ZooKeys 119: 1–10 (2011)
doi: 10.3897/zookeys.119.1501
www.zookeys.org

RESEARCH ARTICLE

A peer-reviewed open-access journal
ZooKeys
Launched to accelerate biodiversity research

Holotype redescription of *Mimobdella japonica* (Hirudinida, Arhynchobdellida, Erpobdelliformes) and taxonomic status of the genus *Mimobdella*

Takafumi Nakano

Department of Zoology, Graduate School of Science, Kyoto University, Kyoto 606-8502, Japan

Corresponding author: *Takafumi Nakano* (nakano@zoo.zool.kyoto-u.ac.jp)

Academic editor: *Robert Blakemore* | Received 11 May 2011 | Accepted 4 July 2011 | Published 15 July 2011

Citation: Nakano T (2011) Holotype redescription of *Mimobdella japonica* (Hirudinida, Arhynchobdellida, Erpobdelliformes) and taxonomic status of the genus *Mimobdella*. ZooKeys 119: 1–10. doi: 10.3897/zookeys.119.1501

Abstract

Mimobdella japonica Blanchard, 1897, the type species of the genus *Mimobdella* Blanchard, 1897, is redescribed based on the holotype. This species is characterized by the following characteristics: mid-body somites novem-annulate, two post-anal annuli, male gonopore in XI/XII, female gonopore in XII/XIII, 9 annuli (one full somite) between gonopores, strepsilaematous pharynx and three myognaths with stylets, possessing post-crop caeca in pairs, ovisacs reaching to XXI a2. The genus *Mimobdella* is placed under the family Salifidae, not Gastrostomobdellidae or Erpobdellidae, according to its possessing three myognaths bearing pharyngeal stylets.

Keywords

Hirudinida, Salifidae, *Mimobdella japonica*, holotype, post-crop caecum, Japan

Introduction

Mimobdella Blanchard, 1897 was originally erected under Herpobdellidae, which is a junior synonym of Erpobdellidae, for macrophagous leeches in Asia without the type species designation (Blanchard 1897). The genus was diagnosed by mid-body somite novem-annulate or septannulate. However, its internal diagnostic characters were not described. Later, Soós (1966) designated *M. japonica* Blanchard, 1897 as the type species of the genus, and also included *Mimobdella* in Erpobdellidae. In Sawyer (1986), however, the genus was placed in the subfamily Gastrostomobdellinae along with *Gastrostomobdella* Moore, 1929, and *Orobdella* Oka, 1895. Gastrostomobdellinae was originally established as the family Gastrostomobdellidae for the two genera,

Gastrostomobdella and *Orobdella* by Richardson (1971). The subfamily belonged to Cylicobdellidae under Hirudiniformes in Sawyer (1986), but has been recently classified as the family under Erpobdelliformes based on the molecular phylogenetic study (Oceguera-Figueroa et al. 2011). Erpobdellidae, Gastrostomobdellidae and Salifidae belong to Erpobdelliformes in their study.

The family Gastrostomobdellidae is characterized by an agnath, euthylaematous pharynx, gastropore and gastroporal duct, whereas Erpobdellidae is characterized by an agnath and strepsilaematous pharynx, and Salifidae is characterized by three myognaths, pharyngeal stylets, and strepsilaematous pharynx (Richardson 1971, Sawyer 1986). It is already clear that leeches of the genera *Gastrostomobdella* and *Orobdella* have the gastrostomobdellid internal characters (Moore 1929, 1935, 1946, Nakano 2010, 2011, Richardson 1971, 1975). However, it is uncertain whether the genus *Mimobdella* belongs to Gastrostomobdellidae, since the internal morphology of the three *Mimobdella* species remains unknown. Therefore, it is urgently needed to reveal the internal anatomy of the type species, *M. japonica*, and clarify the taxonomic position of the genus.

In the original publication about *Mimobdella japonica*, Blanchard (1897) mentioned two specimens without the type designation. One was collected from Japan by Siebold, and was deposited in the National Museum of Natural History Naturalis (Musée de Leyde in his paper). The other one was collected from Nikko, Japan, and was deposited in the Museum für Naturkunde (Musée de Berlin) (Neuhaus pers. com.). The position of the gonopores of the former is different from that of the latter. However, Blanchard gave the diagnosis of *M. japonica* based only on the specimen deposited in the Naturalis (Blanchard 1897: 94). Therefore, the specimen stored in the Naturalis is the holotype for *M. japonica* fixed by monotypy according to Article 73.1.2 of the Code (International Commisson on Zoological Nomenclature 1999).

After its original description was published, this species was redescribed based on other specimens collected from various places in Japan (Oka 1910a, b, 1917, 1923). Oka (1923) noted that *M. japonica* possesses a strepsilaematous pharynx without stylets in the oral cavity. However, the position of the female gonopore in Oka's description (Oka 1923: fig. 1) differs from that in the original description (Blanchard 1897: pl. 6, fig. 16). Thus, there is a possibility that the description of *M. japonica* in Oka (1923) was based on misidentified specimens. However, his description of *M. japonica* was followed in Yang (1996) without any comment on this taxonomic problem. The type series of *M. japonica* thus should be reexamined.

In this paper, the systematic position of the genus *Mimobdella* is determined according to an evaluation of the internal morphology of its type species, *Mimobdella japonica*. The holotype of *M. japonica* is redescribed herein.

Material and methods

I examined one specimen of *Mimobdella japonica*: RMNH.VER.650, holotype, deposited in the National Museum of Natural History Naturalis (RMNH). Two measure-

ments were taken: body length (BL) from the anterior margin of the oral sucker to the posterior margin of the caudal sucker, and maximum body width (BW). Examination, dissection, and drawing of the specimens were accomplished under a stereoscopic microscope with a drawing tube (Leica M125). Numbering conventions are based on Moore (1927): body somites are denoted by Roman numerals and annuli in each somite are given alphanumeric designations.

Taxonomy

Erpobdelliformes Sawyer, 1986
Salifidae Johansson, 1910

***Mimobdella* Blanchard, 1897**
http://species-id.net/wiki/Mimobdella

Type species. *Mimobdella japonica* Blanchard, 1897

Emended diagnosis. Mid-body somites novem-annulate, c1 = c2 < b2 < a2 > c9 = c10 = d21 = d22 < c12. Post-anal annulus present. Pharynx strepsilaematous, with three myognaths separated by triangular papragnaths; each myognath bearing stylets in pairs arranged in tandem. Testisacs multiple. Accessory copulatory pit and gastopore absent.

Remarks. Sawyer (1986) placed three species, *M. japonica*, *M. buttikoferi* Blanchard, 1897, and *M. thienemani* Augener, 1931, under the genus *Mimobdella*. However, Blanchard (1897) described that *M. buttikoferi* does not possess paragnaths (pseudognaths in his paper). Augener (1931) described that the mid-body somites annulation of *M. thienemani* is sexannulate (two large and four short annuli). Their external features do not match the generic diagnostic characters according to the type species. In addition, the internal morphology of the two species has not been reported. Thus, it is questionable whether those two species, *M. buttikoferi* and *M. thienemani*, belong to this genus. Therefore, only one species, *M. japonica*, is certainly included in *Mimobdella*.

***Mimobdella japonica* Blanchard, 1897**
http://species-id.net/wiki/Mimobdella_japonica
Figs 1–4

Mimobdella japonica Blanchard, 1897: 94–95, pl. 6, figs. 16, 17.

Diagnosis. Mid-body somites novem-annulate, generally c1 = c2 < b2 < a2 > c9 = c10 = d21 = d22 < c12. Anus at 172th (antepenultimate)/173th (penultimate) annuli with two post-anal annuli. Post-crop caeca in pairs in XXI c2–c10. Male gonopore at XI/

XII. Female gonopore at XII/XIII. Gonopores separated by 9 annuli (one full somite). Sperm duct reaching to XVI b1. Ovisacs reaching XXI a2.

Material examined. RMNH.VER.650. **Holotype**, slightly contracted specimen, dissected, collected from Japan by P. F. von Siebold.

Description of holotype. Body firm, muscular, gaining regularly in width in caudal direction, dorso-ventrally, depressed, BL 63.0 mm, BW 7.0 mm (Fig. 1). Caudal sucker, ventral, oval, its diameter equal to half of BW (Figs. 1, 2D). Color in life unknown.

Annulation of somites I–VII undecidable, comprised of 17 annuli; 14th annulus with obvious furrow on dorsal, 17th annuli with obvious furrow on dorsal and slight furrow on ventral; 10th and 11th annuli united on venter, forming posterior margin of oral sucker (Fig. 2A, B). Somite VIII sexannulate, b1 (c1, c2 on dorsal) > b2 < a2 < b5 (c9, c10) > c11 (d21, d22) > c12; b2, b5 and c11 with obvious furrow on dorsal and slight furrow on ventral (Fig. 2A, B). Somite IX novem-annulate, c1 = c2 < b2 < a2 > c9 = c10 = d21 = d22 < c12; furrows of c9/c10 and d21/d22 shallower than others. Somites X–XXIIII novem-annulate, generally c1 = c2 < b2 < a2 > c9 = c10 = d21 = d22 < c12 (Fig. 2E); each of b2 of somites XVII–XXIII and a2 of somites XVIII–XXIII with slight furrow; c9 of X being first annulus of clitellum, a2 of XIII being last annulus of clitellum. Somite XXIV octannulate, c1=c2=b2<a2 (b3, b4 on dorsal)>c9=c10<c11 (d21, d22)>c12; a2 with slight furrow on dorsal, c11 with slight furrow (Fig. 2C, D). Annulation of somites XXV–XXVII undecidable, comprised of 8 (167th–174th) annuli, 167th annulus with slight furrow, 172th annulus being last complete annulus on venter (Fig. 2C, D); anus at 172th (antepenultimate)/173th (penultimate) annuli with two post-anal annuli (Fig. 2D).

Anterior ganglionic mass in 13th and 14th annuli. Ganglion VII in 17th annulus. Ganglion VIII in a2 and b5. Ganglia IX–XXIV in a2 of each somite (Fig. 3A). Ganglion XXVI in 169th annulus. Posterior ganglionic mass in 170th–172th annuli.

Figure 1. *Mimobdella japonica* Blanchard, holotype, RMNH.VER.650 **A** Dorsal and **B** ventral view. Scale bar, 5 mm.

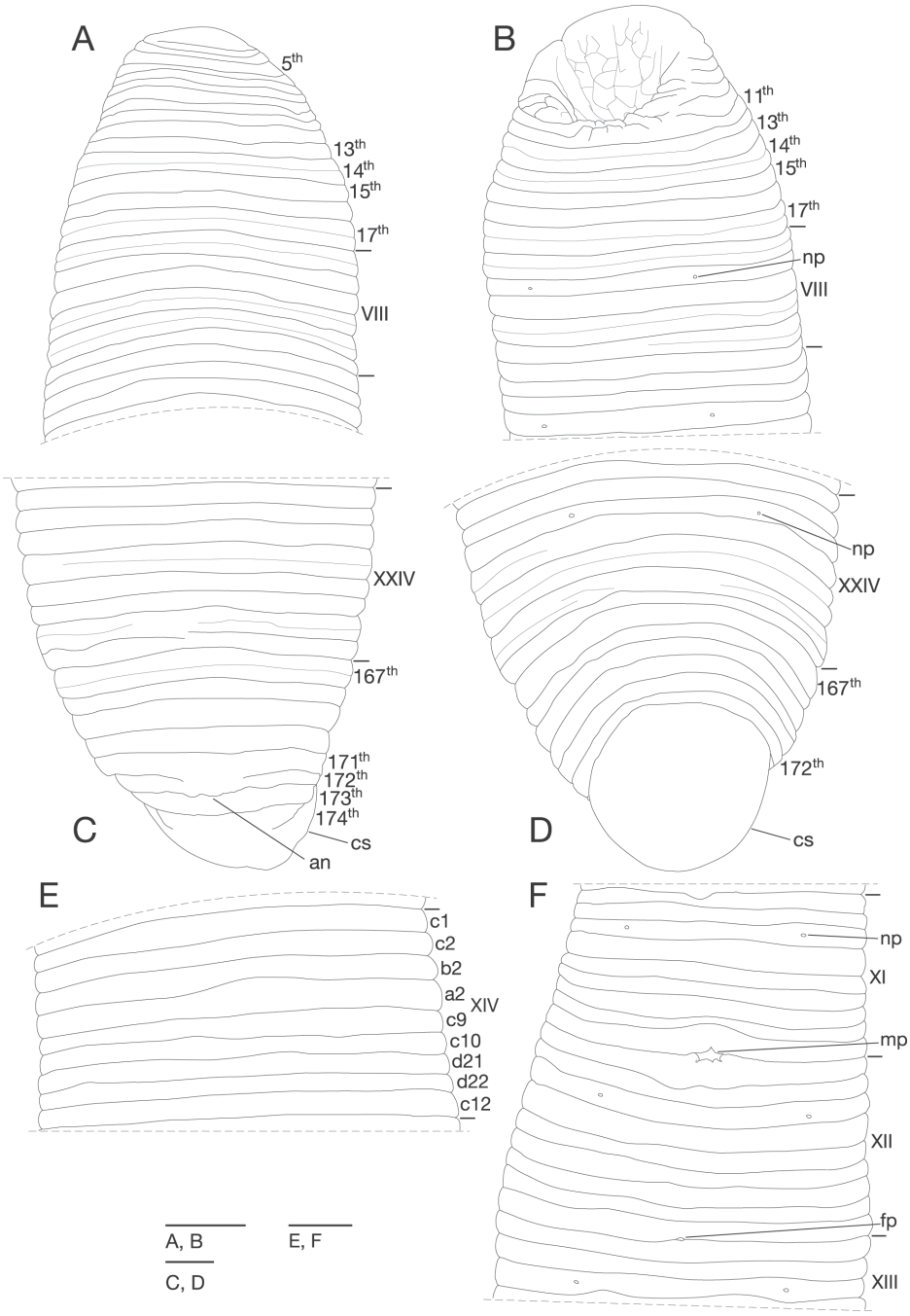


Figure 2. *Mimobdella japonica* Blanchard, holotype, RMNH.VER.650 **A** Dorsal view of somites I–IX b2 **B** ventral view of somites I–IX b2 **C** dorsal view of somites XXIV–XXVII and caudal sucker **D** ventral view of somites XXIV–XXVII and caudal sucker **E** dorsal view of somite XIV **F** ventral view of somites XI–XIII b2. Abbreviations: an, anus; cs, caudal sucker; fp, female gonopore; mp, male gonopore; np, nephridiopore. Scale bars, 1 mm.

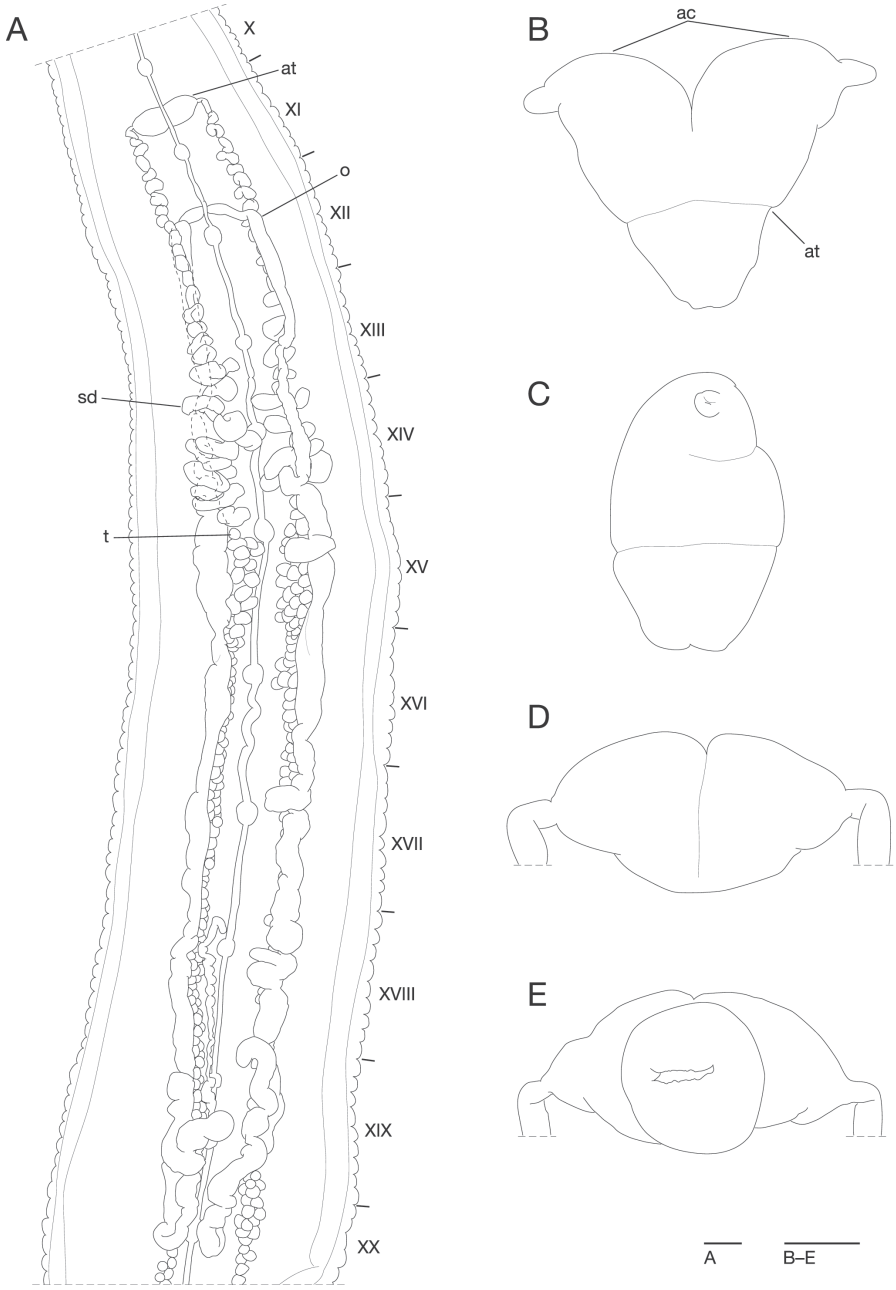


Figure 3. *Mimobdella japonica* Blanchard, holotype, RMNH.VER.650 **A** Dorsal view of reproductive system including ventral nervous system **B** frontal view of male atrium **C** lateral view of male atrium **D** dorsal view of male atrium **E** ventral view of male atrium. Abbreviations: ac, atrial cornu; at, atrium; o, ovisac; sd, sperm duct; t, testisac. Scale bars, 1 mm (A) and 0.5 mm (B–E).

Eyes undetectable. Nephridiopores in 17 pairs in VIII–XXIV, located ventrally at middle of b2 of each somite (Fig. 2B, D, F). Papillae numerous, minute, hardly visible, one row on each annulus.

Pharynx strepsilaematous, reaching to XIV c10/d21, with three myognaths separated by triangular papragnaths (Fig. 4A); each myognath bearing two conic stylets arranged in tandem, parallel to body axis (Fig. 4A). Crop tubular, reaching to XXI a2; post-crop caeca thin-walled, in pairs in XXI c2–c10 (Fig. 4B). Intestine tubular, acaecate, reaching to XIII a2. Rectum tubular, thin-walled.

Male gonopore at XI/XII (Fig. 2F). Female gonopore at XII/XIII (Fig. 2F). Gonopores separated by 9 annuli (Fig. 2F). Testisacs multiple in XVI c2 to 169th annulus, several testisacs on each side in each annulus (Fig. 3A). Sperm ducts in XII c1 to XVI b1, coiled, narrowing at junction with atrial cornu, then turning gently inward toward atrial cornu without pre-atrial loop (Fig. 3A, D, E). Atrium short, muscular with atrial cornu in pairs in XI c12 and XII c1; atrial cornu, curved laterad (Fig. 3B–E). Ovisacs long, slightly folded, tubular in XIII c1 to XXI a2; right ovisac turned anteriorly in XXI a2, reaching to XIX/XX; left ovisac also turned anteriorly in XXI a2, reaching to XIX b2; both ovisacs converged in XIII c1, directly descending to female gonopore (Fig. 3A).

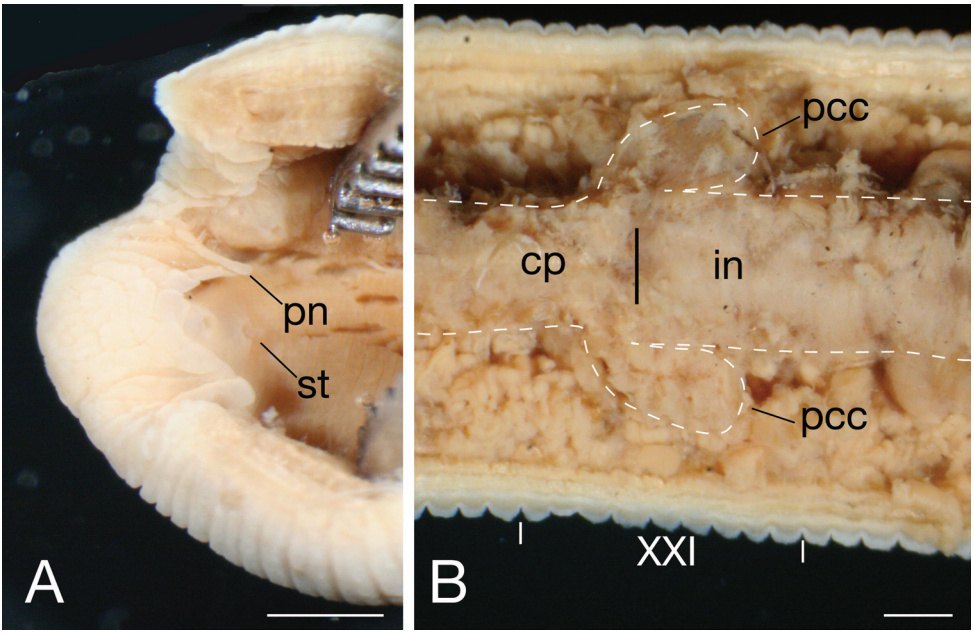


Figure 4. *Mimobdella japonica* Blanchard, holotype, RMNH.VER.6500 **A** ventral view of oral cavity **B** ventral view of junction of crop with intestine. Abbreviations: cp, crop; in, intestine; pcc, post-crop caecum; pn, paragnath; st, stylet. Scale bars, 1 mm.

Discussion

According to the possession of a strepsilaematous pharynx and three myognaths with stylets by the holotype of *Mimobdella japonica*, the genus *Mimobdella* is placed under the family Salifidae, not Gastrostomobdellidae with euthylaematous and agnathous pharynx, or Erpobdellidae with strepsilaematous and agnathous pharynx. The genus *Mimobdella* differs from the other salifid genera in the following combination of characters: 1) mid-body somite novem-annulate; 2) testisacs multiple; and 3) accessory copulatory pit and gastropore absent. In addition to those characteristics, *Mimobdella japonica* possesses rudimentary post-crop caeca in pairs. In the family Salifidae, two leeches of the genus *Barbronia* Johansson, 1918, have been known as possessors of post-crop caeca: *Barbronia arcana* (Richardson, 1970); and *Barbronia assiuti* Hussein and El-Shimy, 1982 (El-Shimy 1996, Hussein and El-Shimy 1982, Richardson 1970). However, the other *Barbronia* species does not bear a crop caecum (Sawyer 1986). On account of the *Barbronia* case, it is uncertain whether post-crop caeca could be treated as a diagnostic character of the genus *Mimobdella*.

The type locality of *Mimobdella japonica* is noted only as Japan on its label and could not be defined further. However, characteristics of two salifid specimens collected from Amamioshima Island, the Ryukyu Archipelago, Japan, are coincident with those of the holotype of *M. japonica* (Nakano pers. obs.). The other large salifid leeches collected from various places in Japan are not identified as *M. japonica* (Nakano pers. obs.). Therefore, there is a possibility that Amamioshima Island is the type locality of this species. However, field surveys are insufficient to determine the island as the type locality.

In accordance with clarifying the taxonomic position of the genus *Mimobdella*, taxonomic relationships between *Mimobdella* and *Odontobdella* Oka, 1923, should be reconsidered. The genus *Odontobdella* belongs to Salifidae according to the description of its type species, *Odontobdella blanchardi* (Oka, 1910) in Oka (1923) (Sawyer 1986). In his paper, Oka noted that *Odontobdella blanchardi* could be distinguished from *Mimobdella japonica* by the presence of pharyngeal stylets although both *M. japonica* and *Od. blanchardi* possess novem-annulate mid-body somites. He concluded that *Mimobdella* and *Odontobdella*, should be treated as distinct genera. His conclusion has been followed in the major taoxonomic works (Sawyer 1986, Soós 1966, Yang 1996). However, the taxonomic status of *Odontobdella* should be reconfirmed, since *Mimobdella japonica* possesses pharyngeal stylets. In addition, *Odontobdella blanchardi* collected from Japan have post-crop caeca, as does *M. japonica* (Nakano pers. obs.), in contrast to several descriptions of *Odontobdella* species (Lai and Chen 2010, Moore 1930, Nesemann 1995, Oka 1923, Yang 1996). Therefore, the type series and topotypes of *Od. blanchardi* should be reexamined to clarify the taxonomic status of the species and genus. There is a possibility that *Odontobdella* will be considered to be a junior synonym of *Mimobdella*. Further faunal surveys and examination of salifid leeches from East Asia will be needed to clarify the type locality of *M. japonica* and reveal the taxonomic relationships between *Mimobdella* and *Odontobdella*.

Acknowledgments

The author is most grateful to Caroline Pepermans (RMNH) and Koos van Egmond (RMNH) for allowing me to examine the holotype of *M. japonica* under their care, and to Professor Tsutomu Hikida (Kyoto University) for his helpful comments and suggestions to improve this manuscript. I am also grateful to Dr Birger Neuhaus (Museum für Naturkunde) for the information about the *Mimobdella* specimen under his care, to Dr Elizabeth Nakajima (Kyoto University) for checking the English of this text, to two anonymous reviewers and Dr Robert J. Blakemore (National Museum of Nature and Science, Tokyo) for their constructive comments on this manuscript, and to Kazuki Kurita for his help in collecting specimens in the field. This study was financially supported in part by a Grant-in-Aid for Biodiversity and Evolutionary Research of Global COE (A06) from MEXT, Japan, to Kyoto University.

References

Augener H (1931) Hirudinea der Deutschen Limnologischen Sunda-Expedition. Archiv fuer Hydrobiologie Supplement 8: 733–758.

Blanchard R (1897) Hirudinées du Musée de Leyde. Notes from the Leyden Museum 19: 73–113.

El-Shimy NA (1996) Revision of the genus *Barbronia* Johansson, 1918 (Hirudinea: Erpobdelliformes: Barbronidae) in Egypt. Zoology in the Middle East 12: 99–104.

Hussein MA, El-Shimy NA (1982) Description of *Barbronia assiuti* n.sp. (Hirudinea) from Assiut, Egypt. Hydrobiologia 94: 17-24. doi: 10.1007/BF00008630

International Commisson on Zoological Nomenclature (1999) International Code of Zoological Nomenclature. International Trust for Zoological Nomenclature, London, 306 pp.

Lai Y-T, Chen J-H (2010) Leech Fauna of Taiwan. National Taiwan University Press, Taipei, 118 pp.

Moore JP (1927) The segmentation (metamerism and annulation) of the Hirudinea. In: Harding WA, Moore JP. The Fauna of British India, including Ceylon and Burma Hirudinea. Taylor and Francis, London, 1–12.

Moore JP (1929) Leeches from Borneo with descriptions of new species. Proceedings of the Academy of Natural Sciences of Philadelphia 81: 267–295.

Moore JP (1930) Leeches (Hirudinea) from China with descriptions of new species. Proceedings of the Academy of Natural Sciences of Philadelphia 82: 169-192.

Moore JP (1935) Leeches from Borneo and the Malay Peninsula. Bulletin of the Raffles Museum 10: 67–79.

Moore JP (1946) Leeches (Hirudinea) from the Hawaiian Islands, and two new species from the Pacific region in the Bishop Museum Collection. Occasional Papers Bernice P Bishop Museum 18: 171–191.

Nakano T (2010) A new species of the genus *Orobdella* (Hirudinida: Arhynchobdellida: Gastrostomobdellidae) from Kumamoto, Japan, and a redescription of *O. whitmani* with the designation of the lectotype. Zoological Science 27: 880–887. doi: 10.2108/zsj.27.880

Nakano T (2011) A new species of *Orobdella* (Hirudinida: Arhynchobdellida: Gastrostomobdellidae) from Tsushima Island, Japan. Species Diversity 16: 39–47.

Nesemann H (1995) On the morphology and taxonomy of the Asian leeches (Hirudinea: Erpobdellidae, Salifidae). Acta Zoologica Academiae Scientiarum Hungaricae 41: 165–182.

Oceguera-Figueroa A, Phillips AJ, Pacheco-Chaves B, Reeves WK, Siddall ME (2011) Phylogeny of macrophagous leeches (Hirudinea, Clitellata) based on molecular data and evaluation of the barcoding locus. Zoologica Scripta 40: 194–203.

Oka A (1910a) Key to leeches from Japan. Doubutsugaku Zasshi 22: 56–64.

Oka A (1910b) Synopsis der Japanischen Hirudineen, mit Diagnosen der Neuen Species. Annotationes Zoologicae Japonenses 7: 165–183.

Oka A (1917) Zoological result of a tour in the Far East. Hirudinea. Memoirs of the Asiatic Society of Bengal 6: 157–176.

Oka A (1923) Sur les deux genres *Mimobdella* Blanchard et *Odontobdella* nov. gen. Annotationes Zoologicae Japonenses 10: 243-252.

Richardson LR (1970) A new Australian "*Dineta*/*Barbronia*-like" leech, and related matters (Hirudinoidea: ? Erpobdellidae). Proceedings of the Linnean Society of New South Wales 95: 221–231.

Richardson LR (1971) Gastrostomobdellidae f. nov. and a new genus for the gastroporous *Orobdella octonaria* Oka, 1895, of Japan (Hirudinoidea: Arhynchobdellae). Bulletin of the National Science Museum (Tokyo) 14: 585–602.

Richardson LR (1975) A new species of terricolous leeches in Japan (Gastrostomobdellidae, *Orobdella*). Bulletin of the National Science Museum Series A (Zoology) 1: 39–56.

Sawyer RT (1986) Leech Biology and Behaviour. Clarendon Press, Oxford, 1065 pp.

Soós Á (1966) Identification key to the leech (Hirudinoidea) genera of the world, with a catalogue of the species. III. Family: Erpobdellidae. Acta Zoologica Academiae Scientiarum Hungaricae 12: 371–407.

Yang T (1996) Annelida Hirudinea. Science Press, Beijing, 261 pp.

ZooKeys 119: 11–27 (2011)
doi: 10.3897/zookeys.119.1706
www.zookeys.org

RESEARCH ARTICLE

A peer-reviewed open-access journal
ZooKeys
Launched to accelerate biodiversity research

A survey of the East Palaearctic Lycosidae (Araneae). 9. Genus *Xerolycosa* Dahl, 1908 (Evippinae)

Yuri M. Marusik[1], Mykola M. Kovblyuk[2], Seppo Koponen[3]

1 *Institute for Biological Problems of the North, Portovaya Str. 18, Magadan 685000 Russia* **2** *Zoological Department, V.I. Vernadsky Taurida National University, Yaltinskaya Str. 4, Simferopol 95007, Crimea, Ukraine* **3** *Zoological Museum, University of Turku, FI-20014 Turku Finland*

Corresponding author: *Yuri M. Marusik* (yurmar@mail.ru)

Academic editor: *Dmitry Logunov* | Received 13 June 2011 | Accepted 1 July 2011 | Published 15 July 2011

Citation: Marusik YM, Kovblyuk MM, Koponen S (2011) A survey of the East Palaearctic Lycosidae (Araneae). 9. Genus *Xerolycosa* Dahl, 1908 (Evippinae). ZooKeys 119: 11–27. doi: 10.3897/zookeys.119.1706

Abstract

Three species of *Xerolycosa*: *X. nemoralis* (Westring, 1861), *X. miniata* (C.L. Koch, 1834) and *X. mongolica* (Schenkel, 1963), occurring in the Palaearctic Region are surveyed, illustrated and redescribed. *Arctosa mongolica* Schenkel, 1963 is removed from synonymy with *X. nemoralis* and transferred to *Xerolycosa*, and the new combination *Xerolycosa mongolica* (Schenkel, 1963) **comb. n.** is established. One new synonymy, *Xerolycosa undulata* Chen, Song et Kim, 1998 **syn. n.** from Heilongjiang = *X. mongolica* (Schenkel, 1963), is proposed. In addition, one more new combination is established, *Trochosa pelengena* (Roewer, 1960) **comb. n**., ex *Xerolycosa*.

Keywords

Wolf spider, Asia, new combination, new synonymy

Introduction

This paper is the first in a series of reviews of the Palaearctic Evippinae Zyuzin, 1985. Evippinae is a relatively small subfamily of wolf spiders restricted to Africa and the Pal-

aearctic Region. Only four species belonging to two genera have been recorded from Europe, *Xerolycosa nemoralis* (Westring, 1861) and *X. miniata* (C.L. Koch, 1834) (both occur throughout Europe), *Evippa eltonica* Dunin, 1994 (easternmost Europe, only a few dozen kms from Asia) (Helsdingen 2010) and "*Evippa*" *apsheronica* Marusik, Guseinov & Koponen, 2003 (Ponomarjov and Tsvetkov 2004; Kovblyuk 2007). Most Evippinae species in the Palaearctic Region have been reported and described from Central Asia and China (cf. Platnick 2011). *Xerolycosa* Dahl, 1908 was assigned to the Evippinae by Zyuzin (1985). It is the most widespread genus in the subfamily, ranging from the Iberian Peninsula to Kamchatka. The genus currently includes five species (Platnick 2011), three of which are restricted to the Palaearctic Region and two occur in the Afrotropical Region. The purpose of this paper is to provide a review of this small genus.

Material and methods

Specimens were photographed using either a JEOL JSM-5200 scanning electron microscope or an Olympus Camedia E-520 camera attached to an Olympus SZX16 stereomicroscope at the Zoological Museum, University of Turku. Digital images were montaged using a "CombineZM" image stacking software. Photographs were taken in dishes of different sizes with paraffin at the bottom. Different sized holes were made in the bottom to keep the specimens in the correct position. Figures had been made previously and in some cases we were unable to generate scale bars for the digital photographs. All measurements are given in mm. Drawings we made either by using a grid method with a MBS-9 stereomicroscope or a Leitz stereomicroscope with a camera lucida. The bleached epigyne of the holotype female was temporarily coloured with Chlorazol Black. Epigynes were macerated using KOH solution. In the tables of leg spination, apical and dorsal spine data are omitted.

Terminology of the copulatory organs follows Zyuzin (1985, 1993).

Abbreviations used in the text: AME, ALE, PME, PLE – anterior median, anterior lateral, posterior median and posterior lateral eyes respectively; pv – proventral; rv – retroventral; v – ventral; p – prolateral; r – retrolateral.

Acronyms:

IBPN	Institute for Biological Problems of the North, Magadan, Russia
MNHN	Muséum National d'Histoire Naturelle, Paris, France
SMFM	Senckenberg Museum, Frankfurt am Main, Germany
SZMN	Siberian Zoological Museum RAS, Novosibirsk, Russia
TNU	Zoology Department, Taurida National University, Simferopol, Ukraine
ZISP	Zoological Institute, St.-Petersburg, Russia
ZMMU	Zoological Museum of the Moscow State University, Russia
ZMUT	Zoological Museum, University of Turku, Finland

Taxonomic survey

Xerolycosa Dahl, 1908
http://species-id.net/wiki/Xerolycosa

Xerolycosa Dahl, 1908: 361. Type species: *Lycosa nemoralis* Westring, 1861.
Saitocosa Roewer, 1960: 889. Type species: *Tarentula flavitibia* Saito, 1934.

Diagnosis. Members of this genus can be easily separated from other Evippinae genera by the fewer number of ventral tibial spines on leg I (3pv & 2rv, or 2–2v), carapace lacking transverse depression (present in *Evippa* Simon, 1882) and lack of pseudo-articulation of tarsi (Fig. 13). *Xerolycosa* can be differentiated by the shape of their copulatory organs. Females have a short droplet-shaped septum (about as long as wide), while in *Evippa* the septum is long and has a well developed septal stem. The male palp in *Xerolycosa* has a shorter course of the seminal duct and a shorter embolus, which is only partly hidden by the tegulum.

Description. Medium-sized (5.5–7.5) dark coloured or spotty lycosids. Carapace spotty or dark coloured with lighter median band and two lateral stripes. Cephalic region not elevated. Chelicerae with 3 promarginal and 2 retromarginal teeth. Inner side of chelicerae with a kind of stridulatory file (Fig. 12). Femora with 3 dorsal spines, tibia and metatarsus with 2 dorsal spines, sometimes poorly developed, tibia and metatarsi with four or five ventral spines (3pv-2rv or 2–2v). Tarsi without transverse furrow.

Male palp: cymbium with several apical spines; tegular apophysis shifted retrolaterally, with bill-like extension directed ventrally. Palea absent, embolus forming almost a circle, only partly hidden by tegulum. Epigyne: fovea (depression) absent, septum droplet-shaped, covered with hairs, almost as wide as high; stem short. Weakly sclerotized parts of epigyne are referred to here as windows (*Wi*).

Comments. *Saitocosa* was synonymised with *Xerolycosa* by Yaginuma (1986: p. 169) through synonymisation of the type species *Tarentula flavitibia* Saito, 1934 with *X. nemoralis.*

Dahl (1908) described *Xerolycosa* and placed only two species in this genus: *X. nemoralis* and *X. miniata*. No type species was selected. It is not clear who selected *X. nemoralis* as the type species. The first clear indication we found was in Roewer's catalogue (Roewer 1954: p. 309). The same species was indicated as the generotype in Roewer's revision of Lycosidae (Roewer 1959: p. 893) and in Bonnet's catalogue (1959: p. 4836).

In Platnick's catalogue (2011) five species are listed under *Xerolycosa*: *X. miniata* (C.L. Koch, 1834), *X. nemoralis* (Westring, 1861), *X. pelengena* Roewer, 1960, *X. sansibarina* Roewer, 1960 and *X. undulata* Chen, Song et Kim, 1998. Roewer's species are known from Africa (Congo and Zanzibar). Judging from the figures, *X. pelengena* is a member of Trochosini, due to its carapace pattern (two dark longitudinal stripes within the median band, just behind the PLE) and epigyne (anchor-shaped septum, and

triangle-shaped hoods of the apical pocket) and seems to belong to *Trochosa*. Therefore, we propose the new combination: *Trochosa pelengena* (Roewer, 1960) comb. n. *Xerolycosa sansibarina,* known from the male sex only, has a carapace and abdominal pattern very different from Evippinae species, and the palp has a distinctly different conformation, typical for the Lycosinae (tegular apophysis stretching horizontally, tip of embolus visible and resting horizontally in a tegular depression). However, we refrain from suggesting a new combination because its generic affinities are currently unclear.

Because of the burrowing behaviour in *X. mongolica* (Schenkel, 1963), believed to be absent in the other species, we first followed A.A. Zyuzin's (personal communication) opinion that it may belong to a separate genus. However, females of *X. nemoralis* are known to excavate shallow depressions in soil (Smola 2007). In addition to behaviour, *X. mongolica* has widely spaced posterior median eyes (one diameter apart) in contrast to the type species, *X. nemoralis,* and *X. miniata* (less than one diameter apart). Study of the male palp and the leg spination revealed no differences between *X. mongolica* and the other species.

Species separation

Xerolycosa species can be distinguished by the shape of the copulatory organs. In addition *X. mongolica* can be recognized by the variegated (spotty) pattern of the carapace and abdomen, and by lacking a light median band. The spination of leg I may help to distinguish males of *X. mongolica*, and females of all species.

The male palps in all three species are rather similar in general appearance. The species can be relatively easy recognized in retrolateral view by the profile of the tegular apophysis (Figs 22–24, 25, 27, 29) and by the shape of the embolic region following dissection, notably the course and length of the embolus, and the seminal duct position (Figs 26, 28, 30). The males of *X. miniata* and *X. nemoralis* have the same spination pattern on leg I (Table 1), but the females have different leg spine formulae (Table 2). The epigynes in the three species are very similar and can be distinguished by the shape of the septum and the "windows" (Figs 31, 33, 35, 37, 39, 41). Additional differences can be found in the spermathecae (Figs 32, 36, 40, 34, 38, 42).

Key to the Palaearctic *Xerolycosa* species

1 Carapace with wide whitish median band **2**
– Carapace without whitish median band ..... ***X. mongolica***
2 Tegular apophysis with well developed ridge, and lower part as high as upper part (Fig. 25), free part of embolus bent (Fig. 26), epigynal windows wider than high (Figs 39, 42) ..... ***X. nemoralis***
– Tegular apophysis has no developed ridge and lower part is higher than upper part (Fig. 27), free part of embolus gradually rounded, epigynal windows droplet-shaped, higher than wide (Figs 31, 33) ..... ***X. miniata***

Table 1. Chaetotaxy of leg I in *Xerolycosa* males.

Species	Segments of leg I			
	femur	**patella**	**tibia**	**metatarsus**
miniata	2p+2r	1p+1r	1p+2r+3-2v	2p+1r+2-2v
mongolica	1 or 2p+2r	1p	0 or 1p+2-2v	1p+2-2v
nemoralis	2p+2r	1p+1r	1p+2r+3-2v	2p+1r+2-2v

Table 2. Chaetotaxy of leg I in *Xerolycosa* females

Species	Segments of leg I			
	femur	**patella**	**tibia**	**metatarsus**
miniata	2p	0	1p+2-2v	2p+2-2v
mongolica	2p	0	0 or 1p+3-2v	2p+2-2v
nemoralis	2p+2r	1p	1p+3-2v	2p+2-2v

Species survey

***Xerolycosa miniata* (C.L. Koch, 1834)**
http://species-id.net/wiki/Xerolycosa_miniata
Figs 6–7, 22, 27–28, 31–34

Lycosa miniata C.L. Koch, 1834: 123, pl. 13–14 (♂♀).
Xerolycosa miniata: Dahl 1908: 361, 364, f. 58 (♂♀).
Xerolycosa miniata: Holm 1947: 24, pl. 4, f. 34–35, pl. 10, f. 26 (♂♀).
Xerolycosa miniata: Roberts 1985: 142, f. 61b (♂♀).
Xerolycosa miniata: Roberts 1995: 223, f. (♂♀).
Xerolycosa miniata: Roberts 1998: 237, f. (♂♀).
Xerolycosa miniata: Almquist 2005: 251, f. 245a-f (♂♀).

For a complete list of references see Platnick (2011).

Material examined. FINLAND (selected records from different parts of the range): 15♂♀ (ZMUT), Nauvo Seili (60°15'N, 21°58'E), sandy sea shore, 16.05.-11.08.1974 (R. Mannila); 1♂ 1♀ (ZMUT), Virolahti Siikasaari (60°28'N, 27°35E), sandy sea shore, 07.05.-13.09.1970 (S. Kännö); 17♂♀ (ZMUT), Pori Yyteri (61°33'N, 21°32'E), among *Empetrum* in sand dune, 14.07.1968 (P.T. Lehtinen); 1♀ (ZMUT), Hailuoto Marjaniemi (65°02'N, 24°36'E), *Elymus* sandy shore, 12.7.1973 (P.T. Lehtinen). **RUSSIA**: ***Adygeya***: 1♂ 1♀ (TNU-2657/18), Caucasian State Reserve, 12 km SE kordon Guzeripl, Pastbishche Abago Mt. Range (43°53–56'N, 40°12–16'E, 1727–2010 m a.s.l.), 18–23.08.2009 (M.M. Kovblyuk). ***Tuva***: 13♂ 11♀ (IBPN), Uyuk River mouth, 52°04'N 94°22'E, 600–700 m, 3–5.06.1995 (Y.M. Marusik). UKRAINE: ***Crimea***: 1♀ (TNU-2187/1), Simferopol Distr., Kesslers' Forest, 8.08.2000 (M.M. Kovblyuk).

Diagnosis. The species differs distinctly from *X. mongolica* by the carapace pattern, having a light longitudinal band and stripes. Males can be distinguished from those of

X. nemoralis by the shorter seminal duct, a bent free part of the embolus and a bent tip, a rounded (not pointed) process of the tegular apophysis, basal part higher than apical (equal in *X. nemoralis*), and the lack of a tegular ridge. Females can be distinguished by the proportions of the epigyne (windows longer than wide, whereas in *X. nemoralis* they are wider than long).

Description. Male. Total length 5.0 (4.7–6.2). Carapace: 2.85 (2.52–3.09) long, 2.1 (1.79–2.22) wide. Carapace length/femur IV ratio 1.2. Habitus and pattern as in Fig. 6; carapace with wide white median band and marginal light stripes.

Length of leg segments:

	femur	**patella**	**tibia**	**metatarsus**	**tarsus**	**Total**
I	1.95	0.85	1.5	1.6	1.13	7.03
II	1.8	0.8	1.35	1.55	1.15	6.65
III	1.85	0.8	1.3	1.85	1.05	6.85
IV	2.38	0.95	1.85	2.8	1.38	9.35

Spination of legs:

	femur	**patella**	**tibia**	**metatarsus**
I	2p+2r	1p+1r	1p+2r+3-2v	2p+1r+2-2v
II	2p+2r	1p	2p+2r+2-2v	2p+1r+2-2v
III	2p+2r	1p+1r	2p+2r+2-2v	2p+2r+2-2v
IV	2p+1r	1p+1r	2p+2r+2-2v	2p+2r+3-2v

Palp as in Figs 22, 27–28, cymbial spines poorly distinct, upper part of tegular apophysis with claw-like outgrowth; embolus relatively thin, following an oval course, tip modified.

Female. Total length 7.0 (4.8–7.4). Carapace: 3.0 (2.46–3.28) long, 2.1 (I. 71–2.42) wide. Carapace length/femur IV ratio 1.25. Habitus and pattern as in Fig. 7; pattern on carapace same as in male but with less distinct lateral light stripes.

Length of leg segments:

	femur	**patella**	**tibia**	**metatarsus**	**tarsus**	**Total**
I	1.75	0.93	1.35	1.35	1.05	6.43
II	1.75	0.9	1.25	1.38	1.03	6.3
III	1.8	0.88	1.2	1.7	1.03	6.6
IV	2.4	1.05	1.85	2.7	1.3	9.3

Spination of legs:

	femur	**patella**	**tibia**	**metatarsus**
I	2p	0	1p+2-2v	2p+2-2v
II	2p	1p	1p+2-2v	2p+2-2v
III	2p+2r	1p+1r	2p+2r+2-2v	2p+2r+2-2v
IV	2p+1r	1p+1r	2p+1r+2-2v	2p+2r+3-2v

Epigyne as in Figs 31–34, sides of stem rounded, windows shaped like inverted droplets, their upper margins almost horizontal.

Distribution. *X. miniata* has a Euro-Mongolian boreo-nemoral range (Marusik et al. 2000) and is known from Portugal to Tuva, north to central Finland and north Ural, and south to Azerbaijan and north-western Mongolia.

***Xerolycosa mongolica* (Schenkel, 1963) comb. n.**
http://species-id.net/wiki/Xerolycosa_mongolica
Figs 1–3, 10, 18–21, 23a-b, 29–30, 35–38.

Arctosa mongolica Schenkel, 1963: 353, f. 204a-c (♀).
Xerolycosa nemoralis: Yu & Song 1988: 118 (incorrect synonymy).
"*Xerolycosa" mongolica*: Logunov, Marusik & Koponen 1998: 139.
"*Xerolycosa" mongolica*: Marusik, Logunov & Koponen 2000: 87.
Xerolycosa undulata Chen, Song & Kim, 1998: 71, f. 7–12 (♂). syn. n.
Xerolycosa undulata: Song, Zhu & Chen 1999: 346, f. 202J (♂).

Material examined. Holotype ♀ (MNHN) "Urga-Tsitsikar, Chaffanjon" [1896] (can refer either to Mongolia or China). **RUSSIA**, ***Tuva*:** 17♂ 2♀ (IBPN & ZMUT), SE Tuva, Erzin Town environs, 50º14'N 95º09'E, 1165 m, dry steppe, 9.06.1995 (Y.M. Marusik & S. Koponen); 13♂ 1♀ (SZMN), SE Tuva, Erzin environs, 50º14'N 95º09'E, 1165 m, *Artemisia-Stipa* steppe, 9.06.1995 (D.V. Logunov); 4♂ (ZMMU), SE Tuva, Tes-Khem Valley, 50°19'N, 95°01'E, 10.06.1995 (Y.M. Marusik); 3♂ (ZMMU), environs of Kyzyl, *Nanophyton erinaceus* semidesert steppe, 6.06.1995 (Y.M. Marusik).

Notes. The holotype female of *X. mongolica* is very pale and the pattern is not visible. The figure in Schenkel (1963), however, corresponds well with the pattern observed in Tuvan specimens. When Yu & Song (1988) synonymized *Arctosa mongolica* and *Xerolycosa nemoralis* they mentioned that the type of *A. mongolica* had been studied. The general appearance of the epigynes in the two species is not similar. The epigynal septum and the windows are more similar to those in *X. miniata* (cf. Figs 31, 33, 35 and 37).

X. undulata was described on the basis of the holotype male from Heilongjiang, not far from Tsitsikar. According to the text (Chen et al. 1999), the type was deposited in the Institute of Zoology in Beijing. However, the type was not found in the collections (Li, personal communication). Comparison of our figures of the male palp of *X. mongolica* and figures of *X. undulata* provided by Chen et al. (1998) leaves no doubts that these two names should be synonymized. It is worth mentioning, that when *X. undulata* was described the male of *X. mongolica* was unknown.

Diagnosis. *X. mongolica* differs distinctly from its congeners by its spotty pattern and lack of longitudinal bands or stripes on the carapace, widely spaced anterior

median eyes (more than one diameter of AME), long filiform embolus, shape of the tegular apophysis, and structure of the epigyne and vulva.

Description. Male. Total length 6.1 (5.6–6.25). Carapace: 3.05 (2.8–3.1) long, 2.1 (1.9–2.1) wide. Carapace length/femur IV ratio 1.07 (1.03–1.12). Habitus and pattern as in Figs 2–3.

Length of leg segments:

	femur	**patella**	**tibia**	**metatarsus**	**tarsus**	**Total**
I	2.3	1.05	2.0	1.85	1.25	8.45
II	2.2	1.0	1.75	1.85	1.15	7.95
III	2.15	0.9	1. 5	2.1	1.05	6.2
IV	2.85	1.05	2.25	3.2	1.45	10.8

Spination of legs:

	femur	**patella**	**tibia**	**metatarsus**
I	1 or 2p+2r	1p	0 or 1p+2–2v	1p+2–2v
II	2p+2r	1p	2p+2–2v	2p+2–2v
III	2p+2r	1p+1r	2p+2r+2–2v	2p+2r+2–2v
IV	2p+2r	1p+1r	2p+2r+2–2v	2p+2r+3–2v

Palp as in Figs 18–21, 23, 29–30, cymbium with distinct spines, apical part of tegular apophysis with triangular extension, embolus filiform along its entire course.

Female. Total length 6.6 (5.7–6.6). Carapace: 2.35 (2.35–2.7) long, 1.7 (1.7–1.85) wide. Carapace length/femur IV ratio 1.18 (1.1–1.18). Habitus and pattern as in Fig. 2.

Length of leg segments:

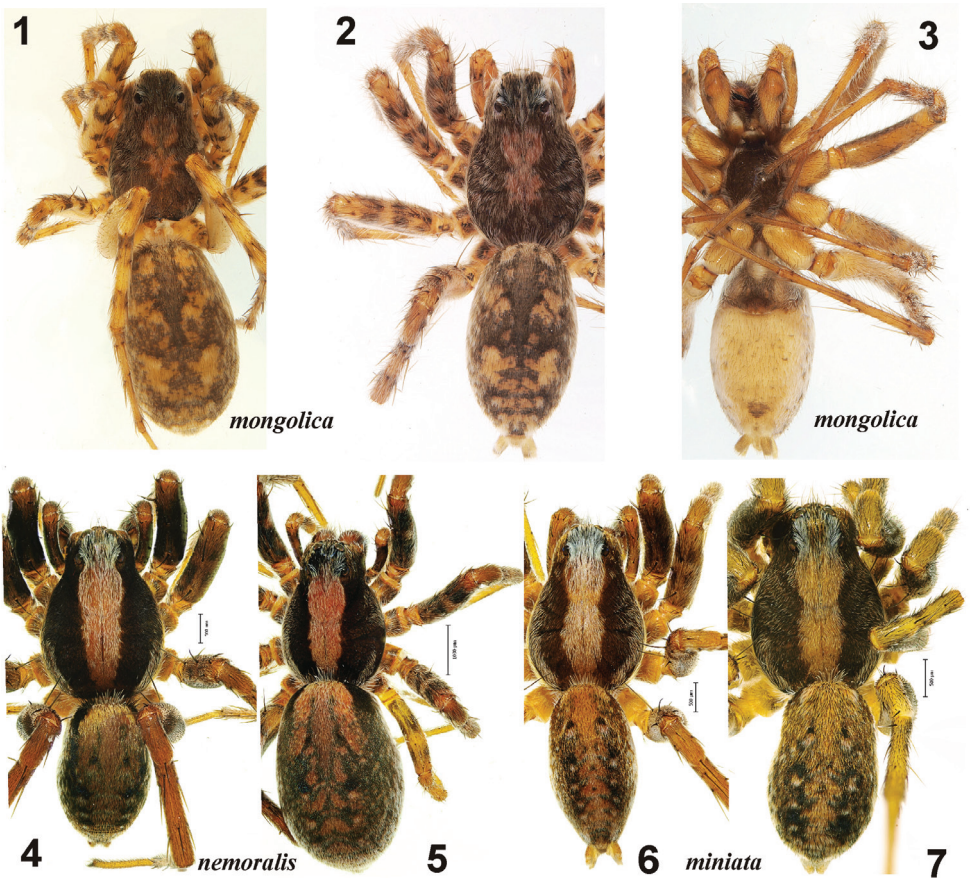
	femur	**patella**	**tibia**	**metatarsus**	**tarsus**	**Total**
I	1.7	0.75	1.3	1.2	0.85	5.8
II	1.6	0.7	1.1	1.1	0.8	5.3
III	1.5	0.7	0. 9	1.4	0.85	4.45
IV	2.0	0.75	1.5	2.35	1.2	7.8

Spination of legs:

	femur	**patella**	**tibia**	**metatarsus**
I	2p	0	0 or 1p+3–2v	2p+2–2v
II	2p+0 or 1r	0	1p+2–2v	2p+2–2v
III	2p+1r	1p+1r	2p+1r+2–2v	2p+2r+2–2v
IV	1 or 2p+2r	1p+1r	2p+2r+2–2v	2p+2r+3–2v

Epigyne as in Figs 35–38, septum almost triangular in shape, upper margins of windows inclined.

Comments. It seems that Schenkel (1963) placed this species in *Arctosa* due to the carapace pattern being typical for the genus (no stripes or bands). *Arctosa mongolica*

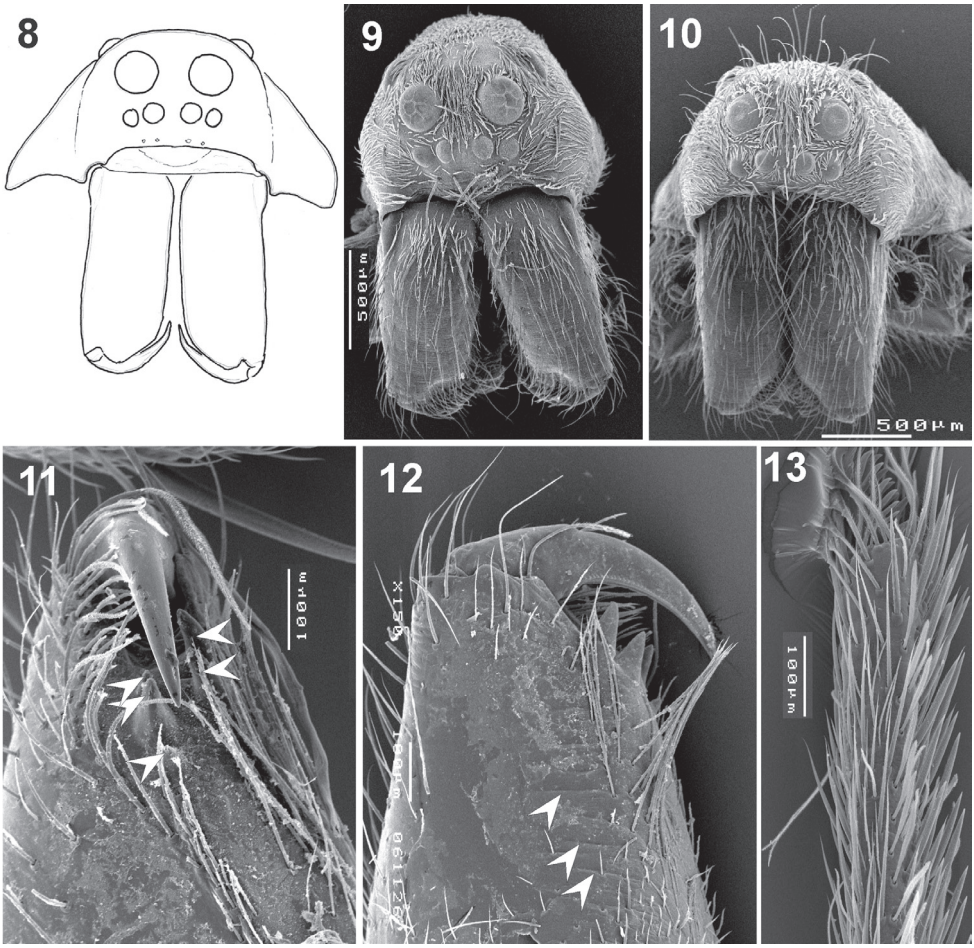


Figures 1–7. General appearance of *Xerolycosa mongolica* **1–3** *X. nemoralis* **4–5** and *X. miniata* **6–7** **1, 5, 7** female, dorsal **2, 4, 6** male, dorsal **3** male, ventral.

was synonymized with *X. nemoralis* by Yu & Song (1988) without examination of the female holotype. Study of the holotype and comparison with European and Siberian specimens of *X. nemoralis* revealed clear differences in pattern, spination and copulatory organs and therefore we remove *X. mongolica* from synonymy and establish a new combination.

Biology. *X. mongolica* females make burrows in the ground in places with sparse steppic vegetation. The burrows are relatively deep 7–10.5 cm and 4–6 mm in diameter (Logunov, personal communication). Apparently males do not construct burrows. These observations were first made by Dmitri Logunov in Tuva. Subsequently we (Koponen and Marusik) witnessed this behaviour. It is worth mentioning that *X. mongolica* seems to be the smallest burrowing wolf spider (Logunov, personal communication).

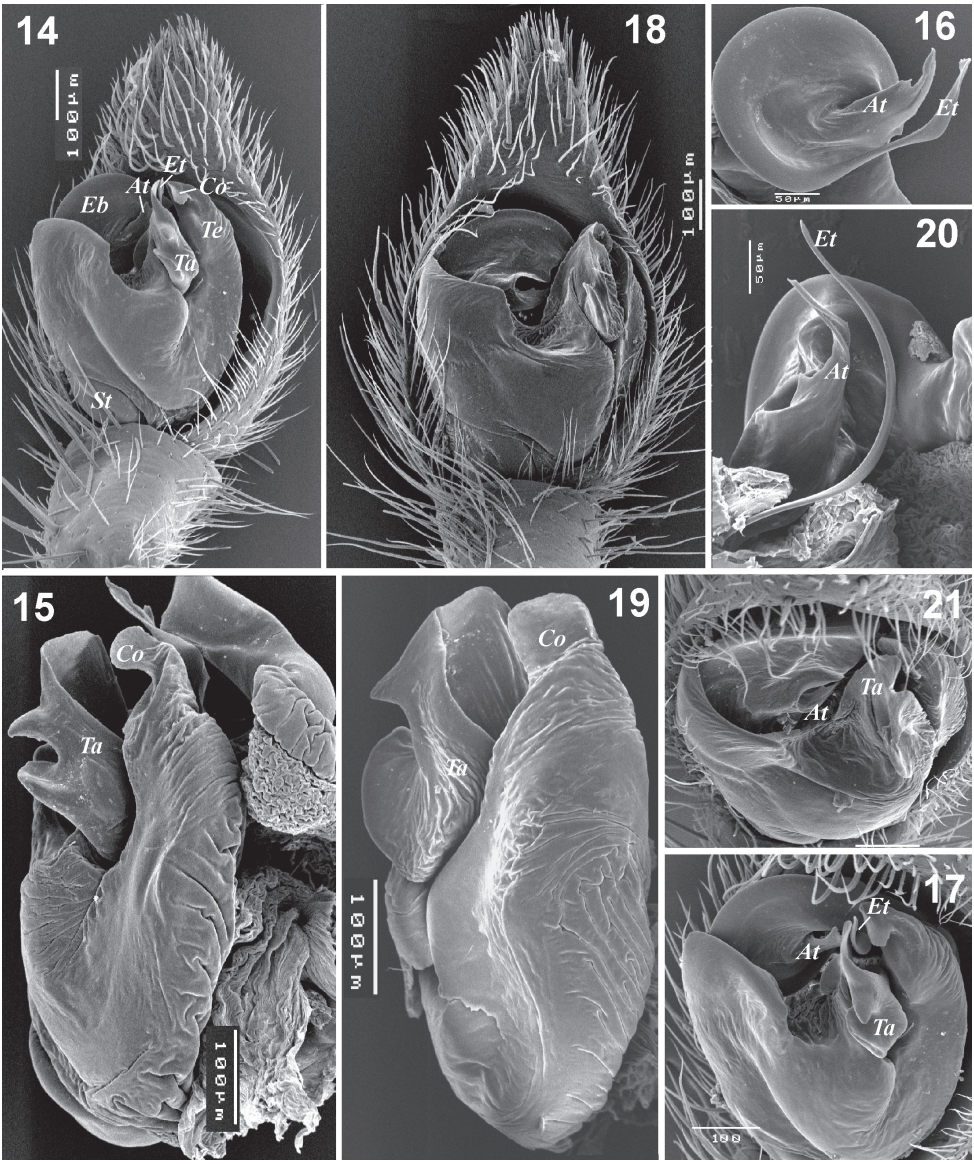
Distribution. The exact distribution of this species is unknown because the type locality is uncertain (Urga-Tsitsikar), and because of incorrect synonymisation its distribution in China is unclear. *X. mongolica* is well documented from Tuva only.



Figures 8–13. Somatic characters of *Xerolycosa nemoralis* **8–9, 11–13** and *X. mongolica* **10 8–10** prosoma, frontal **11–12** – chelicerae, median and inner view **13** tarsus IV, retrolateral. Arrows show cheliceral teeth and stridulatory files.

Xerolycosa nemoralis **(Westring, 1861)**
http://species-id.net/wiki/Xerolycosa_nemoralis
Figs 4–5, 8–9, 11–13, 14–17, 24, 25–26, 39–42

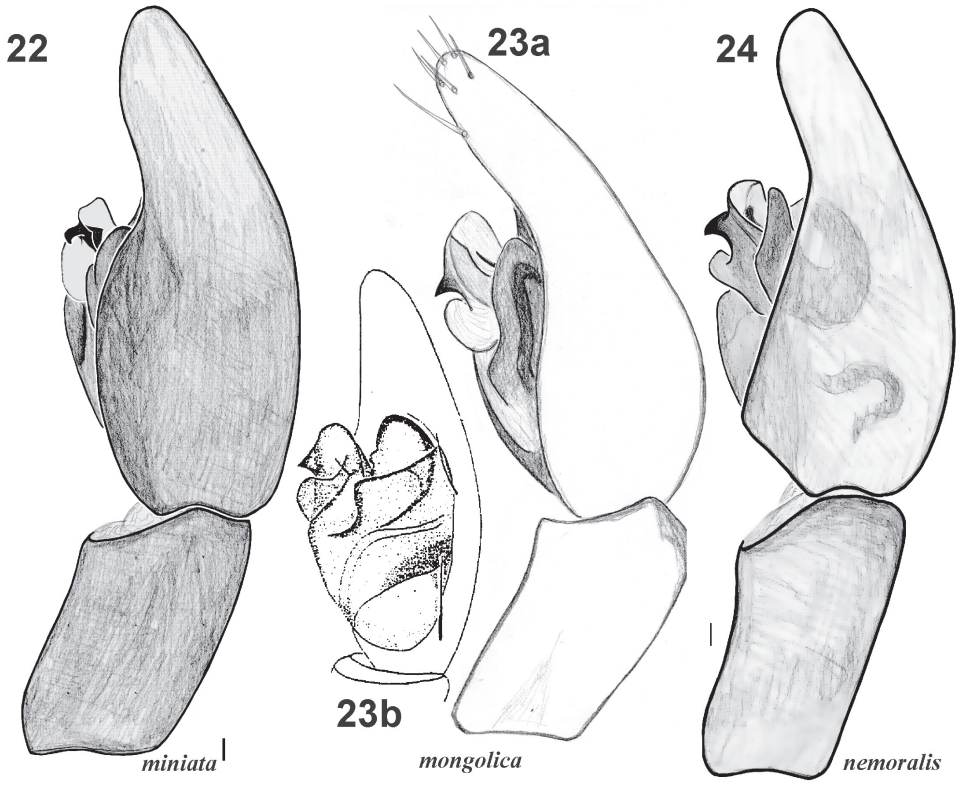
Lycosa nemoralis Westring, 1861: 472 (♂♀).
Xerolycosa nemoralis: Dahl 1908: 361, f. 57 (♂♀).
Tarentula flavitibia Saito, 1934: 355, pl. 13, f. 31, pl. 15, f. 84 (♀).
Xerolycosa nemoralis: Holm 1947: 23, pl. 4, f. 36–37, pl. 10, f. 25 (♂♀).
Saitocosa flavitibia: Roewer 1960: 889.
Xerolycosa nemoralis: Zyuzin 1985: 48, f. 15–16, 20–22 (♂♀).
Xerolycosa nemoralis: Roberts 1985: 140, f. 61a (♂♀).



Figures 14–21. Male palp of *Xerolycosa nemoralis* **14–17** and *X. mongolica* **18–21**. **14, 18** whole palp, ventral **15, 19** – bulbus, lateral **16, 20** embolic division, ventral and ventro-retrolateral **17, 21** whole palp, apical. Abbreviations: ***At*** – terminal apophysis; ***Co*** – conductor; ***Eb*** – base of embolus; ***Et*** – tip of embolus; ***St*** – subtegulum; ***Ta*** – tegular apophysis; ***Te*** – tegular extension.

Xerolycosa nemoralis: Roberts 1995: 222, f. (♂♀).
Xerolycosa nemoralis: Roberts 1998: 236, f. (♂♀).
Xerolycosa nemoralis: Almquist 2005: 252, f. 246a-i (♂♀).

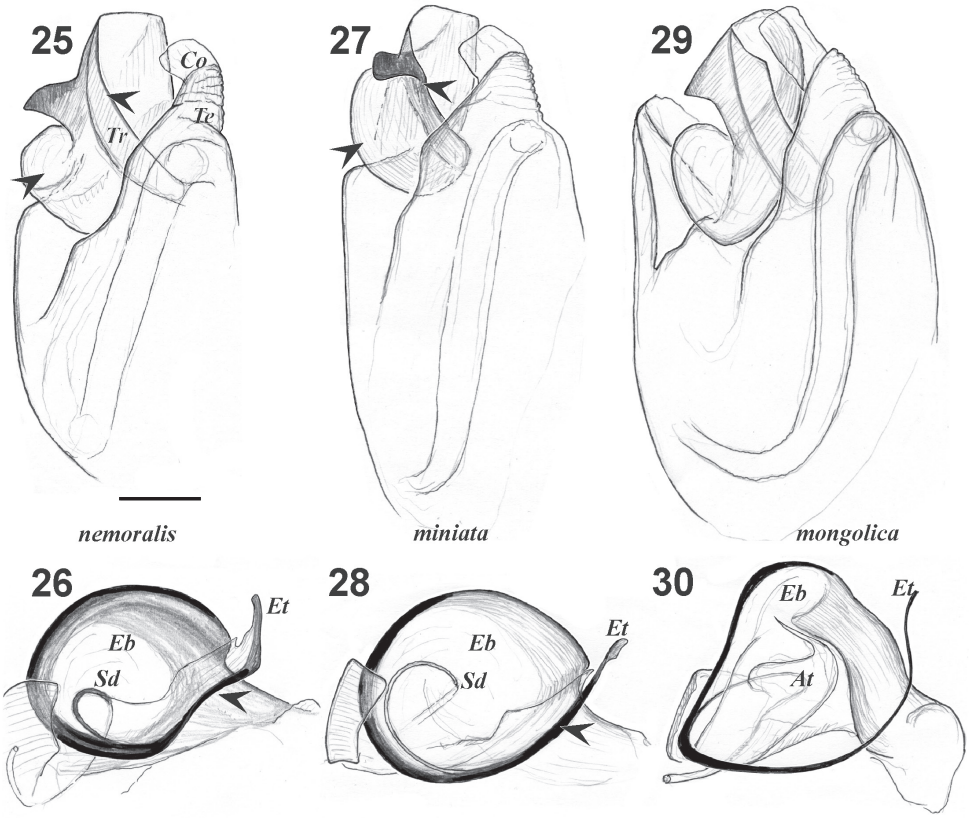
For a complete list of references see Platnick (2011).



Figures 22–24. Male palp of *Xerolycosa miniata* **22** *X. mongolica* **23** and *X. nemoralis* **24 22, 23a, 24** retrolateral **23b** prolateral. **23b** after Chen et al. (1998). (scale bar 0.1 mm).

Misidentification. *Xerolycosa nemoralis*: Yin et al. 1997: 10, f. 3a-d (♀), refer to a species with unclear generic affinities.

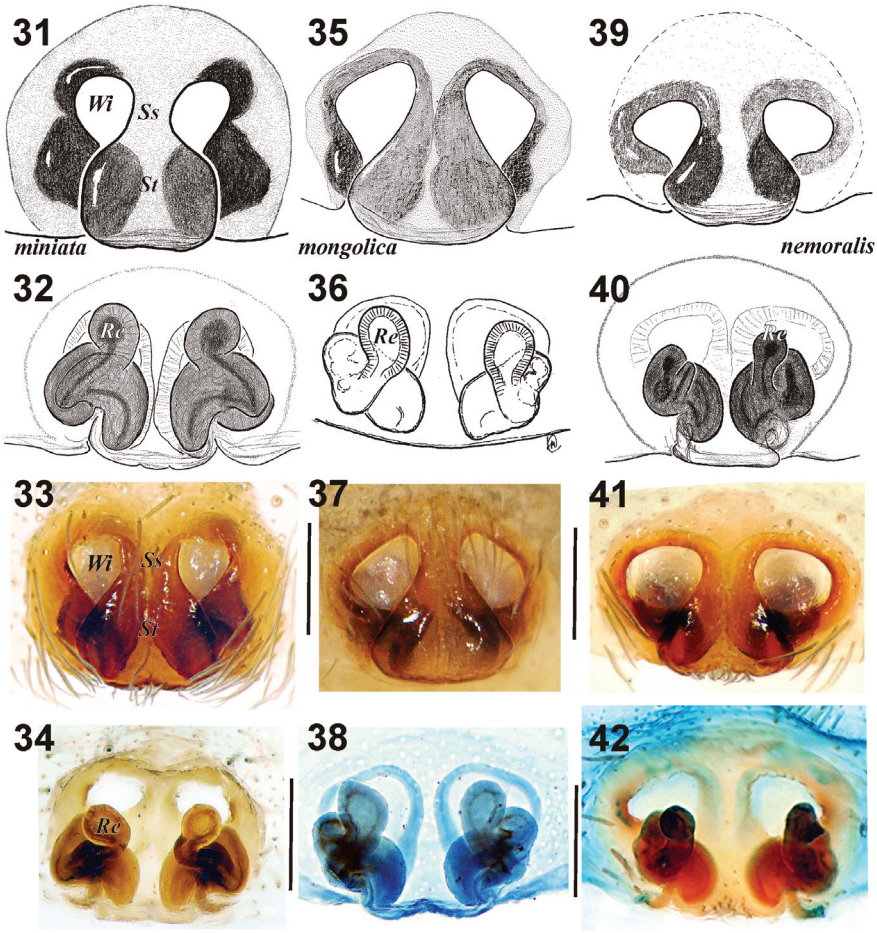
Material examined. FINLAND (selected records from different parts of the range): 18♂♀ (ZMUT), Vuolijoki, Vuottolahti, Lapinniemi (64°13'N, 27°20'E), 16.07.1972 (P.T. Lehtinen); 1♂ (ZMUT), Hammarland Sålis (60°15'N, 19°44'E), dry forest, 26.06.-06.08.1971 (P.T. Lehtinen); 5♂ 4♀ (ZMUT), Turku Kärsämäki (60°30'N, 22°15'E), forest, 24.04.-04.08.1972 (I. Oksala); 12♂♀ (ZMUT), Harjavalta, Sport center (61°17'N, 22°10'E), pine forest, 09.07.-09.08.1992 (S. Koponen). **RUSSIA:** ***Adygeya***: 2 ♀ (TNU-2718/18), Caucasian State Reserve, env. kordon Guzeripl (44°00'N, 40°08'E, ~ 670 m), *Abies* & *Fagus* wood, 13–17.08.2009 (M.M. Kovblyuk); 2 ♀ (TNU-2719/3), Caucasian State Reserve, env. kordon Guzeripl (44°00'N, 40°08'E, ~ 670 m), *Abies* & *Fagus* wood, pitfalls, 16-23.08.2009 (M.M. Kovblyuk). ***Krasnoyarsk Prov.*:** 1♀ (IBPN), West Sayany Mts., Oiskiy Mt. Range, Buiba Riv., 52°47'N 93°18'E, 1230 m, among stones, 20-21.06.1995 (Yu.M. Marusik). ***Sakhalin Island*:** 4♂ 4♀ 13 juv. (IBPN), SE part, Tsapko Vill. env., Zhdanko Mt. Range, 48°06.051'N 142°31.557'E, h 220m, foothill of Vladimirovka Mt., stony debris along temporary creek, 1.08.2001 (Y.M.Marusik); 5♂ 2♀ (IBPN), SE part, env. of



Figures 25–30. Male palp of *Xerolycosa nemoralis* **25–26** *X. miniata* **27–28** and *X. mongolica* **29–30 25, 27, 29** bulbus, retrolateral **26, 28, 30** embolic division, ventral. Arrows indicate differences between *X. miniata* and *X. nemoralis.* Abbreviations: ***At*** – terminal apophysis; ***Co*** – conductor; ***Eb*** –base of embolus; ***Et*** – tip of embolus; ***Sd*** – seminal duct.

Starodubskoye Vil., Naiba River mouth part, 47°24.992'N 142°45.384'E, 23.07.2001 (Y.M.Marusik); 4♂ 5♀ (IBPN), SW part, Krilyon Peninsula, W shore, ca 5 km S of Shebunino Vil., Kitosia River mouth, 36°22.536'N 141°52.562'E, 14-15.08.2001 (Y.M.Marusik). ***Magadan Area*:** 1♂ (IBPN), ca. 30 km N of Magadan, Dukcha River Valley, gravely bank, June 1995 (Y.M.Marusik). ***Kamchatka Province*:** 1♂ (IBPN), Kamchatka Peninsula, 10–12 km N of Paratunka Vil., Yelizovo Forestry, 53.050°N 158.225°E, 15-28.07.2004 (A.S. Ryabukhin). No precise data: numerous males and females have been collected on five ***Kuril Islands*:** Kunashir, Iturup, Urup, Chirpoi and Paramushir.

Diagnosis. The species differs distinctly from *X. mongolica* by the pattern of its carapace, having longitudinal bands and stripes, and by having the anterior median eyes situated more closely together (less than one diameter of AME, more than one diameter in *X. mongolica*). From *X. miniata,* males can be distinguished by their longer seminal duct, rounded embolus, the sharply pointed process of the tegular apophysis



Figures 31–42. Epigyne of *Xerolycosa miniata* **31–34** *X. mongolica* **35–38** and *X. nemoralis* **39–42** **31, 33, 35, 37, 39, 41** ventral **32, 36, 40, 34, 38, 42** dorsal. (**36** & **38** holotype). Abbreviations: ***Re*** – receptaculum; ***Se*** – septum; ***Ss*** – septal stem; ***Wi*** – window of epigyne.

and by the proportions of the epigyne (windows wider than high, whereas in *X. miniata* they are higher than wide). *X. nemoralis* females possess 2 retrolateral spines on femur I whereas the other species have only 2 prolateral spines.

Description. Male. Total length 6.0 (5.5–6.8). Carapace: 2.9 (2.75–2.9) long, 2.0 (1.9–2.0) wide. Carapace length/femur IV ratio 1.23 (1.12–1.23). Habitus and pattern as in Fig. 4.

Palp as in Figs 14–17, 24–26, tip of cymbium with poorly developed spines, upper part of tegular apophysis with bill-shaped extension, embolus relatively thick, free part (=embolus proper) bent, tip modified.

Length of leg segments:

	femur	**patella**	**tibia**	**metatarsus**	**tarsus**	**Total**
I	1.85	0.85	1.5	1.55	1.05	6.8
II	1.85	0.85	1.35	1.4	1.1	6.55
III	1.7	0.8	1.25	1.75	1.05	6.55
IV	2.35	1.0	1.8	2.8	1.35	9.3

Spination of legs:

	femur	**patella**	**tibia**	**metatarsus**
I	2p+2r	1p+1r	1p+2r+3–2v	2p+1r+2–2v
II	2p+2r	1p+1r	2p+2r+2–2v	2p+1r+2–2v
III	2p+2r	1p+1r	2p+2r+2–2v	2p+2r+2–2v
IV	2p+1r	1p+1r	2p+2r+2–2v	2p+2r+3–2v

Female. Total length 6.7 (6.4–7.1). Carapace: 3.25 (2.8–3.35) long, 2.25 (2.0–2.4) wide. Carapace length/femur IV ratio 1.18 (1.14–1.18). Habitus and pattern as in Fig. 5.

Epigyne as in Figs 39–42, windows wider than high, septum with rounded sides.

Comments. Judging from the figures, the record of *X. nemoralis* by Yin et al. (1997: f. 3a-d) from China refers to another species and even a different genus.

Length of leg segments:

	femur	**patella**	**tibia**	**metatarsus**	**tarsus**	**Total**
I	2.25	1.0	1.75	1.7	1.3	8
II	2.15	0.95	1.65	1.65	1.3	7.7
III	2.15	0.9	1. 6	2.0	1.25	6.3
IV	2.75	1.05	2.2	3.25	1.5	10.75

Spination of legs:

	femur	**patella**	**tibia**	**metatarsus**
I	2p+2r	1p	1p+3–2v	2p+2–2v
II	2p+2r	1p	1p+2–2v	2p+2–2v
III	2p+2r	1p+1r	2p+2r+2–2v	2p+2r+2–2v
IV	2p+1r	1p+1r	2p+1r+2–2v	2p+2r+3–2v

Distribution. *X. nemoralis* has a trans-Palaearctic boreo-nemoral range (Marusik et al. 2000) and occurs from the Iberian Peninsula to Kamchatka and the North Kuril Islands, north to the Polar Circle in Lapland and to central Yakutia, south to Azerbaijan and Honshu.

Acknowledgements

We thank the following colleagues who contributed to this study: C. Rollard (MNHN) and Shuqiang Li (Institute of Zoology, Beijing, China) for loan of type material or providing information about types; D.V. Logunov (Manchester, UK) showed us *X. mongolica* in the field and informed us about its burrowing ecology and A.A. Zyuzin's ideas about placement of this species; T. Kronestedt (Stokholm, Sweden) and C. Deltshev (Sofia, Bulgaria) reviewed the manuscript. N. Tsurusaki helped us with Japanese literature and N. Fritzén (Vaasa, Finland) gave us freshly collected specimens of *X. miniata* and *X. nemoralis* that were used for making digital photographs. The English of the final draft was kindly checked by D. Penney (Manchester, UK).

This work was supported in part by the RFFI grants # 09-04-01365 and 11-04-01716-a and by the Karadag Nature Reserve.

References

Almquist S (2005) Swedish Araneae, part 1: families Atypidae to Hahniidae Linyphiidae excluded). Insect Systematics and Evolution 62(Suppl.): 1–284.

Bonnet P (1959) Bibliographia araneorum. Toulouse 2(5): 4231–5058.

Chen J, Song DX, Kim JP (1998) Two new species and two new records of Chinese wolf spiders (Araneae: Lycosidae). Korean Arachnology 14(1): 70–76. [also reprinted in Korean Arachnology 14(2): 66–72]

Dahl F (1908) Araneae, Spinnen. Die Süsswasserfauna Deutschlands 12: 1–12.

Helsdingen PJ van (2010) Fauna Europaea: Araneae. Fauna Europaea version 2.2. http://www.faunaeur.org

Holm Å (1947) Svensk Spindelfauna III. Oxyopidae, Lycosidae, Pisauridae. Entomologiska föreningen, Stockholm, 48 pp.

Koch CL (1834) Arachniden. In: Herrich-Scheffer GAW (Ed) Deutschlands Insekten. Heft,122–127.

Kovblyuk MM (2007) New data about spiders (Aranei) of the Crimea. Problems and perspectives of general entomology. Abstracts of the XIIIth Congress of Russian Entomological Society, Krasnodar, September 9–15, 2007: 152–153. [in Russian]

Logunov DV, Marusik YM, Koponen S (1998) A check-list of the spiders in Tuva, South Siberia with analysis of their habitat distribution. Berichte des Naturwissenschaftlich Medizinischen Vereins in Innsbruck 85: 125–159.

Marusik YM, Logunov DV, Koponen S (2000) Spiders of Tuva, South Siberia. IBPN FEB RAS, Magadan, 252 pp.

Platnick NI (2011) The world spider catalog, version 11.5. American Museum of Natural History. http://research.amnh.org/entomology/spiders/catalog/index.html

Ponomarjov AV, Tsvetkov AS (2004) The generalized data on spiders (Aranei) of the Nature Reserve "Rostovsky". Trudy gosudarstvennogo prirodnogo zapovednika "Rostovski" 3: 84–104. [in Russian]

Roberts MJ (1985) The spiders of Great Britain and Ireland, Volume 1: Atypidae to Theridiosomatidae. Harley Books, Colchester, 229 pp.

Roberts MJ (1995) Collins Field Guide: Spiders of Britain & Northern Europe. HarperCollins, London, 383 pp.

Roberts MJ (1998) Spinnengids. Tirion, Baarn, 397 pp.

Roewer CF (1955) Katalog der Araneae von 1758 bis 1940, bzw. 1954. Bruxelles 2: 1–1751.

Roewer CF (1959) Araneae Lycosaeformia II (Lycosidae). Exploration du Parc national de Upemba Mission G. F. de Witte 55: 1–518.

Roewer CF (1960) Araneae Lycosaeformia II (Lycosidae) (Fortsetzung und Schluss). Exploration du Parc national de Upemba Mission G. F. de Witte 55: 519–1040.

Saito S (1934) Spiders from Hokkaido. Journal of the Faculty of Agriculture, Hokkaido Imperial University 33: 267–362.

Schenkel E (1963) Ostasiatische Spinnen aus dem Muséum d'Histoire naturelle de Paris. Mémoires du Museum national d'Histoire naturelle de Paris (Serie A, Zoologie) 25: 1–481.

Smola V (2007) Prekvapivé chování bežného druhu slídáka. Živa 1: 31–33.

Song DX, Zhu MS, Chen J (1999) The Spiders of China. Hebei Science and Technology Publishing House, Shijiazhuang, 640 pp.

Westring N (1861) Araneae Svecicae. Gothoburgi, 615 pp.

Yaginuma T (1986) Spiders of Japan in colour (new ed.). Hoikusha Publishing Company, Osaka, 350 pp. + 64 pl.

Yin CM, Peng XJ, Xie LP, Bao YH,Wang JF (1997) Lycosids in China (Arachnida: Araneae). Hunan Normal University Press, 317 pp.

Yu LM, Song DX (1988) A revision of the Chinese spiders of the family Lycosidae (Araneae). Sinozoologia 6: 113–121.

Zyuzin AA (1985) Genus and subfamily criteria in the taxonomy of spiders of the family Lycosidae (Aranei), with descriptions of a new genus and two new sub-families. Trudy Zoologicheskogo Instituta Akademii Nauk SSSR 139: 40–51. [in Russian]

Zyuzin AA (1993) Studies on the wolf spiders (Araneae: Lycosidae). I. A new genus and species from Kazakhstan, with comments on the Lycosinae. Memoirs of the Queensland Museum 33(2): 693–700.

ZooKeys 119: 29–36 (2011)
doi: 10.3897/zookeys.119.1629
www.zookeys.org

RESEARCH ARTICLE

A peer-reviewed open-access journal
ZooKeys
Launched to accelerate biodiversity research

A new species of the genus *Epidamaeus* (Acari, Oribatida, Damaeidae) from China

Lixia Xie†, Maofa Yang‡, Rong Huang§

Institute of Entomology, Guizhou University; The Provincial Key Laboratory for Agricultural Pest Management of Mountainous Region, Guiyang, Guizhou, P.R. China, 550025

† *urn:lsid:zoobank.org:author:6E8D796C-AF36-4230-AC7B-61CD9D9E0BB7*
‡ *urn:lsid:zoobank.org:author:79B3BA54-5CBD-43CD-B50C-FAABBBFA4904*
§ *urn:lsid:zoobank.org:author:687D26EC-CD49-43D5-8B02-8D62BCB67A22*

Corresponding author: *Maofa Yang* (yangmaofa@sohu.com)

Academic editor: *Andre Bochkov* | Received 30 May 2011 | Accepted 11 July 2011 | Published 15 July 2011

urn:lsid:zoobank.org:pub:D472D4A4-5EC9-428D-9C8D-B1DAEBE64F27

Citation: Xie L, Yang M, Huang R (2011) A new species of the genus *Epidamaeus* (Acari, Oribatida, Damaeidae) from China. ZooKeys 119: 29–36. doi: 10.3897/zookeys.119.1629

Abstract

The oribatid mite genus *Epidamaeus* Bulanova-Zachvatkina, 1957 from China is reviewed, and a list and key to all known species from China are provided. A new species, *Epidamaeus conjungenus* **sp. n.** is identified, and its morphological descriptions and illustrations are also given. The distinct characteristics of *E. conjungenus* **sp. n.** is the coterminous ridge connected to the base of the notogastral setae. Pseudanal setae undulating attenuate, the proximal half with obvious, thorn-like barbs, the distal half smooth.

Keywords

Epidamaeus, new species, checklist, distribution.

Introduction

Oribatid mites of the genus *Epidamaeus* Bulanova-Zachvatkina, 1957 are known to be very diverse throughout the Northern Hemisphere, especially in Europe and North America (Bayartogtokh 2004). Most species of this genus inhabit the litter of forests,

mosses, decaying woods and organic soil layers, and primarily feed on decomposer or plant pathogenic fungi, therefore, they play an important role in regulation of the density of plant harmful fungi(Bayartogtokh 2000). *Epidamaeus* shows high taxonomic diversity in Europe and some parts of Asia. The genus comprises more than 70 species, that cosmopolitan distributed (Subías 2011). Up to now, only 6 valid species: *E. grandjeani*, *E. cincinnatus*, *E. elegantis*, *E. longispinosus*, *E. yunnanensis*, *E. alticola* from China were described (Wen 1990a, Wang and Norton 1993b, Enami et al. 1994, Wang and Cui 1996a, Chen et al. 2010), but the collection material from different vegetation zones of the country revealed species-richness as that in the other parts of the Palaearctic and Oriental Region. This may be related to the dynamic history of the area, which had a different climate and biota found throughout China.

In the present paper, a new species *Epidamaeus conjungenus* sp. n. were described from Henan Provinces. In addition, a list and key to all known Chinese species were present.

Material and methods

Measurements and descriptions are based on specimens mounted in temporary cavity slides that were studied using a light microscope equipped with a drawing attachment. Body length is measured in lateral view, from the tip of the rostrum to the posterior edge of the ventral plate. Length of leg segments, including the portion inserted into the next segment, is measured in the lateral aspect. The number of specimens measured does not always equal the number of specimens examined because structures are sometimes indiscernible under the circumstances where the specimens are not slide-mounted.

Terminology generally developed by Grandjean (1960) as applied by Norton (1979). All type specimens and other material studied are kept in Oudemans' fluid and deposited in the Institute of Entomology, Guizhou University, Guiyang, China (GUGC).

Taxonomy

***Epidamaeus* Bulanova-Zachvatkina, 1957**
http://species-id.net/wiki/Epidamaeus

Type species: *Oribata bituberculata* Kulczynski, 1902 (Bulanova-Zachvatkina 1957a)

Diagnosis. Body reddish brown, medium sized, light to dark. propodolateral apophyses *P* mostly absent, but rarely present; the formation of tubercles of Prodorsum varied: usually only *Ba* or *Da* present, 3 pairs of tubercles (*Ba*, *Bp*, *Da*) is rare present as *Damaeus*; *La* tubercle can also be present, but weak and indistinct in dorsal view, and never in combination with *Ba* (as in *Kunstidamaeus*); *E*2a and *E*2b missing, *Va* and *Vp* rarely present occasionally. *SS* usually bristle-shaped, in shorter than ss (to 3/4 as long), bristle-shaped, mostly thin. Spinae adnata (*Sa*) usually present (subgen. *Epi-*

damaeus) or absent (subgen. *Akrodamaeus*); The length of legs medium to long; Tibiae I-IV without setae *d*; Setal mostly formula of genua I-IV: 4-4-3-3, rarely 4-4-4-4; Associated setal (setae *d*) formula of genua I-IV: 1-1-1-0; Setal formula of trochanters I-IV: l-1-2-1; Additional ventral seta *v*2" on I and IV missing. 6 g, 1 ag, 2 on, 3 ad. (Weigmann 2006)

Distribution. Palaearctic, Oriental, Nearctic, Neotropical and Australian regions.

Species of genus *Epidamaeus* from China

E. alticola Wang & Cui, 1996

Epidamaeus alticola Wang and Cui 1996a: 321; 1996b: 258.

Material examined. 5♂♂, 4♀♀, China, Qinghai Prov., Xining City, Huzhu National Geological Park(36°57'11"N, 102°28'55"E), from litter under Pteridophytes, 2384 m a.s.l., 23 August 2009, coll. Lixia Xie (GUGC)

Distribution. China (Qinghai).

E. cincinnatus Wang & Norton, 1993

E. cincinnatus Wang and Norton 1993b: 312; Wang et al. 2000: 323.

Material examined. 11♂♂, 6♀♀, China, Hebei Prov., Chengde City, Mt. Wuling (40°36'50"N, 117°28'57"E), from litter under birch, 1362m a.s.l., 25 August 2010, coll. Lixia Xie (GUGC)

Distribution. China (Beijing).

E. elegantis Wang & Norton, 1993

E. elegantis Wang and Norton 1993b: 316-318; Wang et al. 2000: 311.

Material examined. 6♂♂, 3♀♀, China, Fujian Prov., Wuyishan City, Mt. Wuyi (27°45'19"N, 118°02'56"E), from litter under the chestnut trees , 278m a.s.l., 4 August 2008, coll. Zehong Meng (GUGC)

Distribution. China (Fujian, jiangxi).

E. grandjeani Bulanova-Zachvatkina, 1957

E. grandjeani Bulanova-Zachvatkina 1957: 1794-1796; Wen 1990a: 119; Wang et al. 2000: 256.

Distribution. China (Jilin), Russia (Tatarstan).

E. longispinosus Wang & Norton, 1993

E. longispinosus Wang & Norton, 1993b, p. 314-316; Wang, Cui & Liu, 2000, p. 310–311.

Material examined. 4♂♂, 5♀♀, China, Fujian Prov., Wuyishan City, Mt. Wuyi (27°45'24"N, 118°02'46"E), from litter of coniferous forest, 263m a.s.l., 5 August 2008, coll. Zaihua Yang (GUGC)

Distribution. China (Fujian, Jiangxi).

***E. yunnanensis* Enami, Aoki & Hu, 1994**

E. yunnanensis Enami et al. 1994: 43–46; Aoki et al. 2000: 6.

Material examined. 2♂♂, 3♀♀, China, South of Guizhou Prov., Maolan National Nature Reserve (25°19'26"N, 107°55'59"E), from litter under Podocarpus, 819m a.s.l., 16 Sep. 2007, coll. Zaihua Yang (GUGC); 7♂♂, 6♀♀, China, Yunnan Prov., Dali City, Mt. Cang (25°38'38"N, 100°09'53"E), from litter under the pine, 1950m a.s.l., 18 December 2008, coll. Yi Yan (GUGC)

Distribution. China (Yunnan, Guizhou).

Key to species from China

1 Propodolateral apophysis (*P*) present, having tubercles (*La*) ..... ***E. yunnanensis* Enami, Aoki & Hu**

– Propodolateral apophysis (*P*) absent, not having tubercles (*La*) **2**

2 Notogastral setae cincinal, genital seta g_6 far from g_5 ..... ***E. cincinnatus* Wang & Norton**

– Notogastral setae not cincinal, genital setae normal for genus **3**

3 Sensillus (*ss*) aciculiform, aggenital seta (*ag*) lies between Anal aperture and genital aperture ..... ***E. elegantis* Wang & Norton**

– Sensillus (*ss*) rod-like or flagellate, aggenital seta (*ag*) normal for genus..... **4**

4 Sensillus (*ss*) rod-like, seta c_1 longer than other notogastral setae ..... ***E. alticola* Wang & Cui**

– Sensillus (*ss*) flagellate, seta c_1 not longer than other notogastral setae..... **5**

5 Notogastral setae leafy, Spinae adnatae rod-like ..... ***E. grandjeani* Bulanova-Zachvatkina**

– Notogastral setae not leafy, Spinae adnatae not rod-like **6**

6 Coterminous ridge connected to the base of the notogastral setae; Spinae adnatae not long and spinous..... ***E. conjungenus* sp. n.**

– Coterminous ridge not connected to the base of the notogastral setae; Spinae adnatae long and spinous..... ***E. longispinosus* Wang & Norton**

***Epidamaeus conjungenus* sp. n.**

urn:lsid:zoobank.org:act:7B87D6F6-BE4F-408C-8451-A0500B9F4A27

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

Fig. 1

Material examined. Holotype (female in Oudemans' fluid), China: Luoyang city, Mt. Baiyun (34°23'25.18"N, 111°01'23.15"E), Henan province, from litter, 2100 m a.s.l., 16 Aug. 2008, coll. Li-xia Xie. Paratypes. Five adults (2 males, 3 females), with same data as holotype.

Etymology. The specific name "*conjunctus*" is from Latin, and refers to the conjunct ridge.

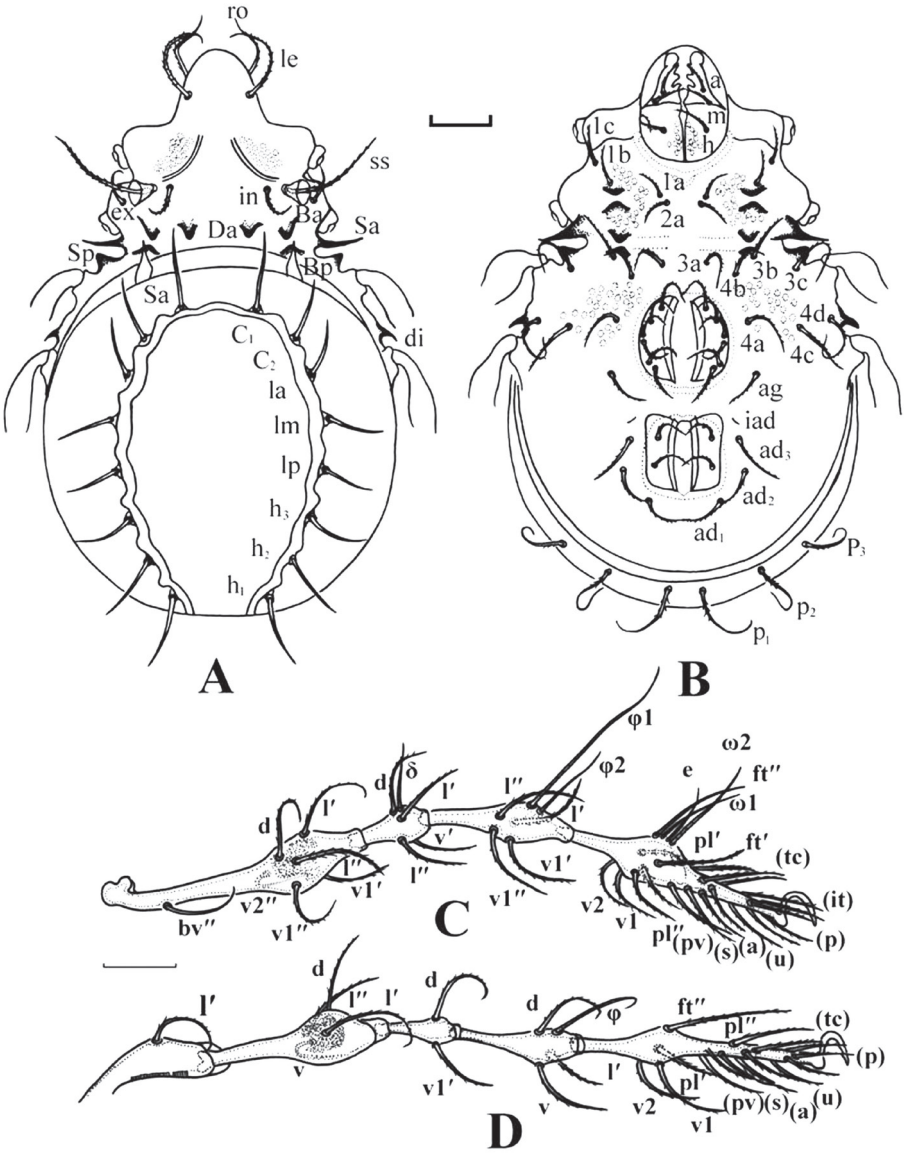


Figure 1. *Epidamaeus conjungenus* sp. n. **A** adult, dorsal view (100 μm) **B** adult, ventral view (100 μm) **C** leg I (100 μm) **D** leg IV (100 μm).

Diagnosis. Prodorsal tubercles *Da, Ba, Bp* present. Sensillus smooth, short, with conspicuous bars. *Sa* triangular, long and acuminate. *Sp* small, triangular. Enantiophysis *E2* and *V* present. *Vp* bearing seta 3*b*. The setae of notogaster acuminate, radially directed. Leg setation as follows, femora 7-6-4-4; genua 4-4-3-2; tibiae 4-4-3-3; tarsi 21-18-18-15.

Dimensions. Body length 913 (holotype), 913- 932 (mean 924, 6 paratypes); body width 605 (holotype), 602- 623 (mean 610, 6 paratypes). Males slightly smaller than females: body length of males holotype and 2 paratypes) 886- 902 (mean 894), body width of males 584- 592 (mean 588); body length of females (4 paratypes) 906-914(mean 910), body width of females (4 paratypes) 596- 624 (mean 610).

Integument. Microtuberculate on all enantiophyses and apophyses, rostrum, lateral prodorsum and around leg acetabula. Cerotegument granules, thick, dense on most of body and legs, except digital part of tarsi. Notogaster with exuvial scalps, legs segments and lateral part of body with dense fungus micelles and adherent debris.

Prodorsum. Tubercles *Da* and *Bp* well developed, broadly rounded; *Ba* represented as high ridge. Propodolateral apophysis (*P*) absent. A ridge presents the side of prodorsum. Setae *ro* (175–183 μm) and *le* (216–221 μm) long, smooth, with conspicuous barbs; mutual distance of pairs *le* slightly less than that of *ro* (1.0:1.1). Interlamellar setae (96–104 μm), dark brown, with small barbs. Exobothridial setae (94–98 μm) smooth, relatively tenuous, attenuate. Sensillus (225–232 μm), with conspicuous barbs, undulating attenuate. Comparative length of prodorsal setae: *ex* < *in* < *ro* < *le* < *ss*.

Notogaster. Almost circular, slightly longer than wide. Anterior and posterior margins broadly rounded in dorsal view. Spinae adnatae large, directed anterolaterad in dorsal view, distance between their bases approximately equal to that between tubercles *Bp*. Notogastral setae of *c*-, *l*- and *h*- series inserted on distinct tubercles. Setae relatively smooth, brown, acuminate. Comparative length: $lm < lp < la = h_3 < h_2 < h_1 = c_1 = c_2$. The respective lengths: 88–94μm, 107–110 μm, 137–142 μm, 147–154 μm and 167–172 μm. Setae c_1, c_2 and *la* directed anterodorsad, other setae radially directed. A conjoint ridge connected to base of all notogastral setae. Mutual distance of setae c_2 twice that of c_1. Pseudanal setae undulating attenuate, the proximal half with obvious, thorn-like barbs, the distal half smooth. Comparative length: $ps_1 > ps_2 > ps_3$.

Ventral region. Epimere I with medial pit and associated groove. Enantiophyses E_2 and *V* well developed, broadly triangular in ventral view. Tubercle *Vp* bearing epimeral seta 3*b*. Parastigmatic tubercle *Sa* long, acuminate and triangular. *Sp* triangular, distinct in ventral view. Length of lateral aspect *Sp* twice as broad as *Sa*. Discidium acuminate, smaller than *Sp*, directed posterolaterad. Ventral setae faintly barbed. Setae 3*c*, 4*d* very long, flagelliform. Epimeral setation: 3-1-3-4. Anogenital region normal, seta ad_3 close to anal valves. Fissure *iad* minute, represented by small, inconspicuous pore in lateral corner of valve. Anal aperture appreciably equal to genital aperture.

Gnathosoma. Infracapitular mentum slightly wider than long, without noticeable microtubercles. Hypostomal setae *a*, *h* and *m* thin, slightly barbed; seta *a* relatively short. Chelicera rather strong, fixed and movable digits with three blunt teeth; setae *cha* and *chb* conspicuously barbed. Palpal setation: 0-2-1-3-8 including solenidion ω.

Legs. Relative lengths (I-IV): 1: 0.84: 0.95: 1.1. Leg IV 1.1 times ventral body length; Femur IV 1.44 times length of trochanter IV. Formulae of leg setation and solenidia: I (1-7- 4- 4- 21) [1-2-2], II (1-6-4-4-18) [1-1-2], III (2-4-3-3-18) [1-1-0], IV (1-4-3-3-15) [0-1-0]; Each solenidion on genu I - III coupled with a respective seta

d, seta *d* longer than solenidion on genu I-III. Solenidion φ_1 on tibia I flagelliform, and 2.2 times longer than φ_2.

Distribution. Known only from the type locality.

Table 1. Leg setation and solenidia of *Epidamaeus conjungenus* sp. n.

Legs	Trochanter	Femur	Genu	Tibia	Tarsus
I	*v*	*d*, *l'*, *l"*, v_1' v_1" *bv"*, v_2"	*d*, *σ*, *l'*, (*v*)	φ_1, φ_2, *l'*, *l"*, (*v*)	*ft'*, *ft"*, *pl'*, *pl"*, (*v*), ω_1, ω_2, *ε*, (*pv*), (*tc*), (*it*), (*p*), (*u*), (*a*), *s*
II	*v*	*d*, *l'*, *l"*, *bv"*, (*v*)	*d*, *σ*, *l"*, (*v*)	*φ*, (*l*), (*v*)	*ft'*, *ft"*, (*v*), ω_1, ω_2, (*pv*), (*tc*), (*it*), (*p*), (*u*), (*a*), s
III	*l'*, *v'*	*d*, *l'*, *ev'*, *v'*	*d*, *σ*, *l'*, *v'*	*d*, *φ*, *l'*, *v'*	*ft*, *v'*, *pv"*, *pv'*, (*tc*), (*it*), (*p*), (*u*), (*a*), *s*
IV	*v*	*d*, *l'*, *ev'*, *v'*	*d*, *l'*, *v'*	*φ*, *l'*, (*v*)	*ft"*, (*v*), (*pv*), (*tc*), (*p*), (*u*), (*a*), *s*

Remarks. *Epidamaeus conjungenus* sp. n. can be readily distinguished from most of known species of *Epidamaeus* by the coterminous ridge connected to the base of the notogastral setae. Pseudanal setae undulating attenuate, the proximal half with obvious, thorn-like barbs, the distal half smooth. Parastigmatic tubercle *Sa* very long, acuminate, Discidium(*di*) acuminate. The strong Spinae adnatae (*Sa*). The Prodorsum of this new species is somewhat similar to *E. verrucatus* described by Enami and Fujikawa (1989), but the setae of notogaster of new species are smooth, and lack of Propodolateral apophysis (*P*) and present tubercles *Da* and *Bp*.

Acknowledgements

We would like to express our heartfelt thanks to Roy A. Norton (College of Environmental Science and Forestry, State University of New York, Forestry Drive, Syracuse, New York, U.S.A) and Sergey G. Ermilov (Laboratory of Entomology, Center of Independent Examinations-NN, Nizhniy Novgorod, Russia) for their encouragement to our research and fervidly sending documents. Thanks are also due to all the people who participated in the specimens' collection, for their friendly help and eager cooperation.

Reference

Aoki J, Yamamoto Y, Hu SH (2000) A checklist of oribatid mites of Yunnan Province in China (Acari, Oribatida). In: Aoki J, Yin WY (Eds) Taxonomical studies on the soil fauna of yunnan province in southwest China. Tokai University Press, Tokyo, 36 pp.

Bayartogtokh B (2000) Two Species of Damaeid Mites (Acari: Oribatida: Damaeidae) from Mongolia, with notes on distribution of the genera *Epidamaeus* and *Dyobelba*. Biogeography 2: 67–79.

Bayartogtokh B (2004) Oribatid mites of the Genus *Epidamaeus* (Acari: Oribatida: Damaeidae) from Eastern Mongolia. J. Acarol. Soc. Jpn 13(2): 161–168. doi:10.2300/acari.13.161

Bulanova-Zachvatkina EM (1957a) Epidamaeus grandjeani Bul.-Zachv., gen. et sp. nov. (Acariformes, Oribatei) from Kuril Islands. Rev. Ent. URSS 36: 547–552.

Bulanova-Zachvatkina EM (1957) Oribatid mites Damaeidae Berl. Genus *Epidamaeus*, Gen. N. (Acariformes, Oribatei). Part II. Zoological magazine, xxxvi, 12: 1792–1801 [in Russian]

Chen J, Liu D, Wang HF (2010) Oribatid mites of China: a review of progress, with a checklist. In: Zhang Z-Q, Hong X-Y, Fan Q-H (Eds) Xin Jie-Liu Centenary: Progress in Chinese Acarology. Zoosymposia 4. Magnolia Press, 199 pp.

Enami Y, Aoki J, Hu SH (1994) Oribatid mites from tropical forests of Yunnan Province in China. IV. Family Damaeidae. Proceeding of the Japanese Society of Systematic Zoology 52: 43–46.

Grandjean F (1960) *Damaeus arvernensis* n sp. (Oribate). Acarologia 2: 250–275.

Norton RA (1979) Damaeidae (Acari: Oribatei) collected by the Hungarian Soil Zoological Expeditions to South America. Folia Ent. Hung. 32: 55–64.

Subías LS (2004) Listado sistemático, sinonímico y biogeográfico de los ácaros oribátidos (Acariformes: Oribatida) del mundo (excepto fósiles). Graellsia 60(número extraordinario): 3–305. [Online version actualized in April 2009] http://www.ucm.es/info/zoo/Artropodos/Catalogo.pdf

Wang HF, Norton RA (1993b) Three new species of *Epidamaeus* from China (Acari: Oribatida: Damaeidae). Acta Zootaxonomica Sinica 18(3): 312–321 [in Chinese with English abstract]

Wang HF, Cui YQ (1996a) Acari: Oribatida. In: Huang FS (Eds) Insects of the Karakorum-Kunlun Mountains. Science Press, Beijing, 321–328.

Wang HF, Cui YQ (1996b) Acari: Oribatida. In: Wu SG, Feng ZJ (Eds) The Biology and Human Physiology in the Hoh Xil Region. Science Press, Beijing, 258–264. [in Chinese with English abstract]

Wang HF, Cui YQ, Liu YH (2000) Acari: Oribatida. In: Huang BK (Eds) Fauna of Insects in Fujian Province of China, Vol. 9. Fujian Science and Technology Publishing House, Fuzhou, 296–323. [in Chinese with English abstract]

Wang HF, Hu SH, Yin SG (2000) The oribatid fauna and distribution in different zones in China. In: Yin WY et al. (Eds) Soil Animals of China. Science Press, Beijing, 251–265. [in Chinese]

Weigmann G (2006) Hornmilben (Oribatida). Die Tierwelt Deutschlands. 76 Tiel. Goecke and Evers, Keltern, 520 pp.

Wen ZG (1990a) Preliminary investigation of soil oribatid mites in Jilin Province. Journal of Northeast Normal University (Suppl.): 115–124. [in Chinese]

ZooKeys 119: 37–52 (2011)
doi: 10.3897/zookeys.119.1451
www.zookeys.org

RESEARCH ARTICLE

A peer-reviewed open-access journal
ZooKeys
Launched to accelerate biodiversity research

Color variability and body size of larvae of two *Epomis* species (Coleoptera, Carabidae) in Israel, with a key to the larval stages

Gil Wizen, Avital Gasith

Tel Aviv University, George S. Wise Faculty of Life Sciences, Department of Zoology, The National Collections of Natural History, Tel-Aviv 69978, Israel

Corresponding author: *Gil Wizen* (wizentrop@gmail.com)

Academic editor: *Achille Casale* | Received 29 April 2011 | Accepted 4 July 2011 | Published 15 July 2011

Citation: Wizen G, Gasith A (2011) Color variability and body size of larvae of two *Epomis* species (Coleoptera, Carabidae) in Israel, with a key to the larval stages. ZooKeys 119: 37–52. doi: 10.3897/zookeys.119.1451

Abstract

Species identification using the characteristics of developmental stages is challenging. However, for insect taxonomy the coloration of larval stages can be an informative feature. The use of live specimens is recommended for this because the color fades in preserved specimens. In this study we examine the possibility of using variation in coloration and color pattern of larvae in order to distinguish between two ground beetles species *Epomis dejeani* (Dejean, 1831) and *E. circumscriptus* (Duftschmid, 1812). We present an atlas and describe the coloration and body size of the three larval stages of the above species based on live specimens. An identification key is given for the three larval instars of the two *Epomis* species.

The first instar larvae of the two *Epomis* species can be easily distinguished based on their color. From the second instar on, the variability in coloration and color patterns increases, creating an overlap in these attributes between larvae of the two species. Except for minor differences in color of the antennae and the base of the mandibles, larvae of the two species are indistinguishable at the second and third larval stages. To the best of our knowledge this is the first attempt to use variation in coloration and color pattern in live larvae in order to identify coleopterans. The color atlas of the larvae enables simple separation of the two *Epomis* species without requiring sophisticated magnifying devices, although it is less straightforward at the second and third larval stages.

We found similar body lengths between the two species for all developmental stages, except for third instar larvae prior to pupation. In the two species the difference in larval body length before pupation positively correlated with that of the adult beetles. More than 70% of the adults' length can be explained by the length of the late third-instar larva; i.e. the large larvae develop into large adults. The larger specimens are the females.

Keywords

Epomis larvae, Carabidae, color atlas, body size

Introduction

Coloration can be an informative feature for insect taxonomy (van Emden 1957, Luff 1993). While the larvae of some ground beetles (Carabidae) have been well studied (reviewed in Lawrence 1991) for other beetles the larval stage is still unknown. Those larvae that have been studied were described according to morphology and structure, with less attention paid to color (e.g. van Emden 1942, Thompson 1979). Of the latter descriptions, some give limited information about the color of ground beetle larvae (e.g. van Emden 1942, Thompson 1979, Luff 1993, Erwin and Medina 2003), but not on pattern and color variability. Information available so far indicates that generally color variability in Coleoptera larvae is rare and so is the case in ground beetle larvae as well (Luff 1993, senior author personal observations).

In a recent study of two Chlaeniini (Carabidae) species of *Epomis*, *E. dejeani* (Dejean, 1831) and *E. circumscriptus* (Duftschmid, 1812), in Israel, we noticed that the larvae display color variation. The genus *Epomis* Bonelli, 1810 consists in ca. 20 species, mostly known from tropical Africa and south and south eastern Asia. Five of the species are from the Palaearctic region (Kryzhanovskij 1983). In mediterranean lands in Europe, this genus is rare and considered endangered (Brandmayr and Algieri 2000). *Epomis* have three larval stages (Elron et al. 2007). The third instar larva of *E. dejeani* was first described by Makarova (2005). Recently, Brandmayr et al. (2010) added a description of the first instar of *E. dejeani* and of the first and third instar larvae of *E. circumscriptus*. In none of the above morphological descriptions, however, is color variation in the larvae mentioned. This may be partly attributed to examination of larvae preserved in formaldehyde and alcohol. Preservation results in fading of the coloration of soft-bodied insects, particularly of the immature stages (McFarland 1964, Moore 1971, Luff 1993).

The taxonomic status of *Epomis* is under debate. Kirschenhofer (2003) considers *Epomis* as a subgenus of *Chlaenius*, whereas Basilewsky (1955) and Makarova (2005) consider it as a separate genus. Brandmayr et al. (2010), who examined and described the larvae of the two discussed species, support the separate standing of *Epomis* as a genus. Here we adopt the latter taxonomic approach.

We describe the variation in coloration and color pattern and body size of the three larval stages of *E. dejeani* and *E. circumscriptus*.

Methods

The three larval stages of *Epomis* are referred to as L1, L2 and L3. Larvae were obtained *ex-ovo* in the laboratory from a dozen females of each species collected in the wild. The two *Epomis* species do not coexist at the same sites. Adults of each species were collected in a different locality from the largest population known for each species. The larvae were reared in a room with constant temperature (25°C ± 1°C) and artificial light. They were kept in one liter plastic containers (10.5 cm high; 14.5 cm

diameter) with moist peat as substrate and were fed with live amphibian metamorphs. Freshly hatched or molted larvae appear uniformly white; the final color appears after about two hours. For this reason we used larvae 10 hours after hatching or 10 hours post-molt for documenting color variability and patterns. We photographed them using a Canon EOS 50D camera with Canon MP-E 65 mm and EF-S 60 mm macro lenses and Canon MT-24EX flash. We also measured larval body length from the tip of the mandible to the end of the abdomen (mandible-abdomen length, MAL) using a caliper (±0.05 mm). L1 was measured after hatching and before molting into L2; L2 was measured after molting and before molting into L3; and L3 was measured after molting and before pupation. We measured the body length of the adults that emerged (from the tip of the mandible to the end of the elytra), and examined the correlation between their body length with that of the late L3.

The statistical analysis was performed using Statistica ver. 8. Due to a small sample size and non-normal distribution of the data we used non-parametric statistical tests (Zar 1998). For comparing body lengths of each larval instar between the two species we used Mann-Whitney test. For analyzing the relationship of pre-pupation, third instar body length with the respective body length of the emerged adult we used Spearman correlation.

We prepared a key to the larvae, incorporating morphological characters described by Brandmayr et al. (2010) with the color characteristics and body length information recorded in this study. The description by Brandmayer et al. is based to a large degree on larvae we provided the senior author. Those larvae were from the same populations described above and were obtained in the same manner.

Results

Coloration and body length of *E. dejeani* larvae

L1, L2 and L3 differ in coloration. Moreover, we found variability in coloration within L2 and L3 stages (Fig. 2, 3 and 7). Median mandible-abdomen length (MAL) of L1 after hatching is 4.8 mm and before molting into L2 it is 8.3 mm (Table 1). The larva is mostly black-dark brown, with the last two or three segments of the abdomen being yellow. The tergite preceding the latter segments is medially yellow and its sides are black. The base of the mandible is pale brown or pale yellow. The retinaculum is reddish-brown and the apex is of similar but paler color. The remaining mouthparts, antennae, legs and urogomphi are pale yellow (Fig. 1). Median MAL of L2 after molting is 8.3 mm and before molting into L3 it is 13.2 mm (Table 1). The main body color of L2 ranges from pale brown with black spots to completely black. The legs and urogomphi are pale yellow and sometimes their base is black. The mandibles are pale brown or black, apex and retinaculum are reddish-brown. The base of the mandible is pale brown. The remaining mouthparts and antennae are pale brown or grey (Fig. 2 and 7). Median MAL of L3 after molting is 13.5 mm and before pupation it is 18.2 mm (Table 1). L3 resembles L2 in coloration, with the main body color ranging from pale

Table 1. Median body length (mm) of *E. dejeani* and *E. circumscriptus* larvae and inter-species MAL comparison (Mann-Whitney test) at different developmental stages. Number in parentheses indicates number of individuals.

Taxa	L1		L2		L3	
	After hatching	Prior to molting	After molting	Prior to molting	After molting	Prior to pupation
E. dejeani	4.8 (12)	8.3 (12)	8.3 (10)	13.2 (10)	13.5 (12)	18.2 (11)
E. circumscriptus	5 (11)	8.5 (9)	8.9 (10)	13 (9)	14 (19)	20.2 (14)
p-value	0.102	0.522	0.088	0.595	0.542	0.00084

brown with black spots to completely black. The legs are pale yellow. The urogomphi are mostly pale yellow but in dark colored larvae the base of the urogomphi is black. The mandibles are pale brown or black, apex and retinaculum are reddish-brown. The base of the mandible is pale brown. The remaining mouthparts and antennae are pale brown or grey (Fig. 3 and 7).

Coloration and body length of *E. circumscriptus* larvae

L1, L2 and L3 differ in coloration. Here too we found variability in coloration within L2 and L3 stages (Fig. 5, 6 and 7). Median MAL of L1 after hatching is 5 mm and before molting into L2 it is 8.5 mm (Table 1). The larva L1 is mostly pale yellow or brownish and on rare occasions brown. In some larvae the sides of the body are grayish-black. The apex and retinaculum are reddish. The remaining mouthparts, antennae, legs and urogomphi are pale yellow. The dark eyes are prominent against the background of the brighter body (Fig. 4). Median MAL of L2 after molting is 8.9 mm and before molting into L3 it is 13 mm (Table 1). The main body color ranges from yellow-brown or white with black and orange spots to completely black with orange spots. The legs and urogomphi are yellow. The mandibles are black, apex and retinaculum are red. The remaining mouthparts are grey or black. The antennae are mostly black except for the two apical segments which are pale yellow (Fig. 5 and 7). Median MAL of L3 after molting is 14 mm and before pupation it is 20.2 mm (Table 1). The main body color ranges from dark brown or white with black and orange spots to completely black with orange spots. On rare occasions the orange spots are missing. The legs and urogomphi are yellow. The mandibles are black, apex and retinaculum are reddish-brown. The remaining mouthparts are grey or black. The antennae are mostly black except for the two last segments which are pale yellow (Fig. 6 and 7).

Except for L3 before pupation, the body length of L1, L2 and L3 of the two *Epomis* species is similar (Mann-Whitney, $p>0.09$, Table 1). Prior to pupation the body length of *E. circumscriptus* L3 is larger than that of *E. dejeani* at the same larval stage (Mann-Whitney, $p<0.001$; Table 1).

Figure 1. Morphs presenting color variability of L1 larvae of *E. dejeani*. Scale bar 2 mm.

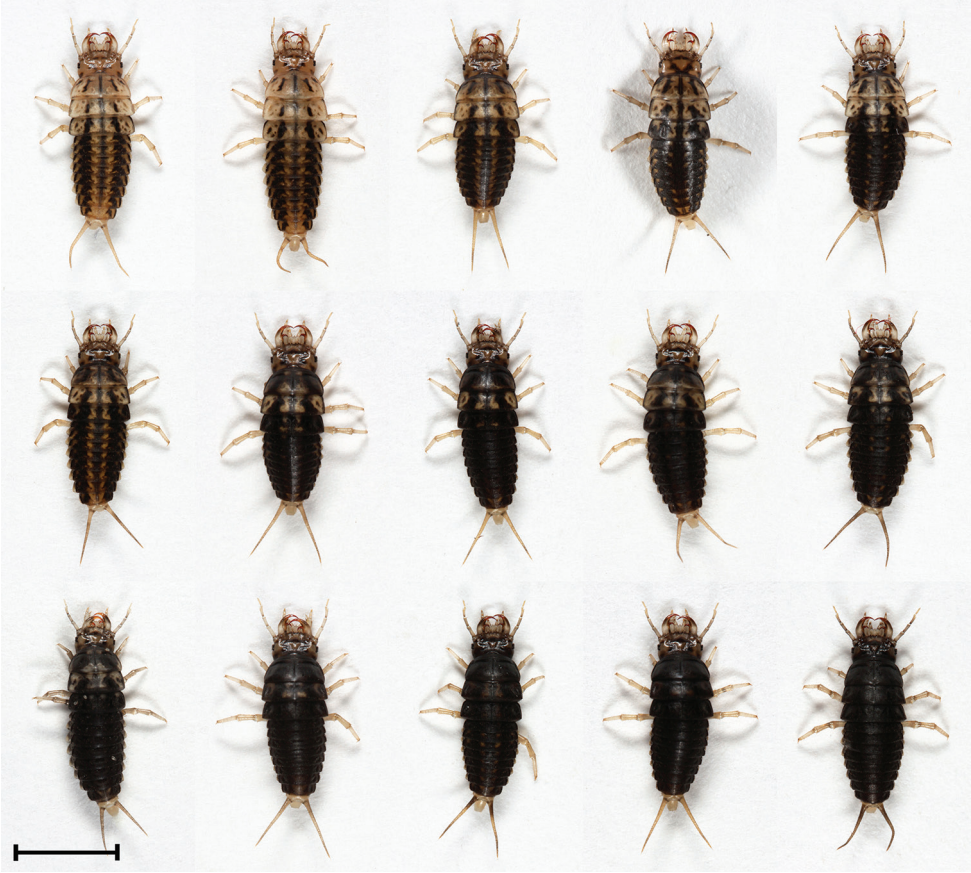


Figure 2. Morphs presenting color variability of L2 larvae of *E. dejeani*. Scale bar 5 mm.

Figure 3. Morphs presenting color variability of L3 larvae of *E. dejeani*. Scale bar 10 mm.

Relationship between pre-pupal instar and adult body length

For each species we compared body length of pre-pupal instar to that of the adult that emerged (Table 2). We found a positive significant correlation between larval and adult body length in each of the two species (Spearman correlation; $p \leq 0.005$). Larger larvae

Figure 4. Morphs presenting color variability of L1 larvae of *E. circumscriptus*. Scale bar 2 mm.

Figure 5. Morphs presenting color variability of L2 larvae of *E. circumscriptus*. Scale bar 5 mm.

Figure 6. Morphs presenting color variability of L3 larvae of *E. circumscriptus*. Scale bar 10 mm.

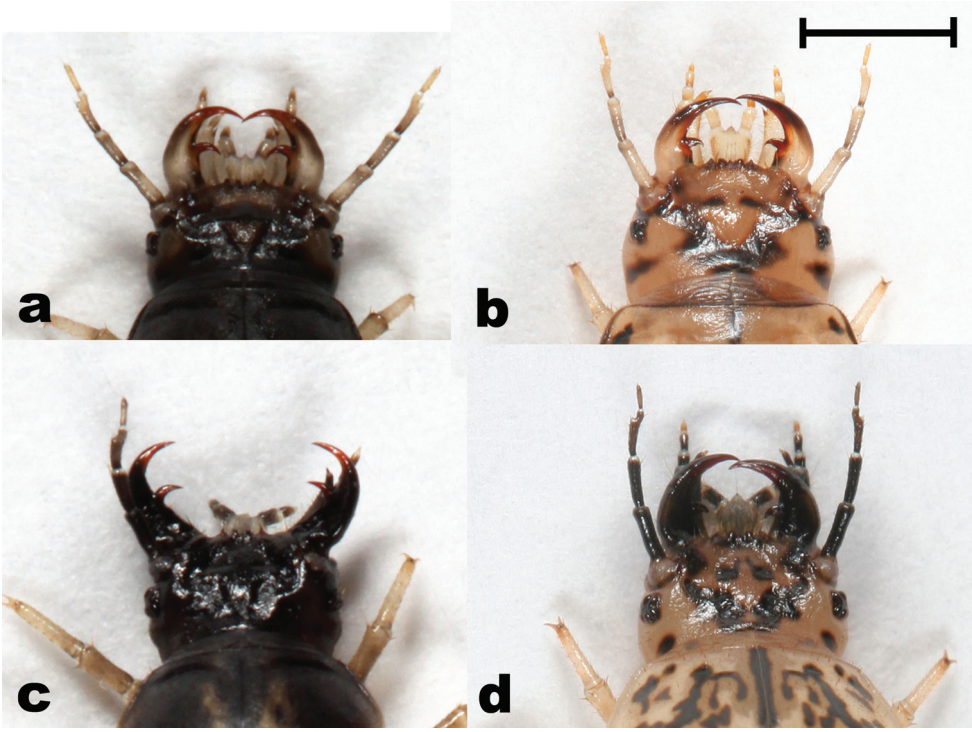


Figure 7. Head (dorsal view) of *Epomis* larvae showing differences in color of antennae and base of mandibles between the two species **a** *E. dejeani*, L2 dark morph **b** *E. dejeani*, L3 pale morph **c** *E. circumscriptus*, L2 dark morph **d** *E. circumscriptus*, L3 pale morph. Scale bar 2 mm.

metamorphosed into larger adults. Larval size explains 72 and 82% of the variability in adult length in *E. dejeani* and *E. circumscriptus*, respectively (Table 2; Fig. 8 and 9). The largest larvae developed into females.

Key to the larvae

1 Body length of the larva is up to 8.5 mm; egg bursters present on forehead, consisting of two rows of denticles; first instar **2**

– Body length of the larva is larger than 8.5 mm; no egg bursters present **3**

Table 2. Range and median of body length (mm) of third instar larvae before pupation and of adults (male and female) of *E. dejeani* and *E. circumscriptus*.

Taxa	Body length (mm)				Sex	Individual number
	L3 before pupation		Adult			
	range	median	range	median		
E. dejeani	17–18.1	17.6	16.5–17.2	17	M	3
	17.2–20	18.5	17.8–18.9	17.8	F	8
E. circumscriptus	18–20.8	19.5	17.9–19.8	18.6	M	8
	20.4–27.8	22.6	19.8–21.6	21	F	6

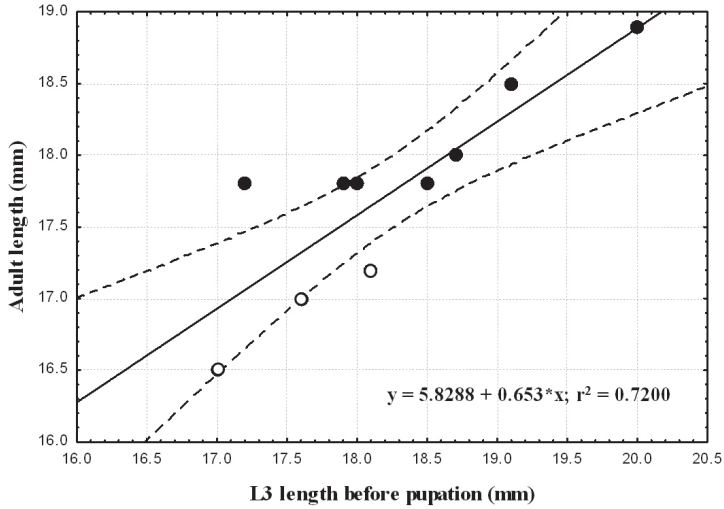


Figure 8. Correlation between adults' body length (mm) and that of third-instar larvae (mm) of *E. dejeani* males (open circles) and females (black circles). Regression equation and coefficient of variation are shown.

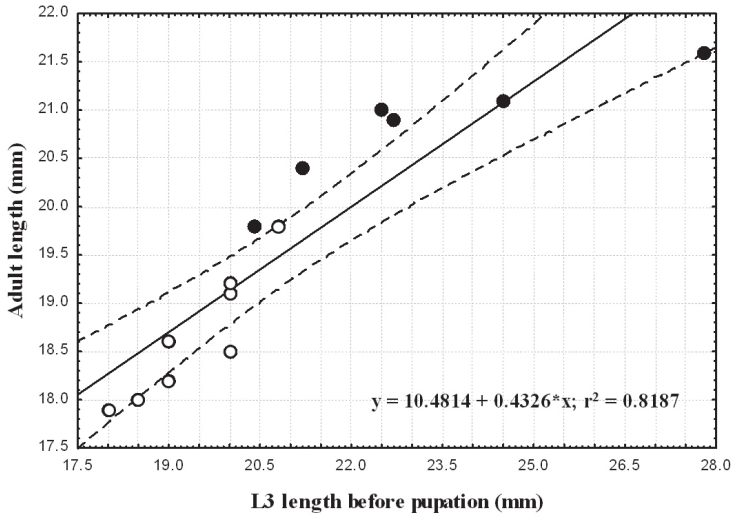


Figure 9. Correlation between adults' body length (mm) and that of third-instar larvae (mm) of *E. circumscriptus* males (open circles) and females (black circles). Regression equation and coefficient of variation are shown.

2 Body length is 5 to 8.5 mm; color is mostly pale yellow or brownish, sometimes brown; body sides can sometimes be grayish-black; mandibles' color is similar to body color, apex and retinaculum are darker and reddish; retinaculum on the same plane as the apical tooth and about the same length as the

latter; both teeth strongly chitinized and curved, forming a strong double complanar hook; the remaining mouthparts, antennae, legs and urogomphi are pale yellow; stemmata are dark and clearly visible against the bright body color (Fig. 1) ..... ***E. circumscriptus***

– Body length is 4.8 to 8.3 mm; color is mostly black-dark brown, the last two or three segments of the abdomen are yellow, the tergite preceding these segments is medially yellow with black sides; mandible base is pale brown or pale yellow, retinaculum reddish-brown and apex of similar but paler color; retinaculum as robust as the apex, bent dorsally and backwards, not at the same plain as the apex, especially on the left side; both teeth strongly chitinized and curved, forming a strong double hook; the remaining mouthparts, antennae, legs and urogomphi are pale yellow; stemmata are poorly pigmented (Fig. 4) ..... ***E. dejeani***

3 Body length of the larva is up to 13.5 mm; second instar **4**

– Body length of the larva is larger than 13.5 mm; third instar **5**

4 Body length is 8.9 to 13.5 mm; color ranges from yellow-brown or white with black and orange spots to uniformly black with orange spots; the mandibles are black, apex and retinaculum are red; the remaining mouthparts are grey or black; the antennae are mostly black except for the two apical segments which are pale yellow; legs and urogomphi are yellow (Fig. 2 and 7) .. .. ***E. circumscriptus***

– Body length is 8.3 to 13.2 mm; color ranges from pale brown with black spots to uniformly black; the mandibles are pale brown or black, mandible base is pale brown, apex and retinaculum are reddish-brown; the remaining mouthparts and antennae are pale brown or grey; legs and urogomphi are pale yellow, urogomphi sometimes black at base (Fig. 5 and 7) ..... ***E. dejeani***

5 Body length is 14 to 20.2 mm; color ranges from dark brown or white with black and orange spots to uniformly black with or without orange spots; the mandibles are black, apex and retinaculum are reddish-brown; the remaining mouthparts are grey or black; the antennae are mostly black with the two last segments which are yellow; legs and urogomphi are yellow (Fig. 3 and 7) .... ***E. circumscriptus***

– Body length is 13.5 to 18.2 mm; color ranges from pale brown with black spots to uniformly black; the mandibles are pale brown or black, mandible base is pale brown, apex and retinaculum are reddish-brown; the remaining mouthparts and antennae are pale brown or grey; legs pale yellow; urogomphi mostly pale yellow, and with a black base in uniformly black colored larvae (Fig. 6 and 7) ..... ***E. dejeani***

Discussion

E. dejeani and *E. circumscriptus* appear in the key to European Carabidae (Trautner and Geigenmüller 1987), which uses characters associated with identification of adults only. Makarova (2005) described for the first time the third-instar larva of *E. dejeani* (preserved specimen). We recently sent all three larval stages of the two *Epomis* species known from Israel to Pietro Brandmayr (University of Calabria, Italy) for description (Brandmayr et al. 2010). Brandmayr et al. reported a clear difference in mandible morphology in the first instar larvae of the two species. In *E. dejeani* larvae the retinaculum is bent dorsally while the apex is bent medially, whereas in *E. circumscriptus* larvae both retinaculum and apex are bent medially. A preliminary description of coloration of preserved larvae (in 70% alcohol) of the first and third larval stages is given. While studying the *Epomis* larvae we noticed that the color of preserved larvae fades with time, making color descriptions based on preserved specimens problematic. Here we present data on developmental changes reflected in variation in coloration and color pattern of the three larval stages, as well as body size. This is based on live specimens reared in the laboratory under the same conditions.

We found variability in color patterns in all larval stages of the two *Epomis* species. A couple of hours after hatching the first instar larvae of the two species can be easily distinguished based on their color. From the second instar on, the variability in coloration and color patterns increases, creating an overlap in these characteristics between larvae of the two species. Except for minor differences in color of the antennae and the base of the mandibles (Fig. 7), larvae of the two species are indistinguishable at the second and third larval stages. We found no significant difference in body length of larvae of the two *Epomis* species, except for the third instar larvae prior to pupation. At this stage the median body length of *E. circumscriptus* larvae is 2 mm longer than that of *E. dejeani* at the same stage. In the two species the difference in larval body length before pupation positively correlated with that of the adult beetles.

Epomis adults are the largest among the Chlaeniini (Basilewsky 1955). Here we found that in both *Epomis* species more than 70% of the adults' length can be explained by the length of the late third instar larva; therefore, the large larvae develop into large adults. The larger specimens were the females. Although we have no additional evidence for a similar correlation between larval and adult body length in other carabids, this phenomenon is known from other Coleoptera (Stern and Emlen 1999).

According to the Catalogue of Palaearctic Coleoptera (Kirschenhofer 2003) and the key to the European Carabidae (Trautner and Geigenmüller 1987), *Epomis* is a subgenus of *Chlaenius*, and adults of *Epomis* are distinguished from their close *Chlaenius* relatives in their larger body length and the shape of their labial palp (Trautner and Geigenmüller 1987). Basilewsky (1955) examined the African fauna of *Epomis* and published a revision calling for separation of the genera. The description of the third instar larva of *E. dejeani* supports this conclusion (Makarova 2005). Brandmayr et al. (2010), who examined and described the larvae of the two species discussed in this study, also support

the separate standing of *Epomis* as a genus within the Chlaeniini tribe. New data on the life history of the *Epomis* larvae (Wizen G and Gasith A, unpublished manuscript) indicate a unique biology of the *Epomis* beetles and therefore support the latter conclusion.

It should be pointed out that *Epomis* is an endangered taxon in the European Mediterranean region. *E. circumscriptus* was classified as a critically endangered species in Italy (Brandmayr and Algieri 2000). In Israel, *Epomis* populations are small and sparsely distributed. These findings and the fact that the larvae depends on a food source that is declining in many parts of the world (Alford and Richards 1999, Blaustein and Kiesecker 2002) suggests special attention for conservation measures that should be taken in order to protect these beetles from extinction.

In conclusion, the color atlas of *Epomis* larvae that we provide present the color pattern of yet little known larval stages of two ground beetle species, moreover it enables a simple separation of the two species without requiring sophisticated magnifying devices (for example ESM). The two species are easily distinguishable at the first larval stage. While the separation is less straightforward at the later stages, it is nonetheless possible by focusing on the color of the antennae and base of the mandibles. Accurate identification requires use of additional taxonomic tools. In another study (Settanni et al. 2009) the researchers used differential coloration of tergites in first instar larvae of two *Berberomeloe* species (Meloidae, Coleoptera) as diagnostic character for identification. However, their results rely on preserved specimens. To the best of our knowledge this is the first attempt to use variation in coloration and color pattern in live larvae in order to identify coleopterans.

Acknowledgments

We thank Pietro Brandmayr and Tullia Zetto-Brandmayr (University of Calabria, Italy) for describing the larvae and for constructive remarks. We thank Thorsten Assman (Leuphana University, Germany) for providing information on past taxonomic status of *Epomis.* Alex Shlagman (Department of Zoology, Tel-Aviv University, Israel) provided essential information on larvae rearing. We are indebted to Naomi Paz (Tel-Aviv University) for editorial assistance. Permit for collecting and rearing the beetles was issued by the Nature and Parks Authority, Israel.

References

Alford RA, Richards SJ (1999) Global amphibian declines: a problem in applied ecology. Annual Review of Ecology and Systematics 30: 133–165. doi:10.1146/annurev.ecolsys.30.1.133

Basilewsky P (1955) Révision des epèces africaines du genre *Epomis* (Carabidae). Transactions of the Royal Entomological Society of London 107: 95–116. doi:10.1111/j.1365-2311.1955.tb00466.x

Blaustein AR, Kiesecker JM (2002) Complexity in conservation: lessons from the global decline of amphibian population. Ecology Letters 5: 597–608. doi:10.1046/j.1461-0248.2002.00352.x

Brandmayr P, Algieri MC (2000) Habitat affinities of Chlaeniine species (Coleoptera, Carabidae) in Calabria and the status of *Epomis circumscriptus*, evaluated by the "*Cronogeonemie*" software. In: Brandmayr et al. (Eds) Natural History and Applied Ecology of Carabid Beetles. Proceedings of the 9th European Carabidologists Meeting, July 1988, Camigliatello, Cosenza (Italy). Pensoft, Series Faunistica 19: 71–78.

Brandmayr P, Bonacci T, Zetto-Brandmayr T (2010) Larval morphology of *Epomis circumscriptus* (Duftschmid 1812) and of first instar *E. dejeani*, Dejean, 1831, (Coleoptera, Carabidae, Chlaeniini), with morphofunctional remarks. Zootaxa 2388: 49–58.

Elron E, Shlagman A, Gasith A (2007) First detailed report of predation on anuran metamorphs by terrestrial beetle larvae. Herpetological Review 38 (1): 30–33.

Emden FI van (1942) A key to the genera of larval Carabidae (Col.). Transactions of the Royal Entomological Society of London 92: 1–99. doi:10.1111/j.1365-2311.1942.tb03318.x

Emden FI van (1957) The Taxonomic Significance of the Characters of Immature Insects. Annual Review of Entomology 2: 91–106. doi:10.1146/annurev.en.02.010157.000515

Erwin TL, Medina RF (2003) The neotropical species *Askalaphium depressum* (Bates): Larval description, first diagnosis and illustrations of immature Ctenodactylini, with natural history notes on the genus and tribe (Coleoptera: Carabidae). Zootaxa 273: 1–15.

Kirschenhofer E (2003) Tribe Chlaeniini Brullé, 1834. In: Löbl I, Smetana A (Eds) Catalogue of Palaearctic Coleoptera, Vol. 1: Archostemata, Myxophaga, Adephaga. Apollo Books, Stenstrup, 347–356.

Lawrence JF (1991) Order Coleoptera (general discussion, family key, many family treatments). In: Stehr FW (Ed) Immature Insects, Vol. 2. Kendall/Hunt Publishing Co, Dubuque, IA, 144–658.

Luff ML (1993) The Carabidae (Coleoptera) larvae of Fennoscandia and Denmark. Fauna Entomologica Scandinavica, vol. 27. Scandinavian Science Press, Leiden, Copenhagen, 1–186.

Makarova EV (2005) The larva of the ground beetle *Epomis dejeani* (Coleoptera, Carabidae). Entomological Review 85: 100–106.

McFarland N (1964) Notes on collecting, rearing and preserving larvae of Macrolepidoptera. Journal of The Lepidopterists' Society 18 (4): 201–210.

Moore BP (1971) Notes on an extraordinary blood-feeding carabid larva (Coleoptera) from Port Elizabeth. Annual of the Natal Museum 20: 479–482.

Settanni C, Di Giulio A, Finoia MG, Bologna MA (2009) Intra- and interspecific analysis of first instar larval morphology in the genus Berberomeloe Bologna 1989 (Coleoptera: Meloidae). Zootaxa 2089: 52–64.

Shiina M, Tachikawa S (1988) The life history of *Epomis nigricans* and its larval stage feeding on toads. Abstracts of the 48th Annual Meeting of the Entomological Society of Japan, Nishibaru, Okinawa, 35 (in Japanese).

Stern DL, Emlen DJ (1999) The developmental basis for allometry in insects. Development 126: 1091–1101.

Tachikawa S (1994) Predation on anurans by *Epomis nigricans* larvae. In: Amazing Life of Insects, Atlas of the 48th Special Exhibition, Otaru Museum, Otaru, 20 (in Japanese).

Thompson RG (1979) Larvae of North American Carabidae with a key to the tribes. In: Erwin TL, Ball GE, Whitehead GE, Halpern AL (Eds) Carabid Beetles: Their Evolution, Natural History, and Classification. The Hague: W. Junk, 209–291.

Trautner J, Geigenmüller K (1987) Tiger Beetles, Ground Beetles: Illustrated Keys to the Cicindelidae and Carabidae of Europe. Aichtal, Josef Margraf, 487 pp.

Zar JH (1998) Biostatistical Analysis (4th Edition). Prentice Hall, Englewood Clifs, New Jersey, 929 pp.

ZooKeys 119: 53–61 (2011)
doi: 10.3897/zookeys.119.1621
www.zookeys.org

RESEARCH ARTICLE

A peer-reviewed open-access journal
ZooKeys
Launched to accelerate biodiversity research

Two remarkable new species of *Prothemus* Champion from China and Thailand, with comments on their systematic status (Coleoptera, Cantharidae)

Yuxia Yang[1,†], Sergey V. Kazantsev[2,‡], Xingke Yang[3,§]

1 *College of Life Science, Hebei University, Baoding 071002, Hebei Province, China* **2** *Insect Centre, Doneskaya str., 13-326, Moscow 109651, Russia* **3** *Key Laboratory of Zoological Systematics and Evolution, Institute of Zoology, Chinese Academy of Sciences, Beijing 100101, China*

† *urn:lsid:zoobank.org:author:5DE2E8C5-0E72-4E81-979F-AA3596D4D9F5*
‡ *urn:lsid:zoobank.org:author:D78E9B05-04CB-4EFF-810E-68AD94FDD27C*
§ *urn:lsid:zoobank.org:author:A2537A31-1150-4780-9724-4C8EAFA7A04C*

Corresponding author: *Xingke Yang* (yangxk@ioz.ac.cn)

Academic editor: *Lyubomir Penev* | Received 30 May 2011 | Accepted 8 July 2011 | Published 15 July 2011

urn:lsid:zoobank.org:pub:78304136-B551-4C40-A3AA-85294C70D10A

Citation: Yang Y, Kazantsev SV, Yang X (2011) Two remarkable new species of *Prothemus* Champion from China and Thailand, with comments on their systematic status (Coleoptera, Cantharidae). ZooKeys 119: 53–61. doi: 10.3897/zookeys.119.1621

Abstract

Two remarkable new cantharid species were described, *Prothemus laticornis* **sp. n.** (CHINA: Yunnan) and *P. lycoceroides* **sp. n.** (THAILAND: Chiang Dao), and provided with illustrations of aedeagi, ultimate abdominal sternites and antennae of both sexes. Their systematic status was discussed, because they differed from all other species of *Prothemus* in the dilated and/or serrate antennae and elytra with distinct longitudinal costae and longer pubescence.

Keywords

Coleoptera, Cantharidae, *Prothemus*, new species, China, Thailand

Introduction

The genus *Prothemus* was proposed by Champion in 1926, with *P. neglectus* originally designated as the type species. Most of the taxonomic work on this genus was contributed by Wittmer (1954a,b, 1972, 1973, 1981, 1982, 1984, 1987, 1993, 1995, 1997a,b), besides, Okushima and Satô (1997, 2002), Okushima (2008) and Švihla (2004, 2005, 2011) added some species. Now this genus has 62 species (including the new species described here), distributed in the Oriental (20 species) and East Palaearctic (42 species) regions (Kazantsev and Brancucci 2007).

Recently, we received two interesting cantharid species from China and Thailand respectively. By the external characters, it was not easy to determine whether they belonged to *Prothemus* or *Lycocerus* Gorham, 1889, or a new genus, because their tarsal claws (pro- and meso-outer tarsal claws each roundly appendiculate in male, while simple in female) and rounded pronotum matched the diagnosis of *Prothemus*, while their serrate antennae and pubescent elytra, which characters were common in some *Lycocerus* species, have not been reported in *Prothemus*. After studying the aedeagi of the two species, we discovered that they were of the typical *Prothemus* type. Based on all the above characters, also taking into account that the same variation in the antennae and pubescence occurred in other genera of Cantharinae, such as *Fissocantharis* Pic, 1921, *Lycocerus* Gorham, 1889 and *Habronychus* Wittmer, 1981, we considered that these species to be the members of *Prothemus*, and described them here under the names of *Prothemus laticornis* sp. n. and *P. lycoceroides* sp. n..

Material and methods

The type specimens are deposited in the Institute of Zoology, Chinese Academy of Sciences, Beijing, China (IZAS), Hebei University Museum, Baoding, China (HBUM) and Dr. SV Kazantsev's private collection at Insect Centre, Moscow, Russia (ICCM).

The aedeagi were detached from the body under a stereoscopic microscope and kept in 10% KOH solution for several minutes, then cleared in 75% alcohol and observed under a compound light microscope. Line figures were drawn with the aid of a camera lucida mounted on a Nikon SMZ 800 stereomicroscope. The scanning electronic micrographs were edited in CORELDRAW 12 and ADOBE PHOTOSHOP 8.0.1. The habitus photos were taken by Canon 450D digital camera with a Canon EF 100mm f/2.8 USM Macro Lens. The body length was measured from the anterior margin of clypeus to apex of elytron, and width was at the point of maximum width of the conjoint elytra. Absolute measurements were used in millimetres (mm).

Taxonomy

***Prothemus laticornis* Y. Yang & X. Yang, sp. n.**
urn:lsid:zoobank.org:act:445C8C99-D76C-4A9F-8CBA-07B2143F15D8
http://species-id.net/wiki/Prothemus_laticornis
Figs 1, 3–9

Type material. Holotype male, CHINA: Yunnan, W. Cangshan, 2100m, 3.vi.2008 (IZAS). Paratypes: one male, Yunnan, Cangshan, 21.v.2009, leg. Shoubin Li (HBUM); one female, Yunnan, Yangbi, Xueshanhe, 2000–2800m, 6–8.vi.2004, leg. Song Wang (IZAS); one female, same data as the latter, leg. Xueyan Guo (IZAS); one female, Yunnan, E. slope Cangshan, Mojian, 2.vi.2009, leg. Jianhui Zeng (HBUM)[above transferred from Chinese labels]; two females, Yunnan, Gaoligong Mts., 1500–2500m, 25.22°N/98.49°E, 17–24.v.1995, leg. V. Kubáň (ICCM).

Distribution. China (Yunnan).

Diagnosis. This new species can be easily distinguished from all others of *Prothemus* by the serrate antennae and elytra with distinct longitudinal costae and longer pubescence.

Description. Male (Fig. 1). Black. Pronotum and elytra red; pronotum with a darkened median longitudinal stripe. Body surface densely covered with black pubescence, except on pronotum and elytra with reddish brown pubescence, slightly longer on elytra.

Head surface densely and finely punctate, slightly depressed on vertex; eye slightly protruding, breadth across eyes narrower than maximum width of pronotum; ultimate maxillary palpomere elongate, securiform, widest near base, acute at apex; antenna (Fig. 3) extending to apical one-third of elytron, antennomere II as long as wide at apex, III–X flattened and subserrate, widened apically, protuberant and rounded at apical inner angles, no more than 1.5 times as long as wide at apices, XI flattened and subparallel-sided, pointed at apex.

Pronotum slightly wider than long, widest near base, anterior and lateral margins rounded, posterior margins nearly straight, all angles rounded, disc distinctly convex, with an obscure median longitudinal groove.

Elytra about 5 times longer than pronotum and 5 times longer than wide at humeri, humeral width distinctly wider than that of posterior margin of pronotum, outer margins distinctly diverging posteriorly and slightly converging at apical one-third, disc surface densely and very finely punctuated, with 3 distinct longitudinal costae.

Abdominal sternite IX (Fig. 8) strongly narrowed apically, and far from extending to lateral margins of ventrite IX in natural state.

Figures 1–2. Male habitus, dorsal view **1** *Prothemus laticornis* sp. n. **2** *Prothemus lycoceroides* sp. n.

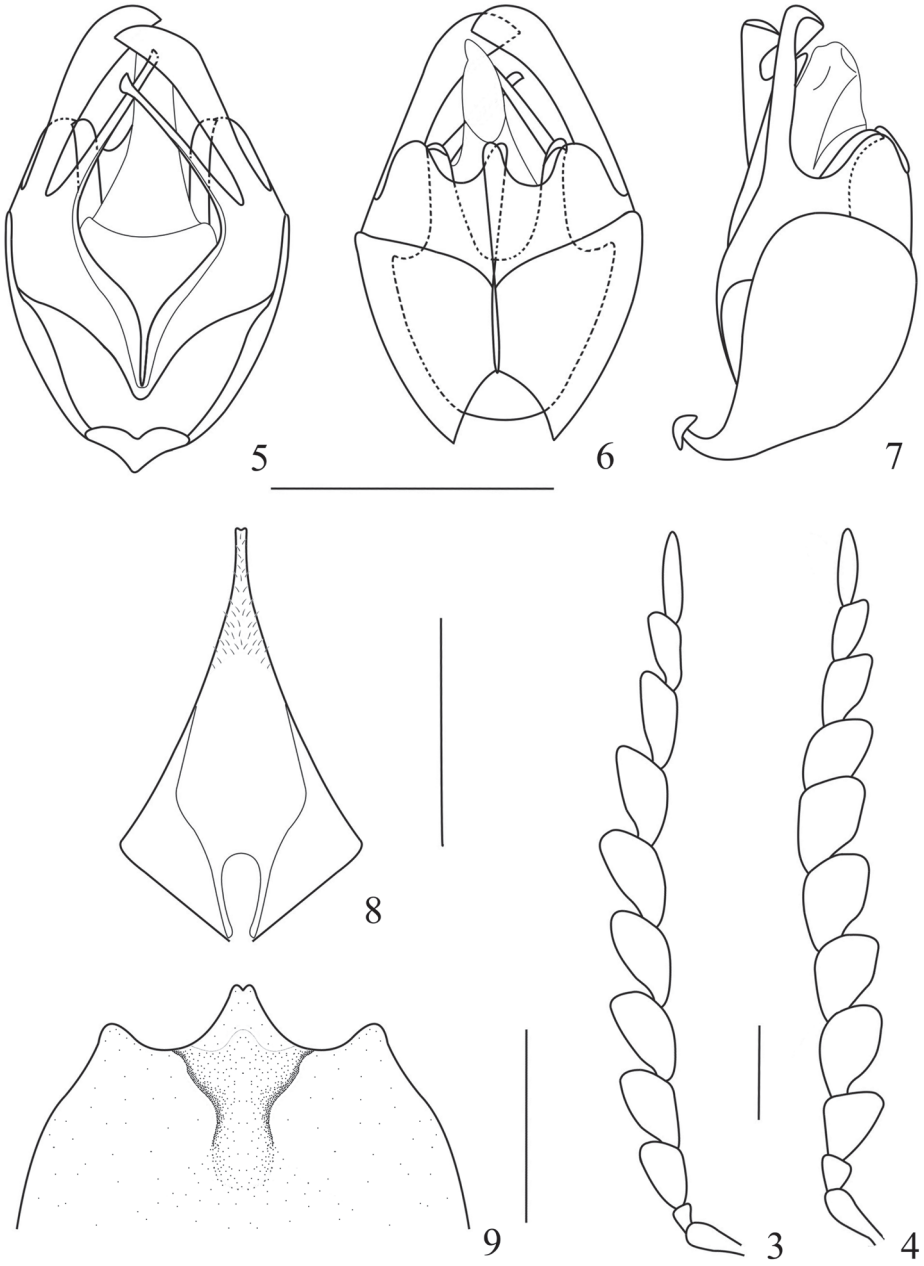
Aedeagus (Figs 5–7) : dorsal plate of each paramere with lateral trunk entirely located in ventral side and slightly widened near apex, middle plate distinctly protuberant and roundly emarginated near inner angle, ventral process of each paramere slightly widened and acute at inner angle, laterophysis stout and as long as middle plate of dorsal plate of each paramere.

Female. Body larger and wider, eye less protruding, antenna (Fig. 4) shorter and wider, pronotum wider than that of male, abdominal sternite VIII (Fig. 9) with a large deep impression and membranous protuberance in middle of posterior margin.

Variation in type series. Legs sometimes mostly brown, pronotum sometimes entirely reddish brown, or with two black markings near middle of anterior and posterior margins respectively. Body length 9.0–13.0 mm, width 3.0–5.0 mm.

Etymology. This new specific name is derived from Latin words *latus* (wide) and *cornu* (antenna), referring to its dilated antennae.

Remarks. The holotype was damaged, its left elytron and right antennomeres VI-II-XI were missing. Paratypes: the male with left antennomeres III–XI and right IX–XI and left pro-leg, one female with left antennomeres III–XI and another female with right antennomeres III–XI were missing.



Figures 3–9. *Prothemus laticornis* sp. n. **3** male left antenna, dorsal view **4** female left antenna, dorsal view **5–7** aedeagus (**5** ventral view **6** dorsal view **7** lateral view) **8** male abdominal sternite IX, ventral view **9** female abdominal sternite VIII, ventral view. Scale bars: 1 mm.

Prothemus lycoceroides **Kazantsev, sp. n.**
urn:lsid:zoobank.org:act:3E254644-AAE8-473B-AB6A-FF3163B4A4EF
http://species-id.net/wiki/Prothemus_lycoceroides
Figs 2, 10–12

Type material. Holotype male, THAILAND, Chiang Dao, 1000m, 19°25'N/98°52'E, 17–24.v.1991, leg. V. Kubáň (ICCM). Paratypes, two males and one female, same data as holotype (ICCM).

Distribution. Thailand (Chiang Dao).

Diagnosis. *Prothemus lycoceroides* sp. n. is fairly similar to *P. laticornis* sp. n., but distinguishable by the narrower antennae, less prominent longitudinal elytral costae and less curved apices of parameres of the aedeagus.

Description. Male (Fig. 2). Black. Pronotum and elytra red; pronotum with a darkened median stripe.

Head surface dorsally densely and finely punctate, slightly depressed between eyes; ultimate maxillary palpomere elongate, securiform, widest near base, acute at apex; antenna extending to apical one-fourth of elytron, antennomere II as long as wide at apex, III–VIII flattened and serrate, at least 2.0 times as long as wide at apices, IX–XI slightly flattened and subparallel-sided (Fig. 10).

Pronotum slightly wider than long, widest near base, all margins and angles rounded, disc distinctly convex, with an obscure median groove.

Elytra long, about 4.75 times longer than pronotum and 3.2 times longer than wide at humeri, humeral width distinctly wider than that of posterior margin of pronotum, almost parallel-sided, disc surface densely and finely punctate, with 2 distinct longitudinal costae.

Aedeagus (Fig. 12): fairly similar to *P. laticornis* sp. n., distinguishable by less curved apices of parameres.

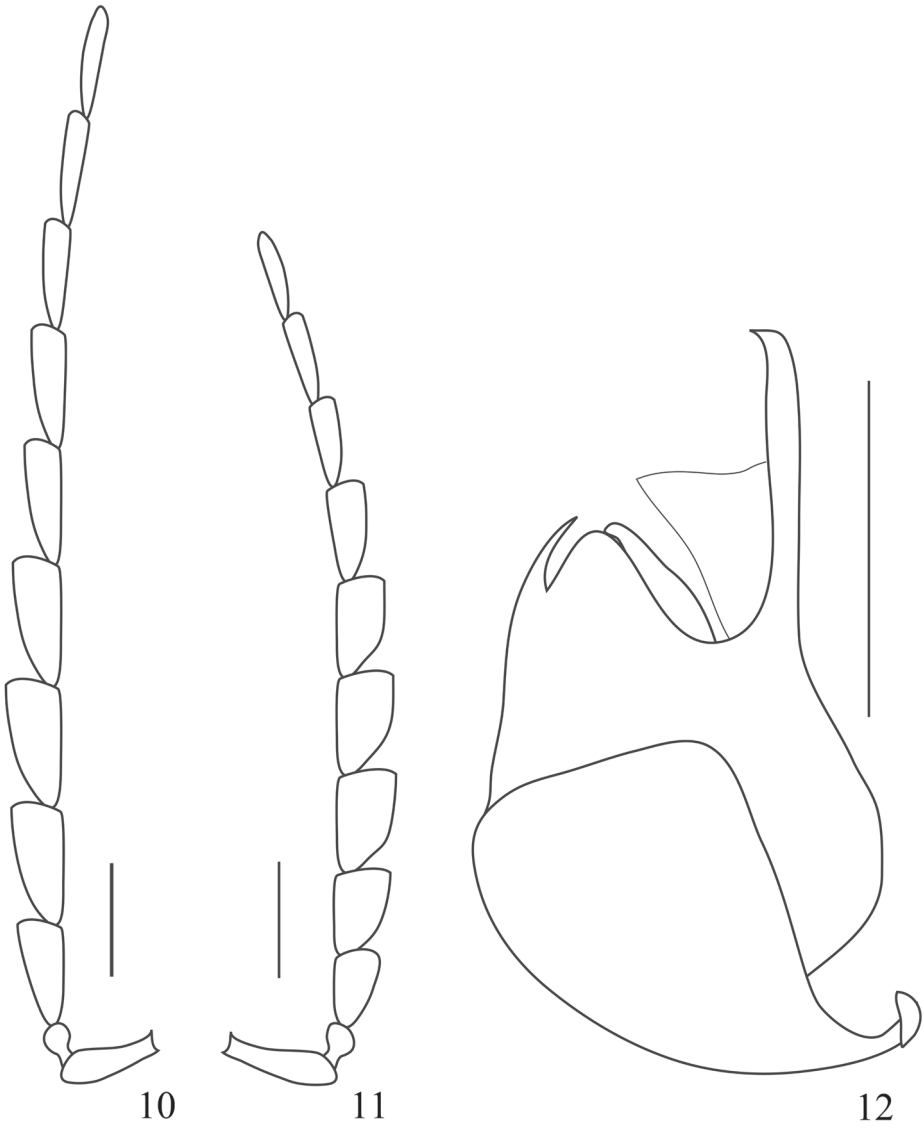
Female. Similar to male, but larger and wider, eye smaller, antenna (Fig. 11) shorter and wider in middle antennomeres.

Body length 13.2–13.8 mm, width 3.0–3.3 mm.

Etymology. The name of the new species is modified from *Lycocerus*, alluding to its similarity to the members of some *Lycocerus* species.

A key to distinguish the new species from all other species of *Prothemus* Champion

1 Antennae dilated and or serrate; elytra covered with distinct longitudinal costae and longer pubescence **2**
– Antennae filiform; elytra never like above ..... **all other species**
2 Antennae wider, male antennomeres III–VIII no more than 1.5 times as long as wide at apices, IX–X distinctly widened ..... ***P. laticornis* sp. n.**
– Antennae narrower, male antennomeres III–VIII at least 2.0 times as long as wide at apices, IX–X slightly widened ..... ***P. lycoceroides* sp. n.**



Figures 10–12. *Prothemus lycoceroides* sp. n. **10** male right antenna, dorsal view **11** female left antenna, dorsal view **12** aedeagus (lateral view). Scale bars: 1 mm.

Discussion

We were greatly surprised to see these strange species at first. Most of their morphological characters showed that they undoubtedly had to be placed in the subfamily Cantharinae. However, judging from the appearance, it was difficult for us to refer them to

any genus. Their tarsal claws and pronotum matched the diagnosis of *Prothemus* very well, but they had dilated and/or serrate antennae and elytra with distinct longitudinal costae and slightly longer reddish brown pubescence, which were hitherto unknown in *Prothemus*, although common in some *Lycocerus* species. Dissection of their male copulatory organs showed they had the typical aedeagi of *Prothemus*. Based on external characters and male genital structures, we supposed that these species should be attributed to *Prothemus*, and their character states of elytra and antennae were considered to be apomorphic within the genus *Prothemus*. In the subfamily Cantharinae, the same variations in antennae and elytra also occurred in the genera *Fissocantharis*, *Habronychus* and *Lycocerus*. Hypothetically they mimic one another and/or some other beetle groups, such as Lycidae, in order to benefit from having similar appearance, for example, to protect themselves better or find more effective ways of attacking prey.

This study provided further proof that appearance of soldier-beetles within a single genus, at least in the subfamily Cantharinae, can vary significantly, while the aedeagal structures appear to be more conservative, apparently because they are subject to the selection pressure of the environment to a lesser extent than most external characters.

Acknowledgements

We were grateful to Dr. Zizhong Yang (Dali University, China) to provide us some studied specimens. This study was supported by the National Natural Science Foundation of China (No. 31010103913) and Science Foundation of Hebei University (No. 2010-203).

References

Kazantsev SV, Brancucci M (2007) Cantharidae. In*:* Löbl I, Smetana A (Eds) Catalogue of Palaearctic Coleoptera, Vol. 4. Apollo Books, Stenstrup, 234–298.

Okushima Y (2008) A new species of the genus *Prothemus* (Coleoptera: Cantharidae) from Taiwan, with records of Taiwanese Cantharidae in the Shibata collection. Special publication of the Japan Coleopterological Society 2: 273–300.

Okushima Y, Satô M (1997) Cantharid beetles of the genus *Prothemus* (Coleoptera, Cantharidae) of the Ryukyu Islands, southwest Japan. Elytra 25: 333–342.

Okushima Y, Satô M (2002) A new small species of the genus *Prothemus* (Coleoptera, Cantharidae) from Taiwan. Special Bulletin of the Japanese Society of Coleopterology 5: 347–350.

Švihla V (2004) New taxa of the subfamily Cantharinae (Coleoptera, Cantharidae) from southeastern Asia with notes on other species. Entomologica Basiliensia 26: 155–238.

Švihla V (2005) New taxa of the subfamily Cantharinae (Coleoptera: Cantharidae) from southeastern Asia with notes on other species II. Acta Entomologica Musei Nationalis Pragae 45: 71–110.

Švihla V (2011) New taxa of the subfamily Cantharinae (Coleoptera: Cantharidae) from southeastern Asia, with notes on other species III. Zootaxa 2895: 1–34.

Wittmer W (1954a) 20. Beitrag zur Kenntnis der palaearktischen Malacodermata (Col.). Mitteilungen der Schweizerischen Entomologischen Gesellschaft 27(2): 109–114.

Wittmer W (1954b) Zur Kenntnis der Cantharidae und Malachiidae der Insel Formosa. Revue Suisse de Zoologie 61(7): 271–282.

Wittmer W (1972) Synonymische und systematische Notizen sowie neue Taxa in Cantharidae (Col.). Verhandlungen der Naturforschenden Gesellschaft in Basel 82(1): 105–121.

Wittmer W (1973) Systematische Berichtigungen in der Fam. Cantharidae (Col.). Mitteilungen der Entomologischen Gesellschaft Basel (N.F.) 23(4): 121.

Wittmer W (1981) 33. Beitrag zur Kenntnis der indo-malaiischen Cantharidae (Col.). Entomologica Basiliensia 6: 387–398.

Wittmer W (1982) 71. Beitrag zur Kenntnis der palaearktischen Cantharidae. Entomologica Basiliensia 7: 340–347.

Wittmer W (1984) Die Familie Cantharidae (Col.) auf Taiwan (3. Teil). Entomological Review of Japan 39(2): 141–166.

Wittmer W (1987) Zur Kenntnis der Gattung *Prothemus* Champion (Coleoptera: Cantharidae). Mitteilungen der Entomologischen Gesellschaft Basel (N.F.) 37(2): 69–88.

Wittmer W (1993) Zur Kenntnis der palaearktischen und indo-malaiischen Cantharidae (Coleoptera). Entomologica Basiliensia 16: 203–253.

Wittmer W (1995) 46. Beitrag zur Kenntnis der indo-malaiischen Cantharidae (Coleoptera). Special Bulletin of the Japanese Society of Coleopterology 4: 407–418.

Wittmer W (1997a) Neue Cantharidae (Col.) aus dem indo-malaiischen und palaearktischen Faunengebiet mit Mutationen. 2. Beitrag. Entomologica Basiliensia 20: 223–366.

Wittmer W (1997b) Neue Cantharidae (Col.) aus China und Vietnam der Ausbeuten von Prof. Dr. Masataka Sato in den Jahren 1995 und 1996. Japanese Journal of Systematic Entomology 3(1): 33–42.

ZooKeys 119: 63–71 (2011)
doi: 10.3897/zookeys.119.1040
www.zookeys.org

RESEARCH ARTICLE

A peer-reviewed open-access journal
ZooKeys
Launched to accelerate biodiversity research

Combining non-invasive methods for the rapid assessment of mammalian richness in a transect-quadrat survey scheme – Case Study of the Horsh Ehden Nature Reserve, North Lebanon

Manal R. Nader[1], Shadi El Indary[2], Bachir Abi Salloum[3], Manale Abou Dagher[4]

1 *Director, Institute of the Environment, University of Balamand, Lebanon; Assistant Professor, Faculty of Science* **2** *Instructor, Institute of the Environment, University of Balamand, Lebanon* **3** *Post-Doc fellow, Department of Pediatrics and Endocrinology, University of Michigan, Ann Arbor, USA* **4** *Instructor, Institute of the Environment, University of Balamand, Lebanon*

Corresponding author: *Manal Nader* (manal.nader@balamand.edu.lb)

Academic editor: *Wieslaw Bogdanowicz* | Received 1 February 2011 | Accepted 1 July 2011 | Published 15 July 2011

Citation: Nader MR, Indary SE, Salloum BA, Dagher MA (2011) Combining non-invasive methods for the rapid assessment of mammalian richness in a transect-quadrat survey scheme – Case Study of the Horsh Ehden Nature Reserve, North Lebanon. ZooKeys 119: 63–71. doi: 10.3897/zookeys.119.1040

Abstract

Lebanon lacks updated information related to the status of mammalian species, their richness and distribution. This study aimed at developing a rapid assessment methodology combining three non-invasive techniques based on the transect-quadrat survey scheme to measure mammalian richness at the Horsh Ehden Nature Reserve. The achieved results showed that the combination of the three techniques, droppings, footprints and photo-trapping for the rapid assessment of mammalian richness supported by Geographical Information System applications is highly effective. Twenty visits covering twenty quadrats out of 49 over a period of nine months allowed the detection of 12 of the 14 targeted species with droppings providing the majority of evidence while footprints and photo-trapping being of equal efficiency. The method can be easily replicated in any region to rapidly assess mammalian richness and the area of activity of the detected species and therefore directing conservation and management activities towards species of interest.

Keywords

Mammals, diversity, Horsh Ehden Nature Reserve, Lebanon

Introduction

Existing baseline data on biodiversity in the Middle East region is poor and sporadic, varies from one country to another and from one species to another. Biodiversity assessments, species status and population dynamic publications are insufficient, particularly for mammalian species (Tohmé et al. 1985, Darwish et al. 1997, Bunaian et al. 1998, Bunaian et al. 2001, Abu Baker et al. 2002, Abu Baker et al. 2003, Yigit et al. 2003, Emre Can 2004, Qarqaz et al. 2005, Abd Rabou et al. 2007, Temple et al. 2009).

Mammalian presence is identified through various non-invasive techniques, mainly footprints, droppings, and feeding signs (Cavallini 1994, Sadlier et al. 2003, Price et al. 2005, Gompper et al. 2006, Abd Rabou et al. 2007, Abi-Said et al. 2007, Bonnaud et al. 2007, De Marinis et al. 2009). Nevertheless, traditional non-invasive techniques to assess mammalian richness are quite time consuming and require extensive resource investment. Lately, new surveying techniques for mammalian studies have become widespread including the increasing dependence on Motion Sensor Cameras (Foresman 2000, Grogan and Lindzey 1999, Trolle and Kery 2005). In addition, mammalian conservation and management strategies are dependent on the efficient and reliable methods for rapid assessment of species richness and abundance (Grogan and Lindzey 1999, Silveira et al. 2003, Trolle and Kery 2005, Gompper et al. 2006), especially in regions where knowledge of mammalian richness is poor and where human and material resources are limited.

The objective of this study was to develop and test a methodology that combines quadrat-transect survey schemes along with non-invasive methods for the rapid assessment of mammalian richness using the Horsh Ehden Nature Reserve (HENR), North Lebanon as the study area.

Materials and methods

Study area

The HENR is situated 100 Km north of the capital Beirut (34°19'N latitude and 36°00' longitude) and occupies a surface area of approximately 1,775 hectares. It ranges in altitude from 1,300 m to 1,950 m with slopes between 10% and 80%. The mean temperature is 9.3°C and the annual rainfall average is 1060 mm with 95 days of snowfall on more than 50% of the protected area. The habitat is a combination of open Mediterranean shrub land, pine/oak forest and cedar/fir forest. Until present, approximately 1058 species of plants, mammals, invertebrates and birds have been recorded in HENR, among them 26 species of mammals (MOE/UL/UNDP 2004). Fourteen out of the 26 are considered as medium to large sized mammals and were targeted in this study.

Sampling

The methodology was based on Williams et al. 2002 with modifications. An ortho-rectified four band satellite image of the HENR dated from the year 2007 was purchased, while several maps showing layers which include the borders of the Reserve, limits of the buffer zone, contour lines (50m) and the land use map (2002) were obtained from the Lebanese Ministry of Environment (http://www.moe.gov.lb). A map of the HENR using a Geographical Information System (GIS) application was produced illustrating the slope gradients (Fig. 1) that allowed identification of the accessible and non-accessible areas for surveying. The accessible area of the Reserve was then divided into 49 quadrats, 500 × 500 m each, giving a total surface area of 250,000 m^2 per quadrat (Fig. 1).

In each quadrat, a line transect sampling was adopted which involves the observation of individuals and their activity along a specific tract (Williams et al. 2002). In total 12,656 m^2 surface area in each quadrat was surveyed where observations covered 3,164 m on foot with a 4 m sight range (2 m to the right and 2 m to the left of the surveyor; Fig. 2). Each quadrat was surveyed over a period of one day.

Animal footprints and droppings spotted during surveying were directly measured, photographed, and identified when possible, and coordinates recorded on an E-trex Summit Global Positioning System (GPS) device (Garmin Ltd. and its subsidiaries, Olathe, Kansas, USA). Photographs were further analyzed and the corresponding spe-

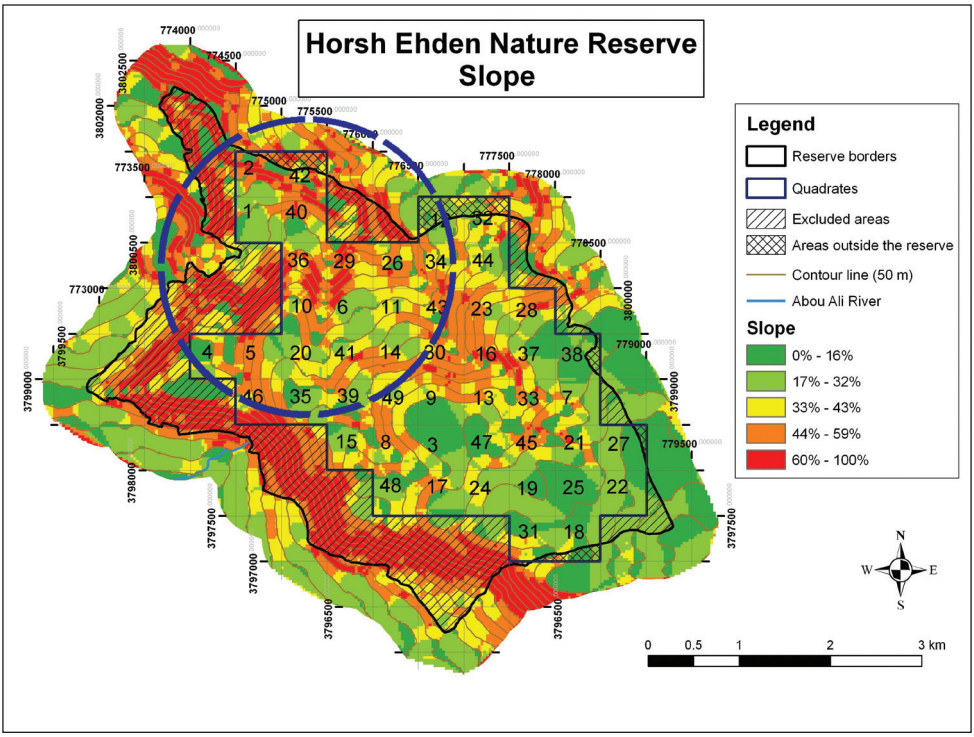


Figure 1. Quadrats and gradient slopes; Blue circle indicates the forested area.

cies identified according to the following four references: Animal Tracks and Signs (Bang 2004), Tracks and Trailcraft (Jaeger 2002), Mammals of North Africa and the Middle East (Stuart 2008) and Mammals of the Holy Land (Qumsiyeh 1996).

Recorded points were then plotted on the map (Fig. 3) using the MapSource 5.4 software (Garmin Ltd. and its subsidiaries, Olathe, Kansas, USA) to classify zones

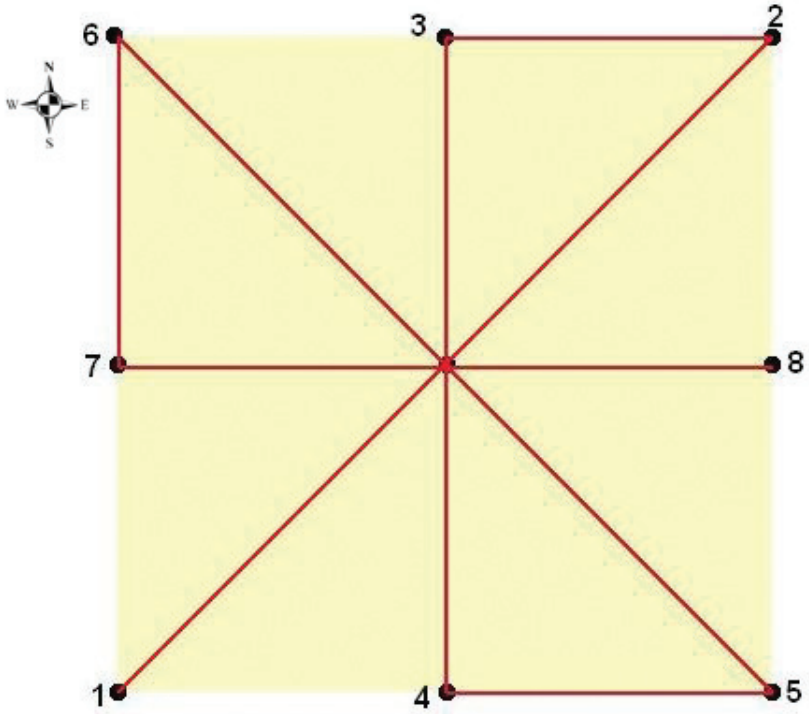


Figure 2. Quadrat travel route.

with high mammalian activity. After localizing mammalian activity, two motion sensor Cuddeback Capture Cameras (Non typical Inc., Falls Park, Wisconsin, USA) with set bait to attract wildlife were deployed to allow visual identification of mammalian species and to further confirm their presence in the Reserve. Photos were extracted on a weekly basis in the field and cameras relocated to predefined new locations. Coordinates of each photo-trapped animal were then downloaded on the mammalian distribution map (Fig. 3).

The testing of the sampling methodology was carried-out in the forested area of the Reserve covering 20 quadrats and their surrounding ecotones (Fig. 1). This area was targeted due to its accessibility during the snowy winter season (the open areas are at high altitudes and not accessible in the winter season), the cover provided to mammals to avoid human disturbance, in addition to the fact that anthropogenic activities increase exponentially during the spring and summer seasons in the open areas and their surrounding (grazing, camping, and hiking). Field activities started on December 1, 2008 and ended on August 31, 2009 with one quadrat surveyed per visit.

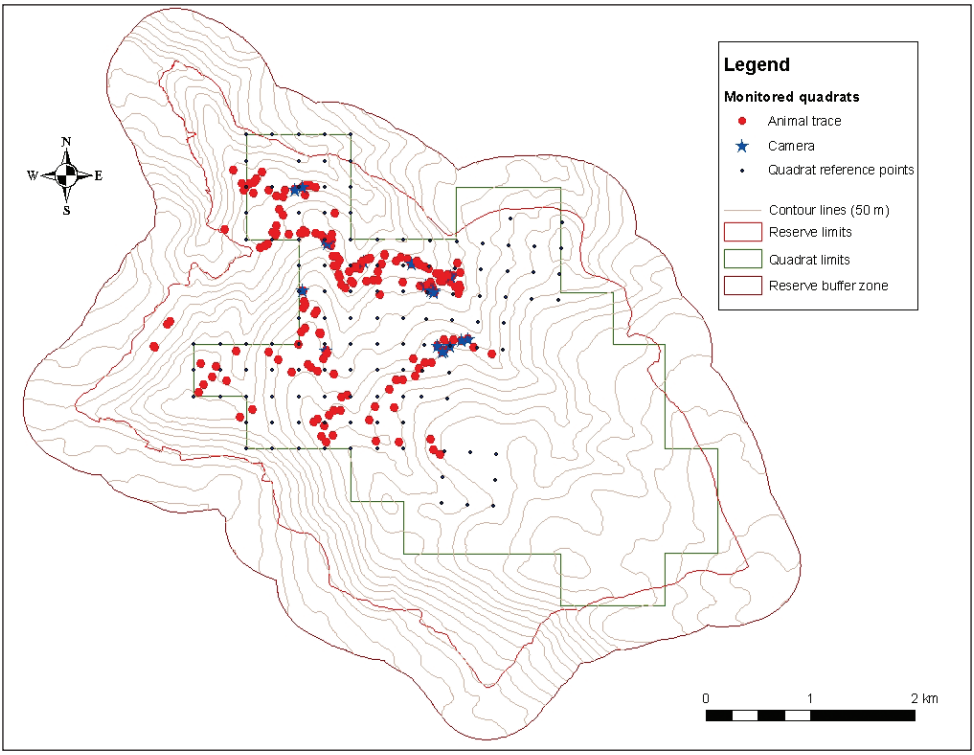


Figure 3. Mammalian distribution map showing the location of mammalian activity and the location of the Motion Sensor Cameras.

Results

In total, 253,120 m^2 were surveyed in 20 days over a period of nine months (one quadrat per day) where 12 medium to large size mammals were identified (Table 1). Two hundred and twelve points were recorded for animal droppings and footprints including 17 points where photos were taken (Fig. 3). Coordinates for the location where photographs of mammals were not captured were excluded from the distribution map. Of the 12 identified medium to large sized mammals, five were detected only by droppings (42%); four by droppings, footprints and photos (33%); one by droppings and footprints (8%); one by droppings and photos (8%); and one by footprints and photos (8%) (Table 1). In addition, droppings were collected for 11 of the 12 species (92%), footprints for six species (50%) and photos for six species (50%).

Discussion

The combination of three non-invasive methods allowed a rapid and extensive coverage of a large surface area of the Reserve that culminated in the identification of

Table 1. List of recorded mammals at the HENR and techniques of their identification.

Scientific Name	Common Name	Identification Technique		
		Dropping	Footprint	Photo
Sus scrofa Linnaeus, 1758	Wild Boar	x	x	x
Vulpes vulpes (Linnaeus, 1758)	Red Fox	x	x	x
Felis silvestris Schreber, 1777	Common Wild Cat	x	x	x
Martes foina (Erxleben, 1777)	Beech Marten	x	x	x
Canis aureus Linnaeus, 1758	Golden Jackal	x	x	
Mustela nivalis Linnaeus, 1766	Least Weasel	x		
Hyaena hyaena (Linnaeus, 1758)	Barbary Hyaena	x		
Erinaceus concolor Martin, 1838	East European Hedgehog	x		
Hystrix indica Kerr, 1792	Indian Crested Porcupine	x		
Lepus capensis Linnaeus, 1758	Cape Hare	x		
Meles meles (Linnaeus, 1758)	Eurasian Badger	x		x
Sciurus anomalus Gueldenstaedt, 1785	Persian Squirrel		x	x

12 medium and large sized mammal species out of 14 listed in previous reports in a relatively short period of time. The use of GIS permitted the exclusion of inaccessible regions from the on-set of sampling activities that led to a substantial reduction in the effort that needed to be invested to cover the target area. In addition, knowledge of the gradient slopes and the main geographical obstacles that may be encountered in each quadrat beforehand allowed the complete sampling of one quadrat per day.

The transect-line sampling revealed that droppings are the most common identification technique for mammalian richness in the HENR (92%), while footprints and photos accounted for 50% each. Droppings tend to remain in the natural environment for longer periods of time than footprints, while photo-trapping is highly dependent on the animal passing in front of the Motion Sensor Cameras. Nevertheless, one mammal, the Persian Squirrel, was identified only through footprints in the snow and its presence in the Reserve was further confirmed through several photos. In addition, during the dry season that stretches for more than five months and the scarce water sources at the HENR lead to the ground drying up for long periods making mammalian footprints very difficult to find. The footprints of the six species detected at the HENR through this technique were found either in snow and/or mud during the wet season.

Even though transect-line sampling tended to be the most efficient in determining mammalian richness, several factors need to be taken into consideration, more specifically for footprints in addition to the challenges experienced from adverse weather conditions. For example, snow conditions may only be appropriate in certain areas for footprint identification and in some cases only for a few days. Furthermore, dense canopy produces thick plant litter that does not allow the mammal to leave footprint markings. Therefore, in addition to the team being qualified in the identification of local fauna, it should run on a flexible schedule that will allow it to take advantage of fresh snowfall and rain. Consequently, assessment of mammalian richness based on

the transect-quadrat survey scheme should concentrate on the collection of droppings while still investing effort in detecting footprints where the habitat is suitable. Fresh snow and wet clay and humid soils after rainfall and around water sources will increase the probability of finding mammalian footprints and as a result increase the chances of detecting animals that may not be detected by other techniques.

Photo-trapping was used to confirm the presence of mammals detected by the transect-quadrat survey by installing the cameras in areas where mammalian activity was detected. It was anticipated that the majority of the identified mammals will be photo-trapped. But contrary to expectations and even though bait was installed, only six out of the 12 targeted species were recorded using this technique. This could be due to the fact that the cameras were installed for only one week in the selected spots reducing the chances of the animal passing in front of the sensor. Nevertheless, the extracted photographs revealed that all the photo-trapped species were active at night, a period where the team could not carry-out any sampling activities. In addition, they provided evidence of adults of several species accompanied by juveniles revealing the presence of breeding populations at the HENR. This information is proving to be essential in directing future research towards species considered of value at the national and regional scales. In addition to its low disturbance impact, the installation and functioning of Motion Sensor Cameras requires low investment and low team experience making it quite attractive in regions where human and material resources limit mammalian richness research activities.

The achieved results showed that the combination of the three non-invasive techniques for the rapid assessment of mammalian richness (droppings, footprints and photo-trapping) supported by GIS application is of outmost relevance. Twelve of the 14 targeted species were identified in a relatively short period of time and their area of activity plotted on a map therefore demonstrating the effectiveness of the approach at the HENR. With the widespread availability of GIS applications, this approach can be easily replicated in any region around the world to rapidly assess mammalian richness and the area of activity of the detected species and therefore direct conservation and management activities towards species of interest.

Acknowledgement

The authors thank the Royal Embassy of the Kingdom of the Netherlands for funding this study. Special appreciation goes to the German Research Foundation (Deutsche Forschungsgemeinschaft) for providing the Institute of the Environment, University of Balamand with books essential for research on wildlife management as well as other environmental subjects and to the Ministry of Environment, Lebanon for providing the necessary maps of the Reserve. Deepest gratitude is extended to the Government Appointed Committee of HENR for supporting and facilitating research activities at the Reserve.

References

Abd Rabou A, Yassin M, Al Agha M, Hamad D, Ali A (2007) Wild mammals in Gaza strip with particular reference to Wadi Gaza. The Islamic University Journal 15(1): 87–109.

Abi-Said M, Marrouch Abi-Said D (2007) Distribution of Striped Hyaena (Hyaena hyaena syriaca Matius, 1882) (Carnivora: Hyaenidae) in urban and rural areas of Lebanon. Zoology of the Middle East 42: 3–14.

Abu Baker M, Amr Z (2002) Status of the Eurasian Badger, *Meles meles*, in Jordan (Carnivora: Mustilidae). Zoology in the Middle East 27: 13–20.

Abu Baker M, Nassar K, Rifai L, Qarqaz M, Al-Melhim W, Amr Z (2003) On the current status and distribution of the jungle cat, *Felis chaus*, in Jordan (Mammalia: Carnivora). Zoology in the Middle East 30: 5–10.

Bang P, Dahlstrom P (2004) Animal Tracks and Signs. Oxford University Press, Inc., New York, 264 pp.

Bonnaud E, Bourgeois K, Vidal E, Kayser Y, Tranchant Y, Legrand J (2007) Feeding ecology of feral cat population on a small Mediterranean island. Journal of Mammology 88(4): 1074–1081. doi:10.1644/06-MAMM-A-031R2.1

Bunaian F, Mashaqbeh S, Youssef M, Buduri A, Amr Z (1998) A new record of the Sand Cat, *Felis margarita* from Jordan. Zoology in the Middle East 16: 5–7.

Bunaian F, Hatough A, Ababanch D, Mashaqbeh S, Zuhair A (2001) The carnivores of the Northeastern Badia, Jordan. Turkish Journal of Zoology 25:19–25.

Cavallini P (1994) Faeces count as an index of fox abundance. Acta Theriologica 39(4): 417–424.

Darwish M, Yousef M, Al-Melhim W, Amr Z (1997) The status of the Stone Marten, *Martes foina syriaca*, in Jordan. Zoology in the Middle East 15: 5–8.

De Marinis A, Masseti M (2009) Mammalian fauna of the Termessos national park, Turkey. Zookeys 31: 221–228. doi:10.3897/zookeys.31.171

Emre Can O (2004) Status, Conservation and Management of Large Carnivores in Turkey. WWF-Turkey, Ankara.

Jaeger E (2002) Tracks and Trailcraft. The Lyons Press Imprint of Piquot Press, Guilford, Connecticut, 381 pp.

Foresman K (2000) Overview of forest carnivore survey efforts in the Bitterroot Mountains. USDA Forest Service Proceedings RMRS-P-17: 53–55.

Gompper M, Kays R, Ray J, Lapoint S, Bogan D, Cryan J (2006). A comparison of noninvasive techniques to survey carnivore communities in Northeastern North America. Wildlife Society Bulletin 34(4): 1142–1151. doi:10.2193/0091-7648(2006)34[1142:ACONTT]2.0.CO;2

Grogan R, Lindzey W (1999) Estimating population size of a low-density black bear population using capture-resight. Ursus 11: 117–122.

Ministry of Agriculture (MoA), Lebanon (1996) La Biodiversité du Liban. http://www.agriculture.gov.lb/bio_div/ft.mami.html

Ministry of Environment MoE/UL/UNDP (2004) Biodiversity Assessment and Monitoring in the Protected Areas/ Lebanon Leb/ 95/ G31, Horsh Ehden Nature Reserve. Lebanese University Press, Beirut.

Price M, Darimont C, Winchester N, Paquet P (2005) Facts from faeces: prey remains in wolf. *Canis lupus*, faeces revise occurrence records for mammals of British Columbia's coastal archipelago. The Canadian Field-Naturalist 119: 192–196.

Qarqaz M, Abu Baker M, Amr Z (2004) Status and ecology of striped hyaena *Hyaena hyaena*, in Jordan. Zoology in the Middle East 33: 5–10.

Qumsiyeh M (1996) Mammals of the Holy Land. Texas Tech University Press, Lubock Texas, 89 pp.

Sadlier L, Webbon C, Baker P, Harris S (2003) Methods of monitoring red foxes Vulpes vulpes and badgers Meles meles: are field signs the answer? Mammal Review 34(1/2): 75–98. doi:10.1046/j.0305-1838.2003.00029.x

Silveira L, Jacomo A, Diniz-Filho J (2003). Camera trap, line transect census and track survey: a comparative evaluation. Biological Conservation 114: 351–355. doi:10.1016/S0006-3207(03)00063-6

Stuart C, Stuart T (2008) Mammals of North Africa and the Middle East. New Holland Publishers ltd., London, 128 pp.

Temple H, Cuttelod A (2009) The status and distribution of Mediterranean mammals. IUCN, Gland, Switzerland and Cambridge. doi:10.2305/IUCN.CH.2009.19.en

Tohmé G, Tohmé H (1985) Les Mammifères Sauvages du Liban. Publications de l'Université Libanaise, Beirut, 189 pp.

Trolle M, Kery M (2005). Camera-trap study of ocelot and other secretive mammals in the northern Pantanal. Mammalia 69 (3–4): 405–412. doi:10.1515/mamm.2005.032

William BK, Nichlos JD, Conroy MD (2002) Estimation of community parameters in: Analysis of Management of Animal Populations. Academic Press an Elsevier Science Imprint, 555–573.

Yigit N, Çolak E, Çolak R, Ozkan B, Ozkurt S (2003) On the Turkish populations of Dryomys nitedula and Dryomys laniger felten and storch. Acta Zoologica Academiae Scientiarum Hungariacae 49(Suppl. I): 147–158.

ZooKeys 119: 73–76 (2011)
doi: 10.3897/zookeys.119.1736
www.zookeys.org

BOOK REVIEW

A peer-reviewed open-access journal
ZooKeys
Launched to accelerate biodiversity research

Book review: Penney D, Selden PA (2011) Fossil Spiders: the evolutionary history of a mega-diverse order. Monograph Series, Volume 1. Siri Scientific Press, Manchester, 128 pp., 87 photographs (hardback)

Yuri M. Marusik

Institute for Biological Problems of the North RAS, Portovaya Str. 18, Magadan, Russia

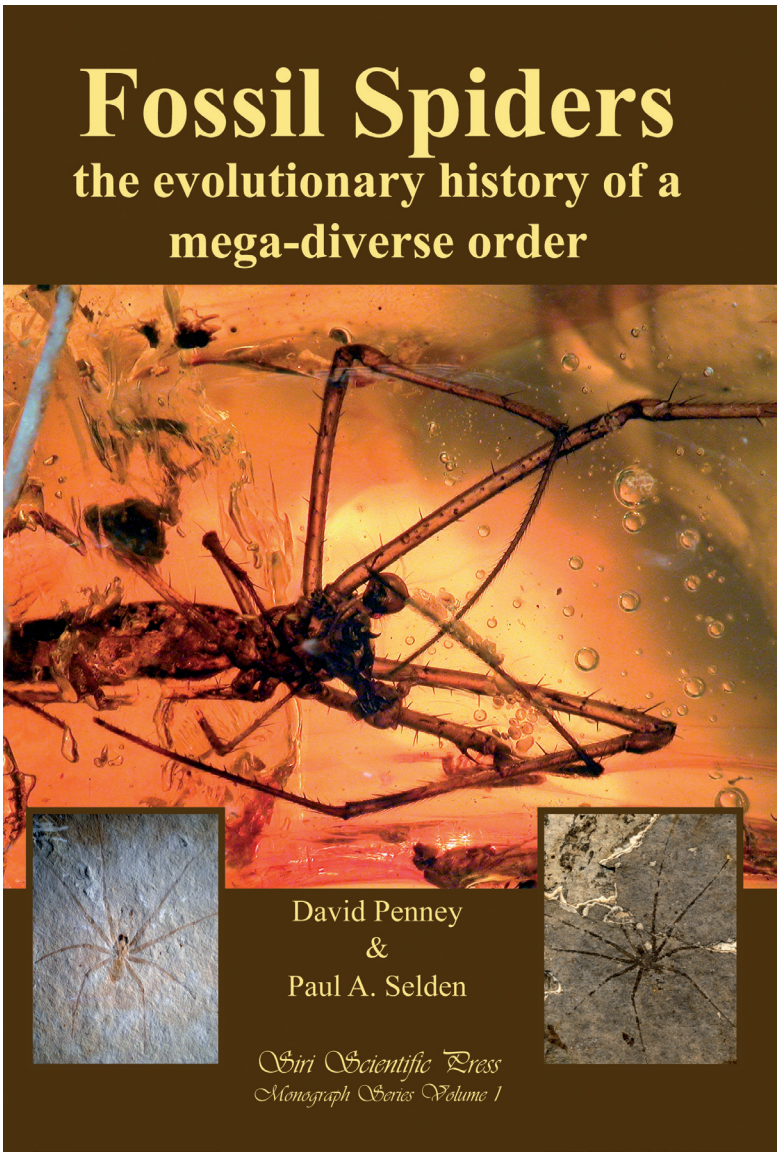
Corresponding author: *Yuri Marusik* (yurmar@mail.ru)

Received 24 June 2011 | Accepted 24 June 2011 | Published 15 July 2011

Citation: Marusik YM (2011) Book review: Penney D, Selden PA (2011) Fossil Spiders: the evolutionary history of a mega-diverse order. Monograph Series, Volume 1. Siri Scientific Press, Manchester, 128 pp., 87 photographs (hardback). ZooKeys 119: 73–76. doi: 10.3897/zookeys.119.1736

Prior to the publication of the book reviewed here, the only books dealing specifically with fossil spiders have been primarily taxonomic monographs, such as those on Dominican and Baltic amber inclusions by Wunderlich (1988, 2004), or broader palaeobiological studies on a particular assemblage, such as Dominican amber spiders by Penney (2008). The coverage of fossil spiders in books on extant spiders is usually restricted to one or two pages at most, and more often than not these include serious errors. This new book is quite different and fills a long standing void in the arachnological literature.

The book begins with an introduction to spiders from a palaeontological perspective, putting their geological longevity into context of the other known fossil and extant arachnid orders, including comparative data for numbers of described extant and fossil species for all orders. The relative diversity of spider sub-orders today is compared with that of the past. The authors provide reasoned support for the importance of fossil spiders in addressing large-scale palaeobiological questions on a global scale, and over long periods of time, including how information on past changes in biogeographical distributions can be correlated with changes in palaeoclimatological factors and the potential of this for predicting the consequences of current climate change. Information is also provided on how the fossil spiders are dated.



The fossil record of spiders is discussed with regard to non-amber fossils (there is a table of 51 important localities with references), including the different modes of preservation with photographic examples (often of holotypes) throughout. The amber spider fossil record follows a similar format with a table of 42 important localities. There is also a section on fossilized spider silk. An important aspect of interpreting fossil assemblages is an understanding of bias in the fossil record and this is covered for both amber and non-amber deposits.

Next follows a highly informative chapter on techniques for the preparation and study of fossil spiders, which will be of great use for new students of palaeoarachnology.

It includes techniques for preparing both amber and non-amber fossils, including how to obtain the best photographs, and also the application of new imaging techniques which allow non-destructive digital dissection of the fossils, such as x-ray computed and synchrotron technology. The images included here are quite exceptional. This is followed by a discussion of the problems associated with identifying and naming fossil spiders, particularly in a neontological context, including critical examples of techniques recently proposed to assist in this process.

There is a chapter on the strictly fossil spider families, which lists all known species and their deposit of origin.The taxonomic status of each family is discussed and it is noted that many are in need of revision. Again, this section includes good photographs including of holotypes.

Approximately half way through, the focus of the book switches from understanding and interpreting the fossil spiders to the application of the palaeontological data. Much use is made of the spider evolutionary tree, which was created by superimposing the cladogram of Araneae over the geological time scale and calibrating it with described fossils. This tree is up-to-date and even includes the recently erected family Penestomidae and the recent synonymy of Microphocommatidae with Anapidae. There is a handy table referencing the oldest fossil of each of the 73 extant spider families known in the fossil record, used to create the evolutionary tree. Topics in this section include originations and radiations (with particular emphasis on diverse families today such as Salticidae, Theridiidae and Lycosidae), mass extinctions, and predator-prey co-radiations, including updated analyses (based on new data) of previously published work by the authors.

The last chapter concerns how fossil spiders can contribute to our understanding of past and present biogeography. The authors present some rather remarkable examples of disjunct distributions between the fossil and extant spider faunas. A table of spider family distributions over time, including recent, Cenozoic and Mesozoic distributions presents the available data in a user-friendly fashion. Importantly, the authors note that it is just as important to look at which families do not appear in the fossil record and provide a table of data for these also, and discuss possible reasons for their exclusion. The book ends with a comprehensive reference section of some 265 entries and an index to family citations. There is a handy reference figure of the geological timescale on page 6.

In conclusion, this is an absolutely unique book in the spider literature to date. It is authoritatively written by two of the leading researchers in this field and provides broad coverage of their combined 50 years experience and expert knowledge. The book is hard back and presented on high quality glossy paper. It is richly illustrated throughout by numerous high quality photographs of fossil spiders. In conclusion, this book deserves a place on the shelves of the libraries of all professional and amateur arachnologists alike, in addition to those of invertebrate palaeontologists.

The book can be ordered via the author: by emailing siri.press@live.co.uk. Price £32.00 plus post and packing. For further details, including ordering online, etc. visit http://www.siriscientificpress.co.uk

References

Penney D (2008) Dominican Amber Spiders: a comparative palaeontological-neontological approach to identification, faunistics, ecology and biogeography. Siri Scientific Press, Manchester, 128 pp.

Wunderlich J (1988) Die Fossilen Spinnen im Dominikanischem Bernstein. Beitr. Araneol., 2: 1–378.

Wunderlich J (Ed.) (2004) Fossil spiders in amber and copal. Beitr. Araneol., 3: 1–1908.