998) and Michener (2007).

The nesting biology of *X. sulcatipes* was studied in Amariah, approximately 25 km northwest of Riyadh, from September 2010 through December 2011. Nests were found on 6 June 2011 at the base of a large hill near an agricultural farm near Wadi Amariah and the highway to Riyadh. Prior to collection the nests were observed for at least an hour to note the coming and going of bees. Most nests were located around 9:00am and collected around 12:00pm. Nests were sealed with plastic and brought to the lab for dissection and study. During four visits (6, 12, 19 June and 28 September 2011) a total of 13 nests were collected (Table 1). Nests were in the dead branches of local milkweeds [*Calotropis procera* (Aiton) (Asclepiadaceae), more widely known as the "Apple of Sodom"] growing in a sparsely vegetative desert area and among date palms, *Phoenix dactylifera* L. (Arecaceae). Nests were measured, sketched, and photographed, and the inhabitants deposited in the KSMA repository.

Table 1. Measurements of sampled nests of *Xylocopa* (*Ctenoxylocopa*) *sulcatipes* Maa from central Saudi Arabia collected in dead wood of two plants. Means are given with standard deviations. n = number of nests sampled for each metric.

	Asclepiadaceae	**Arecaceae**
Metric	***Calotropis procera* (Aiton)**	***Phoenix dactylifera* L.**
Branch length (cm)	147.75±74.59 (n=8)	57.33±6.53 (n=6)
Nest entrance (mm)	9.06±0.78 X 8.85±0.86 (n=8)	10.17±2.17 X 11±2 (n=7)
Height of nest from ground (cm)	83.50±30.3 (n=8)	400±0 (n=6)
Length of nest (cm)	23.61±14.93 (n=7)	11.05±4.36 (n=6)
Branch diameter at nest (cm)	1.88±0.38 (n=8)	6.83±0.41 (n=6)
Internal diameter of nest (cm)	1.28±0.19 (n=8)	1.77±0.12 (n=6)
Number of cells/nest	6.60±5.6 (n=5)	4.50±1.64 (n=6)
Length of cells (mm)	18.8±1.63 (n=30)	20.11±1.37 (n=19)

Systematics

Genus *Xylocopa* Latreille
Subgenus *Koptortosoma* Gribodo

This is the largest and most widespread subgenus of carpenter bees, with at least 196 recognized species ranging throughout Subsaharan Africa to the Mediterranean countries of that continent, Dalmatia, the Arabian Peninsula, southwestern Asia, and southern Asia east to the Philippines, Taiwan, and Japan, and south through Indonesia, New Guinea, and the Bismarck Archipelago to southernmost Australia (Michener 2007). The subgenus can be recognized by the female mesoscutellum having a sharp truncation overhanging the metanotum (as in subgenus *Mesotrichia* Westwood) and surpassing the posterior margin of the latter, and males with unmodified tegulae (elongate in *Mesotrichia*) (Michener 2007).

***Xylocopa* (*Koptortosoma*) *aestuans* (Linnaeus)**

http://species-id.net/wiki/Xylocopa_aestuans
Figs 1–11

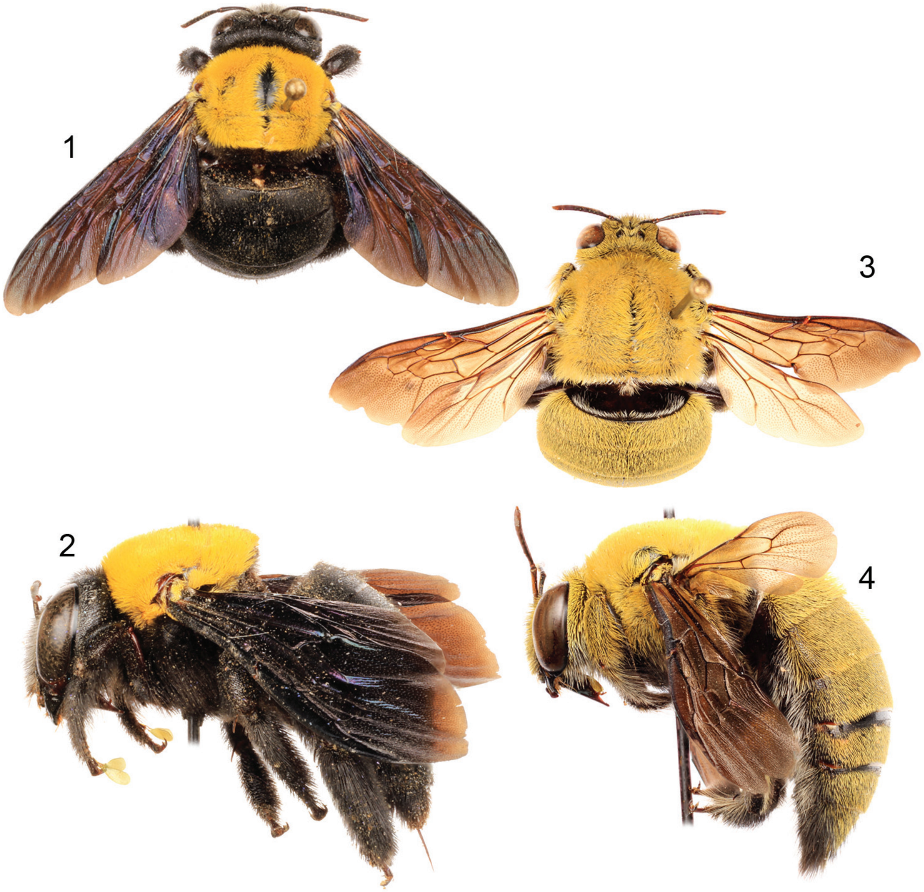
Apis aestuans Linnaeus, 1758: 579 [♀].
Xylocopa aestuans (Linnaeus); Illiger 1806: 151.

Diagnosis. *Xylocopa aestuans* can be most readily distinguished from other Saudi Arabian large carpenter bees by the following: female face with largely white or pale pubescence (Fig. 5), mesosomal dorsum densely covered by yellow pubescence obscuring underlying integument (Figs 1, 2); mandible bidentate at apex; posterodorsal margin of mesoscutellum projecting beyond posterior margin of metanotum; pygidial plate unarmed. Male covered by dense yellow pubescence (Figs 3, 4, 6); first metasomal tergum with subhorizontal dorsal surface abruptly and angulately separated from declivitous anterior surface; gradulus of first metasomal tergum transverse, lateral extremities not directed posteriorly; male terminalia as in figures 7–11.

Comments. *Xylocopa aestuans* is one of the widespread and ubiquitous of large carpenter bee species. There has been considerable debate regarding the identity of the species of *Koptortosoma* similar to *X. aestuans* (i.e., considering them synonyms, subspecies, or separate species), with different authors of varying opinions how to segregate the minor variation into natural taxonomic entities (e.g., Lieftinck 1964). The Saudi Arabian populations have been at times considered to the belong to the largely African, *X. pubescens* Spinola, although the genitalia of those populations are quite dissimilar from true *X. pubescens*. Indeed, the genitalia (Figs. 7–11) and other characters are certainly more alike the more easterly populations of *X. aestuans* and there seems little reason at this time to not consider the central Saudi Arabian populations as such, as was done by Shalaby (1961). The species has also been recorded from the United Arab Emirates (Harten 2005; Dathe 2009). Biological accounts, largely from India or Southeast Asia, have been provided by Dover (1924), Monod (1977), Binti (1992), El-Borollosy and Ismail (1972: note that these observations may be of *X. pubescens*, the identity of their material requires checking), and Punekar et al. (2010).

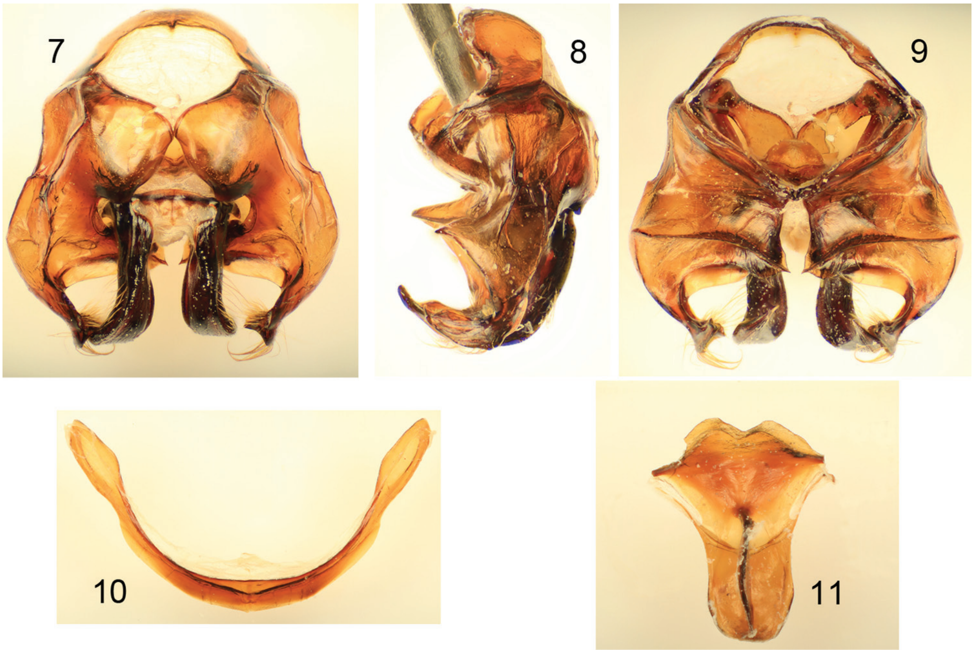
Subgenus *Ctenoxylocopa* Michener

This is a widespread, albeit not very diverse, subgenus of Old World carpenter bees (Maa 1970; Michener 2007). The lineage can be recognized by the prolonged posterior pronotal lobes and elevated process of the spiracles on the third metasomal tergum in



Figures 1–4. Habitus photomicrographs of *Xylocopa* (*Koptortosoma*) *aestuans* (Linnaeus) from central Saudi Arabia. **1** Female, dorsal **2** Female, lateral **3** Male, dorsal **4** Male, lateral.

Figures 5–6. Faces of *Xylocopa* (*Koptortosoma*) *aestuans* (Linnaeus) from central Saudi Arabia. **5** Female **6** Male.



Figures 7–11. Male terminalia of *Xylocopa* (*Koptortosoma*) *aestuans* (Linnaeus) from central Saudi Arabia. **7** Genital capsule, dorsal aspect **8** Genital capsule, lateral aspect **9** Genital capsule, ventral aspect **10** Seventh metasomal sternum **11** Eighth metasomal sternum.

males, while females are noteworthy for the combination of a row of tubercles along each margin of the metabasitibial plate, the tridentate mandibles, and a single spine on the outer apex of the metatibia.

Xylocopa (*Ctenoxylocopa*) *sulcatipes* Maa

http://species-id.net/wiki/Xylocopa_sulcatipes
Figs 12–22

Xylocopa (*Ctenoxylocopa*) *sulcatipes* Maa, 1970: 739 [♂♀].

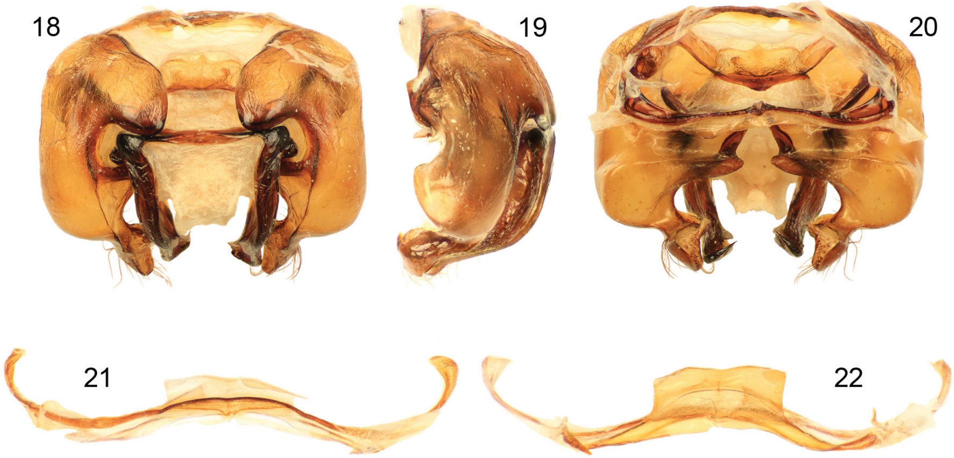
Diagnosis. *Xylocopa sulcatipes* can be most readily distinguished from other Arabian large carpenter bees by the following: Female with face with largely black pubescence (Fig. 16), mesosomal dorsum largely covered by black pubescence not obscuring underlying integument (Figs 12, 13); mandible tridentate at apex; mesoscutellum not projecting over metanotum, apical margin rounded in profile; pygidial plate armed on each side with subapical spine. Male covered by largely fuscous to black pubes-

Figures 12–15. Habitus photomicrographs of *Xylocopa* (*Ctenoxylocopa*) *sulcatipes* Maa from central Saudi Arabia. **12** Female, dorsal **13** Female, lateral **14** Male, dorsal **15** Male, lateral.

cence except face, dorsum of mesosoma, and apicolateral patches of first metasomal tergum with predominantly white or pale setae (Figs 14, 15, 17); first metasomal tergum with subhorizontal dorsal surface rounding into declivitous anterior surface; gradulus of first metasomal tergum laterally curved posteriorly; male terminalia as in figures 18–22.

Comments. Maa (1970) recorded *X. sulcatipes* from Saudi Arabia, Yemen, Israel, and Transcaspia (likely northern Iran, or southwesternmost Turkmenistan), while Vicidomini (2004) gave localities in Jordan. The records of *X. fenestrata* from the United Arab Emirates (Dathe 2009) are likely *X. sulcatipes*, and this material should be dissected and compared with the images herein (Figs. 18–22) as well as those of Maa (1970). We have found that Maa's (1970) characterization of the terminalic differences holds well for observed populations and the species he recognized appear to be good (Engel pers. obs.).

Figures 16–17. Faces of *Xylocopa* (*Ctenoxylocopa*) *sulcatipes* Maa from central Saudi Arabia. **16** Female **17** Male.



Figures 18–22. Male terminalia of *Xylocopa* (*Ctenoxylocopa*) *sulcatipes* Maa from central Saudi Arabia. **18** Genital capsule, dorsal aspect **19** Genital capsule, lateral aspect **20** Genital capsule, ventral aspect **21** Seventh metasomal sternum **22** Eighth metasomal sternum.

Key to the Species of *Xylocopa* in Central Saudi Arabia

1 Males **2**

– Females **3**

2 Bee covered by dense yellow pubescence; first metasomal tergum with subhorizontal dorsal surface abruptly and angulately separated from declivitous anterior surface; gradulus of first metasomal tergum transverse, lateral extremities of gradulus not directed posteriorly; terminalia as in figures 7–11 .. .. ***X. aestuans*** **(Linnaeus)**

– Bee covered by largely fuscous to black pubescence except face, dorsum of mesosoma, and apicolateral patches of first metasomal tergum with predominantly white or pale setae; first metasomal tergum with subhorizontal dorsal surface rounding into declivitous anterior surface; gradulus of first metasomal tergum laterally curved posteriorly; terminalia as in figures 18–22 .... ***X. sulcatipes*** **Maa**

3 Mesosomal dorsum densely covered by yellow pubescence obscuring underlying integument; face with largely white or pale pubescence; pygidial plate unarmed; posterodorsal margin of mesoscutellum projecting beyond posterior margin of metanotum; mandible bidentate at apex ... ***X. aestuans*** **(Linnaeus)**

– Mesosomal dorsum largely covered by black pubescence not obscuring underlying integument; face with largely black pubescence; pygidial plate armed on each side with subapical spine; mesoscutellum not projecting over metanotum, apical margin rounded in profile; mandible tridentate at apex .... ***X. sulcatipes*** **Maa**

Biological Notes on *X. sulcatipes* at Amariah

The biology of *X. sulcatipes* has been the focus of several extensive ecological and behavioral studies, principally in Israel (e.g., Eisikowitch 1986; Gerling et al. 1983, 1989; Hefetz 1983; Kronenberg and Hefetz 1984; Stark 1989, 1992a, b; Stark et al. 1990; Surholt et al. 1990; Velthuis 1987; Velthuis and Gerling 1980; Velthuis et al. 1984; Willmer 1988). Our observations do not differ from those of the previous studies except that we have focused more on the architecture of the nests rather than the particular ecology of the species, which is already well characterized. The species is bivoltine and foraged from March through November. The area around Amariah, where our observations were made, is a typical central Saudi Arabian desert environment. Vegetation is thinly scattered and comprised mostly native plants, including several promising foraging flowers and nesting sites throughout the season. Among these, *C. procera* was found to be the most commonly used for nesting and provisioning resources. The pithy and rather straight stems of suitable diameter of *C. procera* make them ideal for nest construction (e.g., Figs 23–27). Secondarily, *P. dactylifera* was used as a nesting substrate (with five such nests collected). Detail measurements of the nests observed are provided in table 1. Given the different overall physical structure of these substrates it is not surprising that nests in *C. procera* had a single, linear nest tube extending to each side of the entrance (Figs 23–27), while those in *P. dactylifera* consisted of a more gallery-like structure, similar in this regard to the variation observed for *X.* (*Stenoxylocopa*) *artifex* Smith (Silveira 2002). In all of the nests the pollen masses were compact, well kneaded, and mixed with sufficient nectar to leave them moist (Fig. 26). Where observed, individual pollen loaves were fully consumed and the larvae defecated pellet-like feces which were placed to its back or at the bottom of the cell. As observed elsewhere for this species, cells were arranged linearly, but never with cells closer than 1–1.5 times an individual cell length from the nest entrance. Also similar to observations made elsewhere on this species (e.g., Gerling et al. 1989), some nests were found

Figures 23–26. Photographs of nests of *Xylocopa* (*Ctenoxylocopa*) *sulcatipes* Maa in stems of *Calotropis procera* (Aiton) in central Saudi Arabia. **23** Nest entrance in stem of *C. procera* in the wild **24** Opened nest with series of larvae in individual cells **25** Opened nest with pupae **26** Individual pollen mass with egg situated on top.

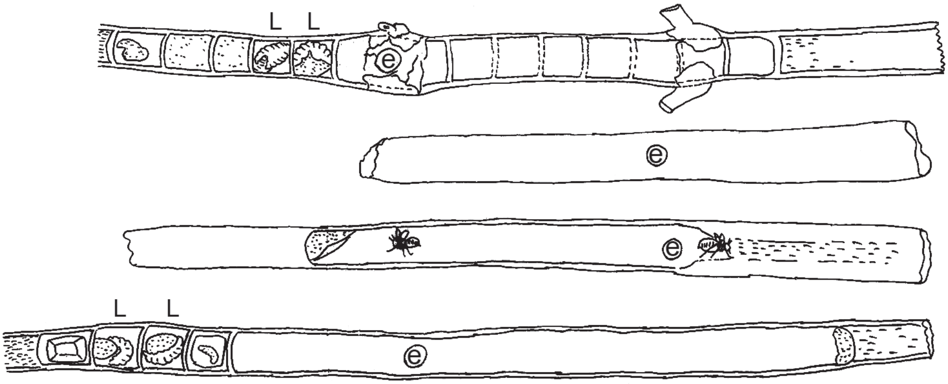


Figure 27. Diagrams of representative nests of *Xylocopa* (*Ctenoxylocopa*) *sulcatipes* Maa in stems of *Calotropis procera* (Aiton) in central Saudi Arabia. L = larva; e = nest entrance. Line illustrations by M.A. Hannan.

to comprise several newly emerged females along with an older female, all of whom participated in foraging but apparently built their own cells, although further observations are needed to clarify this point.

Although *X. sulcatipes*, like other *Xylocopa*, is polylectic, females were observed foraging mostly from *C. procera* and it was there that males were seen to approach and grab females for mating. In addition to foraging at *C. procera*, females were observed visiting *Reseda alba* L. (Resedaceae) and radish [*Raphanus sativus* L. (Brassicaceae)]. Given that species of *Xylocopa* may be useful for agricultural pollination (Keasar 2010) it may be beneficial for standing crops in central Saudi Arabia to be surrounded by suitable native vegetation including *C. procera*, thereby providing ample nesting sites to encourage the establishment of sustainable and large populations of these bees. No associated organisms were found among the nests observed.

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References

Al-Ahmadi AZ, Salem MM (1999) Entomofauna of Saudi Arabia: General Survey of Insects Reported in the Kingdom of Saudi Arabia. Part I: Checklist of Insects. Academic Publishing and Press, Riyadh, Kingdom of Saudi Arabia, 240 pp.

Binti IR (1992) Foraging and nesting behaviour of carpenter bee, *Xylocopa aestuans*. Malaysian Applied Biology 21(2): 85–91.

Boontop Y, Malaipan S, Chareansom K (2008) Large carpenter bees in Thailand and biology of *Xylocopa nasalis* (Westwood). Thailand Natural History Museum Journal 3(1): 5–15.

Dathe H (2009) Order Hymenoptera, superfamily Apoidea: Families Colletidae, Andrenidae, Halictidae, Melittidae, Megachilidae and Apidae. Arthropod Fauna of the UAE 2: 335–432.

Dover C (1924) Some observations on the bionomics of *Xylocopa aestuans* Linn. (Apidae). Transactions of the Royal Entomological Society of London 72(1/2): 144–149. doi: 10.1111/j.1365-2311.1924.tb03354.x

Eardley CD (1983) A taxonomic revision of the genus *Xylocopa* Latreille (Hymenoptera: Anthophoridae) in southern Africa. Entomology Memoir, Department of Agriculture, Republic of South Africa 58: 1–67.

Eardley CD (1993) Complementary descriptions and new synonyms of some Afrotropical Anthophoridae (Hymenoptera). African Entomology 1(2): 145–150.

Eisikowitch D (1986) Morpho-ecological aspects on the pollination of *Calotropis procera* (Asclepiadaceae) in Israel. Plant Systematics and Evolution 152(3–4): 185–194. doi: 10.1007/BF00989426

El-Borollosy FN, Ismail MA (1972) Nesting habits and flight behaviour of *Xylocopa aestuans* L. (Hymenoptera: Apidae). Bulletin de la Société Entomologique d'Égypte 56: 399–405.

Engel MS (2001) A monograph of the Baltic amber bees and evolution of the Apoidea (Hymenoptera). Bulletin of the American Museum of Natural History 259: 1–192. doi: 10.1206/0003-0090(2001)259<0001:AMOTBA>2.0.CO;2

Engel MS (2011) Systematic melittology: Where to from here? Systematic Entomology 36(1): 2–15. doi: 10.1111/j.1365-3113.2010.00544.x

Engel MS (In press) On the classification of the bee genus *Manuelia* (Hymenoptera: Apidae). Acta Entomologica Slovenica 20(1).

Flores-Prado L, Flores SV, McAllister BF (2010) Phylogenetic relationships among tribes in Xylocopinae (Apidae) and implications on nest structure evolution. Molecular Phylogenetics and Evolution 57(1): 237–244. doi: 10.1016/j.ympev.2010.06.019

Gerling D, Hurd PD, Jr, Hefetz A (1983) Comparative behavioral biology of two Middle East species of carpenter bees (*Xylocopa* Latreille) (Hymenoptera: Apoidea). Smithsonian Contributions to Zoology 369: 1–33.

Gerling D, Velthuis HHW, Hefetz A (1989) Bionomics of the large carpenter bees of the genus *Xylocopa*. Annual Review of Entomology 34: 163–190. doi: 10.1146/annurev.en.34.010189.001115

Gonzalez VH, Gonzalez MM, Cuellar Y (2009) Notas biológicas y taxonómicas sobre los abejorros del Maracuyá del género *Xylocopa* (Hymenoptera: Apidae, Xylocopini) en Colombia. Acta Biológica Colombiana 14(2): 31–40.

van Harten A (2005) The Insects of the United Arab Emirates: A Checklist of Published Records. Dar Al Ummah, Abu Dhabi, UAE, 86 pp.

Hefetz A (1983) Function of secretion of mandibular gland of male in territorial behaviour of *Xylocopa sulcatipes* (Hymenoptera: Anthophoridae). Journal of Chemical Ecology 9(7): 923–931. doi: 10.1007/BF00987815

Hurd Jr PD (1958) Observations on the nesting habits of some New World carpenter bees with remarks on their importance in the problem of species formation. Annals of the Entomological Society of America 51(4): 365–375.

Hurd Jr PD (1978) An Annotated Catalog of the Carpenter Bees (Genus *Xylocopa* Latreille) of the Western Hemisphere (Hymenoptera: Anthophoridae). Smithsonian Institution Press, Washington, DC, 106 pp.

Hurd Jr PD, Moure JS (1960) A New World subgenus of bamboo-nesting carpenter bees belonging to the genus *Xylocopa* Latreille (Hymenoptera: Apoidea). Annals of the Entomological Society of America 53(6): 809–821.

Hurd Jr PD, Moure JS (1963) A classification of the large carpenter bees (Xylocopini) (Hymenoptera: Apoidea). University of California Publications in Entomology 29: 1–365.

Illiger K (1806) William Kirby's Familien der Bienenartigen Insekten mit Zusätzen, Nachweisungen und Bemerkungen. Magazin für Insektenkunde 5: 28–175.

Keasar T (2010) Large carpenter bees as agricultural pollinators. Psyche 2010: 1–7. doi: 10.1155/2010/927463

Kronenberg S, Hefetz A (1984) Comparative analysis of Dufour's gland secretions of two carpenter bees (Xylocopinae: Anthophoridae) with different nesting habits. Comparative Biochemistry and Physiology, B, Comparative Biochemistry 79(3): 421–425. doi: 10.1016/0305-0491(84)90399-7

Le Goff G (2004) A propos de *Xylocopa* (*Koptortosoma*) *pubescens* Spinola, 1838 (= *Xylocopa aestuans* auct. nec Linne = *Xylocopa leucothorax* auct. nec De Geer): Un masque senegalais nidifie; rappel de la designation de l'espece; la "vraie" *Xylocopa aestuans* L. (Insecta - Hymenoptera - Apoidea - Apidae - Xylocopinae). Bulletin de Phyllie 19: 10–15.

Leys R (2000) A revision of the Australian carpenter bees, genus *Xylocopa* Latreille, subgenera *Koptortosoma* Gribodo and *Lestis* Lepeletier & Serville (Hymenoptera: Apidae). Invertebrate Systematics 14(1): 115–136. doi: 10.1071/IT98014

Leys R, Cooper SJB, Schwarz MP (2002) Molecular phylogeny and historical biogeography of the large carpenter bees, genus *Xylocopa* (Hymenoptera: Apidae). Biological Journal of the Linnean Society 77(2): 249–266. doi: 10.1046/j.1095-8312.2002.00108.x

Lieftinck MA (1964) The identity of *Apis aestuans* Linné, 1758, and related Old World carpenter-bees (*Xylocopa* Latr.). Tijdschrift voor Entomologie 107(3): 137–158.

Linnaeus C (1758) Systema Naturae per regna tria natura, secundum classes, ordines, genera, species, cum characteribus, differentiis synonymis, locis [10th Edition, revised]. Laurentii Salvii, Holmiae [Stockholm], 824 pp.

Maa TC (1970) A revision of the subgenus *Ctenoxylocopa* (Hymenoptera: Anthophoridae). Pacific Insects 12(4): 723–752.

Maeta Y, Sakagami SF, Shiokawa M (1985) Observations on a nest aggregation of the Taiwanese bamboo carpenter bee *Xylocopa* (*Biluna*) *tranquebarorum tranquebarorum* (Hymenoptera, Anthophoridae). Journal of the Kansas Entomological Society 58(1): 36–41.

Maeta Y, Miyanaga R, Sugiura N (1996) Additional notes on the nesting habits of the Taiwanese bamboo carpenter bee, *Xylocopa* (*Biluna*) *tranquebarorum tranquebarorum* (Hymenoptera, Anthophoridae). Japanese Journal of Entomology 64: 669–680.

Michener CD (2007) The Bees of the World [2nd Edition]. Johns Hopkins University Press, Baltimore, 953 pp.

Minckley RL (1998) A cladistic analysis and classification of the subgenera and genera of the large carpenter bees, tribe Xylocopini (Hymenoptera: Apidae). Scientific Papers, Natural History Museum, University of Kansas 9: 1–47.

Monod T (1977) Percement de la fleur de *Tecoma stans* (L.) par *Xylocopa aestuans* (L.) à Nouakchott (Mauritanie). Bulletin de l'Institut Fondamental d'Afrique Noire, Série A, Sciences Naturelles 39(1): 169–176.

Pereira M, Garófalo CA (2010) Biologia da nidificação de *Xylocopa frontalis* e *Xylocopa grisescens* (Hymenoptera, Apidae, Xylocopini) em ninhos-armadilha. Oecologia Australis 14(1): 193–209. doi: 10.4257/oeco.2010.1401.11

Prager SM, Hunter FF (2011) Relationships between nest architecture and behavior in *Xylocopa virginica* (Hymenoptera: Apidae). Journal of Insect Behavior 24(1): 293–306. doi: 10.1007/s10905-011-9256-x

Punekar SA, Kumaran NKP, Bhat HR (2010) Observations on an unusual behaviour in the carpenter bee *Xylocopa aestuans* (Latreille, 1802) (Hymenoptera: Apidae) of the Western Ghats, India. Journal of Threatened Taxa 2(10): 1232–1233.

Raju AJS, Rao SP (2006) Nesting habits, floral resources and foraging ecology of large carpenter bees (*Xylocopa latipes* and *Xylocopa pubescens*) in India. Current Science 90(9): 1210–1217.

Sakagami SF, Laroca S (1971) Observations on the bionomics of some Neotropical xylocopine bees, with comparative and biofaunistic notes (Hymenoptera, Anthophoridae). Journal of the Faculty of Science, Hokkaido University, Series VI, Zoology 18(1): 57–127.

Shalaby F (1961) A preliminary survey of the insect fauna of Saudi Arabia. Bulletin de la Société Entomologique d'Égypte 45: 211–228.

Silveira FA (2002) The bamboo-nesting carpenter bee, *Xylocopa* (*Stenoxylocopa*) *artifex* Smith (Hymenoptera: Apidae), also nests in fibrous branches of *Vellozia* (Velloziaceae). Lundiana 3(1): 57–60.

Stark RE (1989) Beobachtungen zur Nestgrundung und Brutbiologie der Holzbiene *Xylocopa sulcatipes* Maa (Apoidea: Anthophoridae). Mitteilungen der Deutschen Gesellschaft für Allgemeine und Angewandte Entomologie 7(1): 252–256.

Stark RE (1992a) Cooperative nesting in the multivoltine large carpenter bee *Xylocopa sulcatipes* Maa (Apoidea: Anthophoridae): Do helpers gain or lose to solitary females? Ethology 91(4): 301–310.

Stark RE (1992b) Sex ratio and maternal investment in the multivoltine large carpenter bee *Xylocopa sulcatipes* Maa (Apoidea: Anthophoridae). Ecological Entomology 17(2): 160–166. doi: 10.1111/j.1365-2311.1992.tb01174.x

Stark RE, Hefetz A, Gerling D, Velthuis HHW (1990) Reproductive competition involving oophagy in the socially nesting bee *Xylocopa sulcatipes*. Naturwissenschaften 77(1): 38–40. doi: 10.1007/BF01131797

Surholt B, Greive H, Baal T, Bertsch A (1990) Non-shivering thermogenesis in asynchronous flight muscles of bumblebees? Comparative studies on males of *Bombus terrestris*, *Xylocopa sulcatipes* and *Acherontia atropos*. Comparative Biochemistry and Physiology, A, Molecular and Integrative Physiology 97(4): 493–499.

Velthuis HHW (1987) The evolution of sociality: Ultimate and proximate factors leading to primitive social behaviour in carpenter bees. Experientia 54: 405–430.

Velthuis HHW, Gerling D (1980) Observations on territoriality and mating behaviour of the carpenter bee *Xylocopa sulcatipes*. Entomologia Experimentalis et Applicata 28(1): 82–91.

Velthuis HHW, Wolf Y, Gerling D (1984) Provisioning and preparation of the brood cell in two carpenter bees, *Xylocopa sulcatipes* Maa and *Xylocopa pubescens* Spinola (Hymenoptera: Anthophoridae). Israel Journal of Entomology 18: 39–51. doi: 10.1111/j.1570-7458.1980.tb02990.x

Vicidomini S (2004) Sistematica e distribuzione degli Xylocopini (Hymenoptera: Apidae: Xylocopinae): Nuove e rare segnalazioni. Giornale Italiano di Entomologia 11(52): 99–101.

Willmer PG (1988) The role of insect water balance in pollination ecology: *Xylocopa* and *Calotropis*. Oecologia 76(3): 430–438.

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Taxonomic overview of *Polymixis serpentina* (Treitschke, 1825) species-group, with the description of a new species (Lepidoptera, Noctuidae, Xyleninae)

Oleg Pekarsky[1,†]

1 *H-1068 Budapest, Felsőerdősor u. 16-18, Hungary*

† *urn:lsid:zoobank.org:author:40DC027F-FCF3-4953-AC60-C071E814A768*

Corresponding author: *Oleg Pekarsky* (opbp@t-online.hu)

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Abstract

The taxa of the *Polymixis serpentina* (Treitschke, 1825) species-group are revised. The external and genital features of all known taxa and a new species, *P. ivanchiki* **sp. n.** (Lebanon, Israel, Turkey and Iran) are described and illustrated. *P. serpentina iatnana* Hacker, 1996, is treated here as a species distinct from *P. serpentina* (**stat. n.**). A diagnostic comparison of the members of the species-group is provided; descriptions of the genitalia of *Polymixis serpentina minoica* Fibiger, 1992 and *P. iatnana* are given for the first time.

Keywords

Lepidoptera, Noctuidae, *Polymixis serpentina* species-group, new species, Lebanon

Introduction

Polymixis Hübner, [1820] is a Palearctic genus of the subfamily Xyleninae. During the last thirty years several remarkable works have been published dealing with the taxonomic aspects of the genus (Beck 1996, 1999; Ronkay et al. 2001). In the latest revisionary work (Witt and Ronkay 2011) *P. serpentina* is attributed to the subgenus *Polymixis* Hübner, [1820]. Actually, two insular subspecies are distinguished: *P. serpentina minoica* from Crete and *P. serpentina iatnana* from Cyprus; both were described based on external features only. The authors (Fibiger 1992; Hacker 1996) stated in the descriptions that the genitalia show no difference between the subspecies. The existing differences in genitalia structures of the three subspecies of *P. serpentina* are described and discussed in detail in the present paper.

Systematic part

Polymixis ivanchiki **sp. n.**

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http://species-id.net/wiki/Polymixis_ivanchiki
Figs 1–2

Holotype. Male, Lebanon N., Fnaideg env., h-1440m, 12.x.2007, leg. Krueger, Saldaitis; slide No.: OP0941m (coll. O. Pekarsky, deposited in the HNHM Budapest).

Paratypes. Lebanon. 4 ♂♂, 1 ♀ Caza Dchare, Berhalioun, h-700m, 22.x.2008, leg. Punta, slide No: OP1352m (male) (coll. O. Pekarsky); 20 ♂♂, 6 ♀♀ from the same locality (coll. A. Floriani); 4 ♂♂, 1 ♀ Caza Dchare, Berhalioun, Dayrouna mt., h-1200 m, 24–25.x.2008, leg. E. Punta, (coll. A. Floriani); 1 ♀ Caza Aaakkar, Bezbina, h-700m, 26.x.2008, leg. Punta, (coll. O. Pekarsky); 1 ♂ from the same locality, (coll. A. Floriani); 2 ♀♀ Cedrus Mts., Aayoun Urghouch, h-2130m, 10.x.2007, leg. Krueger, Saldaitis; 1 ♀ Laqlouq env., h-1600m, 14.x.2007, leg. Krueger, Saldaitis, slide No: OP0942f (female) (coll. O. Pekarsky); 1 ♀ 60 km S v. Beirut, 30.X.1963, leg. E. & A. Vartian, slide No: OP1347f (female) (coll. NHMW). Turkey. 1 ♂, 2 ♀♀ Turkey, Prov. Hatay, 6 km N of Yayladagi, 1100 m, 36 00 E, 36 05 N, 20.x.1993, leg. Gy. Fábián, B. Herczig, Gy. László, K. Szeőke, slide No: OP1029f (female) (coll. G. Ronkay); 1 ♂, Prov. Urfa, Halfeti, valley of Euphrat, 500 m, 37°52'E, 37°14'N, 19.x.1993, leg. Gy. Fábián, B. Herczig, Gy. László, K. Szeőke, slide No: OP1428m (male) (coll. G. Ronkay). Israel. 1 ♂, N. Galilea, Nimrod, 800 m., 10–20.10.2004, ligh trap (coll. P. Gyulai), 2 ♂♂, Jerusalem, X.2006, leg. V. Kravchenko, slide No: OP1632m (male) (coll. O. Pekarsky), 4 ♂♂, 6 ♀♀ SW-Iran, Berge O v. Kasri Shirin, 24.x.1963, leg. Kasy & Vartian, slide Nos: OP1348m (male), OP1349f (female) (coll. NHM Vienna).

Diagnosis. *Polymixis ivanchiki* is a sister taxon of *P. serpentina* and is hardly distinguished externally from it, although the genitalia show clearly recognisable differences in both sexes. The forewing pattern of the two species is very similar, only the shape of reniform stigma show certain specific features. The reniform stigma of *P. ivanchiki* is slenderer, more S-shaped with a finely lunulate inner dark line, whereas that of *P. serpentina serpentina* is larger and more or less elliptical, with more parallel sides. The male genitalia of the two species are similar in most characters. The most significant difference between the two species is the shape of juxta. *Polymixis ivanchiki* has a characteristic anchor-like juxta, wide medially, and tapered evenly posteriorly into a long acutely angled process with a posteriorly tapering lateral process on each side with serrated inner edges at their tips; the juxta of

Figures 1–8. Adults. **1, 2** *Polymixis ivanchiki* sp. n. **1** holotype male, Lebanon **2** paratype female, Lebanon **3, 4** *P. serpentina serpentina* **3** male, Slovenia **4** female, Slovenia **5, 6** *P. serpentina minoica* **5** male, Greece, Crete **6** female, Greece, Crete **7, 8** *P. iatnana* **7** paratype male, Cyprus **8** female, Cyprus.

P. serpentina has wide posterior extension, less broad medial part and the two lateral arms lack the apical serration.

The most conspicuous difference between the female genitalia of two species can be found in the shape of the antrum. The posterior (anal) margin of the antrum of *P. ivanchiki* has a very deep cleft, which reaches the middle of antrum, whereas *P. serpentina* has only a slight, shallow cleft.

Description. Male (Fig. 1). Wingspan 38–40 mm, length of forewing 19 mm. Head, thorax and forewing dark brownish grey mixed with black hair-like scales.

Forewing elongate, narrow; costa straight with white patches; outer margin with rather straight termen; most elements of forewing pattern rather blurred, except prominent white-defined reniform stigma; all but one crosslines black; basal line straight; subbasal line zigzagged; antemedial line waved; medial fascia a row of black streaks; postmedial line curved and dentate; subterminal line discontinuous, pale whitish, strongly sinuous, defined by short, black arrowhead spots at inner side; terminal line a row of tiny blackish triangles; orbicular stigma more or less rounded, formed by two black lateral arches filled with ground colour; reniform stigma large, white with narrow, black, lunulate inner line; fringes (cilia) as ground colour, finely chequered by whitish streaks at veins. Hindwing shining white with some black scales on veins, discal spot pale gray, terminal line black; cilia pale yellow mixed sparsely with black hair-like scales.

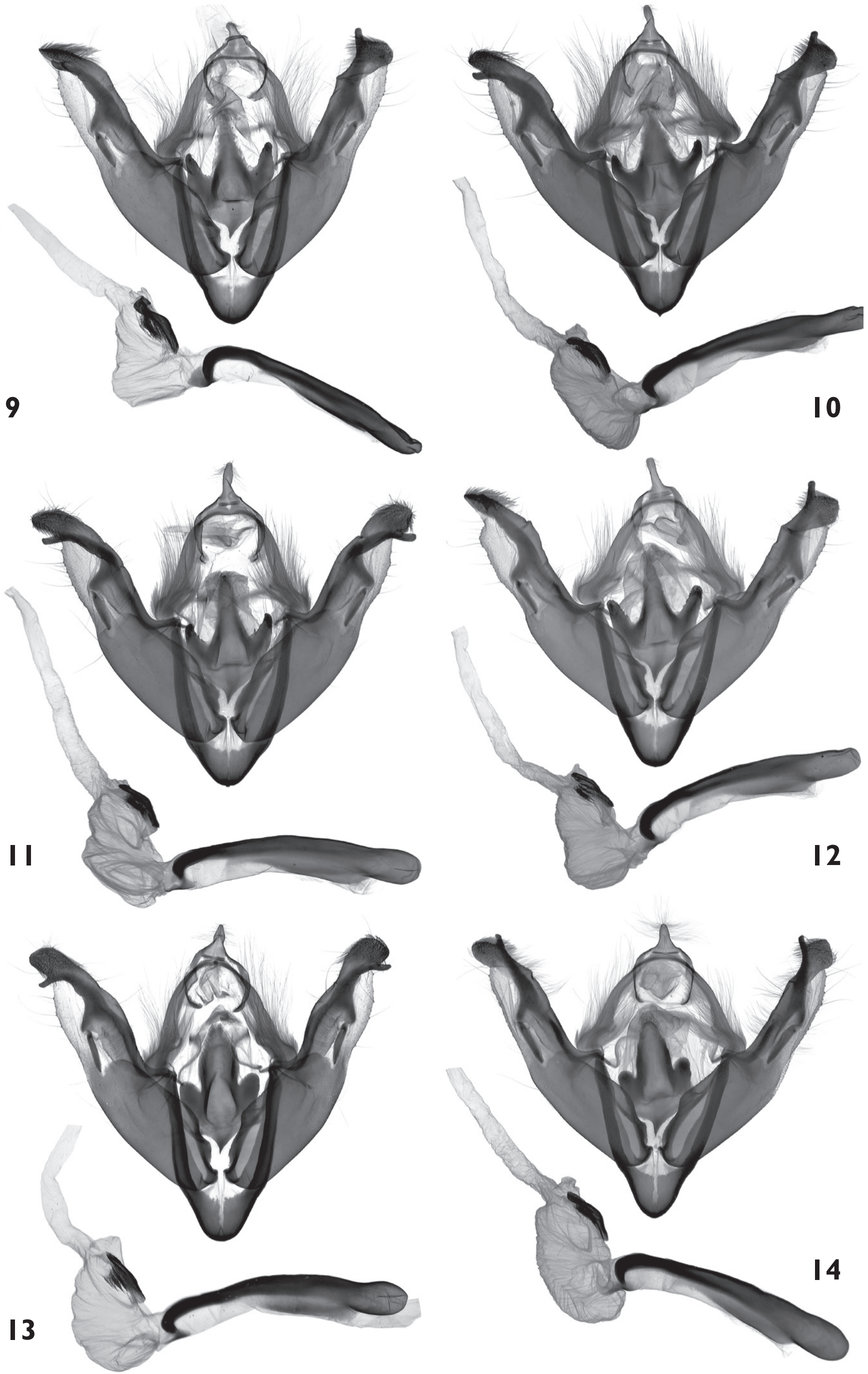
Female (Fig. 2). As male but with considerably darker suffused hindwing.

Male genitalia (Figs 9–12). Genital armature well-sclerotized; uncus weak, small and short, flattened and broad at base, tapering towards finely rounded and slightly hairy apex; tegumen broad, 0.67 times length of vinculum; penicular lobes small, rounded, bearing long setae; juxta anchor-like wide medially with two narrow and posteriorly tapered lateral arms with serrated inner edges towards apex; central posterior process long, thin, evenly tapering posteriorly; vinculum U-shaped. Valvae elongate with narrower distal half; cuculli asymmetrical, left one small and narrow, right one larger, apically more rounded, ventral surfaces densely setose on both cuculli; corona absent; sacculus large, elongate; clavus represented by a long, flat hump; clasper (harpe) straight, bar shaped; ampulla long, stick-like, with evenly tapered distal half and broad, reversed Y-shaped base. Aedeagus cylindrical, curved ventrally in distal part. Vesica tubular, everted forward then bent dorsad; basal tube short, subbasal bulb much wider, inflated, armed by narrow, elongated terminal field of spiniform cornuti; distal diverticulum small.

Female genitalia (Figs 25–27). Ovipositor medium-long, papillae anales elongated, hairy, with long setae on sides and shorter setae apically. Apophyses anteriores strong, with spatulate tips; apophyses posteriores thin and slightly longer than apophyses anteriores. Antrum (ostium bursae) large, broad, trapezoidal, strongly sclerotized, incised caudally forming deep cleft on ventral surface extending from posterior margin almost to middle of antrum. Ductus bursae flattened, semi-tubular, strongly sclerotized, medially folded and twisted. Appendix bursae conical, with sclerotized ribs and wrinkles; corpus bursae membranous, ovoid with four signum-stripes of different lengths.

Etymology. The new species named in honour of Ukrainian zoologists, Ivanchik Taisiya Semenivna (1937-2007) and Ivanchik Grigoriy Semenovich (1929–2011), teachers of Department of Zoology, Faculty of Biology, Yuriy Fedkovych Chernivtsi National University.

Distribution. The species is distributed in the Near East (Israel, Lebanon, SW Iran) and the southern parts of Turkey (provinces Hatay and Urfa).



Figures 9–14. Male genitalia. **9–12** *Polymixis ivanchiki* sp. n. **9** holotype, Lebanon, slide No. OP0941m **10** paratype, Lebanon, slide No. OP1352m **11** paratype, SE Turkey, slide No. OP1428m **12** paratype, SW Iran, slide No. OP1348m **13, 14** *Polymixis serpentina serpentina* **13** Slovenia, slide No. OP0939m **14** Croatia, slide No. OP1333m.

Polymixis serpentina serpentina (Treitschke, 1825)

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

Figs 3, 4

Material examined. Slovenia, slide Nos: ♂ OP0939m, ♀ OP0940f; Croatia, slide Nos: ♂ OP1333m, ♀♀ OP1334f, RL7061f; Macedonia, slide Nos: ♂ OP1445m, ♀ OP1446f; Bulgaria, slide Nos: ♂OP1455m, ♀ OP1335f; Greece, slide Nos: ♂♂ OP1014m, OP1336m, OP1338m, ♀♀ OP1015f, OP1337f, OP1339f; Italy, Puglia, slide Nos: ♂♂ OP1443m, OP1452m ♀♀ OP1444f, OP1453f; Greece, Rodos, slide No: ♂ OP1038m, ♀ OP1039f; Turkey, Nos: ♂♂ OP1035m, OP1037m, ♀♀ OP1028f, OP1036f.

Male genitalia (Figs 13–20)**.** A detailed description of genitalia of this taxon is given by Ronkay et al. (2001). To this text it is possible to add only some more details of the characteristic structure of the juxta. In the typical populations of *P. serpentina serpentina* from Croatia the juxta has a wide posterior extension and medial part has a posterolaterally directed lobe or lateral arm on each side without any serration.

Female genitalia (Figs 28–36)**.** Described by Ronkay et al. (2001). In addition that description, it is worth highlighting the importance of the shape of the posterior margin of the antrum, which has only a slight, rounded concavity in the middle. This shape of antrum is characteristic for the *P. serpentina serpentina* populations from Croatia (type locality) and adjacent areas (Slovenia, Bulgaria) (Figs 28–30). Females from the more eastern areas (north and central Greece, central and south Turkey) have the posterior margin of antrum more deeply incised (Figs 31–36). It should be noted that the genitalia figure in *Noctuidae Europaeae* 5 (Fig. 141) shows the male genitalia of *P. serpentina minoica*, whereas Fig. 335 illustrates the female genitalia of the nominate subspecies.

Note. Moths from Rhodes Island have some slight differences in male genital structure; further studies on a larger sample of material are needed to clarify the taxonomic situation of this insular population. It is not impossible that this population represents another, as yet undescribed, subspecies of *P. serpentina*.

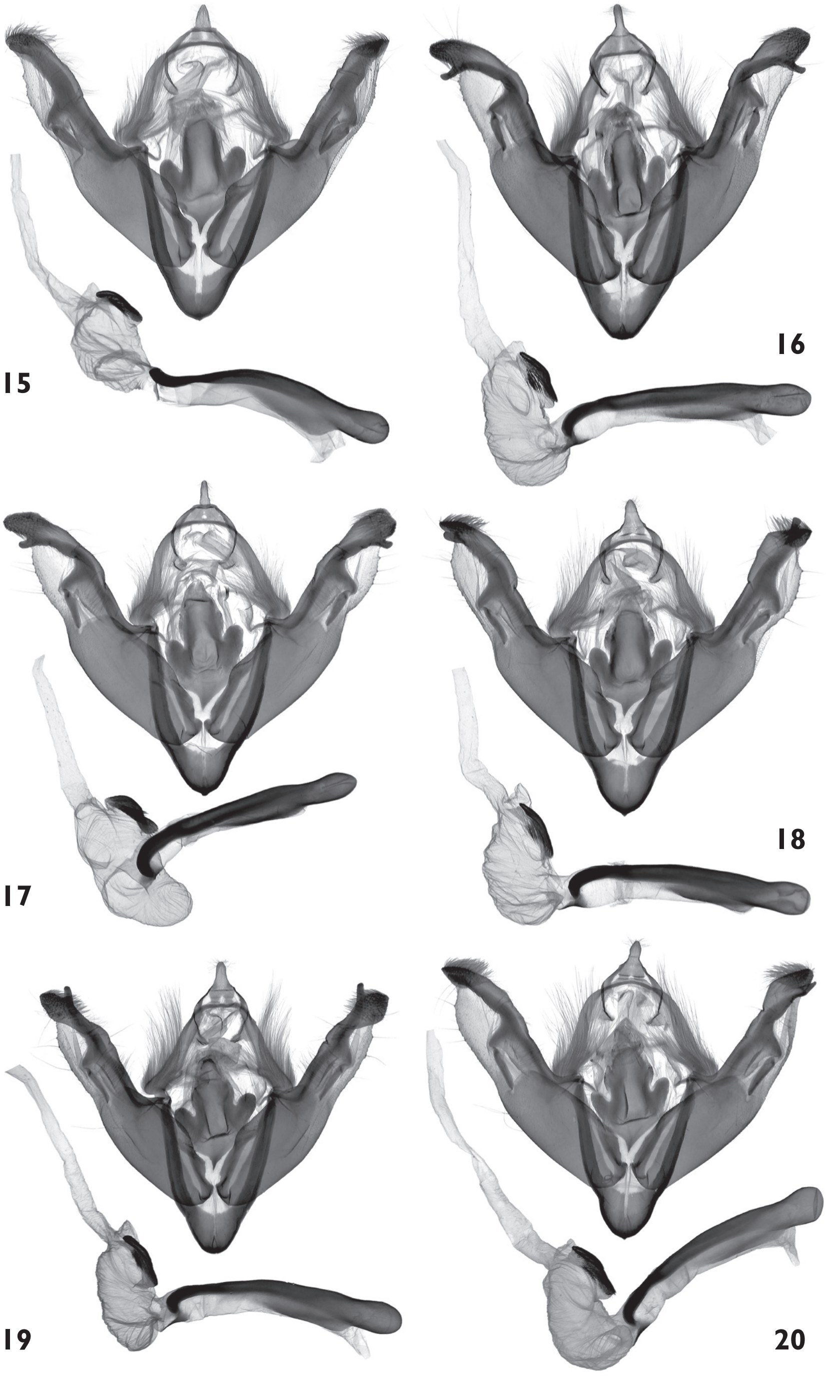
Polymixis serpentina minoica Fibiger, 1992

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

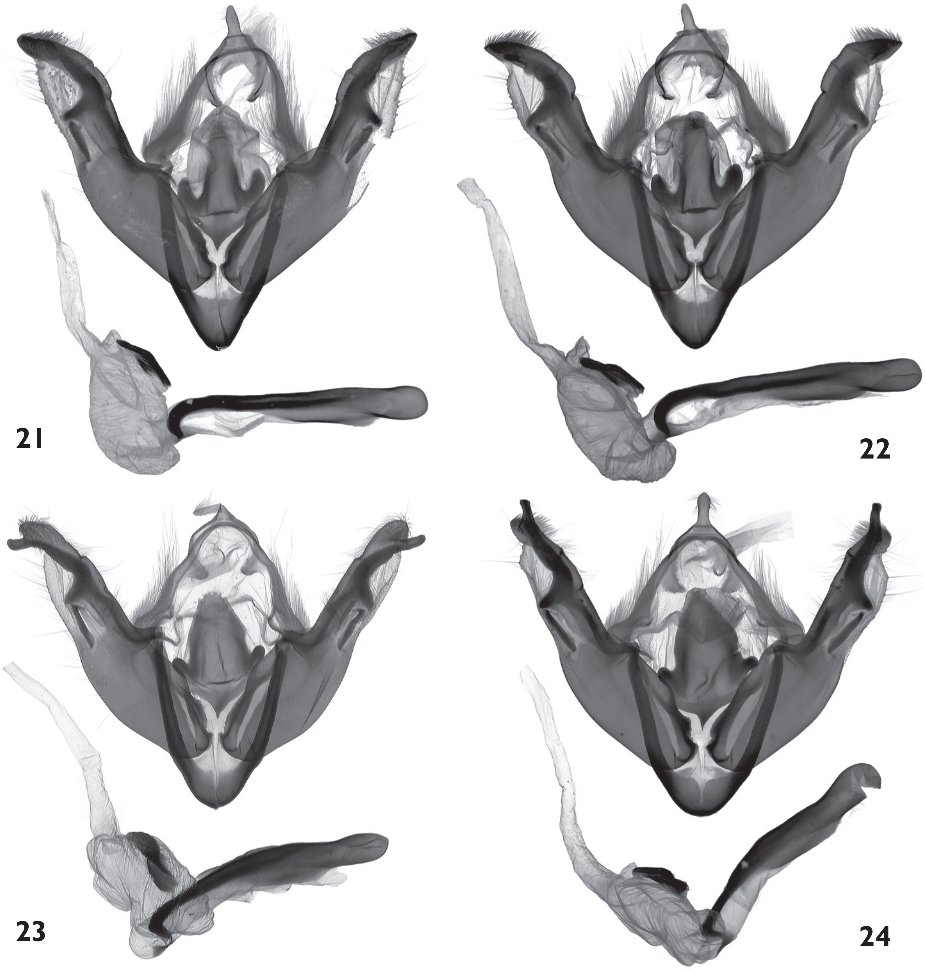
Figs 5, 6

Material examined. Greece, Crete slide Nos: ♂♂ OP1283m, OP1345m, ♀♀ OP1284f, OP1340f, OP1346f.

Male genitalia (Figs 21, 22)**.** The genitalia of this taxon were not described in the original description. It was stated that there were no differences between the two subspecies. There are, however, some recognisable differences between the structure of the genitalia of the Cretan and the other populations of *P. serpentina*. The ground plan of the male genitalia of *P. serpentina minoica* and the nominotypical subspecies



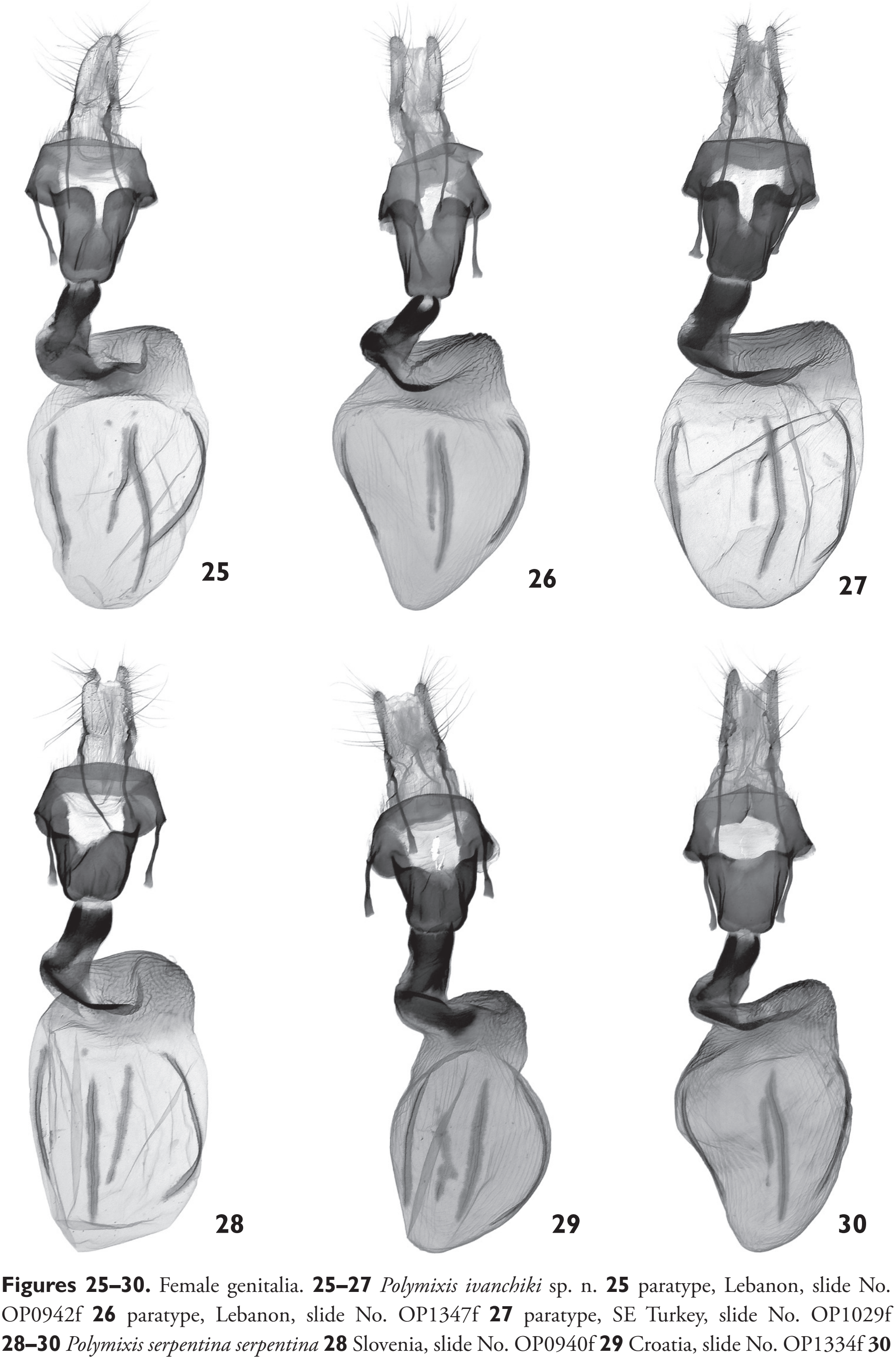
Figures 15–20. Male genitalia. **15–20** *Polymixis serpentina serpentina* **15** Central Greece, slide No. OP1014m **16** Greece, Rhodos, slide No. OP1038m **17** Turkey, Antalya prov., slide No. OP1035m **18** Turkey, Ankara prov., slide No. OP1037m **19** Italy, Puglia, slide No. OP1443m **20** Bulgaria, slide No. OP1455m.



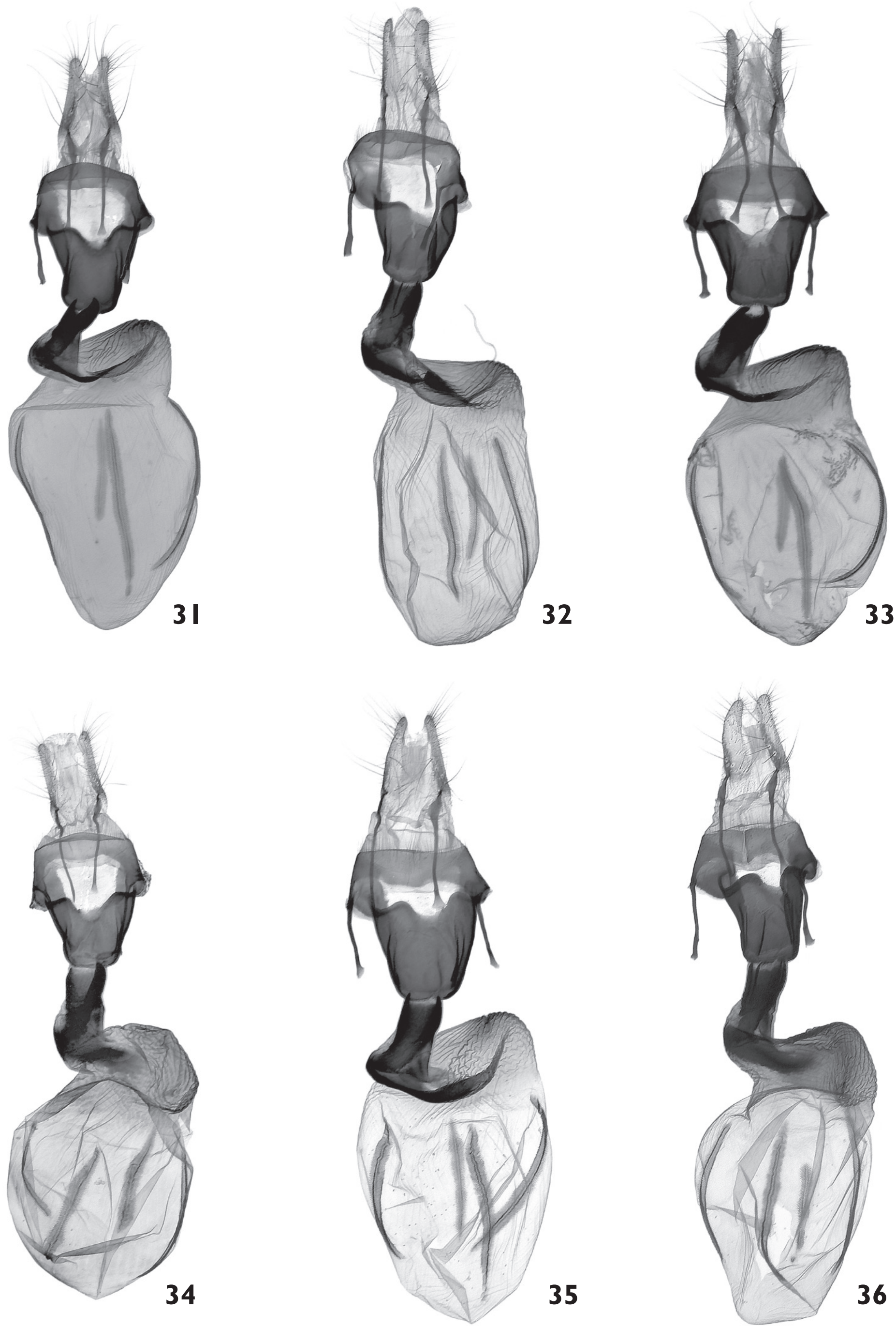
Figures 21–24. Male genitalia. **21, 22** *Polymixis serpentina minoica* **21** Greece, Crete, slide No. OP1283m **22** Greece, Crete, slide No. OP1345m **23, 24** *Polymixis iatnana* **23** Cyprus, slide No. OP1030m **24** Cyprus, slide No. OP1282m.

is the same, but the shape of the juxta is different and all parts of the posterior half of valvae are more massive, being more intensively sclerotized. The posterior extension of juxta is similar to that of *P. serpentina serpentina*, but its lateral arms are more elongated, slightly curved, and significantly more divergent from the basal plate. The valvae are wider, and the costa, triangular basal plate, and its extension, appear rough and massive due to their stronger sclerotization; *P. s. serpentina* has narrower valvae with all parts of their distal sections being finer and thinner.

Female genitalia (Figs 37–39)**.** The copulatory organ of ssp. *minoica* differ from those of the ssp. *serpentina* in the on average shallower concavity on the posterior margin of antrum.

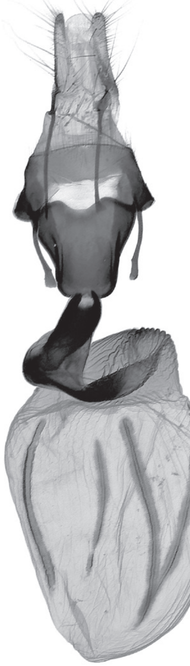


Figures 25–30. Female genitalia. **25–27** *Polymixis ivanchiki* sp. n. **25** paratype, Lebanon, slide No. OP0942f **26** paratype, Lebanon, slide No. OP1347f **27** paratype, SE Turkey, slide No. OP1029f **28–30** *Polymixis serpentina serpentina* **28** Slovenia, slide No. OP0940f **29** Croatia, slide No. OP1334f **30** Bulgaria, slide No. OP1335f.



Figures 31–36. Female genitalia. **31–36** *Polymixis serpentina serpentina* **31** NE Greece, Kirki, slide No. OP1339f **32** Central Greece, Amfissa, slide No. OP1015f **33** Greece, Peloponnes, slide No. OP1337f **34** Greece, Rhodos, slide No. OP1039f **35** Turkey, Antalya county, slide No. OP1036f **36** Turkey, Icel county, slide No. OP1028f.

37



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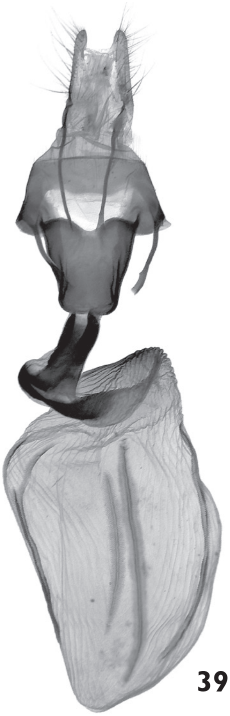

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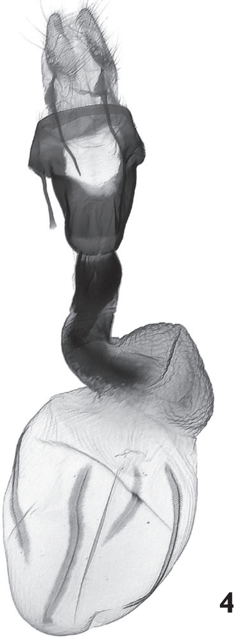

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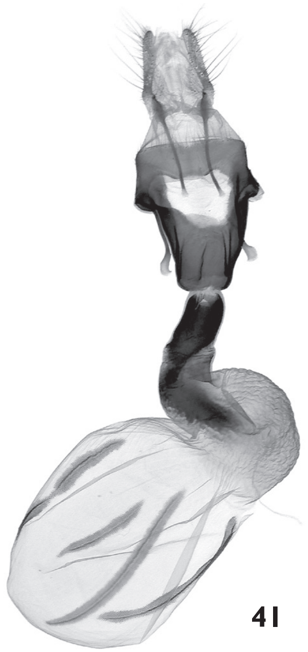

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Figures 37–41. Female genitalia. **37–39** *P. serpentina minoica* **37** Greece, Crete, slide No. OP1284f **38** Greece, Crete, slide No. OP1340f **39** Greece, Crete, slide No. OP1346f **40, 41** *P. iatnana* **40** Cyprus, slide No. OP1031f **41** Cyprus, slide No. OP1041f.

Polymixis iatnana Hacker, 1996, stat. n.

http://species-id.net/wiki/Polymixis_iatnana
Figs 7, 8

Material examined. Cyprus, Slide Nos; ♂♂ OP1030m Paratype, OP1282m, ♀♀ OP1031f, OP1041f.

Male genitalia (Figs 23, 24)**.** The original description contains the following text about the genitalia structure: “Ohne Berücksichtigung der sowohl beim Männchen als auch beim Weibchen nahezu identischen Genitalstrukturen würde man sie für eine gut ausgeprägte Art betrachten“. The genitalia of both sexes show, however, clearly visible differences, especially in shape of juxta and antrum. *P. iatnana* has a wide, shield-like juxta with a wide posterior extension and very small drop-like lateral arms.

Female genitalia (Figs 40, 41)**.** The female genitalia are characterized by the very wide and shallow concavity on the posterior margin of the antrum, which extends from one lateral edge to the other, whereas this incision is in the middle of the posterior margin in the two other subspecies.

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References

Beck H (1996) Systematische Liste der Noctuidae Europas (Lepidoptera, Noctuidae). Neue entomologische Nachrichten 36: 1–122.

Beck H (1999) Die Larven der Europäischen Noctuidae. Revision der Systematik der Noctuidae (Lepidoptera: Noctuidae). Herbipoliana 5(1): 1–859.

Fibiger M (1992) Contribution to the knowledge of the Lepidoptera fauna of Greece. Noctuidae in Crete during November 1991 – with a description of one new species and three new subspecies (Lepidoptera, Noctuidae). Esperiana 3: 379–390.

Hacker H (1996) Ergänzungen zu “Die Noctuidae Vorderasiens” und neuere Forschungsergebnisse zur Fauna der Türkei II (Lepidoptera). Esperiana 4: 273–330.

Ronkay L, Yela J, Hreblay M (2001) Hadeninae II. Noctuidae Europaeae, volume 5. Entomological Press, Sorø, 206 pp.

Witt Th J, Ronkay L (Eds) (2011) Lymantriinae – Arctiinae, including Phylogeny and Check List of the Quadrifid Noctuoidea of Europe. Noctuidae Europaeae, volume 13. Entomological Press, Sorø, 448 pp.

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RESEARCH ARTICLE

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A review of the alderfly genus *Leptosialis* Esben-Petersen (Megaloptera, Sialidae) with description of a new species from South Africa

Benjamin W. Price[1,2,3,†], Xingyue Liu[2,‡], Ferdy C. de Moor[1,2,§], Martin H. Villet[2,|]

1 *Department of Freshwater Invertebrates, Albany Museum, Somerset Street, Grahamstown 6140, South Africa* **2** *Department of Zoology & Entomology, Rhodes University, University Road, Grahamstown 6140, South Africa* **3** *Current address: Department of Ecology & Evolutionary Biology, University of Connecticut, 75 North Eagleville Road, Storrs, 06269, CT, USA* **4** *Department of Entomology, China Agricultural University, Beijing 100193, China*

† *urn:lsid:zoobank.org:author:AD44475A-AEAB-4659-A70F-6C5E90DD9056*
‡ *urn:lsid:zoobank.org:author:D516AAA7-FE8A-4AA9-BC89-F356DFBAEA3E*
§ *urn:lsid:zoobank.org:author:C287AFF1-5243-4104-95FA-CD78361A6CF1*
| *urn:lsid:zoobank.org:author:187BF163-2366-4718-B03F-F6BCD288179A*

Corresponding author: *Xingyue Liu* (liu_xingyue@yahoo.com.cn)

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Abstract

The monotypic South African alderfly genus *Leptosialis* Esben-Petersen, 1920 is reviewed and *Leptosialis africana* Esben-Petersen, 1920 is redescribed. In the process a new species of alderfly *Leptosialis necopinata* **sp. n.** from the Eastern Cape and KwaZulu-Natal provinces of South Africa is recognised and described. Within Sialidae the new species most closely resembles *L. africana*. A key to the two species of *Leptosialis* using both adult and larval characters is provided.

Keywords

Sialidae, *Leptosialis*, taxonomy, South Africa

Introduction

The Afrotropical Megaloptera fauna have historically received very little attention and only four species of alderfly (Sialidae) are currently recognised: *Sialis vanderweelei* Aspöck & Aspöck, 1983 (Egypt), *Protosialis afra* Navás, 1936 and *P. madegassa* Navás, 1927 (Madagascar), and *Leptosialis africana* Esben-Petersen, 1920 (South Africa). *Leptosialis* Esben-Petersen was established from adult specimens collected in the Cedarberg Mountains of the Western Cape Province. Additional localities and illustrations were provided by Barnard (1931, 1940). Crass's (1949) description of putative larvae of *L. africana* used specimens collected in the Eastern Cape and KwaZulu-Natal provinces, approximately 1000 km from the type locality.

With very few specimens in museum collections, it is clear that these African alderflies are rarely encountered insects. The adults have historically been collected in summer amongst riparian vegetation associated with the still reaches of slow-flowing streams, and the larvae inhabit slow flowing streams with clay or silt substrates (Crass 1949, Mansell 2003).

While examining the Iziko South African Museum and Albany Museum collections, two distinct phenotypes of putative *L. africana* adults were found, corresponding to the two disjunct regions from which they have been recorded. The specimens from the Eastern Cape and KwaZulu-Natal provinces are distinct enough from Western Cape *L. africana* to warrant recognition as a new species. Crass's (1949) larval material from the Eastern Cape and KwaZulu-Natal correspond to the new species.

Materials and methods

The specimens included in the present study are deposited in three collections: the Albany Museum, Grahamstown (AMGS), the Natural History Museum, London (NHM), and the Iziko South African Museum, Cape Town (SAMC). Label data for the specimens are presented in quotation marks; information from different labels is separated by a virgule (/), and information on different lines of a label is separated by commas. Information in square brackets clarifies or augments the often cryptic text on the specimen label(s) and provides their geographic coordinates.

Terminalia preparations were made by clearing the distal half of the abdomen in a cold, saturated potassium hydroxide (KOH) solution for 8–10 h. After neutralising the KOH with acetic acid and water, the distal half of the abdomen was transferred to glycerine for further dissection and examination. Following examination, the cleared terminalia was placed in a microvial containing glycerine and pinned beneath the specimen. The terminologies of venation and terminalia follow Wootton (1979) and Aspöck and Aspöck (2008), respectively. Wing and body measurements were made from photographs of whole specimens with reference to the photographed scale bar.

Taxonomy

Genus *Leptosialis* Esben-Petersen

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

Leptosialis Esben-Petersen, 1920: 502. Type species: *Leptosialis africana* Esben-Petersen, 1920: 502 (original designation).

Diagnosis. The adults of *Leptosialis* are characterized by the following morphological traits: the narrowly elongated forewing, which is about 3.0–4.0 times longer than wide; the distally branched Rs; the MA either unbranched, bifurcated or trifurcated; the MP distally branched or with one or both main branches bifurcated; the male 9th tergum with a pair of posterolateral, digitiform processes; the paired ectoproct; the 11th gonocoxite in caudal view ventrally with a pair of acute, hook-like processes. At present no characters can be used to distinguish the larvae of the genus *Leptosialis* from other alderfly genera, many of which currently lack larval description.

Description. Adults (Figs 1–4). Forewing length ~8–11 mm in males; ~11–12 mm in females. Body: generally brown or blackish-brown. Head: antenna pilose approximately half the length of the forewing; ocelli absent, or represented by three very small tubercles on vertex; labrum ~4.0–5.0 times wider than long, lateral margins rounded, front margin slightly emarginated. Prothorax > two times wider than long. Legs: yellow or dark brown, bearing dense setae; tarsal claws reddish brown. Wings: Forewing 3.0-4.0 times longer than wide, minutely hirsute, margins pilose; costal area broadened basally; subcostal area with five to eight distinct costal crossveins proximally; sc-r absent; Rs distally branched, MA either unbranched, bifurcated or trifurcated, MP distally branched or with one or both main branches bifurcated, CuA bifurcated; three or four crossveins between R and Rs. Hindwing as broad or slightly broader than forewing, about 3.0 to 3.5 times as long as wide; two or three distinct costal crossveins proximally; venation similar to forewing, with three crossveins between R and Rs. Male genitalia: 9th tergum transversely arched, with a pair of posterolateral, digitiform processes; ectoproct paired, small, roundly inflated ventrad; 11th gonocoxite in caudal view ventrally with a pair of acute, hook-like processes. Female genitalia: 7th sternum broad, posterior margin distinctly produced; 9th gonocoxite broad, apex bearing small, stout gonostylus.

Larvae (Figs 22–23). Head: yellow to reddish brown. Thorax: pro-, meso- and metathorax orange to reddish brown, with distinct reticulated patterns of yellowish marks. Legs: pale yellow, bearing dense setae; tarsal claws reddish brown; Abdomen: dark purplish or blackish brown dorsally with paired, pale, submedian, comma-shaped marks on each segment; anal prolegs and hooked claws absent; elongated caudal filamentous appendage present; 7 pairs of pale yellow lateral abdominal gills present.

Remarks. The genus *Leptosialis* is the only representative of the Sialidae in South Africa. Because wing venation is quite different between the two *Leptosialis* species, it is difficult to find a stable morphological diagnosis for this genus. The male ninth tergum with a pair of digitiform processes could be the most important character to distinguish *Leptosialis* from its closely related genera, *Stenosialis* and *Austrosialis*. The two species may be distinguished using the following key.

Key to *Leptosialis*

1 **Adults:** (Figs 1, 2) Forewing narrowly rounded with MA and both branches of MP simple (Barnard 1931: fig. 12). **Male:** terminalia with 11th gonocoxite broadly triangular dorsoventrally, with a pair of short, simple hook-like processes ventrally, visible in caudal view. **Female:** (Fig. 15) 8th gonocoxite small, subtriangular. **Larvae:** (Fig. 22) Head reddish brown; pro-, meso- and metathorax reddish brown, distinctly with reticulated patterns of yellowish marks; abdomen blackish brown.................................. ***Leptosialis africana***

– **Adults:** (Figs 3, 4) Forewing broadly rounded with MA branches bi- and trifurcated and with one or both branches of MP bifurcated (Fig. 9). **Male:** terminalia with 11th gonocoxite narrowly triangular dorsoventrally, with a pair of long, hook-like processes with additional subterminal hook ventrally, visible in caudal view (Figs 18-19). **Female:** 8th gonocoxite large, terminally divided to form a pair of subtriangular lobes, obtusely protruding posterolaterally (Fig. 21). **Larvae:** (Fig. 23) Head orange, slightly darkened medially on frons; prothorax orange, dorsally with indistinct marks, meso- and metathorax castaneous with reticulated yellowish marks; abdomen dark purplish-brown with paired, pale, submedian, comma-shaped marks on each segment (Fig. 1: Crass 1949) .... ***Leptosialis necopinata* sp. n.**

Leptosialis africana Esben-Petersen

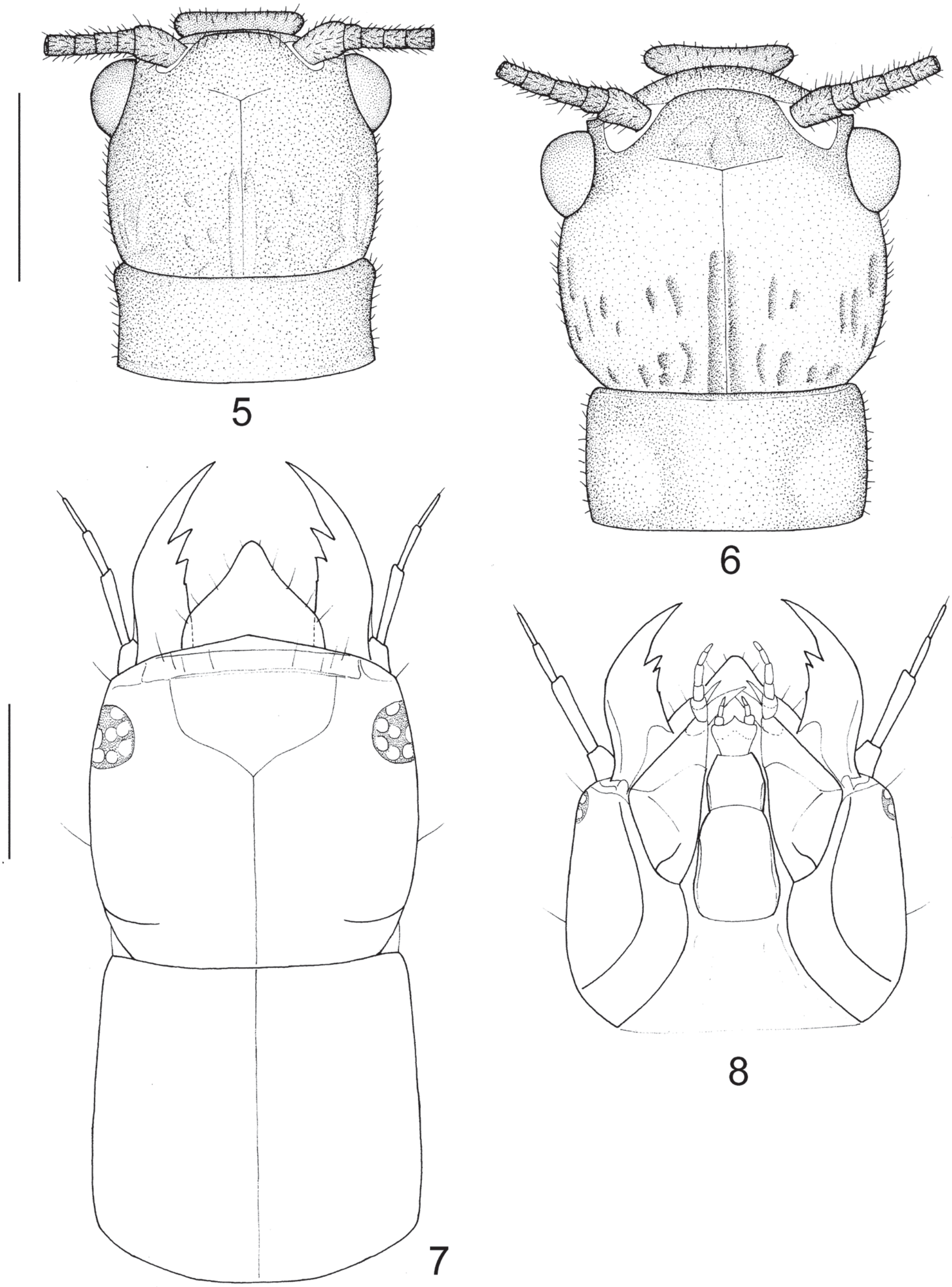
http://species-id.net/wiki/Leptosialis_africana
Figures 1–2, 5–6, 10–15, 22

Leptosialis africana Esben-Petersen, 1920: 502. Type locality: South Africa (Great Winterhoek Mountains).

Type material. Holotype, male [see remarks below] (pinned; Fig. 1), South Africa: Western Cape: "G[rea]t. Winterhoek Mts., Tulbagh [33°8'S 19°10'E], XI.1916, K.H. Barnard / SAM-MEG-A000041 / Holotype" (SAMC).

Other material. 1 male (pinned, Fig. 2), South Africa: Western Cape: "G[rea]t. Winterhoek Mts., Tulbagh, [33°8'S, 19°10'E], XI.1932, K.H. Barnard / SAM-MEG-A000042" (SAMC); 1 female (pinned), South Africa: Western Cape: "Hottentots Holland Mts., Steenbras [34°6'S, 18°58'E], XI.1932, K.H. Barnard, SAM-MEG-A000043" (SAMC); 1 male (pinned), South Africa: Western Cape: "Caledon Distr., R. Zonder End, Oudebosch [34°9'S, 19°54'E], XII.1919, K.H. Barnard / 1930-131" (NHM); 2 larvae (in alcohol), South Africa: Western Cape:

Figures 1–4. Habitus images of *Leptosialis* species. **1** *Leptosialis africana* Esben-Petersen, female, holotype **2** same, male **3** *Leptosialis necopinata* sp. n. male, holotype **4** same, female. Scale bars = 5.0 mm



Figures 5–8. Head and prothorax of *Leptosialis*. **5** *Leptosialis africana*, head and pronotum of male adult, dorsal view **6** same of female adult, dorsal view **7** *Leptosialis necopinata* sp. n., head and pronotum of larva, dorsal view **8** same, head of larva, ventral view. Scale bar = 1.0 mm.

"Bettys Bay, Small Vlei [34°21'S, 18°56'E], 18.I.1957, [A.D. Harrison and J.D. Agnew] / FRW 128C" (AMGS).

Diagnosis. The adults of *L. africana* may be easily distinguished from adults of *L. necopinata* sp. n. by the shape and venation of the forewing, where the wings of *L. africana* are narrowly rounded compared to being broadly rounded to truncated in *L. necopinata* sp. n. In addition, the wings of *L. africana* show MA and both branches of MP all simple, while *L. necopinata* sp. n. has MA and one or both branches of MP all bearing additional forks. The larvae of *L. africana* may be distinguished by the reddish brown head and thorax dorsally with distinct yellowish marks that are lacking in *L. necopinata* sp. n.

Description. Adult male (Fig. 2). Forewing length 8.1 mm, hindwing length 7.0 mm (n = 1). Head (Fig. 5): pale to dark brown, frons and clypeus black; vertex with a pair of raised black vittae medially and several small, raised, black protrusions laterally. Compound eyes blackish brown, strongly produced. Antennae dark brown, pilose, approximately half the length of the forewing. Mouthparts yellowish brown, diminutive. Thorax (Fig. 5): entirely blackish brown. Legs yellow, bearing dense yellowish setae; coxae blackish brown; femora pale brown; 1st-3rd tarsomeres distally pale brown; 4th and 5th tarsomeres brown; tarsal claws reddish brown. Wings narrowly rounded, brown, slightly darker proximally; veins brown. Forewing nearly 4.0 times as long as wide; five to eight distinct costal crossveins proximally; sc-r absent; Rs distally branched, MA unbranched, MP distally branched, and CuA bifurcated; three or four crossveins between R and Rs. Hindwing slightly broader than forewing, about 3.5 times as long as wide; two or three distinct costal crossveins proximally; venation similar to forewing, with three crossveins between R and Rs. Abdomen: blackish brown. Terminalia (Figs 10–13) with 9th tergum transversely arched, with a pair of digitiform processes posterolaterally that curve slightly ventromedially; anterior and posterior margins slightly concave arcuately in dorsal view; 9th sternum slightly longer than 9th tergum; posterior margin moderately produced; 9th gonocoxite in lateral view nearly elliptical; ectoproct paired, small, roundly inflated ventrad; 11th gonocoxite broadly triangular dorsoventrally, dorsal margin slightly sinuous in dorsal view, with a pair of short and acutely hook-like processes ventrally in caudal view.

Adult female (Figs 1, 6). Forewing length 11.1 mm, hindwing length 10.2 mm (n = 2). Larger than male, but similar in colouration and venation. Terminalia (Figs 14-15) with 7th sternum broad, posterior margin distinctly produced; 8th gonocoxite rather small, subtriangular; 9th gonocoxite broad; apex with small, stout gonostylus, ectoproct feebly sclerotized, small, suboval.

Larva (Fig. 22). Head reddish brown; thorax reddish brown, distinctly marked with complicate patterns of yellowish marks; legs pale yellow, bearing dense setae, tarsal claws reddish brown. Abdomen blackish brown dorsally with pale yellow lateral abdominal gills.

Distribution. South Africa: Western Cape (Fig. 24).

Remarks. The type specimen was noted by Esben-Petersen in his description as male, but its abdomen and genitalia are now lost. This species of alderfly shows sexual dimorphism, with females being larger than males. Although it lacks an abdomen, the holotype is probably a female, based on comparison with confirmed male and female specimens, and contrary to the original description.

Leptosialis necopinata Price, Liu, de Moor & Villet, sp. n.

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http://species-id.net/wiki/Leptosialis_necopinata
Figures 3–4, 7–9, 16–21, 23

Type locality. South Africa: KwaZulu-Natal: Kokstad [30°33'S, 29°25'E].

Type material. Holotype, male (pinned; Fig. 3), SOUTH AFRICA: KwaZulu-Natal: “Kokstad [30°33'S, 29°25'E], I.1941, [possibly R.S. Crass] / GEN 2081A / HOLOTYPE” (AMGS). Paratypes, 1 male, 5 female (all pinned), same data as holotype, male “GEN 2081B / PARATYPE” females “GEN 2081C / PARATYPE” (AMGS).

Other material. SOUTH AFRICA: 1 female (pinned), Eastern Cape: “Maclear Municipal Dam [31°4'0"S, 28°18'36"E], 27.III.1993 [F.C. de Moor and H.M. Barber-James] / ECR 124S” (AMGS); 2 female (pinned), KwaZulu-Natal: “Tugela river [30°6'0"S, 29°11'24"E], 15.XI.1959, [M. Chutter] / GEN 380H” (AMGS); 3 larvae (in alcohol), KwaZulu-Natal: “Mooi River [29°15'0"S, 29°58'12"E], 15.VI.1995, [C.W.S. Dickens] / MOI 52K” (AMGS); 4 larvae (in alcohol), KwaZulu-Natal: “Mooi River [29°21'36"S, 29°53'24"E], 4.I.1996, [F.C. de Moor, C.W.S. Dickens & R.S. Crass] / MOI 69H” (AMGS).

Etymology. The specific epithet ‘*necopinata*’ is a feminine adjective in the second declension which refers to the Latin for unexpected or unforeseen, following the discovery of the adults strikingly different from *L. africana* and relating to the unforeseen occurrence of this second species in the relatively well-sampled waters of South Africa.

Diagnosis. The adults of *L. necopinata* sp. n. may be easily distinguished from adults of *L. africana* in having broadly rounded to truncated wings compared to narrowly rounded wings in the latter species. In addition the forewing venation of *L. necopinata* sp. n. has MA and one or both branches of MP all forked distally, whereas those of *L. africana* are fused into three simple veins. The larvae of *L. necopinata* sp. n. can be distinguished from *L. africana* by the paler colouration of head and thorax, which lack distinct marks on the vertex and pronotum.

Description. Adult male (Fig. 3). Forewing length 10.6 mm, hindwing length 9.8 mm (n = 2).

Head (Fig. 7) black, slightly pale brown surrounding posterior margin of compound eyes; vertex with a pair of raised black vittae medially, and several small raised black protrusions laterally Compound eyes blackish brown, strongly produced. Antennae blackish brown, pilose, approximately half the length of the forewing. Mouthparts blackish brown. Thorax (Fig. 8) entirely black. Legs dark brown throughout, bearing dense brown setae; tarsal claws reddish brown. Wings (Fig. 9) distally broadly rounded to truncate, brown, slightly darker proximally; veins brown. Forewing approximately 3.0 times as

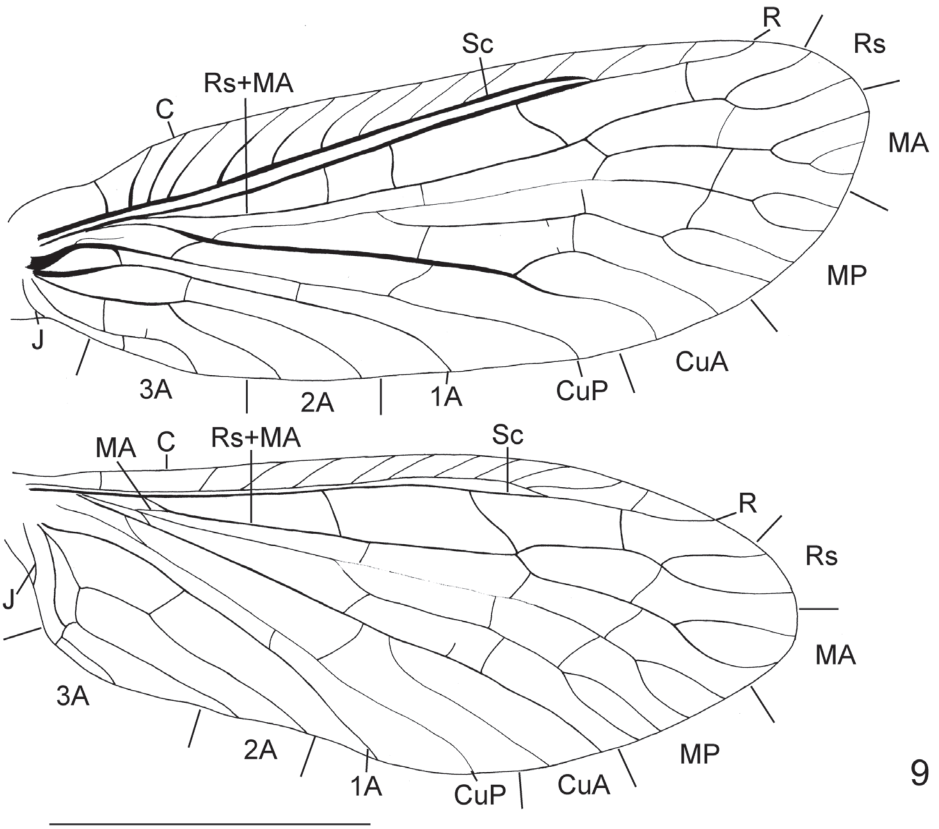
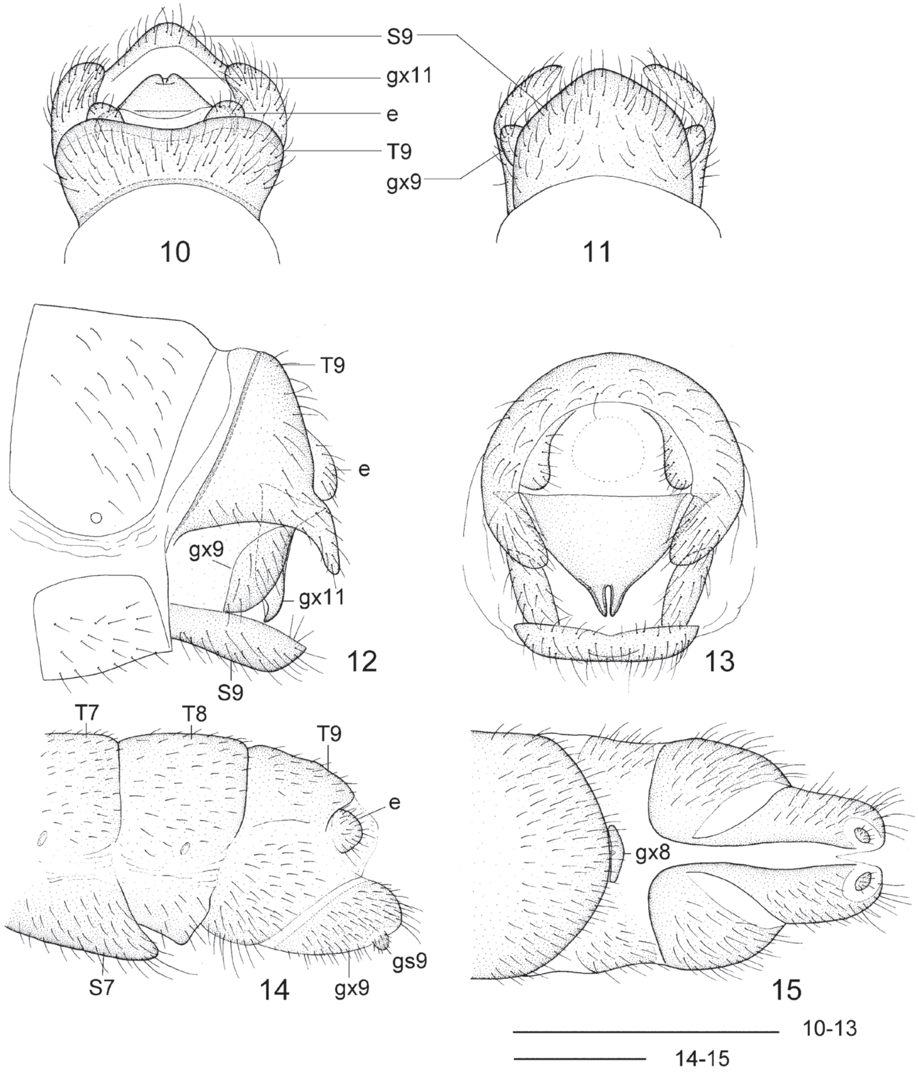


Figure 9. Wing venation of *Leptosialis necopinata* sp. n. Scale bar = 5.0 mm.

long as wide; proximally with five to eight distinct costal crossveins; sc-r absent; RS distally branched, MA bifurcated or trifurcated, MP with one or both main branches bifurcated, and CuA bifurcated, three or four crossveins between R and Rs. Hindwing as broad as forewing, about 3.0 times as long as wide; with two or three distinct costal crossveins proximally; venation similar to forewing, with three crossveins between R and Rs. Abdomen blackish brown. Terminalia (Figs 16–19) with 9th tergum transversely arched, with a pair of digitiform processes posterolaterally that curve slightly ventromedially; anterior and posterior margins slightly arcuately concave in dorsal view; 9th sternum slightly longer than 9th tergum, posterior margin moderately produced; 9th gonocoxite in lateral view nearly elliptical; ectoproct paired, small, roundly inflated ventrad; 11th gonocoxite broadly triangular dorsoventrally, dorsal margin slightly sinuous in dorsal view, ventrally with a pair of acute hook-like processes in caudal view, in lateral view ventral processes with an anteriorly directed, hook-shaped accessory protuberance one third along its length.

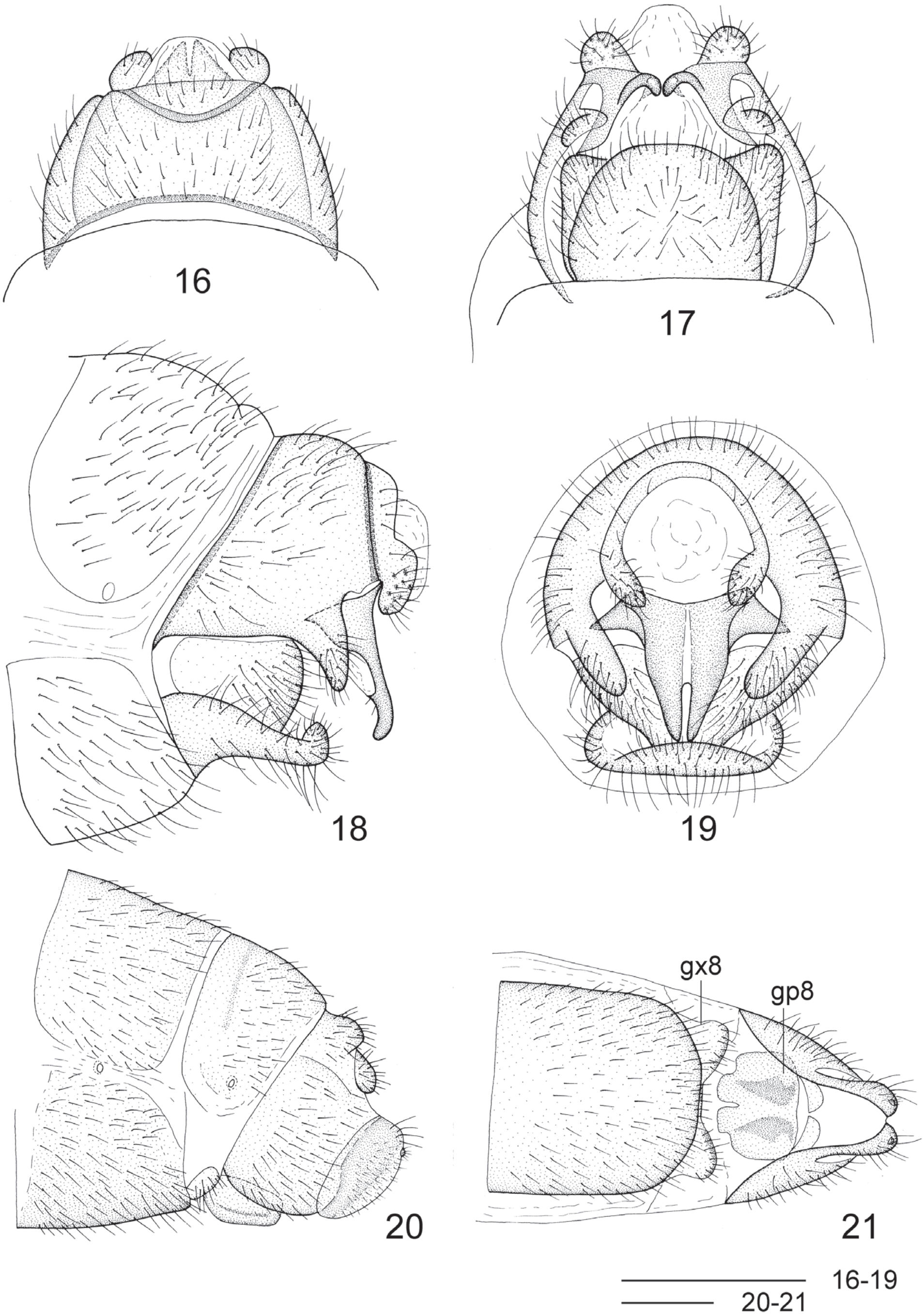
Adult female (Fig. 4). Forewing length 11.7 mm, range 11–12 mm, hindwing length 10.4 mm, range 10–11 mm (n = 5). Larger than male, but similar in colouration and wing venation. Head pale to dark brown, with frons and clypeus black; vertex with a pair of raised black vittae medially, and several small raised black markings



Figures 10–15. *Leptosialis africana* Esben-Petersen. **10** male terminalia, dorsal view 11 male terminalia, ventral view **12** male terminalia, lateral view **13** male terminalia, caudal view **14** female terminalia, lateral view **15** female terminalia, ventral view. T7-9: seventh to ninth tergum; S7-9: seventh to ninth sternum; gx8, 9 **11** eighth, ninth and eleventh gonocoxite; gs9: ninth gonostylus; e: ectoproct. Scale bars = 0.5 mm.

laterally. Terminalia (Figs 20–21) with 7th sternum broad, with posterior margin feebly produced; 8th gonocoxite almost separated into a pair of subtriangular lobes, which are obtusely protruding posterolaterally; 9th gonocoxite broad, apex with small, stout gonostylus; ectoproct feebly sclerotized, small, suboval.

Larva. Head (Figs 7, 8, 23) yellow, slightly darkended medially on frons. Prothorax (Fig. 7) yellow to orange, dorsally with indistinct markings, meso- and metathorax castaneous with reticulated yellowish markings; Legs pale yellow, bearing dense setae,



Figures 16–21. *Leptosialis necopinata* sp. n. **16** male terminalia, dorsal view **17** male terminalia, ventral view **18** male terminalia, lateral view; **19** male terminalia, caudal view **20** female terminalia, lateral view **21** female terminalia, ventral view. gx8: eighth gonocoxite; gp8: eighth gonapophyses. Scale bars = 0.5 mm.

Figures 22–23. *Leptosialis* larvae, showing color patterns on head and thorax **22** *Leptosialis africana* **23** *Leptosialis necopinata* sp. n. Scale bar = 1.0 mm.

tarsal claws reddish brown; Abdomen dark purplish-brown dorsally with paired, pale, submedian, comma-shaped marks on each segment; lateral abdominal gills pale yellow.

Distribution. South Africa: Eastern Cape and KwaZulu-Natal provinces (Fig. 24).

Remarks. The larvae of *L. necopinata* sp. n. have been described in detail by Crass (1949).

Discussion

At first glance *L. necopinata* sp. n. appears to belong to the Australian endemic genus *Stenosialis* (Liu et al. 2008). However, the male genitalia of *L. necopinata* sp. n. are generally similar in structure to those of *L. africana*, confirming the taxonomic status of the new species within the genus *Leptosialis*. Although the forewing venation of *L. necopinata* sp. n. is similar to that of *Stenosialis* and *Austrosialis* based on the two-branched Rs, 2 or 3-branched MA, and 4-branched MP, the hindwing of *L. necopinata* sp. n. also has a four-branched MP, which is different from the always three-branched MP in both Australian genera (Liu *et al.* 2008). The diagnosis of the venation in *L. necopinata* sp.

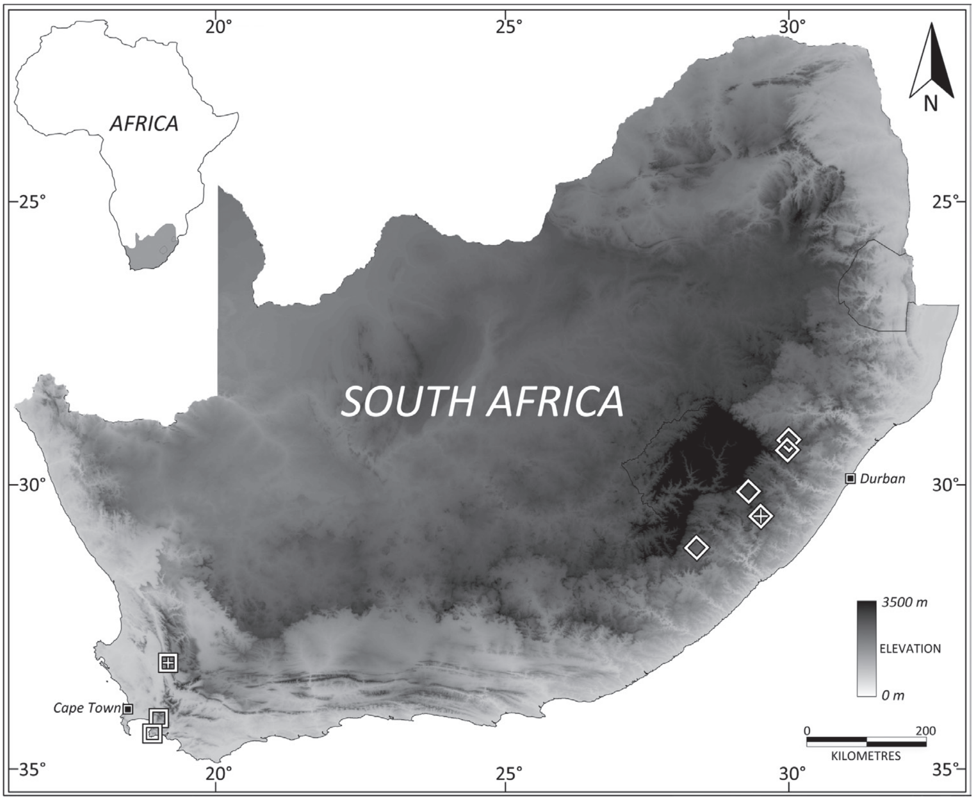


Figure 24. Distribution map of specimens housed in the Iziko and Albany Museums in South Africa. *Leptosialis africana*: open squares, *Leptosialis necopinata* sp. n.: open diamonds. Type localities for each species indicated with "+". Shading indicates elevation. Localities correspond to the supplementary text file.

n. does not provide synapomorphies for *Leptosialis* because it may be a plesiomorphic ground plan of sialid venation, which is very similar to the earliest alderfly fossil, *Dobbertinia reticulata* Handlirsch, from the Lower Jurassic of Germany (Ansorge 2001). The venation of Sialidae genera is very conserved and indicative of symplesiomorphies (Flint 1973). A world revision of the genera using genitalic differences is needed to confirm placement of the genera and species. The possible synapomorphic character of *Leptosialis* might be the male 9th tergum with a pair of digitiform posterior projections, although this character is also present in an extinct alderfly species *Protosialis herrlingi* Wichard (2002) from the Eocene Baltic amber. Further clarification on the phylogenetic status of *Leptosialis* awaits a rigorous study of the phylogeny of the world Sialidae.

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References

Ansorge J (2001) *Dobbertinia recticulata* Handlirsch 1920 from the Lower Jurassic of Dobbertin (Mecklenburg/Germany) – the oldest representative of Sialidae (Megaloptera). Neues Jahrbuch für Geologie und Palaontologie Monatshefte 2001: 553–564.

Aspöck U, Aspöck H (2008) Phylogenetic relevance of the genital sclerites of Neuropterida (Insecta: Holometabola). Systematic Entomology 33: 97–129. doi: 10.1111/j.1365-3113.2007.00396.x

Barnard KH (1931) The Cape alder-flies. Transactions of the Royal Society of South Africa 29: 169–184.

Barnard KH (1940) Additional records, and descriptions of new species, of South African alder-flies (Megaloptera), may-flies (Ephemeroptera), caddis-flies (Trichoptera), stone-flies (Perlaria), and dragon-flies (Odonata). Annals of the South African Museum 32(6): 609–615. doi: 10.1080/00359193109518830

Crass RS (1949) Records of alderflies (Megaloptera) from Natal and the Eastern Cape, with a description of the larva of *Leptosialis africana* (E.-P.). Annals of the Natal Museum 11(3): 519–522.

Esben-Petersen P (1920) New species of neuropterous insects from South Africa (Ephemerida, Megaloptera and Embiidina). Annals of the South African Museum 17: 499–505.

Flint OS Jr. (1973) The Megaloptera of Chile. Revista Chilena de Entomologia 7: 31–45.

Liu XY, Catanach TA, Oswald JD (2008) Interactive Digital Key to the Sialidae Genera of the World. Version 1.0. http://lacewing.tamu.edu/keys/Sialidae/ [accessed on 5 January 2012]

Mansell MW (2003) Chapter 3: Megaloptera. In: de Moor IJ, Day JA, de Moor FC (Eds) Guides to the Freshwater Invertebrates of Southern Africa Volume 8: Insecta II, Water Research Comission Report No. TT 214/03, 72–78.

Wichard W (2002) Eine neue Schlammfliege aus dem Baltischen Bernstein (Megaloptera: Sialidae). Mitteilungen aus dem Geologisch-Paläontologischen Institut der Universität Hamburg 86: 253–261.

Wootton RJ (1979) Function, homology and terminology in insect wings. Systematic Entomology 4: 81–93. doi: 10.1111/j.1365-3113.1979.tb00614.x

Appendix

Localities of specimens housed in the Iziko and Albany Museums in South Africa. (doi: 10.3897/zookeys.201.2623.app) File format: Comma Separates List (csv).

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Four new species of *Dolichopoda* Bolivar, 1880 from Southern Sporades and Western Turkey (Orthoptera, Rhaphidophoridae, Dolichopodainae)

Mauro Rampini[1,†], Claudio Di Russo[1,‡], Mehmet Sait Taylan[2,§], Arianna Gelosa[3,|], Marina Cobolli[1,¶]

1 *Dipartimento di Biologia e Biotecnologie "C. Darwin" (Zoologia), Università degli Studi di Roma "La Sapienza", Viale dell'Università 32, 00185 Roma, Italy* **2** *Biology Department, Science Institute, Akdeniz University Dumlupınar Boulevard Post Code: 07058 Campus Antalya, Turkey* **3** *Via Accademia degli Agiati 120, 00147 Roma, Italy*

† *urn:lsid:zoobank.org:author:8FCA68CF-9971-4D39-8F56-5997C07761A0*
‡ *urn:lsid:zoobank.org:author:A9A1AB82-C02C-4A73-BABC-FDEED9FEB198*
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Corresponding author: *Mauro Rampini* (mauro.rampini@uniroma1.it)

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Abstract

A description of four new species of *Dolichopoda* Bolivar, 1880 (Orthoptera, Rhaphidophoridae) from Eastern Aegean region (Southern Sporades), including Western Turkey, is reported. This brings to a total of 11 the number of *Dolichopoda* species recorded for caves of the Aegean area. Overall, these species show a high degree of morphological homogeneity and they are very close to *D. paraskevi* Boudou-Saltet, 1973 from Crete and *D. naxia* Boudou-Saltet, 1972 from Cyclades (Naxos Island). The Western Turkish species are morphologically not closely related to the other Anatolian species; this suggests an independent origin for the taxa occurring in the Southern Taurus and Black Sea regions. These new data help to better define the already high level of diversity of the Hellenic *Dolichopoda* and strengthen the hypothesis that the central area of dispersal for the genus would correspond to the ancient Aegean plate.

Keywords
Cave crickets, *Dolichopoda*, new species, Eastern Aegean, Western Turkey

Introduction

The subfamily Dolichopodainae Brunner von Wattenwyl, 1888 (Orthoptera, Rhaphidophoridae) is limited to the Northern hemisphere; several species belonging to the genus *Dolichopoda* Bolivar, 1880 inhabit caves of Southern Europe and Asia Minor. To date the genus includes a total 48 species (Heller et al. 1998, Otte 2000, Eades et al. 2012). The genus *Dolichopoda* is mainly widespread in the Mediterranean area from the Pyrenees to the Caucasus (Baccetti 1982, Di Russo and Sbordoni 1998); its diversity in terms of species richness peaks in Southern and South Eastern Europe (Mediterranean basin, Apennines, Balkan and Peloponnesus). In particular, 25 of the known species have been reported for many caves in continental and insular Greece (Boudou-Saltet 1983, Willemse 1984, Rampini et al. 2008). Among these, seven species only are found on Aegean Islands: *D. naxia* Boudou-Saltet, 1972 from Naxos, *D. thasosensis* Chopard, 1964 from Thasos, *D. cassagnaui* Boudou-Saltet, 1971, *D. makrykapa* Boudou-Saltet, 1980 and *D. ochtoniai* Boudou-Saltet, 1983 from Eubea, *D. saraolakosi* Boudou-Saltet, 1983 from Skyros and *D. paraskevi* Boudou-Saltet, 1973 from Crete. On the other hand, until now only five species of this genus were recorded for Turkey (Bolivar 1899, Di Russo and Rampini 2006, Galvagni 2006, Di Russo et al. 2007, Rampini and Di Russo 2008, Taylan et al. 2011, Ünal 2011). Two of these (*D. sbordonii* Di Russo and Rampini, 2006 and *D. lycia* (Galvagni, 2006)) are limited to caves around Antalya, while other two (*D. aranea* Bolivar, 1899 and *D. pusilla* Bolivar, 1899) are restricted to a few localities of the Eastern Taurus and only *D. noctivaga* Di Russo and Rampini, 2007 is widespread in caves and epigean habitats in Northern Turkey throughout the Black Sea region (Taylan et al. 2011).

In recent years several *Dolichopoda* were collected by us for the first time in caves of the Southern Sporades and Aegean Turkey. At a first examination these new populations did not show remarkable morphological differences resulting all very similar and close to one other. However, a genetic study based on mitochondrial DNA (mtDNA) revealed a noticeable level of genetic divergence, comparable to that usually found among morphologically divergent species of the genus (Allegrucci et al. 2009, Taylan et al. 2011). These interesting results prompted us to carry out a more detailed morphological survey of these taxa. This allowed us to describe four new *Dolichopoda* species from the Eastern Agean: two from caves on Samos, one on Kalymnos and one from the Aegean Turkey (İzmir and Aydın Province).

All these new species are attributable to the sub-genus *Dolichopoda* s. str. (Baccetti 1958), because of the absence of spines on all femora, the occurrence of spines on the fore tibia and a non-bifurcate epiphallus.

The material was brought together by M.S. Taylan, M. Rampini and C. Di Russo for collective study and deposition in: Museum of Zoology, University of Rome

"La Sapienza" (MZUR); Akdeniz University, Science Institute, Biology Department, Antalya, Turkey (AUZM). The localities of the studied species are presented on the distribution map shown in Figure 22.

Systematics

***Dolichopoda* (*Dolichopoda*) *sutini* Rampini & Taylan, sp. n.**

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http://species-id.net/wiki/Dolichopoda_sutini
Figures 1–5

Type-locality. The Sütini cave is situated on the road from Selçuk to Sirince (İzmir Province, Turkey).

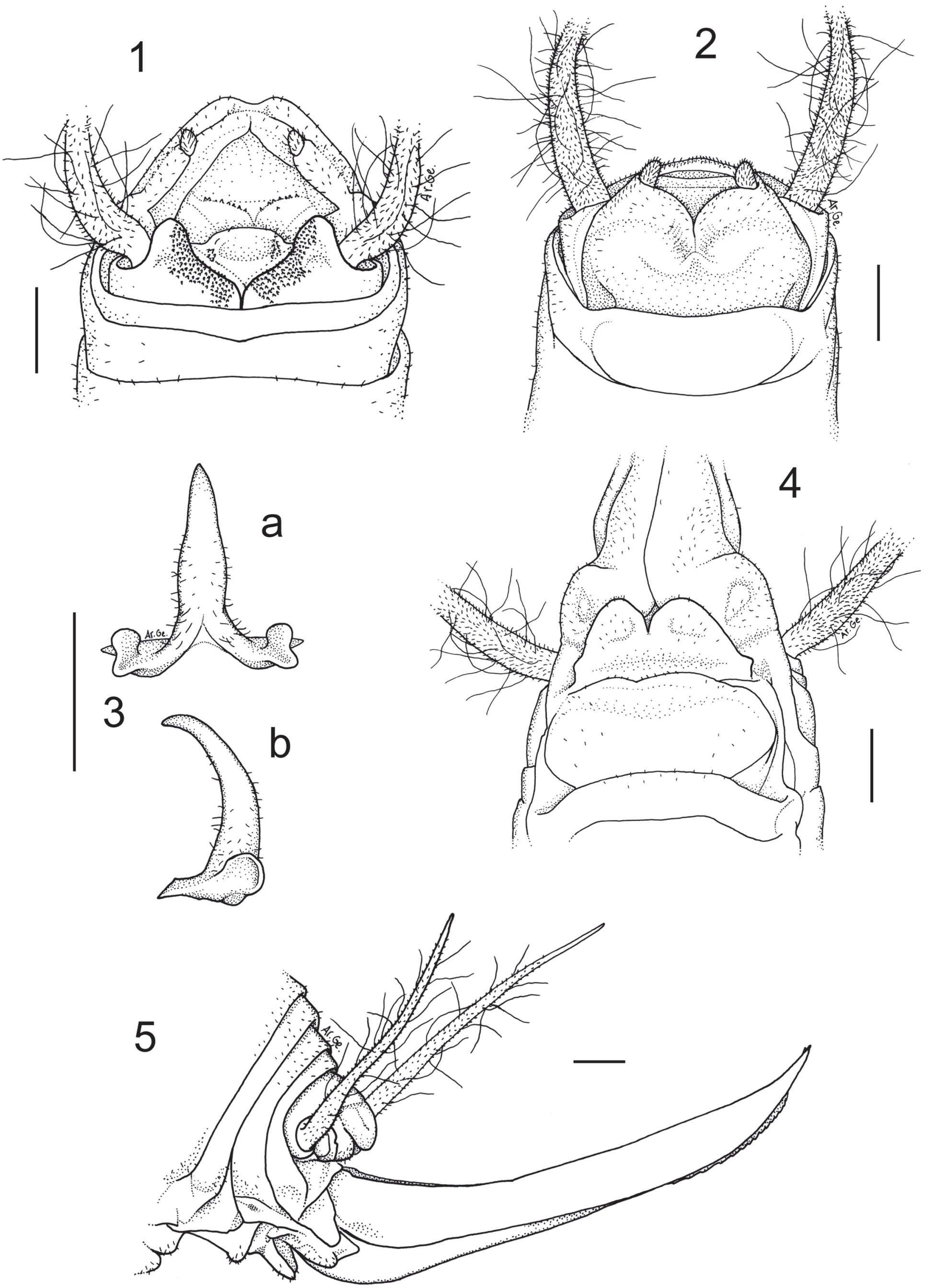
Material examined. Thirty-three specimens.

Type material. Holotype male. Turkey, İzmir, Selçuk, Sütini cave, 27.06.2008, M.S. Taylan leg. (AUZM).

Paratypes: 5 males, 5 females, 1 nymph, same data and collector as for holotype; 1 male,12 females, 8 nymphs, Turkey, Aydın, Söke, Aşıkali cave, 13.07.2009, M.S. Taylan leg. (AUZM).

Differential diagnosis. The size is relatively small with the hind legs strongly elongated. This species is close to Aegean species *D. naxia* from Naxos, and *D. paraskevi* from Crete but differs from them for the number of spines on the hind tibia (19); these are 25 in *D. naxia* and 16 in *D. paraskevi*. The tenth tergite differs from that of *D. naxia* and *D. paraskevi* for the shape and size of the lateral lobes and for the deeper medial incision. The male subgenital plate appears close to that of *D. paraskevi* while it differs from *D. naxia*; here the lateral lobes are trapezoidal. The median process of the epiphallus, flattened and rather enlarged at the base, is very close to that of *D. paraskevi*, while in *D. naxia* it is narrow and more elongated. From a lateral view the median process differs from that of the other two species being more curved. The female subgenital plate, with rounded lobes, is similar to that of *D. paraskevi* but differs from *D. naxia* for the deeper medial incision between lobes. The ovipositor, similar in length and shape, is different only for the number of denticles on the inferior valves.

Description. Male (holotype)**.** Body colour pale-testaceous, uniform with the exception of the posterior margins of the tergites, which are darker. Legs long, slender and yellow-testaceous in colour with the femora unarmed. Fore tibia armed with 4/5 spines on both sides of the inferior edge and a pair of spurs of equal length on the apex. Mid tibia with 3/4 short spines on both sides of the upper edge, 4/5 spines on the lower edge and two apical spurs similar to those of the fore tibia. The hind tibia is longer with 18/19 spines of varying length on both sides of the upper edge and 1/3 homogeneous spines on the lower edge. Tenth tergite on the posterior edge with two prominent lateral lobes triangular in shape with rounded apex separated from one another by a deep median incision (Figure 1). Subgenital plate globular at the bottom, with a deep



Figures 1–5. *Dolichopoda sutini* sp. n. Holotype male, **1** X tergite, dorsal view **2** subgenital plate, ventral view **3** epiphallus: a- dorsal view, b- lateral view. Female **4** subgenital plate, ventral view **5** ovipositor, lateral view. Scale bars: 1 mm.

median incision that runs for half of the total length; the symmetrical lateral lobes, triangular in shape, hold two evident styli cylindrical in shape (Figure 2). The epiphallus is sclerotized and shows a median process relatively long, almost flattened and with an acute apex; it appears large at the base and without lateral constrictions; from the side, the median process is uniformly thickened and curved; the basal processes are rather developed and slightly divergent (Figure 3 a, b). The accessory apparatus is sclerotized and composed by an uneven Y shaped piece, showing strong spines at the base, and by even partially trapezoidal valves.

Length (mm): body 14.0; pronotum 3.0; fore femora 16.2; middle femora 16.5; hind femora 22.4; fore tibia 16.8; middle tibia 17.3; hind tibia 30.2; hind tarsus 10.2; 1st article of hind tarsus 5.0.

Female**.** The length of the body ranges between 14.8–15.9 mm (ovipositor excluded) and the general form of the female is similar to the male. The subgenital plate is triangular (Figure 4), with two prominent lobes deeply incised and rounded at the posterior edges. The ovipositor has an average length of 10 mm, rather enlarged at the base and little curved on the superior edge (Figure 5).

The superior valves have a pointed apex and curves upwards, whereas the inferior valves are a little shorter than the superior ones, are rounded at the apex and have 16–17 denticles.

Etymology. The new species name refers to the Sütini cave in Selçuk (İzmir Province).

***Dolichopoda* (*Dolichopoda*) *giulianae* Rampini & Di Russo, sp. n.**

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http://species-id.net/wiki/Dolichopoda_giulianae
Figures 6–10

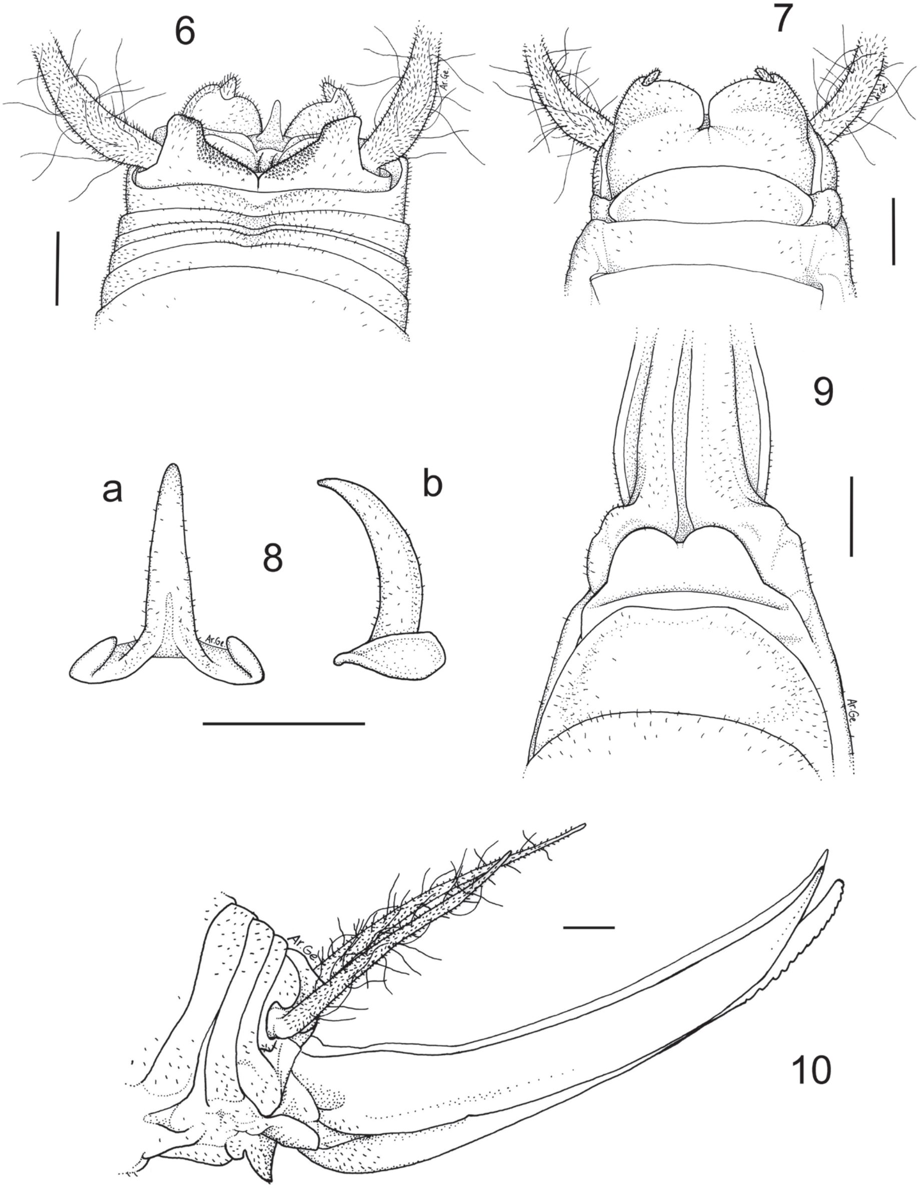
Type-locality. In the North-West part of Pythagorion (Samos Island) is located the monastery of Panaghia Spiliani; here, 95 steps lead down into a big cave with a church that is dedicated to the Virgin Mary. The caves was originally used to extract blocks of massive limestone to build walls and many buildings for the town of Samos.

Material examined. Sixteen specimens.

Type material. Holotype male, Greece, Samos Isl., Pythagorion, Panaghia Spiliani cave, 04.04.2008, M. Rampini, C. Di Russo leg. (MZUR).

Paratypes: 4 males, 2 females, 3 nymphs, same locality date and collectors as holotype (MZUR). 1 female, 5 nymphs, same locality as holotype 21.08.2002, F. Gasparo leg. (MZUR).

Differential diagnosis. The overall appearance of this new species is very similar to that *D. sutini* from İzmir. Differences are found in the squared and divergent lobes of the tenth male tergite, in the shape of the epiphallus (less enlarged at the base) and in the shorter styli of the subgenital plate. The female subgenital plate is similar to that of *D. paraskevi* but differs from *D. sutini* for the more rounded lobes. The ovipositor has fewer apex denticles on the inferior valves.



Figures 6–10. *Dolichopoda giulianae* sp. n. Holotype male **6** X tergite, dorsal view **7** subgenital plate, ventral view **8** epiphallus, **a** dorsal view **b** lateral view. Female **9** subgenital plate, ventral view **10** ovipositor, lateral view. Scale bars: 1 mm.

Description. Male (holotype). Size relatively small. Body and appendages coloration as in the previous species. Femora unarmed. Fore tibia armed with 3 spines on both sides of the upper edge and 3/5 spines on the lower edges. Mid tibia with 5 short spines on both sides of the upper edge, 4 spines on the lower edge. The hind tibia is longer with 19/22 spines of varying length on both sides of the upper edge and 0/2 homogeneous spines on the lower edge. The tenth tergite shows two prominent lobes on the posterior edge, almost squared at the apex (Figure 6). The subgenital plate, globular at the bottom, is similar to that of *D. sutini*. The lateral lobes, triangular in shape, hold two short conical styli (Figure 7). The epiphallus is sclerotized and shows a long flattened median process, acute at the apex; from the side, it appears uniformly curved (Figure 8 a, b). The accessory apparatus looks similar to that of *D. sutini*.

Lenght (mm): body 14.5; pronotum 3.5; fore femora 14.0; middle femora 14.0; hind femora 22.0; fore tibia 15.5; middle tibia 16.5; hind tibia 28.0; hind tarsus 11.0; 1st segment of hind tarsus 5.5.

Female. General appearance as in the male. The length of the body ranges between 15.0 and 18.0 mm (ovipositor excluded). The subgenital plate is trapezoidal with two rounded lobes (Figure 9). The ovipositor has an average length of 11.0 mm, is rather enlarged at the base and is regularly curved on the superior edge (Figure 10); the apex is pointed and curved upwards. The inferior valves have 15 apical denticles.

Etymology. The new species is dedicated to our colleague and friend Giuliana Allegrucci for her useful and active collaboration in this study.

***Dolichopoda* (*Dolichopoda*) *kalithea* Di Russo & Rampini, sp. n.**

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http://species-id.net/wiki/Dolichopoda_kalithea
Figures 11–15

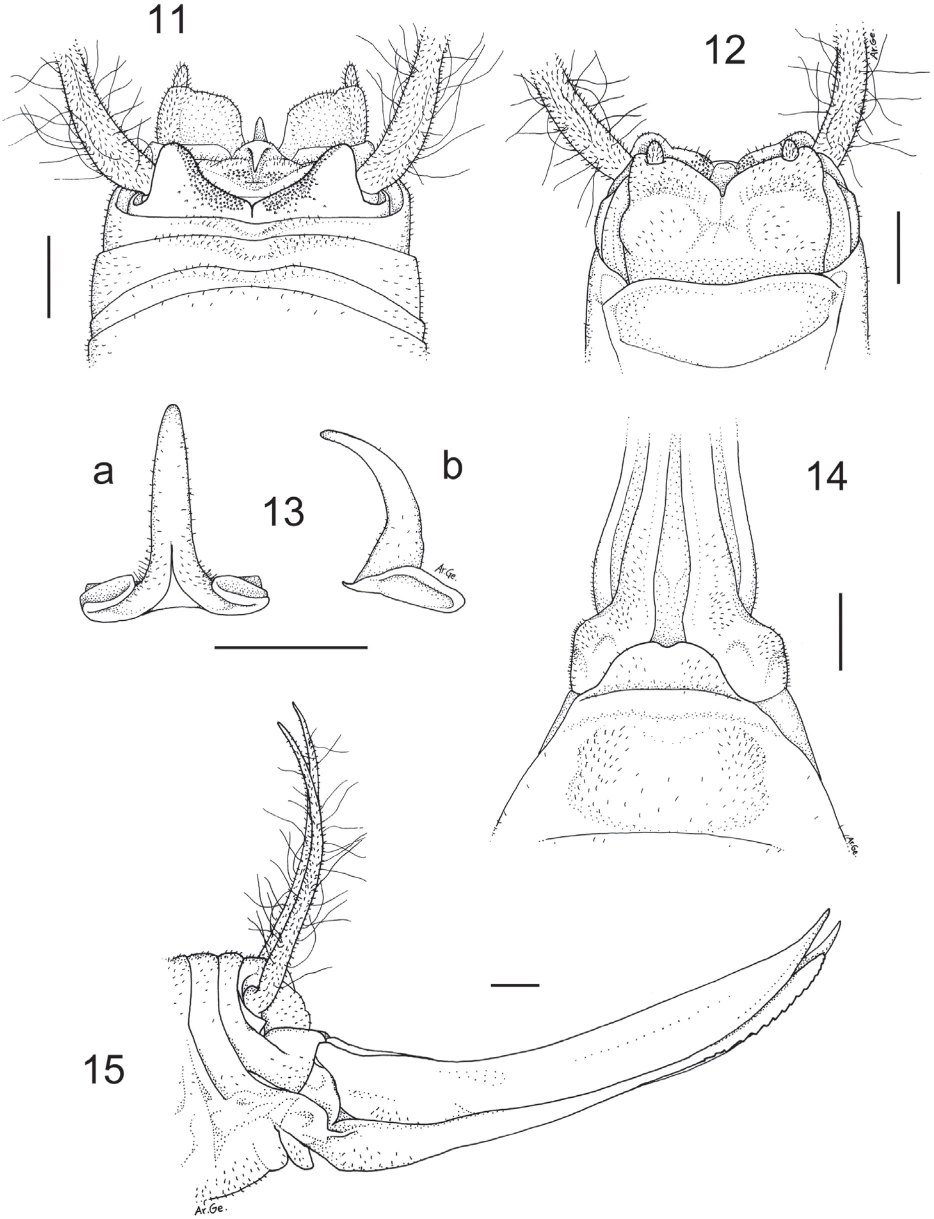
Type-locality. The cave, with a chapel inside, is located East of Kalithea village in the Western part of Mount Kerkis, inside the canyon Kakoperato, which starts from a little monastery called Panaghias Kakoperato. The cave is known for the presence of the endemic Staphylinid rove beetle *Tychobythinus brachati* Besuchet, 2008.

Material examined. Sixteen specimens.

Type material. Holotype male, Greece, Samos Isl., Mount Kerkis, Kakoperato canyon, 660 m, Kakoperato cave (or Trypa Tse-Tse cave), 05.04.2008, C. Di Russo, M. Rampini leg.

Paratypes: 6 males, 1 male, 2 nymphs, same locality, date and collectors (MZUR). South-Eastern slopes of Mount Kerkis, Marathokampos, 320 m, Sarandaskaliotissa cave (near Pythagoras cave), 1 male, 2 females, 3 nymphs, 05.04.2008, C. Di Russo, M. Rampini leg. (MZUR).

Differential diagnosis. Shape and coloration as in the previous species. Size relatively large, with very long legs. This species, owing to the triangular lobes of the tenth tergite (almost fully separated by a large concavity) and to the trapezoidal lobes of the subgenital plate is close to *D. naxia*. On the contrary the pronounced curve of the median process of the epiphallus differs markedly from that of *D. naxia* while it resembles that of *D. sutini* and of *D. giulianae*. The female subgenital plate differs from that of both *D. sutini* and *D. giulianae* for the lower incision between the two lobes.



Figures 11–15. *Dolichopoda kalithea* sp. n. Holotype male, **11** X tergite, dorsal view **12** subgenital plate, ventral view **13** epiphallus **a** dorsal view **b** lateral view. Female **14** subgenital plate, ventral view **15** ovipositor, lateral view. Scale bars: 1 mm.

Description. Male (holotype). Body and appendages coloration as in the previous species. Femora unarmed. Fore tibia armed with 1/4 spines on both sides of the upper edge and 3/5 spines on the lower edges. Mid tibia with 1/4 short spines on both sides of the upper edge, 4 spines on the lower edge. The hind tibia is longer with 13/20 spines of varying length on both sides of the upper edge and 0/3 homogeneous spines on the lower edge. The tenth tergite has two triangular lobes quite developed and separated by a large concavity (Figure 11). The subgenital plate shows two trapezoidal lobes, straight on the posterior edges and separated by a relatively short incision (Figure 12); the lobes hold two prominent cylindrical styli. The epiphallus is sclerotized and shows a quite flattened median process with an enlarged base; laterally, it appears rather thick at the base and strongly arched distally (Figure 13). The accessory apparatus is similar to that of the previous species.

Length (mm): body 16.0; pronotum 3.0; fore femora 13.0; middle femora 14.0; hind femora 21.5; fore tibia 15.5; middle tibia 16.5; hind tibia 27.0; hind tarsus 10.5; 1st article of hind tarsus 5.0.

Female. General appearance as in the male. The length of the body ranges between 19.0 and 21.0 mm (ovipositor excluded). The subgenital plate is rounded and slightly incised in the middle (Figure 14). The ovipositor has an average length of 12.0 mm, rather enlarged at the base and regularly curved on the superior edge (Figure 15). The superior valves have a pointed apex and curves upwards, the inferior valves have 14 denticles .

Etymology. The new species takes its name from the Kalithea village.

***Dolichopoda* (*Dolichopoda*) *calidnae* Rampini & Di Russo, sp. n.**

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http://species-id.net/wiki/Dolichopoda_calidnae
Figures 16–21

Type-locality. Foot of the Mt. Flaska, in the cave of the Nymphs**,** also called the cave of the Seven Virgins.

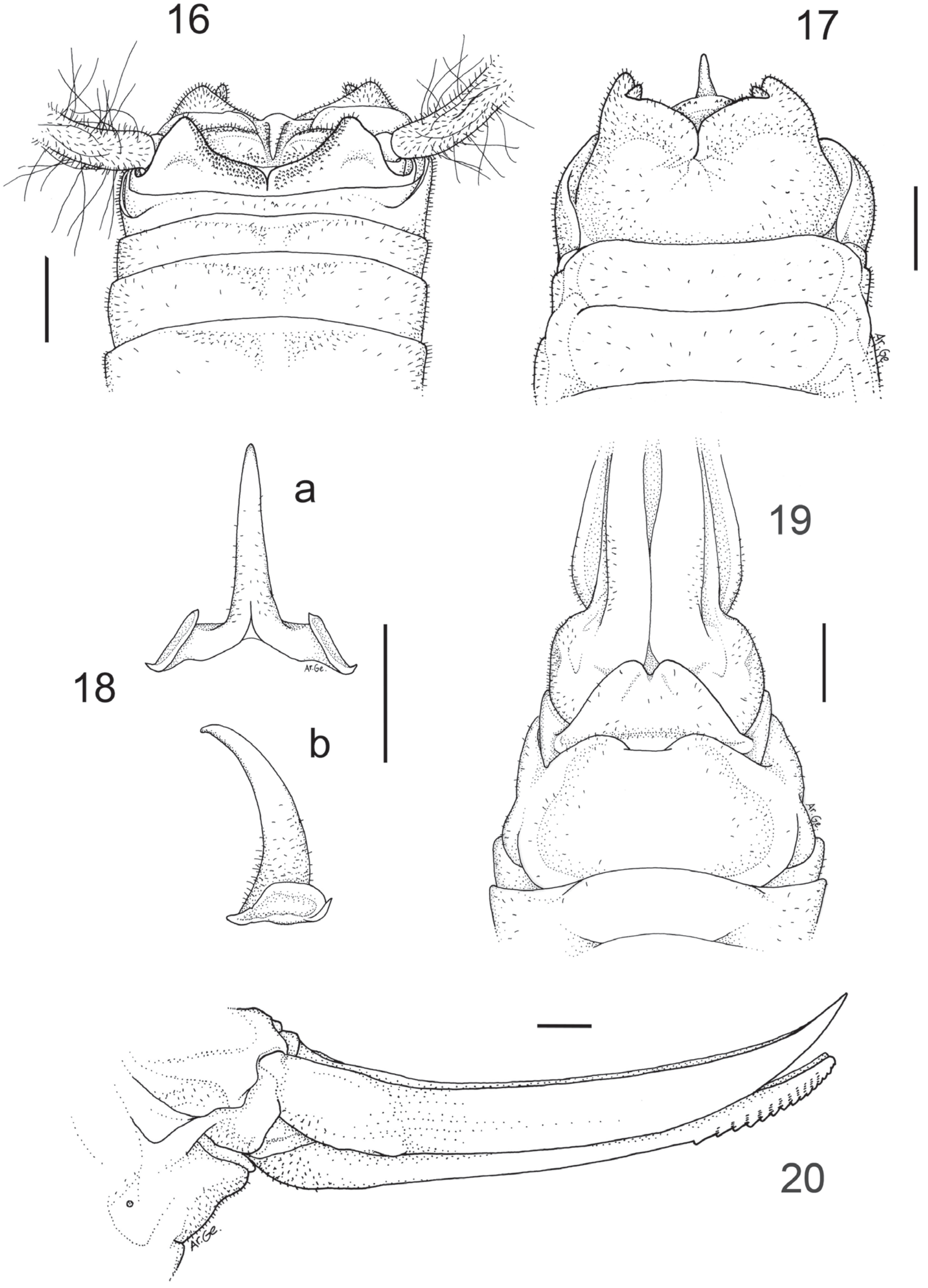
Material examined. Fifteen specimens.

Type material. Holotype male, Greece, Kalymnos Isl., Pothia, Seven Virgins cave (Sanctuary of the Nimphs or Epta Parthenes cave), 28.03.2004, M. Rampini, C. Di Russo leg.

Paratypes: 1 male, 5 females, same data and collectors; Skalia village, Skalia cave (Mts Flaska), 3 males, 5 nymphs, 28.03.2004, M. Rampini, C. Di Russo leg. (MZUR).

Differential diagnosis. Colour of the body uniformly pale-testaceous, legs more yellowish. The male tenth tergite shows expanded lateral lobes of triangular shape with an acute apex. The subgenital plate, with trapezoidal lobes, is similar to that of *D. naxia* but with short apical styli on the posterior edge. The epiphallus is long and slender as in *D. naxia*, with a little curved median process, stretched and narrower than in the previous species. The female subgenital plate is morphologically different from that of all the other species showing a triangular shape with two moderately incised lobes in the middle.

Description. Male (holotype). Size rather large. Coloration uniformly pale-testaceus. Legs long and more light in colour. Femora unarmed. Fore tibia armed with 5 spines on both sides of the inferior edge and 3/4 spines on the lower edges. Mid-tibia



Figures 16–20. *Dolichopoda calidnae* sp. n. Holotype male **16** X tergite, dorsal view **17** subgenital plate, ventral view **18** epiphallus **a** dorsal view **b** lateral view. Female **19** subgenital plate, ventral view **20** ovipositor, lateral view. Scale bars: 1 mm

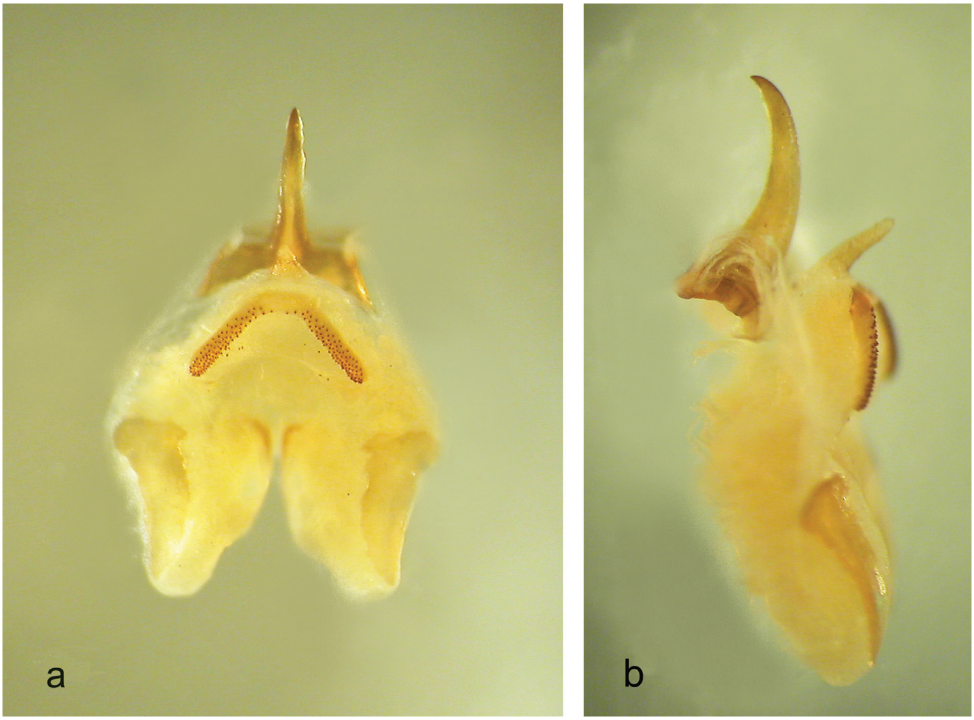


Figure 21. *Dolichopoda calidnae* sp. n., holotype male, epiphallus and accessory apparatus **a** dorsal view **b** lateral view.

with 4 short spines on both sides of the upper edge, 4/5 spines on the lower edge. The hind tibia is longer with 21/24 spines of varying length on both sides of the upper edge and 2/3 homogeneous spines on the lower edge. Eighth and ninth abdominal tergites show a sinuous posterior edge, the eighth one is hollower centrally. The tenth tergite, similar to those of the previous species, shows on the posterior edge two large lateral lobes, triangular in shape, with rather rounded apex (Figure 16). Subgenital plate globular at the bottom, with a deep middle incision that runs for half of the total length (Figure 17). Lateral lobes trapezoidal, with two short conical styli. The epiphallus is sclerotized and shows a median process relatively long, almost cylindrical and acute apically. From the side, it appears large at the base and uniformly curved. The basal processes are squared, rather developed and slightly divergent (Figure 18 a, b). The accessory apparatus is similar to that of the previous species (see photo in Figure 21 a, b).

Length (mm): body 17.5; pronotum 3.5; fore femora 14.3; middle femora 14.5; hind femora 22.5; fore tibia 15.9; middle tibia 16.7; hind tibia 26.9; hind tarsus 11.0; 1st article of hind tarsus 5.5.

Female. General appearance as in the male. The length of the body ranges between 16.0–17.0 mm (ovipositor excluded). The subgenital plate is triangular with two moderately incised lobes in the middle (Figure 19). The ovipositor has an average length of 11.0 mm, it is enlarged at the base and regularly curved on the superior edge (Figure 20).

The superior valves have a pointed apex and curves upwards, whereas the inferior valves are rounded apically and have 15 denticles.

Etymology. The new species takes its name from the Calidnae Islands (Kalymnos, Leros and Telendos) cited by Homer in Iliad.

Discussion

Here we describe three new species belonging to the cave cricket genus *Dolichopoda* from the Aegean Greek Islands (Southern Sporades) and one from the Western Turkish coast. Considering the additional seven species already reported for the area, there is now a total of 11 recorded species of *Dolichopoda* that currently inhabit caves of the region (Figure 22). These new data, therefore, document the high diversity of the genus in the Hellenic region (25 species in total) reinforcing the hypothesis of a central area of dispersal of *Dolichopoda* corresponding to the ancient Aegean plate (Ruffo 1955).

The new species are all morphologically homogeneous, due to a strong similarity of most of the characters examined (i.e. tenth tergite, epiphallus, accessory apparatus and female subgenital plate). Based on these characters the new species show a clear affinity with *D. naxia* from the Cyclades and with *D. paraskevi* from Crete (see Table 1). On the other hand, they are well separated from *D. thasosensis*, an endemic taxon of the Thasos Island (Tracia), showing a peculiar trilobate shape of the tenth tergite, and from the western species from Eubea and Skyros. These latter species are characterized by a bifurcate apex of the epiphallus and for this reason Boudou-Saltet (1983) placed them in the different sub-genus *Petrochilosina* (*D. makrykapa* Boudou-Saltet, 1980, *D. ochtoniai* Boudou-Saltet, 1983, *D. cassagnaui* Boudou-Saltet, 1971 from Eubea and *D. saraolakosi* Boudou-Saltet, 1983 from Skyros). The sub-genus includes also three additional species (*D. insignis* Chopard, 1955, *D. petrochilosi* Chopard, 1954 and *D. vandeli* Boudou-Saltet, 1970) from Central Greece (Attica and Beotia). Finally, the species *D. sutini* from the western Turkish coast doesn't show any affinity to the other Anatolian species, supporting its indipendent origin from the *Dolichopoda* species living in caves of the Southern Taurus and the Black sea region (Taylan et al. 2011).

The strong morphological homogeneity of this Eastern Aegean species complex, whose range extends now from the Aegean coast of Turkey to the caves of Eastern Crete, clearly suggests a common origin from an ancestor that presumably occupied the eastern part of the ancient Aegean plate. As reported by Allegrucci et al. (2009), the radiation of the genus *Dolichopoda* in this area may have been triggered by the combination of changes in sea level and the relatively humid climate occurring during the Messinian. In that study the origin of the Cretan species *D. paraskevi* was estimated at 4.9 million years ago (Mya), shorthly after the end of Messinian salinity crisis (dated at 5.3 Mya). After this period Crete became permanently isolated promoting speciation of *D. paraskevi*. The split of *D. naxia* (Naxos) from the Eastern Aegean species (Allegrucci et al. 2009), presumably started around 3 Mya. This dating coincides with the separation of the southern Cyclades from the northern Cyclades plateau dated at 3.5

Figure 22. Distribution of troglophilous species of *Dolichopoda* in Aegean Region. **1** *D. sutini* sp. n. (Sütini cave, Selçuk, İzmir) **2** *D. giulianae* sp. n. (Panaghia Spiliani cave, Pythagorion, Samos) **3** *D. kalithea* sp. n. (Kakoperato cave, Kalithea, M. Kerkis, Samos) **4** *D. calidnae* sp. n. (Seven Virgins cave, Pothia, Kalymnos) **5** *D. thasosensis* (Drakotrypa cave, Thasos) **6** *D. makrykapa* (Piyi Nyphi cave, Makrykapa, Eubea) **7** *D. cassagnaui* (Aghia Trias cave, Karystos, Eubea) **8** *D. ochtoniai* (unnamed cave at North Est of Eubea) **9** *D. saraolakosi* (Lynaria caves, Skyros) **10** *D. naxia* (Za cave, Filotas, Naxos) **11** *D. paraskevi* (Aghia Paraskevi cave, Skotino, Iraklion, Crete).

Mya, suggesting that *D. naxia* probably represents an old lineage of eastern origin. Finally the affinity of the three new species from the easternmost Aegean islands (Samos and Kalimnos) could be explained in light of the palaeogeography of the area; both islands were in fact connected to continental Asia Minor until recently (i.e. Pleistocene). The age of these species dates back to the end of the Pliocene and the beginning of the Pleistocene, fitting thus with the geological evolution of the islands.

Table 1. Mean values of 11 morphological parameters of the Aegean *Dolichopoda* species here studied (dimension in mm).

	D. sutini	*D. calidnae*	*D. giulianae*	*D. kalithea*	*D. naxia*[1]	*D. paraskevi*[2]
Body	13.50	18.00	15.00	16.50	19.00	14.5
Pronotum	3.00	3.50	3.50	3.00	4.00	3.00
1 Femora	16.00	14.00	14.00	13.00	16.00	14.5
2 Femora	15.00	15.00	14.00	13.50	16,00	14.00
3 Femora	22.00	23.00	22.00	21.00	25.00	23.50
1 Tibia	17.00	16.00	16.00	15.00	17.00	17.00
2 Tibia	16.50	17.00	17.00	16.00	18.00	17.00
3 Tibia	30.00	30.00	29.00	27.00	33.00	30.50
Hind tarsus	10.00	11.00	11.00	10.00	11.50	10.50
I°art.h.tarsus	5.00	5.50	5.50	5.00	5.50	5.50
Ovipositor	10.00	11.00	11.00	12.00	11.50	11.50

[1] Boudou Saltet 1972, [2] unpublished data (Rampini and Di Russo)

Of particular interest is the situation on Samos Island, where two species (*D. kalithea* and *D. giulianae*) co-occurr. The differentiation of these two closely related species could be explained by the different geological origin of their cave habitats that could have acted as a geographic and/or ecological barrier preventing gene flow. Kakoperato and Sarandaskaliotissa caves, inhabited by *D. kalithea*, open to the Eastern slopes of Mount Kerkis, a massif of dolomitic marble of Cretaceous origin. On the other hand, the Panaghia Spiliani cave, where *D. giulianae* lives, is placed in a lacustrine limestone formation of Neogene origin (Ring et al. 1999). The strong affinity between these two species and *D. sutini* from Selçuk (Turkey) is justified by the proximity of Samos to the Turkish coast (the island now is separated from the Western Anatolian coast by a channel less than 1.5 Km wide and 30.0 m deep), suggesting that a connection between Samos and the Turkish coast probably existed until the recent Holocene (Stiros et al. 2000, Kayan 2004).

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References

Allegrucci G, Rampini M, Gratton P, Todisco V, Sbordoni V (2009) Testing phylogenetic hypotheses for reconstructing the evolutionary history of *Dolichopoda* cave crickets in the eastern Mediterranean. Journal of Biogeography 36: 1785–1797. doi: 10.1111/j.1365-2699.2009.02130.x

Baccetti B (1958) Notulae orthopterologicae IX. Osservazioni cariologiche sulle *Dolichopoda* italiane. Redia 43: 315–327.

Baccetti B (1982) Ortotteri cavernicoli italiani. (Notulae orthopterologicae XXXVI). Lavori della Società Italiana di Biogeografia, Verona 1978 (n. s.) 6: 195–200.

Bolivar I (1899) Orthoptères du voyages de M. Martinez Escalera dans L'Asie Mineure. Annales de la Société entomologique de Belgique 43: 583–607.

Boudou-Saltet P (1970) Les Dolichopodes (Orth. Rhaph.) de Grèce. II. Une nouvelle espèce: *D. vandeli* . Biologia gallo-hellenica 3: 89–97

Boudou-Saltet P (1971) Les Dolichopodes (Orth. Rhaph.) de Grèce.III. *Dolichopoda cassagnaui* n. sp. Bulletin de la Société d'Histoire Naturelle de Toulouse 107: 295–300.

Boudou-Saltet P (1972) Les Dolichopodes (Orth**.** Rhaph.) de Grèce. V. Deux nouvelles espèces *Dolichopoda naxia* et *D. steriotisi*. Biologia gallo-hellenica 4(1): 99–108.

Boudou-Saltet P (1973) Les *Dolichopodes* (Orth**.** Rhaph.) de Grèce. VIII. Nouvelles espèces de Crète. Biologia gallo-hellenica 5: 58.

Boudou-Saltet P (1980) Les Dolichopodes (Orth. Rhaph.) de Grèce. IX. Une nouvelle espèce en Eubée: *D. makrykapa*. Biologia gallo-hellenica 9: 123–134.

Boudou-Saltet P (1983) Sur les *Dolichopoda* (Orth. Rhaph.) du sous-genre *Petrochilosina*. Mémories de Biospéleologie 10: 321–323.

Chopard L (1954) Contribution à l'étude des orthoptéroïdes cavernicoles. Notes Biospéologiques 9: 27–36.

Chopard L (1955) Les Dolichopodes de Grèce. Notes Biospéologiques 10: 31–34.

Chopard L (1964) Descriptions d'Orthoptères cavernicoles de Grèce. Bulletin de la Sociétè entomologique de France 69: 17–20.

Di Russo C, Sbordoni V (1998) Gryllacridoidea. In: Juberthie C, Decu V (Eds), Encyclopedia Biospeleologica. Vol. II. Moulis, Bucarest, 989–1001.

Di Russo C, Rampini M (2006) A new species of *Dolichopoda* from caves of Southern Turkey (Orthoptera, Rhaphidophoridae). Fragmenta entomologica, Roma 38 (1): 7–14.

Di Russo C, Rampini M, Landeck I (2007) The cave crickets of North-East Turkey and Trans-Caucasian regions, with description of two new species of the genera *Dolichopoda* and *Troglophilus* (Orthoptera, Rhaphidophoridae). Journal of Orthoptera Research 16(1): 67–76. doi: 10.1665/1082-6467(2007)16[67:TCCONT]2.0.CO;2

Eades DC, Otte D, Cigliano MM, Braun H (2012) OSF: Orthoptera Species File Online (version 2.0/4.1). http://Orthoptera.SpeciesFile.org

Galvagni A (2006) Nuovo genere e nuova specie di Dolichopodinae dell'Anatolia Sud-Occidentale: *Hellerina lycia* n. sp. (Insecta Orthoptera Rhaphidophoridae). Atti della Accademia Roveretana degli Agiati 8(6): 75–83.

Heller KG, Korsunovskaya O, Ragge DR, Vedenina V, Willemse F, Zhantiev RD, Franstsevich L (1998) Check-List of European Orthoptera. Articulata 7: 1–61.

Kayan İ (2004) Interpretations on the sea-level changes along the coasts of Kuşadası Bay and Samos Island. II. International symposium on the Aegean Islands, 2–3 July, Gökçeada, Çanakkale, 31–41.

Otte D (2000) Orthoptera species files. Vol. VIII. Gryllacrididae, Stemopelmatidae, Cooloolidae, Schizodactylidae, Anostostomatidae, Rhaphidophoridae. The Orthopterist Society, Philadelphia, 97 pp.

Ring U, Laws S, Bernet M (1999). Structural analysis of a complex nappe sequence and late-orogenic basins from the Aegean Island of Samos, Greece. Journal of Structural Geology 21:1575–1601. doi: 10.1016/S0191-8141(99)00108-X

Rampini M, Di Russo C (2008) On Southern Anatolian *Dolichopoda* Bolivar, 1880 with taxonomic notes on the genus *Hellerina* Galvagni, 2006 (Orthoptera, Rhaphidophoridae). Fragmenta entomologica, Roma 40(2): 229–236.

Rampini M, Di Russo C, Pavesi F, Cobolli M (2008) The genus *Dolichopoda* in Greece. A description of new species from the Ionian Regions and Peloponnisos (Orthoptera, Rhaphidophoridae). Zootaxa 1923: 1–17.

Ruffo S (1955) Le attuali conoscenze della fauna cavernicola della regione pugliese. Memorie di Biogeografia Adriatica 3: 1–143.

Stiros SC, Laborel J, Laborel-Deguen F, Papageorgiou S, Evin J, Pirazzoli PA (2000) Seismic coastal uplift in a region of subsidence: Holocene raised shorelines of Samos Island, Aegean Sea, Greece. Marine Geology 170: 41–58. doi: 10.1016/S0025-3227(00)00064-5

Taylan MS, Di Russo C, Rampini M, Cobolli M (2011) The Dolichopodainae and Troglophilinae cave crickets of Turkey: an update of taxonomy and geographic distribution (Orthoptera, Rhaphidophoridae). Zootaxa 2829: 59–68.

Ünal M (2011) Turkish Orthptera Site (TOS). www.orthoptera-tr.org

Willemse F (1984) Catalogue of the Orthoptera of Greece. Fauna Graeciae I. Hellenic Zoological Society, Athens (88–92), 275 pp.

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RESEARCH ARTICLE

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A new species of *Caligus* (Copepoda, Siphonostomatoida) from the plankton of the Caribbean coast of Venezuela with a key to species

Eduardo Suárez-Morales[1,†], Humberto Camisotti[2,‡], Alberto Martín[2,§]

1 *El Colegio de la Frontera Sur (ECOSUR), Av. Centenario Km. 5.5, A.P. 424, Chetumal, Quintana Roo 77000, Mexico* **2** *Laboratorio de Crustáceos Peracáridos, Departamento de Estudios Ambientales e INTECMAR, Centro de Biodiversidad Marina. Universidad Simón Bolívar, A.P. 89000 Caracas, Venezuela*

† *urn:lsid:zoobank.org:author:BACE9404-8216-40DF-BD9F-77FEB948103E*
‡ *urn:lsid:zoobank.org:author:85579E89-2E0F-4133-AC54-62D9A79FF6AB*
§ *urn:lsid:zoobank.org:author:234946C6-FF3F-49CB-A90E-7AECD1BE8CAF*

Corresponding author: *Eduardo Suárez-Morales* (esuarez@ecosur.mx)

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Abstract

During a survey of the zooplankton community of Bahía Amuay, Venezuelan Caribbean, specimens of an undescribed species of *Caligus* Müller were collected. It resembles *C. xystercus* Cressey and *C. ocyurus* Cressey, both known only from the Caribbean Sea. The new species can be distinguished from these and other congeners by a combination of characters including the armature of legs 1 and 4, but mainly by its unique female genital complex. This is the first species of *Caligus* described from Venezuela. The species is described in full and a key to the species of the genus recorded in Venezuela is provided.

Keywords

Parasitic copepods, Bahía Amuay, marine zooplankton, crustaceans, biodiversity

Introduction

The siphonostomatoid copepods of the genus *Caligus* Müller, 1785 are one of the most diverse and representative crustacean parasites of teleost fish (Boxshall and Halsey 2004; Ho and Lin 2004). They are usually recorded as ectoparasitic forms attached to the hosts, but in many cases they can be found in the plankton (Venmathi Maran and Ohtsuka 2008). Records of parasitic copepods of Venezuelan marine teleosts are relatively scarce (Luque and Poulin 2007). This is particularly true in the Caribbean Sea, a region in which the parasitological research is lagging despite the high number of parasite species harbored by Caribbean fish (Bunkley-Williams and Williams 1994; Luque and Poulin 2007). Previous surveys of the caligid fauna of Venezuela are relatively scarce and up to 10 species of *Caligus* have been recorded from this country (Ho and Bashirullah 1977; Legarde 1989; Williams and Bunkley-Williams 1996; Díaz Díaz 2000; Zambrano et al. 2003).

A recent (February 21–24, 2012) biological survey of the planktonic fauna was carried out at the Bay of Amuay, a coastal system on the northern coast of Venezuelan Caribbean coast, which is also an important oil extraction site with pollution problems (Pomares Ferraz et al. 2008). Specimens of the copepod genus *Caligus* were recorded in these samples. These individuals represent a new species which is described here and compared with its closest congeners. An identification key to the species of *Caligus* recorded from Venezuela is also provided.

Material and methods

Adult female and male individuals of a caligid copepod of the genus *Caligus* were recovered from plankton samples obtained from Bahía Norte, a shallow coastal system which is part of the Bay of Amuay (11°46'32"N, 70°13'51"W), in the northwestern coast of Venezuela. The plankton fauna from this area was surveyed during several days (February 21–24, 2011) by performing horizontal hauls with a standard plankton net (0.5 mm mesh size, 0.3 m mouth diameter). Specimens were fixed shortly after collection in 70% ethanol. Specimens of *Caligus* were sorted from these samples and processed for identification by transferring them to glycerol and then pure glycerine. Drawings were prepared using a camera lucida mounted on an E-200 Nikon compound microscope. Terminology of the body parts and appendages follows Ho and Lin (2004). Type specimens were deposited in the collection of Zooplankton held at El Colegio de la Frontera Sur (ECOSUR), Unidad Chetumal (ECO-CHZ), Quintana Roo, Mexico.

Systematics

Order Siphonostomatoida Thorell, 1859
Family Caligidae Burmeister, 1835
Genus *Caligus* Müller, 1785

Caligus evelynae sp. n.

urn:lsid:zoobank.org:act:40EC2919-0E77-4150-B670-C74AC8C3CD0A
http://species-id.net/wiki/Caligus_evelynae
Figs 1–3

Material examined. Holotype female, collected February 21, 2011 by D. Arocha, D. Querales and F. Cancines, Bay of Amuay, Venezuela. Specimen undissected, ethanol-preserved, vial (ECO-CHZ-07565). Allotype male, same date, collector, and site, undissected, ethanol-preserved, vial (ECO-CHZ-07566).

Type locality. Bay of Amuay, Venezuelan Caribbean, 11°46'32"N, 70°13'51"W, plankton.

Host. Unknown.

Description of female. Body shape as shown in Fig. 1A, with cephalic shield ellipsoidal with curved lateral margins. Total length 2.55 mm, greatest width 1.1 mm (measured at widest part of cephalothorax). Cephalothorax comprises more than half total length (1.33 mm). Genital complex longer than wide (1.2 x 0.71 mm) with irregularly undulated outer margins and rugged ventral and dorsal surfaces; postero-lateral region protruding posteriorly. Abdomen subquadrate, about as long as wide, genital complex approximately 3.4 times longer than abdomen. Caudal rami subrectangular about 1.2 times longer than wide, armed with 3 long terminal, one small outer and one small inner pinnate setae (Fig. 2I). Lunules spaced by the length of about 1.5 times the lunule diameter.

Antennule (Fig. 1C) with the usual structure found in *Caligus*, 2-segmented, proximal segment distinctly longer than distal segment, armed with 22 plumose setae. Distal segment bearing 12 setae (1 of which is subdistal) plus two aesthetascs.

Antenna (Fig. 1D) claw recurved at right angle near tip with small, proximal accessory process; posterior process heavily sclerotized, pointed, but not sharply so. Postantennal process (Fig. 1Eb) sickle-shaped, with rounded tip, with two basal papillae, proximalmost armed with three setae, the other with a single, branched seta. Another papilla with two setae located nearby on sternum.

Maxillule represented by bluntly pointed subtriangular process and basal papilla bearing three small setae (Fig. 1Ea). Maxilla (Figs 1F, G) 2-segmented, brachiform; proximal segment (lacertus) unarmed; distal segment (brachium) slender, with subdistal flabellum on outer margin. Terminal elements, calamus and canna unequally long, the latter about half the length of the former. Maxilliped (Fig. 1H) robust, without protrusions in basal region; subchela about one-half length of basal segment. Terminal claw slightly shorter than shaft, armed with short proximal seta.

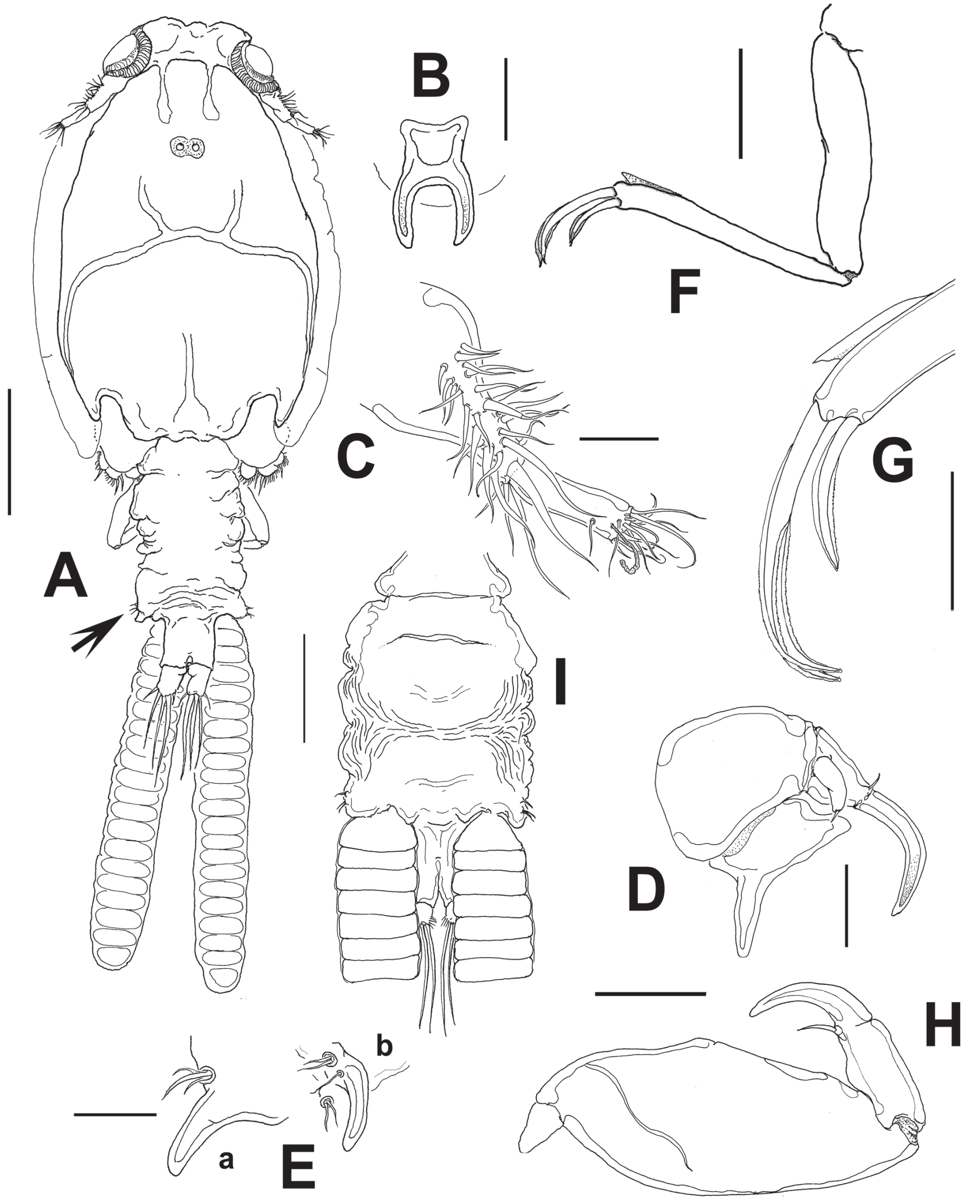

Figure 1. *Caligus evelynae* sp.n., adult female from Venezuela: **A** habitus, dorsal view **B** sternal furca, ventral view **C** antennule **D** antenna **E** postantennal process (**b**) and maxillule (**a**) **F** maxilla **G** detail of calamus and canna **H** maxilliped **I** genital complex and abdomen, ventral view. Scale bars: **A, I**=0.5 mm, **B–F, H** =0.1 mm, **G**=0.05 mm.

Sternal furca (Fig. 1B) tines slightly incurved, membranous on outer margin and longer than base. Leg 1 (Fig. 2A) coxa with patch of very fine spinules in addition to long setulated outer seta and short inner seta. Mammiliform papilla on distal position of seg-

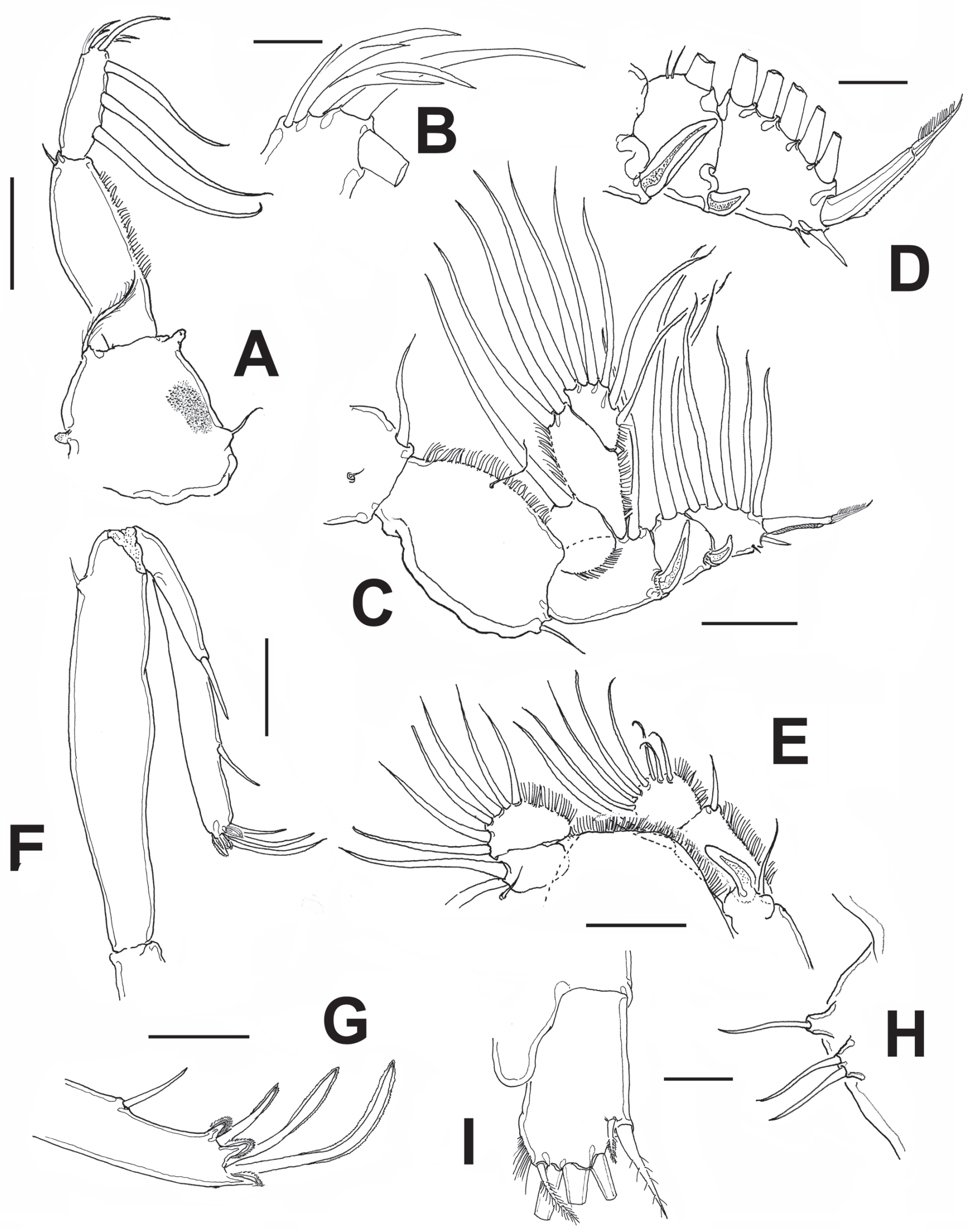

Figure 2. *Caligus evelynae* sp.n., adult female from Venezuela: **A** first leg **B** detail of distal elements of first leg **C** second leg **D** detail of exopodal segments of second leg **E** third leg **F** fourth leg **G** detail of terminal elements of fourth leg **H** fifth leg **I** caudal ramus, dorsal. Scale bars: **A,C, F, E**=0.1 mm, **B, D, G, H, I**=0.025 mm.

ment. First exopodal segment with row of short hair-like elements. Last exopod segment bearing 3 medial pinnate setae and 2 terminal spines, each with accessory process, with additional medial distal seta; usual small seta on outer terminal corner not seen (Fig. 2B).

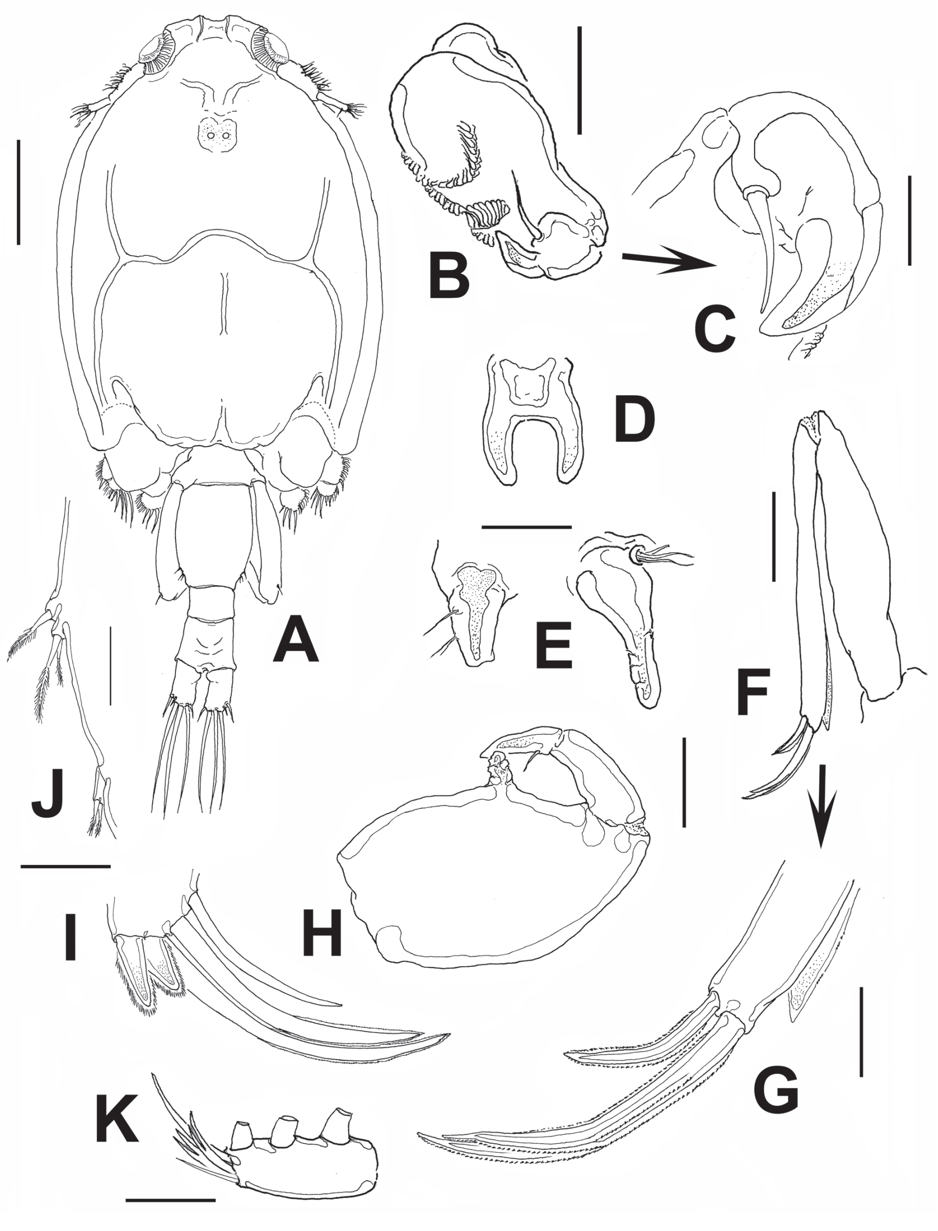

Figure 3. *Caligus evelynae* sp.n., adult male from Venezuela: **A** habitus, dorsal view **B** antenna **C** detail of distal part of antenna **D** sternal furca, ventral view **E** postantennal process and maxillule **F** maxilla **G** detail of calamus and canna **H** maxilliped I fourth leg, detail of distal elements **J** fifth and sixth legs **K** first leg, distal segment of exopod. Scale bars: **A**=0.5 mm, **B,D–F, H**=0.1 mm, **C, G, I, J**=0.03 mm; **K**=0.07 mm.

Leg 2 (Fig. 2C) coxa small, with long plumose seta on inner margin and setule-bearing papilla on middle-outer surface. Basipodite robust, with small seta on outer edge and a setule-bearing papilla on middle inner margin. First exopodal segment bearing spine reaching across second segment to proximal margin of third segment; second segment with much shorter spine recurved on outer margin, spine reaching to middle of last segment. Distal segment with short spine on outer margin plus one short setule. Terminal spine sclerotized, articulated, as long as distal segment (Fig. 2D). All setae on medial margins of all segments pinnate.

Leg 3 (Fig. 2E) exopod first segment with stout, slightly recurved, terminal spine with thin flange on outer lateral margin nearly reaching to third segment; setae as in figure and typical of genus; second endopodal segment with single inner pinnate seta, second segment with 6 pinnate setae.

Leg 4 (Figs 2 F,G) uniramous, brachiform; exopod 2-segmented. Protopod with short plumose seta in distal outer margin. First exopodal segment with terminal seta not reaching base of middle lateral seta of last segment. Second exopodal segment bearing 3 unequally long setae, outermost shortest and medial longest; each with pecten at base.

Armature of rami of legs 1–4 as follows (Roman numerals indicating spines and Arabic numerals, setae):

exopod	endopod	
Leg 1	1-0; III, 4	vestigial
Leg 2	I-1; I-1; II, 5	0-1; 0-2; 6
Leg 3	I-0; I-1; III, 4	0-1; 6
Leg 4	I-0; I, III	absent

Leg 5 represented by two small papillae on posterolateral corner of genital complex, one armed with two setae, the other with one seta (arrowed in Fig. 1A, Fig. 2H).

Description of male. Body (Fig. 3A) larger than female, 3.1 mm long excluding setae on caudal rami. Cephalothoracic shield roughly ovoid in shape, 1.78 mm long and 1.35 mm wide (excluding marginal hyaline membranes: 0.07 mm). Frontal plates well developed and carrying moderately large lunules separated by 1.5 the diameter of a lunule; free margin of thoracic zone projecting slightly beyond tips of lateral zones; sinuses moderately deep. Fourth pediger separated from genital complex, roughly hexagonal in shape, about twice longer than wide. Genital somite subrectangular. Abdomen 1mm long, represented by two somites; proximal somite subquadrate, anal somite distinctly longer than wide. Caudal ramus subrectangular, slightly longer than wide, bearing 3 short (one inner, two outer) setae, and 3 long terminal setae. Inner margin naked.

Antennule as in female.

Antenna (Fig. 3B, C) 3-segmented; proximal segment slender, unarmed, second segment largest, armed with 3 corrugated pads, 1 along inner margin, 2 transverse on outer surface; terminal segment smallest, armed with single basal seta and short, robust hook.

Sternal furca as in female, tines slightly more robust (Fig. 3D). Postantennal process short, distally truncate, armed with one proximal and two medial setae (Fig. 3E).

Maxillule (Fig. 3E) longer than in female, comprising distally blunt dentiform process bearing basal papilla armed with one short and two long setal elements.

Maxilla (Fig. 3F, G) 2-segmented; proximal segment (lacertus) unarmed, slightly shorter than brachium; distal segment (brachium) with subterminal hyaline membrane and two terminal unequal elements (canna about half as long as calamus).

Maxilliped (Fig. 3H) 3-segmented, robust, first segment with medial cylindrical protuberance; second and third segments forming a subchela with subterminal seta.

Leg 1 (Fig. 3K), 2, 3, and 4 as in female, except for relatively shorter outermost terminal claw (Fig. 3I).

Leg 5 (Fig. 3J) located on middle of lateral margin of genital complex, represented by two papillae, one (proximalmost) armed with short seta and the other with two short, slender setae. Leg 6 (Fig. 3J) represented by single papilla armed with two short, pinnate seta.

Etymology. The new species is named after Dr. Evelyn Zoppi de Roa, an esteemed Venezuelan researcher who pioneered much of the zooplankton research in this country and has lead new generations of planktologists during her long career.

Remarks. This species is closely related to other two species of *Caligus* described from the Northwestern tropical Atlantic: *Caligus ocyurus* Cressey, 1991and *C. xystercus* Cressey, 1991, they all share a longer than wide genital complex, a relatively short abdomen, a similar structure and armature of legs 1 with three inner setae on the last segment and four distal elements, two of them with accessory spines. They have also a fourth leg armed with 5 spines; the three terminal spiniform elements are of different lengths, the outermost being longest. Cressey (1991) distinguished *C. ocyurus* from *C. xystercus* by the proportions of the caudal rami and the abdomen; these structures are not longer than wide in *C. xystercus*, as it occurs in *C. ocyurus.* Also, the postantennal process of *C. ocyurus* is much stouter and broader at the tip than in *C. xystercus.* The new species has a postantennal process as in *C. xystercus*, not spatulate or particularly wide distally as in *C. ocyurus*. In *C. xystercus* the caudal rami are equally long as wide and in *C. ocyurus* they are twice as long as they are wide, whereas they are 1.5 times longer than wide in *C. evelynae*. The new species shares with *C. ocyurus* a claw-like terminal segment of the male antenna, a relatively short outermost distal seta of the second exopodal segment of leg 1, and the female is smaller than the male. The new species can be readily distinguished from *C. ocyurus* by the shape of the cephalothoracic shield, which is clearly ellipsoidal with curved lateral margins in *C. evelynae* sp. n. (see Fig. 1A) and it is rectangular with straight lateral margins in *C. ocyurus* (Cressey 1991, fig. 127). In *C. evelynae* sp. n., the basipodal segment of leg 1 lacks a large medial protuberance present in *C. ocyurus* (Cressey 1991, fig. 131). The sternal furca is clearly different in both species; tines are straight, relatively long, widely separated, and distally tapered in *C. ocyurus* (Cressey 1991, fig. 130) whereas they are shorter, more robust, incurved and distally rounded in *C. evelynae*. The maxillule is slender in the new species vs. a stronger, more robust condition in *C. ocyurus* (Cressey 1991, fig. 129c). The armature of leg 4 is different; distal elements differ in length and proportion in both species; the size of the short outermost element is about 1/3 the length of the medial element, which in turn is about half the length of the innermost element; this pattern differs in *C. evelynae* sp. n., in which the shortest element is about half the length of the medial one and this is about 0.75 times as long as the innermost element. In *C. ocyurus* the male genital somite is as long as wide, with protuberant lateral margins (Cressey 1991, fig. 135), whereas in the new species this somite is longer than wide with weakly produced lateral margins. The male antenna is described as bifid by Cressey (1991) and it is not bifid in the new species. Also, the size and position of the pads differ in the new species (see Fig. 3B vs Cressey 1991, fig. 136); particularly, the new species has a longitudinal adhesion pad along the inner margin whereas this margin is smooth in *C. ocyurus* (Cressey 1991, fig. 136).

Following Cressey's (1991) criteria, these three species can be separated from the other known *Caligus* species of the Gulf of Mexico and Caribbean Sea by the following characters. The structure and armature of the exopod of the fourth leg with a 2-segmented exopod bearing 5 spines is a character shared by at least 11 species of the genus in this region (Cressey 1991). This group of species can be distinguished from C. *asperimanus* Pearse, 1951*, C. berychis* Wilson, 1935*, C. bonito* Wilson, 1905*, C. haemulonis* Krøyer, 1863*, C. mutabilis* Wilson, 1905, and C. *suffuscus* Wilson, 1913 in having short setules along the outer margin of the second leg endopod instead of patches of spinules. This group of species can be distinguished from the remaining 6 other species with setules on the second leg endopodal segments as follows: the female *C. chelifer* Wilson, 1905 has a 2-segmented abdomen and very short lateral setae on the exopod of leg 1, vs. a 1-segmented female abdomen and relatively longer setae on the leg 1 exopod; *C. praetextus* Bere, 1936 bears unique "hooded" distal spines on the exopod of leg 1, and two of the terminal elements of leg 4 are equally long, about half the length of the inner element, *C. afurcatus* Wilson, 1913 has also two equal terminal elements on leg 4, reduced caudal rami, relatively short lateral seta of the distal exopodal segment of leg 1, a reduced sternal furca, and a relatively long outer spine on the first exopodal segment of leg 2; in C. *rufimaculatus* Wilson, 1905 the sternal furca tines are clearly spatulate, with an enlarged distal margin, caudal rami only slightly longer than wide, *C. productus* Dana, 1852 lacks medial lateral setae on leg 1 and has no accessory spines on leg 1 exopod.

Overall, the main character distinguishing the new species, *C. evelynae*, is the peculiarly strong, irregular undulation of the genital complex; another species with a genital complex bearing undulated margins reported in the region is *C. undulatus* Shen and Li, 1959 (Suárez-Morales et al. in press), but in this species the first leg has a different armature, with four distal elements, the genital complex is trapezoidal vs. a subrectangular shape in the new species; the abdomen is shorter in *C. evelynae* (30% length of genital complex), whereas in *C. undulatus* the abdomen is clearly longer (67%). Also, undulation in *C. undulatus* is relatively shallow and regular, contrasting with the pattern found in *C. evelynae*. This species was originally described from specimens in plankton samples from China (Shen and Li 1959) and has been recorded only from the water column, hosts remain unknown (Venmathi Maran and Ohtsuka 2008). Other species of *Caligus* with an undulate or rugose genital complex are *C. lobodes* (Wilson, 1911) and *C. rugosus* Shiino, 1959. The new species differs from the former in the body shape, which is quite different, the genital complex is trapezoidal and the abdomen is as wide as the genital complex; lobes are symmetrical, lunules are widely separated from each other and it has a forked maxillular process (Wilson 1911), thus differing from the pattern described for *C. evelynae*. In *C. rugosus* the genital complex is also irregularly lobulated but it is produced posteriorly, forming large posterolateral processes which are absent in the new species. Also, the sternal furca has very wide, wing-like tines (Shiino 1959, fig. 1G) *vs.* regular, slender tines in *C. evelynae*.

It is interesting to point out that these three very similar species of *Caligus* (*C. xystercus*, *C. ocyurus*, *C. evelynae*) appear to be restricted to the Northwestern Atlantic (Cressey 1991) following the pattern described by Ho and Lin (2003) in reference to another group of Old World species of *Caligus* with a well-defined geographic affinity. This criterion motivated their revision of New World records of these Old World species and the naming of a new species from the Caribbean Sea, which was formerly identified as *C. epinepheli* Yamaguti, 1936 by Cressey (1991). Hence, it appears that this group of related species from the Gulf and the Caribbean basins, in which we include also *C. rufimaculatus*, are probably restricted to this region. Based on the available data, there are about 31 nominal species of *Caligus* known in the Gulf of Mexico and the Caribbean (Wilson 1913; Cressey 1991; Bunkley-Williams and Williams 1994; Álvarez-León 2009; Suárez-Morales et al. 1998, 2003, in press). Only a few of them are known to be restricted to this geographic region, including *C. xystercus*, *C. ocyurus*, *C. kabatae* Cressey, 1991, *C. pomacentrus* Cressey, 1991, *C. cresseyi* Ho and Lin, 2003, and probably the new species, *C. evelynae*. More taxonomical surveys are yet to be developed in order to reveal more of the potentially highly diverse caligid fauna in the region.

Key to the species of *Caligus* recorded from Venezuela (females)

1	Leg 4 exopod with three segments	**2**
–	Leg 4 exopod with two segments	**4**
2	Abdomen more than three times as long as cephalothoracic shield	***C. bennetti* Causey, 1953**
–	Abdomen about as long as or slightly longer than cephalothoracic shield	**3**
3	Inner margin of second exopodal segment of leg 1 with three short setal elements, without postero-lateral process on genital complex	***C. chorinemi* Krøyer, 1863**
–	Inner margin of second exopodal segment of leg 1 unarmed; rounded, strongly developed postero-lateral processes on genital complex	***C. productus* Dana, 1852**
4	Abdomen one segmented	**5**
–	Abdomen two or three-segmented	**10**
5	Abdomen short, about 0.2 times as long as genital complex	***C. atromaculatus* Wilson, 1913**
–	Abdomen not as short	**6**

6 Abdomen about 0.6 times as long as genital complex, without postero-lateral processes on genital complex...**7**

– Abdomen as long as genital complex (or even longer), with strongly protruding postero-lateral processes on genital complex...... ***C. bonito*** **Wilson, 1905**

7 Inner margin of second endopodal segment of leg 2 armed with short, slender setae...**8**

– Inner margin of second endopodal segment of leg 2 armed with tooth-like elements.. ***C. asperimanus*** **Pearse, 1951**

8 Genital complex rugose, with undulate lateral margins ......***C. evelynae*** **sp.n.**

– Genital complex differently built **9**

9 Middle two of the terminal elements of leg 1 with accessory process.. ***C. rufimaculatus*** **Wilson, 1905**

– Middle two of the terminal elements of leg 1 without accessory process.. ***C. constrictus*** **Heller, 1865**

10 Abdomen three-segmented.......***C. coryphaenae*** **Steenstrup & Lütken, 1861**

– Abdomen two-segmented **11**

11 Claws of leg 4 decreasing in length from the inner to outer margin, inner setae of distal exopodal segment of leg armed with spines .... ***C. mutabilis*** **Wilson, 1905**

– Claws of leg 4 with middle and outer elements being equally long and about half the length of inner claw, inner setae of distal exopodal segment of leg setulated ....***C. irritans*** **Heller, 1865**

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References

Álvarez-León R (2009) Asociaciones y patologías en los crustáceos dulceacuícolas, estuarinos y marinos de Colombia: aguas libres y controladas. Revista de la Academia Colombiana de Ciencias 33: 129–144.

Boxshall GA, Halsey SH (2004) An Introduction to Copepod Diversity. The Ray Society, London, 966 pp.

Bunkley-Williams L, Williams EH Jr (1994) Parasites of Puerto Rican Freshwater Sport Fishes. Puerto Rico Department of Natural and Environmental Resources, San Juan, PR and Department of Marine Sciences, University of Puerto Rico, Mayaguez, PR, 168 pp.

Cressey R (1991) Parasitic copepods from the Gulf of Mexico and Caribbean Sea. III. *Caligus*. Smithsonian Contributions to Zoology 497: 1–53. doi: 10.5479/si.00810282.497

Díaz Díaz O (2000) Copépodos ectoparásitos del pez luna *Mola mola* (Giglioli, 1883) (Pisces: Molidae) en el Golfo de Cariaco, Venezuela. Boletín del Instituto Oceanográfico de la Universidad de Oriente, Cumaná 39: 11–17.

Ho JS, Bashirullah AKM (1977) Two species of caligid copepods (Crustacea) parasitic on marine fishes of Venezuela, with discussion of *Metacaligus* Thomsen, 1949. Journal of Natural History 11: 703–714. doi: 10.1080/00222937700770601

Ho JS, Lin CL (2003) Solution to the taxonomic confusion surrounding *Caligus epinepheli* Yamaguti, a caligid copepod (Siphonostomatoida) parasitic on marine fishes. Zoological Studies 42: 268–283.

Ho JS, Lin CL (2004) Sea Lice of Taiwan (Copepoda: Siphonostomatoida: Caligidae). The Sueichan Press, Keelung, 388 pp.

Legarde PG (1989) Crustáceos parásitos en peces marinos de la zona central de Venezuela. Boletín del Instituto Oceanográfico de la Universidad de Oriente, Cumaná 28: 135–144.

Luque JL, Poulin R (2007). Metazoan parasite species richness in Neotropical fishes: hotspots and the geography of biodiversity. Parasitology 134: 865–878. doi: 10.1017/S0031182007002272

Pomares Ferraz O, Leal I, Rengel J, Morán H, Jurado J (2008) Evaluación de las causas de un evento de mortalidad masiva de moluscos bivalvos en la Bahía de Amuay, Venezuela. Revista de Investigaciones Marinas 29(2): 131–144.

Shen CJ, Li HL (1959) Parasitic copepods from fishes of China. IV. Caligoida, Caligidae (3). Acta Zoologica Sinica 11: 12–20.

Shiino SM (1959) Ostpazifische parasitierende Copepoden. Reports of the Faculty of Fisheries of the Prefectural University of Mie 3: 267–333.

Suárez-Morales E, Kim IH, López-Salgado I (1998) An illustrated record and range extension of *Caligus chelifer* (Copepoda, Siphonostomatoida) in the Gulf of Mexico. Gulf Research Reports 10: 57–60.

Suárez-Morales E, Kim IH, Escamilla-Sánchez JB (2003) An illustrated record and complementary description of *Caligus rufimaculatus*Wilson (Copepoda, Siphonostomatoida) from Mexico. Caribbean Journal of Science 39: 151–154.

Suárez-Morales E, Kim IH, Escamilla JB (in press) On some caligids (Copepoda, Caligidae) from the plankton of a coastal lagoon of the Gulf of Mexico with description of a new species of *Metacaligus*. Zoological Studies 51.

Venmathi Maran BA, Ohtsuka S (2008) Descriptions of caligiform copepods in plankton samples collected from East Asia: accidental occurrences or a new mode of life cycles? Plankton Benthos Research 3: 202–215. doi: 10.3800/pbr.3.202

Williams EH Jr, Bunkley-Williams L (1996) Parasites of offshore big game fishes of Puerto Rico and the western Atlantic. Puerto Rico Dept. of Natural and Environmental Resources, San Juan, PR, and University of Puerto Rico, Mayaguez, PR, 382 pp.

Wilson CB (1913) Crustacean parasites of West Indian fishes and land crabs, with descriptions of new genera and species. Proceedings of the US National Museum 44: 189–277. doi: 10.5479/si.00963801.44-1950.189

Zambrano JLF, Rojas CS, León YR (2003) Parásitos en juveniles de *Lutjanus griseus* de la Laguna de la Restinga, Isla de Margarita, Venezuela. Interciencia 28: 463–468.