ZooKeys 134: 1–13 (2011)
doi: 10.3897/zookeys.134.1673
www.zookeys.org

RESEARCH ARTICLE

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

Erotylidae (Insecta, Coleoptera) of Poland – problematic taxa, updated keys and new records

Rafał Ruta[1], Paweł Jałoszyński[2], Paweł Sienkiewicz[3], Szymon Konwerski[4]

1 *Department of Biodiversity and Evolutionary Taxonomy, Zoological Institute, Wrocław University, Przybyszewskiego 63/77, 51–148 Wrocław, Poland* **2** *Museum of Natural History, Wrocław University, Sienkiewicza 21, 50–335 Wrocław, Poland* **3** *Department of Entomology and Landscape Protection, Poznań University of Life Sciences, Dąbrowskiego 159, 60–594 Poznań, Poland* **4** *Natural History Collections, Adam Mickiewicz University, Umultowska 89, 61–614 Poznań, Poland*

Corresponding author: *Rafał Ruta* (scirtes@biol.uni.wroc.pl)

Academic editor: *Michael Thomas* | Received 7 June 2011 | Accepted 30 August 2011 | Published 6 October 2011

Citation: Ruta R, Jałoszyński P, Sienkiewicz P, Konwerski S (2011) Erotylidae (Insecta, Coleoptera) of Poland – problematic taxa, updated keys and new records. ZooKeys 134: 1–13. doi: 10.3897/zookeys.134.1673

Abstract

New data concerning the occurrence of pleasing fungus beetles (Coleoptera: Erotylidae) in Poland are given, with a focus on rare and difficult to identify Central European taxa. *Cryptophilus* cf. *integer* (Heer) (Cryptophilinae) is reported from the Polish territory for the first time based on adult and larval specimens collected in the Wielkopolska-Kujawy Lowland. Identification problems concerning species of *Cryptophilus* introduced to Europe are discussed. *Triplax carpathica* Reitter (Erotylinae) is recorded from the Białowieża Primeval Forest, which is the first known non-Carpathian finding of this species, located in the close proximity of the Polish-Belarussian UNESCO World Heritage Site "Białowieża Forest". Discussion of *T. carpathica* being conspecific with Siberian *T. rufiventris* Gebler is provided. New Polish localities of several other Erotylidae are reported, and an updated key to Central European species of *Triplax* is given. The *Triplax* key is supplemented with dorsal and ventral habitus images of all treated *Triplax* species. One of the rarest Central European erotyline species *Combocerus glaber* (Schaller) is recorded from xerothermic grasslands in North-West Poland.

Keywords

Coleoptera, Erotylidae, Cryptophilinae, Erotylinae, *Cryptophilus*, *Triplax carpathica*, new records, Central Europe, Poland, Białowieża Primeval Forest

Introduction

The systematics of pleasing fungus beetles (Erotylidae) has undergone significant changes within the past decade, and according to the currently accepted classification (Węgrzynowicz 2007) all species hitherto known to occur in Poland belong to the subfamily Erotylinae. Four genera have been recorded from Poland: *Combocerus* Bedel, *Dacne* Latreille (both in the tribe Dacnini), *Triplax* Herbst and *Tritoma* Fabricius (tribe Tritomini) (Mazur 1983; Burakowski et al. 1986; Węgrzynowicz 2007). The larvae of *Combocerus* remain unknown, but adults occur in plant debris (Franc 2001); whereas the remaining genera develop in saproxylous fungi (Burakowski et al. 1986). Most European Erotylidae are included in the European red list of saproxylic beetles (Nieto and Alexander 2010).

Distributions of most Erotylidae in Poland are inadequately known and published faunistic data are relatively scarce. Some species have only been recorded from the southern arch of mountains or from few localities within the most species-rich (and intensively surveyed) national parks, but their true ranges may be broader. For example, *Triplax collaris* (Schaller) was previously known in Poland only in the Białowieża Primeval Forest (Burakowski et al. 1986), but it was recently found in a distant and distinctly different forest near Poznań (Jałoszyński and Węgrzynowicz 2007).

Herein, we extend the Polish checklist of pleasing fungus beetles by reporting new findings; we also give new district records of several rare Erotylidae, and discuss taxonomic problems concerning two species.

Methods and conventions

Depositories: [HNHM] – Hungarian Museum of Natural History (Budapest, Hungary); [LBJK] – coll. L. Borowiec et J. Kania (Wrocław, Poland); [MIZ] – Museum and Institute of Zoology of Polish Academy of Sciences (Warsaw, Poland); [MNHW] – Museum of Natural History, Wrocław University (Wrocław, Poland); [SMNS] – Staatliches Museum für Naturkunde (Stuttgart, Germany); [PJ] – coll. P. Jałoszyński (Wrocław, Poland); [RR] – coll. R. Ruta (Wrocław Poland); [SK] – coll. S. Konwerski (Poznań, Poland).

Specimen handling and imaging. Dry-mounted adult specimens and an ethanol-preserved larva were used for the study; when necessary beetles were detached in warm water from mounting cards to examine ventrites. The body length was measured from the anterior margin of pronotum to the apex of elytra. Specimens showed on color plates are from MIZ, SMNS, PJ and RR. Habitus images were taken by a Nikon Coolpix 4500 camera mounted to a Nikon SMZ 1500 dissecting microscope (all species of *Triplax*) or by an Olympus C-750UZ camera equipped with a Raynox MSN-505 close-up lens (larva and adult of *Cryptophilus*). Image stacks were processed using Helicon Focus 4.62 and Photoshop 7.0 CE (*Triplax*) or Combine ZP and Corel Photo-Paint 8 (*Cryptophilus*). Scanning electron micrographs of uncoated specimens were taken by a HITACHI S-3400N scanning electron microscope at MIZ.

Collectors: JK – J. Kania; JMG – J. M. Gutowski; JS – J. Szypuła; JSA – J. Sawoniewicz; KK – K. Kowalczyk; LB – L. Borowiec; LBU – L. Buchholz; MW – M. Wanat; PJ – P. Jałoszyński; PS – P. Sienkiewicz; RR – R. Ruta; SK – S. Konwerski.

Other abbreviations: f. sec. – forest section; nat. res. – nature reserve; N.P. – national park; BL – body length; BW – maximum body width. An asterisk is used to mark first species records for particular districts of Poland (according to the division of Burakowski et al. 1973).

Taxonomy

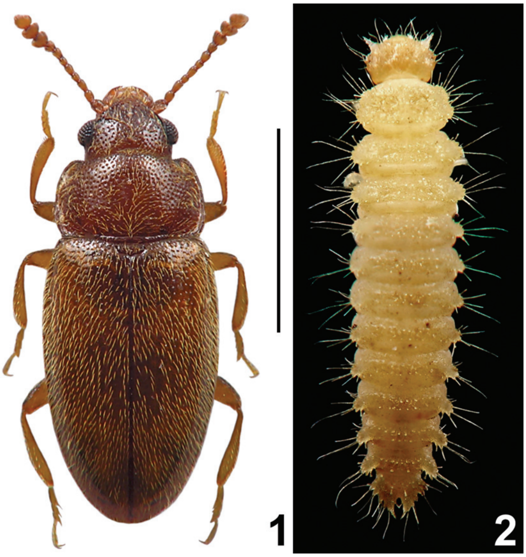
Cryptophilus cf. *integer* (Heer, 1841)

http://species-id.net/wiki/Cryptophilus_cf._integer
Figs 1, 2

Material examined. Poland*, Wielkopolska-Kujawy Lowland: Włocławek (UTM: CD63), compost heap, 1 adult and 1 larva, 26 VIII 2010, leg. PJ [PJ].

In the Palearctic Region, Cryptophilinae are represented by a single species of the East Chinese genus *Chinophagus* Lyubarsky, and the broadly distributed *Cryptophilus* Reitter with nine species (Węgrzynowicz 2007). External morphology of *Cryptophilus* superficially resembles that of many Cryptophagidae and for a long time members were placed in that family, despite historical work by Ganglbauer who reclassified Erotylidae and included *Cryptophilus* in Diphyllini, Erotylinae (Ganglbauer 1899). However, Ganglbauer's broad concept of Erotylidae (including Cryptophagidae and Biphyllidae) was disputable and not followed by subsequent authors. *Cryptophilus* was included in Languriidae (currently Languriinae within Erotylidae) by Sen Gupta and Crowson (1971) and Lawrence (1991); in Erotylidae, Cryptophilinae by Chûjô (1969); in Erotylidae, Xenoscelinae by Węgrzynowicz (2002); and in Erotylidae, Cryptophilinae in major modern catalogues and revisions (e.g. Leschen and Buckley 2007; Węgrzynowicz 2007).

The only *Cryptophilus* species reported from many European countries, including western and southern neighbours of Poland, is *C. integer* (Heer, 1841). The species was originally described in *Cryptophagus* Herbst, and indeed can be easily misidentified by an inexperienced coleopterist as a member of the Cryptophagidae. The latter family has never been popular among Polish entomologists and species in some genera (e.g. *Cryptophagus*) are difficult to identify. Therefore, the fact that *Cryptophilus* has been found only recently in Poland can be explained either by a possible misidentification as Cryptophagidae in institutional and private collections, or by current expansion or introduction. The major difference between cryptophagids and cryptophilines is the developement of the procoxal sockets, which are open or nearly open in Cryptophagidae and closed in Erotylidae. The larvae of *Cryptophilus* (Fig. 2) can be possibly misidentified as *Monotoma* Herbst (Monotomidae) or *Epuraea* Erichson (Nitidulidae); they all share a similar body shape and granulate or tuberculate dorsum, and occur in



Figures 1–2. *Cryptophilus* cf. *integer* (Heer); habitus of adult **1** and larva **2** Scale bar = 1 mm.

similar habitats (often together). Unambiguous determination of Central European specimens can be made based on structures of the head capsule, mouthparts and terminal abdominal segments. Among others, the shape of the mandibles is clearly different: in *Cryptophilus* the prostheca is very large, subtriangular, and the mandible lacks a subapical accessory tooth; in *Monotoma* the prostheca is inconspicuous and the subapical accessory tooth present, very long and slender; in *Epuraea* the prostheca is developed as an elongate brush of hairs and the accessory tooth is absent.

Cryptophilus integer is associated with decaying plant matter (e.g. compost heaps). The genus needs a comprehensive revision before world species can be confidently identified. Due to this taxonomic problem the true identity of species recorded from Europe requires verification by specialists (Węgrzynowicz, pers. comm.). Therefore, although presenting the first Polish finding of *Cryptophilus* is justified, the identification of specimens must be treated as uncertain. Therefore we treat all previously published European records of *Cryptophilus* as tentatively identified pending verification by comparison of type specimens.

Triplax carpathica Reittter, 1890

http://species-id.net/wiki/Triplax_carpathica
Figs 4, 15

Type material examined. Holotype, **Romania** (originally "Hungaria bor."), Marmaros, Coll. Reitter [HNHM].

New material: Poland, Białowieża Primeval Forest*: Czerlonka vic., f. sec. 494 (FD84), 1 X 2000, 1 ex., leg. JMG [RR]; Olszanka-Myśliszcze nat. res. (FD83), 17

VIII 2000, 1 ex., leg. MW [MNHW]. **Bieszczady Mts.:** Wetlina, Muchanin Wierch (FV04), 20 VIII 1970, 6 exx. [MIZ].

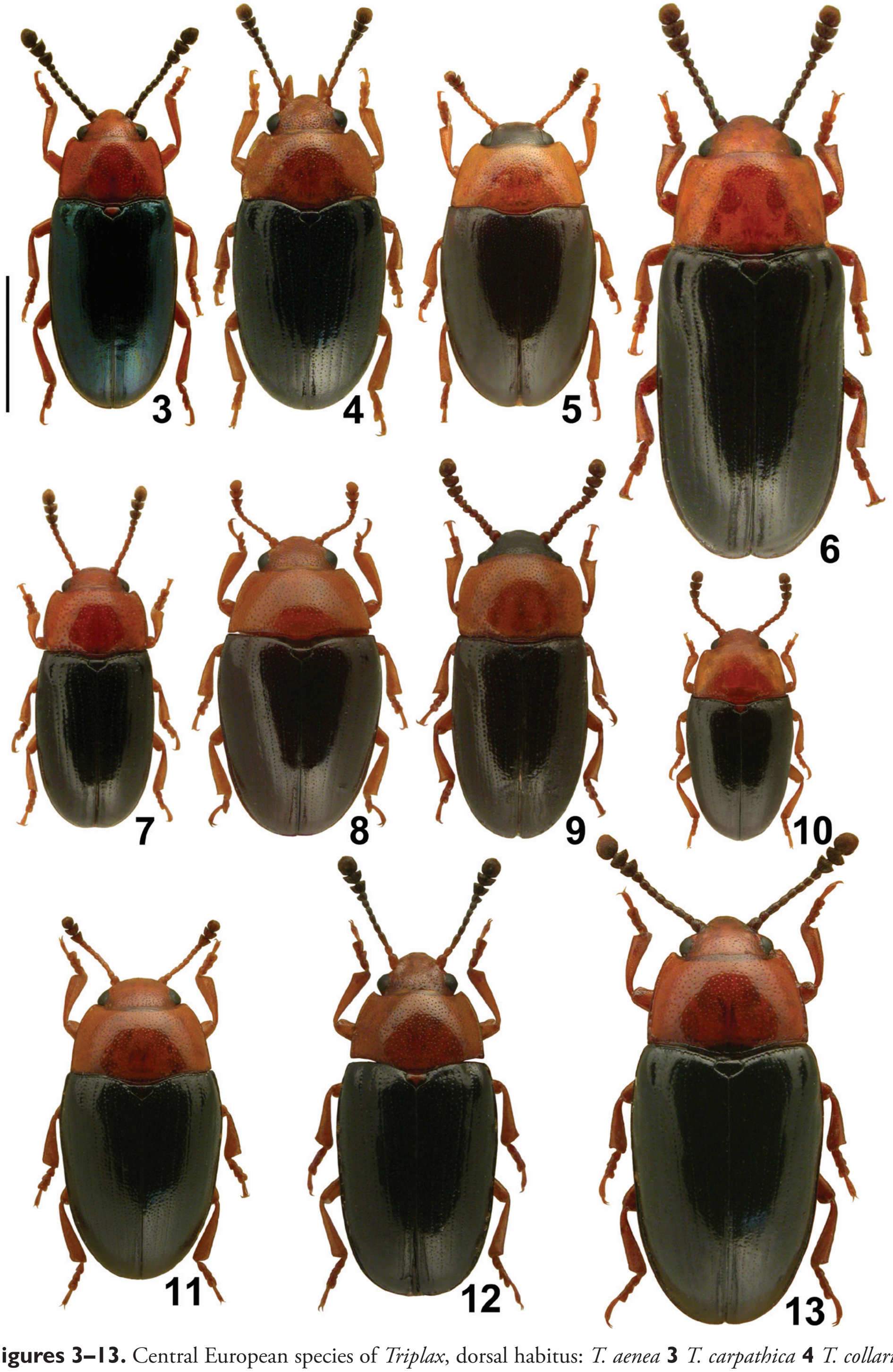
Among the beetles recently collected in the Białowieża Primeval Forest, two specimens possibly belonging to *T. carpathica* were found. This species was described from Romanian Carpathians (Reitter 1890), and recorded in Poland only from Bieszczady Mts. (Borowiec 1984). Its occurrence outside the Carpathian Range in northeastern Poland seemed highly unlikely. To unambiguosly confirm the species identity, the holotype of *T. carpathica* was examined, and the Polish specimens were found to be conspecific with the type. It is plausible that *Triplax carpathica* is another species with primarily Eastern Palearctic distribution that extends westwards to the Białowieża Primeval Forest in Central Europe (see the discussion of taxonomic problems below). The rare beetles *Pytho kolwensis* Sahlberg (Pythidae) and *Xylobanellus erythropterus* (Baudi) (Lycidae) are other examples of a similar distribution. The new findings of *T. carpathica* confirm the important value of woodlands surrounding the protected part of the Białowieża Forest, which is one of the last and largest primeval forests in Europe. Only a part of the forest is currently included in the Białowieża National Park and a UNESCO World Heritage Site. However, adjacent unprotected areas also show a remarkable biodiversity and may be important for survival of disjunct populations of *T. carpathica* and other rare insects.

A taxonomic problem was encountered when characters of the holotype of *T. carpathica* were compared with existing descriptions and keys. Previously, the only feature reported to differentiate *T. carpathica* from the East Palearctic *T. rufiventris* Gebler, 1823 (= *T. amurensis* Reitter, 1879), i.e. presence/absence of femoral lines, seemed dubious at best. Iablokoff-Khnzorian (1975) in his identification key stated that *T. carpathica*, but not *T. rufiventris*, has all femoral lines present ("toutes les lignes fémorales présentes"). However, the holotype of *T. carpathica* exhibits no traces of femoral lines on the metaventrite. Unfortunately, we were not able to study the type specimens of *T. rufiventris* and *T. amurensis* (both presumably in the Muséum National d'Histoire Naturelle, Paris) to clarify the true status of these taxa. A comprehensive revision of Palearctic *Triplax* remains beyond the scope of the present paper. However, we note that the identity of some species and their geographic distributions remain unclear and require further study.

***Triplax aenea* (Schaller, 1783)**

http://species-id.net/wiki/Triplax_aenea
Figs 3, 14

Material examined. Baltic Coast: Lubin (VV66), Wolin Is., 3 V 1991, 5 exx., leg. MW [MNHW]. **Pomeranian Lake District*:** Szczecin (VV71), 2 VI 2004, 2 exx. caught in sticky trap on *Aesculus hippocastanum* in city park "Ogród Dendrologiczny im. Stefana Kownasa", leg. SK [SK], 3 VI 2004, 3 exx. under bark of a rotten trunk in city park "Park im. Fryderyka Chopina", leg. SK [SK]; Stara Rudnica (VU45) ad



Figures 3–13. Central European species of *Triplax*, dorsal habitus: *T. aenea* **3** *T. carpathica* **4** *T. collaris* **5** *T. elongata* **6** *T. lacordairei* **7** *T. lepida* **8** *T. melanocephala* **9** *T. pygmaea* **10** *T. rufipes* **11** *T. russica* **12** and *T. scutellaris* **13** Scale bar = 1.0 mm.

Cedynia, 29 IV 2010, 1 ex. on freshly cut poplar, moist meadow, leg. PJ [PJ]. **Podlasie*:** Sobibór (FC80) ad Włodawa, ad Bug river (sifted), 28 VII 2001, 1 ex., leg. MW [MNHW]. **Białowieża Primeval Forest:** Białowieża (FD94), meadows near N.P. 13 VI 1983, 3 exx., leg. MW [MNHW]; Białowieża N.P. (FD94), 15–27 VI 1991, 1 ex., leg. LB [LBJK], f. sec. 398, 27 VI 1991, 1 ex., leg. MW [MNHW]. **Lower Silesia:** Wrocław-Świniary (XS37), 27 IV 1991, 4 exx., leg. LB [LBJK]. **Kraków-Wieluń Upland:** Ojcowski N.P., Chełmowa Góra (DA16), 13 VI -1 VII 2004, 1 ex., leg. LBU [RR]. **Roztocze***: Bukowa Góra nat. res. (FB30), 21 IX 1987, 3 exx., 9 VI 1988, 2 exx., 12 VI 1989, 3 exx., 17 VI 1989, 1 ex., leg. LB [LBJK], 22–23 VI 1990, 2 exx., leg. JK [LBJK]. **Bieszczady Mts.:** Wetlina PGR (FV04), 20 VII 1994, 4 exx., 22 VII 1994, 2 exx., leg. LB [LBJK]; Wetlina-Jawornik (FV04), 22 VII 1968, 1 ex., leg. K. Smulikowski [MIZ].

One of the most common *Triplax* species in Poland, but previously not recorded from several districts.

Triplax collaris (Schaller, 1783)

http://species-id.net/wiki/Triplax_collaris
Figs 5, 16

Material examined. Białowieża Primeval Forest: Białowieża vic. (FD84), f. sec. 425, oak-hornbeam forest, 12 VI 1983, 1 ex., leg. MW [MNHW]; Białowieża N.P. (FD94), 15–27 VI 1991, 10 exx., leg. LB, f. sec. 399, 18 VI 1991, 1 ex., leg. JK [LBJK].

The only well documented localities of this rare species are in the Białowieża Primeval Forest and Wielkopolska-Kujawy Lowland (Jałoszyński and Węgrzynowicz, 2007).

Triplax rufipes (Fabricius, 1787)

http://species-id.net/wiki/Triplax_rufipes
Figs 11, 22

Material examined. Podlasie*: Białystok (FD49), Antoniuk nat. res., 11 VII 2001, 1 ex., leg. JSA [MNHW]; Białowieża (FD94), meadows near N.P. 13 VI 1983, 3 exx., leg. MW [MNHW]; Białowieża N.P. (FD94), f. sec. 368/398/399, 2 exx., leg. MW [MHNW]. **Roztocze*:** Bukowa Góra nat. res. (FB30), 9 VI 1988, 2 exx., 8 VI 1989, 2 exx., leg. LB [LBJK], 22–23 VI 1990, 4 exx., leg. JK et LB [LBJK]. **Świętokrzyskie Mts.:** Białe Ługi nat. res. (DB82), 8 VII 2007, 1 ex., leg. RR [RR]; Świętokrzyski N.P., Święta Katarzyna (DB93), f. sec. 147g, 12–25 VIII 2009, 1 ex., leg. LBU [RR]. **Sudety Zachodnie Mts.*:** Szklarska Poręba Średnia (WS33), 16–24 VII 1995, 1 ex., leg. LB [LBJK].

A rare species, recently recorded from the southern part of Poland.

Triplax russica (Linnaeus, 1758)

http://species-id.net/wiki/Triplax_russica
Figs 12, 23

Material examined. Pomeranian Lakeland: Bielinek nad Odrą (VU46), 29 IV 2010, 2 exx. on Polyporaceae fungi growing on a beach tree, leg. PJ & PS [PJ]; Bukowskie Bagno nat. res. (WU98) ad Niekursko, 30 V 2006, 1 ex., leg. RR [RR]. **Wielkopolska-Kujawy Lowland:** Biedrusko vic. (XU22), military range, 24 VI 2006, 1 ex., 20 VIII 2007, 1 ex., both in hornbeam-oak forest , leg. SK [SK]; Rogalin (XT38) ad Poznan, 17 V 2011, leg. PS [PJ]; Piła-Kalina (XU28), 9 V 1998, 1 ex., leg. RR [RR]; Skoroszów (XT50), 6 VIII 1991, 1 ex., leg. LB [LBJK]; Stawy Przemkowskie nat. res. (WT51), 20 V 2007, 1 ex., leg. LB [LBJK]; Poznań, Maltańskie lake (XU30), 14 VI 2004, 1 ex. on a sticky trap on a pine tree, leg. SK [PJ]; Puszczykowo vic. ad Poznań (XT29), 21 V 2010, 1 ex. on a fungus growing on a beech tree; 8 VI 2010, 2 exx. on a fungus growing on a beech tree, leg. PJ [PJ]; Buczyna Szprotawska (WT40), 19 V 2007, 2 exx., leg. RR [RR]. **Podlasie*:** Sobibór (FC80) ad Włodawa, ex *Leccinum scabrum*, 4–6 VIII 2000, 1 ex., leg. MW [MNHW]. **Lower Silesia:** Lwówek Śląski (WS46), in an oak alley, VII 2007, 1 ex., leg. RR [RR]. **Świętokrzyskie Mts.:** Św. Krzyż (EB03), 6 VII 1978, 6 exx., leg. KK [MNHW], 21 V 1992, 3 exx., leg. LB [LBJK]. **Roztocze:** Bukowa Góra nat. res. (FB30), 9 VI 1988, 2 exx., 17 VI 1989, 1 ex., leg. LB [LBJK], 22–23 VI 1990, 2 exx., leg. JK [LBJK]. **Bieszczady Mts.:** Wetlina PGR (FV04), 22 VII 1994,2 exx., leg. LB [LBJK]; Wetlina-Jawornik (FV04), 22 VII 1968, 1 ex., leg. K. Smulikowski [MIZ]; Wetlina, Muchanin Wierch (FV04), 20 VIII 1970, 6 exx. [MIZ].

The most common species of *Triplax* in Poland.

Triplax scutellaris Charpentier, 1825

http://species-id.net/wiki/Triplax_scutellaris
Figs 13, 24

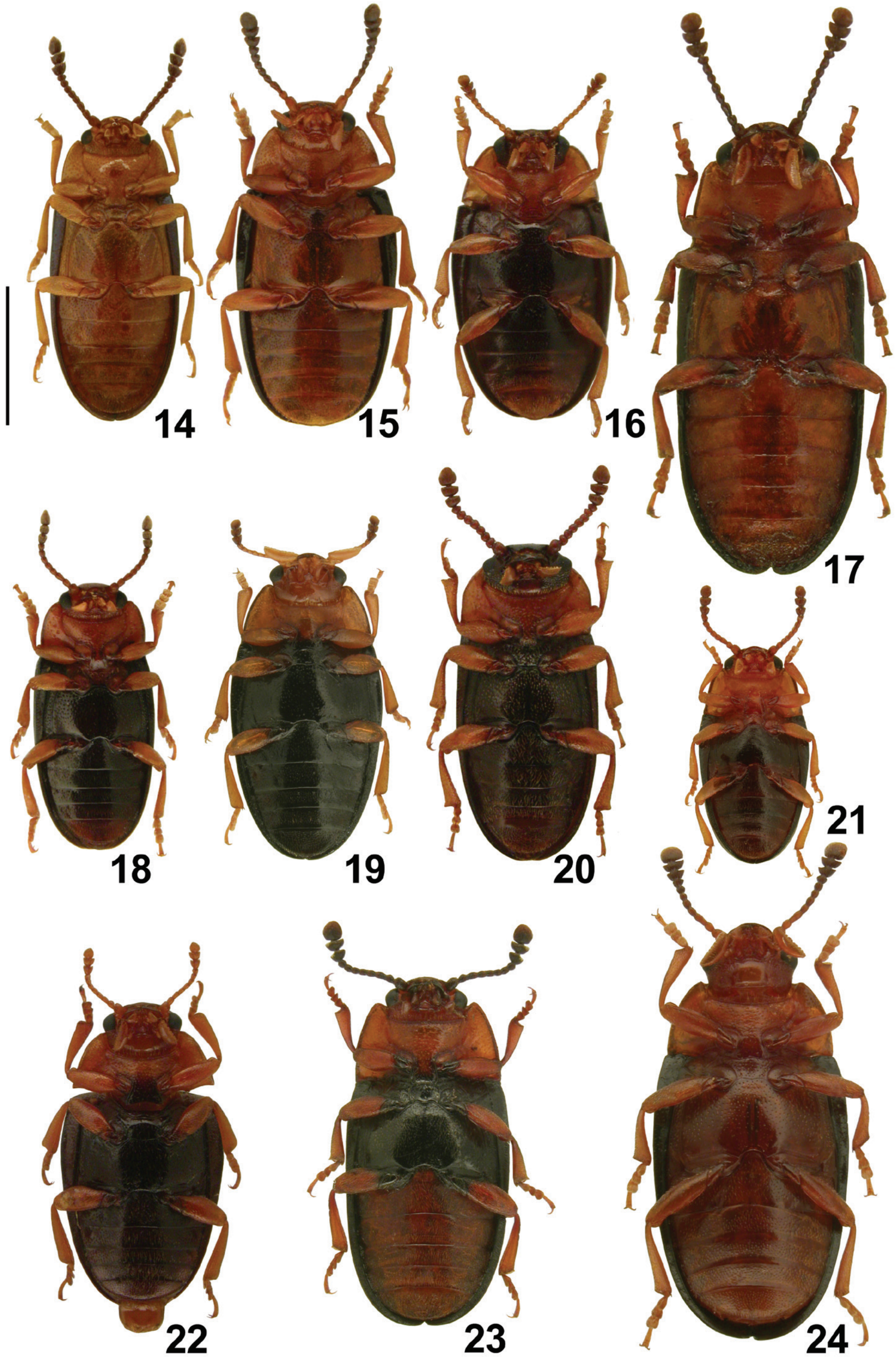
Material examined. Białowieża Primeval Forest: Białowieża N.P., 4 VIII 1992, 1 ex., leg. JS [LBJK]. **Bieszczady Mts.:** Wetlina PGR (FV04), 20 VII 1994, 3 exx., 22 VII 1994, 2 exx., 24 VII 1994, 9 exx., 27 VII 1994, 2 exx., leg. LB [LBJK]; Wetlina-Jawornik (FV04), 22 VII 1968, 3 exx., leg. K. Smulikowski [MIZ].

This species has been rarely collected in Poland. However, the new findings demonstrate that *T. scutellaris* is not uncommon in the Bieszczady Mts.

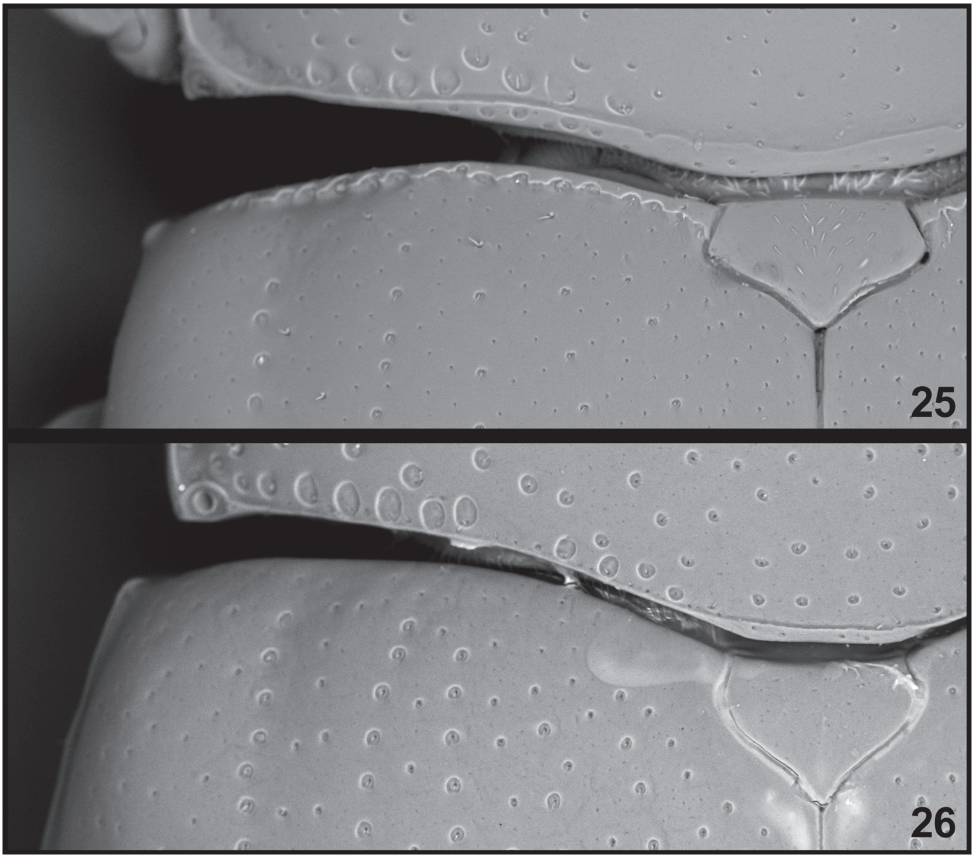
Combocerus glaber (Schaller, 1783)

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

Material examined. Wielkopolska-Kujawy Lowland*: Laski (VU71), xerothermic grassland *Potentillo-Stipetum* with *Stipa joannis* Čelak. in a deep ravine surrounded by



Figures 14–24. Central European species of *Triplax*, ventral habitus: *T. aenea* **14** *T. carpathica* **15** *T. collaris* **16** *T. elongata* **17** *T. lacordairei* **18** *T. lepida* **19** *T. melanocephala* **20** *T. pygmaea* **21** *T. rufipes* **22** *T. russica* **23** and *T. scutellaris* **24** Scale bar = 1.0 mm.



Figures 25–26. *Triplax*, basal part of elytra (SEM micrographs); *Triplax russica* **25** and *Triplax scutellaris* **26**.

fields, 4 VI 2009, 1 ex., leg. PS [SK], 28 V 2010, 1 ex., leg. PS [PJ]; Laski (VU71), xerothermic grassland *Adonido-Brachypodietum* in a deep ravine surrounded by fields, 28 V 2010, 1 ex., leg. PS [PJ].

This species is rare in Poland, although it has been recorded from scattered localities (Burakowski et al. 1986), and was recently recorded in Poland in the Białowieża Primeval Forest (Byk et al. 2006).

Tritoma subbasalis Reitter, 1896

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

Material examined. Podlasie*: Szostaki (EE90) ad Burzyn, 17 VI 2010, 3 exx., leg. RR [RR, SK]. **Lublin Upland*:** Poleski N.P., Łukie Lake vic. (FB49), 22 V 2004, 2 exx., leg. RR [RR].

This rare species is restricted to the eastern part of Poland.

Dacne rufifrons **(Fabricius, 1775)**

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

Material examined. Bieszczady Mts.: Wetlina State Agricultural Farm (FV04), 27 VII 1994, 2 exx., leg. JK [LBJK].

A rare species, known from scattered localities in various regions of Poland.

Updated key to *Triplax* species of Central Europe

Triplax carpathica was not included in any of the previously published identification keys to Central European Erotylidae (Vogt 1967, Mazur 1983). Therefore, an updated key is presented below, comprising all Central European *Triplax* species (Figs. 3–24). Species known from adjacent areas and which may occur in Poland are denoted with an asterisk.

1 Basal margin of elytra crenulate (Fig. 25), often forming a distinct ridge..... **2**
– Basal margin of elytra smooth, without crenulation (Fig. 26)...................... **9**
2 Head black **3**
– Head yellowish-red **4**
3 Body elongate oval, distinctly rounded; BL 3.3–4.0 mm .... ***T. melanocephala*** **(Latreille)***
– Body broadly oval, sides distinctly rounded; BL 3.3–4.0 mm .... ***T. collaris*** **(Schaller)**
4 Entire venter yellowish-red.. **5**
– Meso- and metaventrite black **6**
5 Elytra metallic bluish or greenish; BL 3.6–4.4 mm; sides of body rounded .... ***T. aenea*** **(Schaller)**
– Elytra black, without metallic hue; BL 6.0–6.5 mm; sides of body subparallel. .... ***T. elongata*** **Lacordaire**
6 Abdominal sternites yellowish-red; BL 5.1–6.7 mm.... ***T. russica*** **(Linnaeus)**
– Abdominal sternites entirely or largely black.. **7**
7 Body oval, sides rounded; BL 3.9–4.1 mm .... ***T. rufipes*** **(Fabricius)**
– Body elongated, sides subparallel **8**
8 Antennomere III much longer than II; BL 3.0–4.2 mm .... ***T. lacordairei*** **Crotch***
– Antennomere III slightly longer than II; BL 2.0–3.0 mm .... ***T. pygmaea*** **Kraatz***
9 Meso-, metaventrite and abdominal sternites black; body stout (BL/BW 1.7–1.8); BL 3.3–5.0 mm... ***T. lepida*** **(Faldermann)**
– Entire venter yellowish-red, body larger and more oblong (BL/BW 1.9–2.0). **10**
10 Scutellum yellowish-red, elytral punctures shallow; BL 4.2–4.9 (n=16, mean 4.6).. ***T. scutellaris*** **Charpentier**

– Scutellum always black, eelytral punctures deep; BL 3.9–4.5 (n=9, mean 4.1).. ***T. carpathica*** **Reitter**

Acknowledgments

We are indebted to Prof. J. M. Gutowski (Forest Research Institute, Białowieża, Poland) for his kind gift of the *T. carpathica* specimen used in the present study, Dr. O. Merkl (HNHM) for sending the type of *T. carpathica*, Dr. W. Schawaller (SMNS) for sending the specimen of *T. pygmaea*, and Dr. P. Węgrzynowicz (Łódź University, Poland) for confirming our identification of *T. carpathica* and comments on the genus *Cryptophilus*. We also thank Prof. L. Borowiec and Dr. J. Kania (Wrocław University, Poland), who made data and specimens from their collections available. The first author's studies were partially supported by the Wrocław University stipend for young researchers financed by The European Social Fund ("Human Resources Development" Operational Programme).

References

Borowiec L (1984) *Triplax carpathica* Reitter, 1890 (Col., Erotylidae), a new species of beetle for the fauna of Poland. Przegląd Zoologiczny 28(1): 73–74. [In Polish]

Burakowski B, Mroczkowski M, Stefańska J (1973) Chrząszcze Coleoptera, Biegaczowate – Carabidae, cz. 1. Catalogus faunae Poloniae XXIII, 2: 1–234. [In Polish]

Burakowski B, Mroczkowski M, Stefańska J (1986) Chrząszcze Coleoptera, Cucujoidea, cz. 2. Catalogus faunae Poloniae XXIII, 13: 1–278. [In Polish]

Byk A, Mokrzycki T, Perliński S, Rutkiewicz A (2006) Saproxylic beetles – in the monitoring of anthropogenic transformations of Białowieża Primeval Forest. In: Szujecki A (Ed) Zooindication-based monitoring of anthropogenic transformations in Białowieża Primeval Forest. Warsaw Agricultural University Press, Warsaw, 325–397.

Chûjô M (1969) Erotylidae (Insecta: Coleoptera). Fauna Japonica. Academic Press of Japan, Tokyo, 316 pp.

Franc V (2001) Beetles of the family Erotylidae (Coleoptera) in the Slovakian fauna. Acta Universitatis Comenianae 44: 63–69.

Ganglbauer L (1899) Die Käfer von Mitteleuropa. Die Käfer der österreichisch-ungarischen Monarchie, Deutschlands, der Sweiz, sowie des französischen und italienischen Alpengebietes. Dritter Band. Familienreiche Clavicornia. Sphaeritidae, Ostomidae, Byturidae, Nitidulidae, Cucujidae, Erotylidae, Phalacridae, Thorictidae, Lathridiidae, Mycetophagidae, Colydiidae, Endomychidae, Coccinellidae. [II]. Druck und Verlang Carl Gerold's Sohn, Wien, 409–1046.

Iablokoff-Khnzorian S M (1975) Etude sur les Erotylidae (Coleoptera) Paléarctiques. Acta Zoologica Cracoviensia 20: 201–266.

Jałoszyński P, Węgrzynowicz P (2007) A new record of *Triplax collaris* (Schaller) in Poland (Coleoptera, Erotylidae). Entomological News (Poznań) 26(1): 61–62. [In Polish] http:// pte.au.poznan.pl/we/2007/10_kr_don.pdf [accessed 7.VI.2011]

Lawrence J (1991) Languriidae (Cucujoidea) (including Crytophilidae), Erotylidae (Cucujoidea) (including Dacnidae), Biphillidae (Cucujoidea), pp. 471–476. In: Stehr FW (ed.) Immature Insects. Vol. 2. Kendall/Hunt Publishing Company, Dubuque, Iowa.

Leschen RAB, Buckley TR (2007) Multistate Characters and Diet Shifts: Evolution of Erotylidae (Coleoptera). Systematic Biology 56(1): 97–112. doi: 10.1080%2F10635150701211844

Mazur S (1983) Zadrzewkowate - Erotylidae, Wygłodkowate - Endomychidae. Keys for the identification of Polish insects XIX, 74–75: 1–32. [In Polish]

Nieto A, Alexander KNA (2010) European Red List of Saproxylic Beetles. Luxembourg: Publications Office of the European Union: 1–44. http://ec.europa.eu/environment/nature/conservation/species/redlist/downloads/European_saproxylic_beetles.pdf [accessed 7.VI.2011]

Reitter E (1890) Neue Coleopteren aus Europa, den angrenzeden Ländern und Sibirien, mit bemerkungen über bekannte Arten. Deutsche Entomologische Zeitschrift 1890: 385–396.

Sen Gupta T, Crowson RA (1971) A review of classification of the family Languriidae (Coleoptera: Clavicornia) and the place of Languriidae in the natural system of Clavicornia. Memoirs of the Zoological Survey of India 15: 1–42.

Vogt H (1967) Erotylidae. In: Fraude H, Harde KW, Lohse GA (eds.) Die Käfer Mitteleuropas. Band 7. Clavicornia. Goecke und Evers, Krefeld: 104–109.

Węgrzynowicz P (2002) Morphology, phylogeny and classification of the family Erotylidae based on adult characters (Coleoptera: Cucujoidea). Genus 13(4): 435–504. http://www.biol.uni.wroc.pl/cassidae/Erotylidae%20classification.pdf [accessed 7.VI.2011]

Węgrzynowicz P (2007) Family Erotylidae Latreille, 1802. In: Löbl I, Smetana A (eds.) Catalogue of Palaearctic Coleoptera, vol. 4. Apollo Books, Stenstrup, 935 pp.

ZooKeys 134: 15–31 (2011)
doi: 10.3897/zookeys.134.1707
www.zookeys.org

RESEARCH ARTICLE

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

Two new *Typhloreicheia* species from Sardinia and their biogeographical significance (Coleoptera, Carabidae, Scaritinae)

Achille Casale[†], Paolo Marcia[‡]

Dipartimento di Zoologia e Genetica Evoluzionistica, Università di Sassari, Via Muroni 25, 07100 Sassari (Italy)

† *urn:lsid:zoobank.org:author:7488DBB2-9447-4698-8613-5E90D5C7228D*
‡ *urn:lsid:zoobank.org:author:505E7088-28A6-46BA-88BD-9343C99BC36E*

Corresponding author: *Paolo Marcia* (casale@uniss.it)

Academic editor: *Augusto Taglianti* | Received 13 June 2011 | Accepted 2 August 2011 | Published 6 October 2011

urn:lsid:zoobank.org:pub:0B88CDFB-8FB6-4915-8130-A545F019CC07

Citation: Casale A, Marcia P (2011) Two new *Typhloreicheia* species from Sardinia and their biogeographical significance (Coleoptera, Carabidae, Scaritinae). ZooKeys 134: 15–31. doi: 10.3897/zookeys.134.1707

Abstract

Typhloreicheia monacha **sp. n.** and *T. ilianae* **sp. n.** are described from two caves of Central-Eastern Sardinia (Nuoro province): the Bue Marino cave and the Nurra 'e Pradu cave, respectively. Both caves are located in the part of the island where many highly specialised subterranean carabid beetles are localised. *T. monacha* is apparently related to two other species of the same area, i.e. *T. onnisi* Casale & Magrini, 2004 and *T. elegans* (Dodero, 1916); *T. ilianae* is closely related to *T. henroti* Jeannel, 1957, known from a cave near Dorgali. Relationships and diagnostic features among these taxa are discussed and illustrated, and a key for identification of the specialised subterranean *Typhloreicheia* species of Sardinia is provided. The hypothesis of adaptive radiation of Reicheiina species in Sardinia, recently proposed by the senior author of this contribution, is further elaborated in light of new data.

Keywords

Coleoptera, Carabidae, Scaritinae, *Typhloreicheia*, new species, Sardinia, adaptive radiation

Introduction

The subtribe Reicheiina is a lineage of endogean and hypogean carabid beetles, currently classified in the tribe Clivinini of the subfamily Scaritinae of the family Carabidae (Vigna Taglianti 2005), including so far (as genera "close to *Reicheia*": Jeannel 1957) about 150 species (Balkenohl 2003, Lorenz 2005, Grebennikov et al. 2009). External structural attributes of Reicheiina are markedly homogeneous: most of the species are small-sized carabids (1–4 mm) with reduced or absent eyes, moniliform antennae, fossorial prothoracic legs (typical of Scaritinae), the posterior angles of pronotum obliterated and rounded, short pronotal peduncle and the lack of a basal annular constriction on the pronotum. A few taxa, such as the subterranean *Spelaeodytes mirabilis* L. Miller, 1863, living in caves of the Eastern Adriatic coast (Croatia), display markedly troglomorphic adaptive features (Casale et al. 1998 a, b).

Work with Reicheiina beetles is hampered by the small sizes of its representatives and by the scarcity of material, some taxa being known from one or a few specimens. Morphological characters currently employed in defining various members of Reicheiina are those of external body shape and male genitalia, while immature stages, for example, are still completely unknown.

Monophyly of Reicheiina has never been adequately demonstrated and a distinct possibility exists that the group is an artificial assemblage of unrelated subterranean scaritine clades (Grebennikov et al. 2009). Overall subtribe's existence and its current placement in the tribe Clivinini and generic composition are more a result of gradually evolving taxonomic treatment, initiated by Holdhaus (1924), Jeannel (1957) and Basilewsky (1980), rather than a reflection on its hypothesised monophyly.

However, the monophyly of the Euro-Mediterranean core of Reicheiina formed by the genus *Typhloreicheia* and its relatives is highly plausible. In Sardinia, the genus *Typhloreicheia* Holdhaus, 1924 is markedly diversified (Casale 2009). In this contribution, the authors describe two new morphologically specialized *Typhloreicheia* species from caves of Sardinia, and debate some biogeographical aspects of this discovery.

Material and methods

Newly designated Sardinian *Typhloreicheia* type specimens were collected during speleological or biospeleological investigations. All subsequent focused attempts to obtain further individuals by using pitfall traps or baits were unsuccessful.

Male genitalia were dissected, dehydrated in ethanol, cleared in cold KOH, examined and illustrated, using standard techniques before their definitive inclusion on microscope slides attached to the respective specimens. Line drawings were made using a camera lucida attached to stereomicroscopes Wild M-5, and a microscope Leitz Orthoplan.

Photographs of male genitalia were prepared by Paolo Magrini (Florence), with a Nikon D1 digital camera mounted on a Nikon Labophot II binocular microscope. P. Magrini also prepared distributional maps of *Typhloreicheia* in Sardinia.

The median lobe of aedeagus is synonym of phallus of authors. The proximal gonocoxite 1, and the more distal gonocoxite 2 (in the sense of Liebherr and Will 1998), are synonyms of stylomere 1 and stylomere 2 of authors, respectively.

Acronyms:

TL	body Total length, from the anterior margin of clypeus to the apex of elytra, measured along the elytral suture.
L	overall body length, from apex of mandibles to apex of elytra, measured along the suture.
PL/PW	ratio length of Pronotum, as linear distance from the anterior to the posterior margin (peduncle included), measured along the midline to the maximum Width of Pronotum.
EL/EW	ratio length of Elytra, as linear distance from the basal ridge to the apex, measured along the elytral suture to the maximum Width of Elytra.
EL/PW	ratio maximum Width of Elytra to maximum Width of Pronotum
AL	length of antenna.

Collections:

CCa	all type specimens are preserved in Casale Collection (University of Sassari, Italy)

Results

Typhloreicheia monacha sp. n.

urn:lsid:zoobank.org:act:D1845710-A731-46D0-9904-65DD4662188E
http://species-id.net/wiki/Typhloreicheia_monacha

Type locality. Italy, Central-Eastern Sardinia: Dorgali (Nuoro province), Cala Gonone: Bue Marino cave *(speleological inventory number: 12 Sa/NU), 0 m a.s.l.,* 40°14'51"N - 9°37'29"E

Type material. Holotype male with the following data: I – Sardegna, Dorgali (NU), Gr. Bue Marino 10.IX.2006 P. Marcia leg.; paratypes: female, same data as holotype; female: I – Sardegna, Urzulei (NU) Codula di Luna, Gr. Su Spiria 1988 Sa/NU 23.VII.1995 R. Loru leg. (CCa).

Etymology. The Latin noun "*monachus–a*" (= monk) recalls the monk seal *Monachus monachus* (Hermann, 1779), the so-called "Bue Marino", in the tradition of the Mediterranean languages, from which the type locality cave derives its name. Monk seal is presently one of the most endangered mammalian species of the Mediterranean fauna, although it was still present in the Eastern coast of Sardinia until the '60s of the past century.

Diagnosis. *Typhloreicheia monacha* new species, for both its external features and characteristics of male genitalia, seems to be related to *T. onnisi* Casale & Magrini, 2004, known from three caves in the Gairo region (Central-Eastern Sardinia), and, to a lesser extent, to *T. elegans* (Dodero, 1916) known from a cave of Arcuerì Mt. near Seui. The male features of the latter, however, are still unknown.

From *T. onnisi* the new species can be distinguished mainly by its stouter and wider head, with more convex genae; by its wider pronotum, with anterior angles larger and more prominent, and lateral margins more rounded and less constricted toward the base; by the elytra shorter, with lateral margins with more numerous (23–25) (14–16 in *T. onnisi*) and more prominent marginal teeth; and by the different shape of the aedeagus (see Figures 3–4).

Description. A medium-large sized *Typhloreicheia* species (TL: 2.95–3.08 mm; L: 3.28–3.40 mm).

Body elongate, convex (Figure 1). Colour testaceous reddish, antennae and mouthparts slightly paler. Integument shiny, polished; microsculpure with fine, hardly visible microlines in form of isodiametric mesh pattern on head and elytra, almost vanished on pronotum.

Head with ocular part of genae regularly convex, constricted toward the neck. Eyes absent. Supra-antennal plates separated from genae by deep and broad furrow; frontal furrows very deep, transversally wrinkled; vertex with an evident, convex tubercle in the middle; antennae moderately elongate (AL: 1.31 mm in male holotype), antennomeres 3–10 slightly longer than wide.

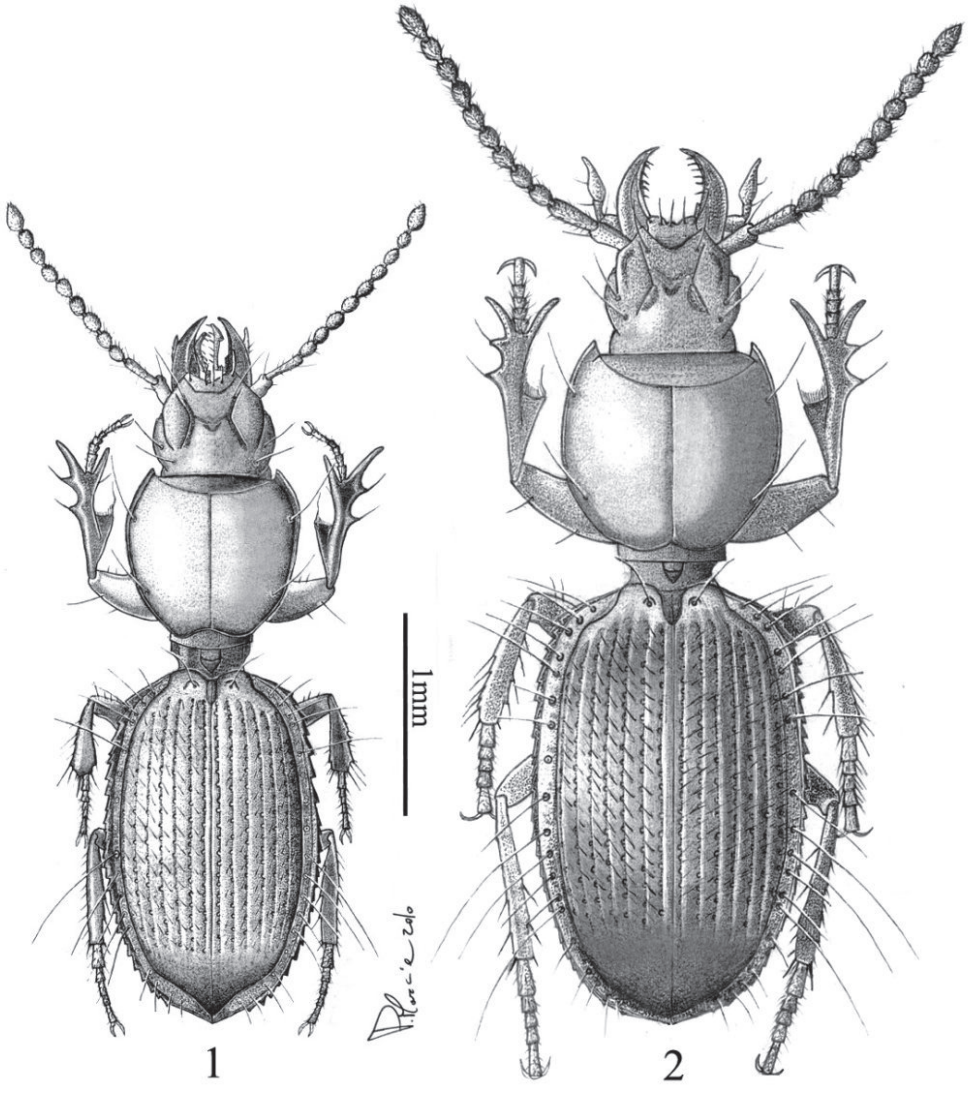
Pronotum moderately convex, elongate (PL/PW: 1.0), with its maximum width at the anterior third; sides moderately rounded, slightly attenuated in front, markedly constricted to the basal peduncle; anterior angles acutely prominent; median furrow narrow and deeply impressed; lateral furrows very narrow and superficial.

Elytra elongate-ovate (EL/EW: 1.6), distinctly wider than pronotum (EW/PW: 1.21), convex, with their maximum width in the middle; humeri broadly rounded; lateral furrows wide, flattened, not narrowed at apex; lateral margin reflexed, with numerous (23–25), small but acutely prominent marginal teeth; striae all evident, deeply punctuate, gradually disappearing at apex; elytral intervals moderately convex, intervals 2–7 each bearing a series of short, erected setae; umbilicate series of 16–19 punctures along stria 8.

Male genitalia as in Figure 3. Median lobe of aedeagus markedly curved, with short, rounded and flattened apex. Endophallus with developed, apical copulatory piece and an elongate packet of serrate scales in the middle. Parameres each with two apical setae.

Female genitalia (examined, not illustrated) without any peculiar characteristic: gonocoxites 2 rather short, regularly curved outwards, each with two moderately elongate, robust spiniform setae on the outer side, the distal of them being distinctly longer and thickener than the proximal one.

Distribution and habitat. Two specimens of *T. monacha* sp. n. were collected during one of bio-speleological expeditions organized in the last years by the authors.



Figures 1–2. *Typhloreicheia monacha* sp. n., male holotype, dorsal aspect **2** *Typhloreicheia ilianae* sp. n., male holotype, dorsal aspect.

The specimens were walking on sandy, humid soil on the banks of the subterranean lakes in the inner parts of the Bue marino cave, in the same habitat as those noted for the molopine carabid beetle *Speomolops sardous* Patrizi, 1955 and its larva (Casale et al. 2010). The Bue Marino cave, with 48 subterranean species reported so far, is the Sardinian cave richest in hypogean fauna (Casale et al. 2008). An additional female individual was collected by Roberto Loru in the same environmental conditions during a speleological exploration in the nearby Su Spiria cave (1988 Sa/NU) 40°10’42”N - 9°33’54” E, 165 m a.s.l. (Urzulei, Codula Ilune, hypogean system of Su

Palu - Grutta de Monte Longos caves), and was erroneously attributed to *T. henroti* (Casale & Magrini 2004).

In spite of many subsequent investigations in both these caves, including setting pitfall traps, no further individuals of this species have been obtained. *T. monacha*, like other species of the same genus in Sardinia (and most so-called troglobiont species: Giachino & Vailati 2010), seems to be a deep crevices dweller, which occasionally penetrate in large hypogean systems accessible to the humans, and are never collected by shifting soil.

Relationships. The following features of *T. monacha* sp. n. suggest its affinities with the *elegans* species group (Jeannel 1957; Casale and Magrini 2004): medium-large sized body, elytra with intervals 2–7 each bearing a series of erected setae and lateral margins serrate from the humeral angle to apex, shape of aedeagus and structure of endophallus. With the discovery of *T. ilianae* new species, however, this group appears non-monophyletic (see below, in relationships of *T. ilianae*). Therefore, *T. elegans*, *T. onnisi* and *T. monacha* sp. n. are separated in the *elegans* species group (in the new sense) distinct from the *henroti* species group (see below).

Typhloreicheia ilianae sp. n.

urn:lsid:zoobank.org:act:B5A1C382-9E73-4F50-B15A-611522B1F9A7
http://species-id.net/wiki/Typhloreicheia_ilianae

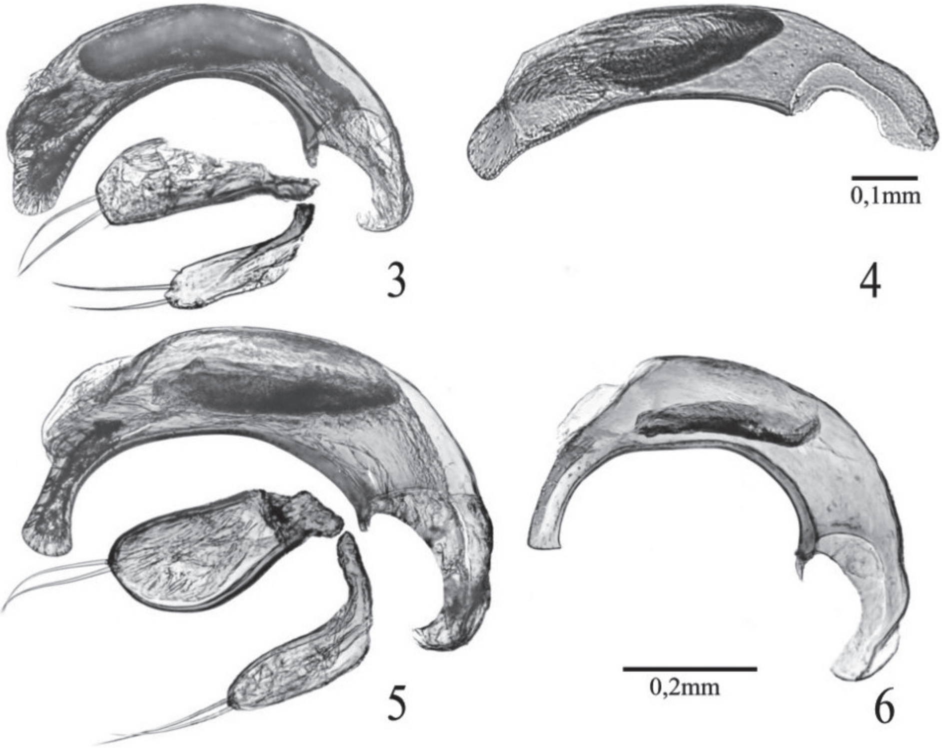
Type locality. Italy, Central-Eastern Sardinia: Oliena (Nuoro province), Corrasi Mt.: Nurra 'e Pradu cave (speleological inventory number: 3083 Sa/NU), 1220 m a.s.l. , 40° 15'27.0"N, 009° 25'45.3"E

Type material. Holotype male with the following data: I – Sardegna, Oliena (NU), M. Corrasi 26.I.2008 P. Marcia", "Gr. Nurra 'e Pradu" (CCa).

Etymology. The name derives from the Oliena village at the base of the Corrasi mountain in which this new species, and many other hypogean organisms were discovered. An ancient legend says that the inhabitants (*Ilienses* in Latin) of Troy (*Ilios* in ancient Greek), after the fall of the town to the Greeks, reached Sardinia and founded a village named Iliana, which subsequently became Oliena.

Diagnosis. *Typhloreicheia ilianae* is the largest in size among the Sardinian congeners known so far, with its TL: 3.64 and L: 4.05 (male holotype). It is evidently related to *T. henroti* Jeannel, 1957 (see features of the median lobes of aedeagus in respective species: Figures 5–6), but can be distinguished from the latter mainly by its larger size (TL: 3.10 – 3.65, L: 3.40 - 3.86 in *T. henroti*); by wider and more robust head, with supra-antennal plates more prominent laterally, by more convex genae markedly constricted to the neck, by antennomeres 3–11 more thickened, and by anterior angles of both clypeus and labrum more acutely prominent; and by the different shape of the median lobe of aedeagus (Figures 5–6).

Description. A large sized *Typhloreicheia* species (TL: 3.64; L: 4.05 mm, in male holotype).



Figures 3–6. *Typhloreicheia* spp., male genitalia, right lateral aspect: **3** *T. monacha* sp. n., median lobe f aedeagus and parameres **4** *T. onnisi* Casale & Magrini, median lobe of aedeagus **5** *T. ilianae* sp. n., median lobe of aedeagus and parameres **6** *T. henroti* Jeannel, median lobe of aedeagus.

Body elongate but robust, convex (Figure 2). Colour testaceous reddish, antennae and mouthparts slightly paler.

Integument shiny, highly polished; microsculpure with fine, hardly visible microlines in form of isodiametric mesh pattern on head and elytra, almost vanished on pronotum.

Head robust, with ocular part of genae markedly convex, constricted toward the neck. Eyes absent. Anterior angles of clypeus acutely prominent. Supra-antennal plates prominent laterally, with outer margin beaded, separated from genae by deep and broad furrow; frontal furrows very deep, with shallow wrinkles in the posterior tract; vertex with an evident, convex tubercle in the middle; antennae elongate (AL: 1.58 mm in male holotype) but robust, thickened; antennomeres 6–10 slightly longer than wide.

Pronotum markedly convex, relatively wide (PL/PW: 0.95), with its maximum width at the basal third; sides moderately rounded, slightly narrowed in front, markedly constricted to the basal peduncle; anterior angles acutely prominent; median furrow very shallow; lateral furrows very narrow and superficial.

Elytra elongate-ovate (EL/EW: 1.62), distinctly wider than pronotum (EW/PW: 1.24), convex, with their maximum width in the middle; humeri broadly rounded;

lateral furrows wide, flattened, not narrowed at apex; lateral margin reflexed, elytra with lateral margins with numerous (24) prominent marginal teeth; striae deep, deeply punctuate, all evident, gradually disappearing et apex; elytral intervals convex, intervals 2–7 each bearing a series of short, erected setae; umbilicate series of 16–19 punctures along stria 8.

Male genitalia as in Figure 5. Median lobe of aedeagus markedly curved, with long apical lamina, which is widened, hatched-like distally. Endophallus with a reduced, inconspicuous apical copulatory piece and an elongate packet of serrate scales in the middle. Parameres each with two apical setae.

Female genitalia: unknown.

Distribution and habitat. *Typhloreicheia ilianae* sp. n. is known only from the type locality. The holotype was sampled in wet soil under big stones in a small pit (- 3.7 m), which represents the entrance of a large hypogean system, reaching the depth of 101 m. The associated subterranean fauna includes some of the most specialised troglomorphic endemic Sardinian elements, such as *Sardaphaenops supramontanus supramontanus* Cerruti & Henrot, 1956 (Coleoptera, Carabidae, Trechini) and *Patriziella sardoa* Jeannel, 1956 (Coleoptera, Cholevidae, Leptodirini), both described from a nearby cave Nurra ‘e Sas Palumbas. The Nurra ‘e Pradu cave is also one of the few localities of Sardinia from which the large sized, trogloxenic centipede *Plutonium zwierleini* Cavanna, 1881 is reported (Zapparoli 2009). We sampled in this cave the following taxa, all endemic to central-eastern Sardinia and representing new faunal records: the orthopteran *Acroneuroptila* cf. *sardoa* Baccetti, 1960, the sphodrine carabid beetle *Laemostenus pippiai* (G. Fiori, 1961) (A. Casale det.), the cholevid beetle *Ovobathysciola majori* (Reitter, 1885) (A. Casale det.), and the terrestrial snail *Tacheocampylaea carotii* (Paulucci 1882) (S. Birindelli det.). Subsequent trapping in this cave using pitfall traps, did not produce additional individuals of *T. ilianae*.

Relationships. *Typhloreicheia ilianae* is the largest among the Sardinian species known so far, exceeding the large size of *T. kraussei* (Reitter, 1914), a typical endogean, not hypogean species reaching 3.69 mm in length (Leo et al. 2005). Nevertheless, any relationship of *T. ilianae* sp. n. with *T. kraussei* (Reitter, 1914) and its adelphotaxon *T. manto* (Holdhaus, 1924), both typically endogean, not hypogean species, are highly unlikely. Both latter species have elytral setiferous pores present in intervals 2, 3, 5 and 7 only, and the lateral margins serrate only in the basal half. Furthermore, in these taxa the features of the median lobe of aedeagus are markedly dissimilar to those of *T. ilianae* sp. n., and the apical copulatory piece in endophallus is lacking in *T. kraussei* (Leo et al. 2005).

The new taxon appears related to *T. henroti* Jeannel, 1957, known from the Gurennoro cave (= Pisanu cave, 215 Sa/NU, near Dorgali). Both species are similar in having large-sized body and elytral lateral margins bearing numerous (21–24) teeth extending all the way from the humeral angle to elytral apex. Also both species share the peculiar shape of the median lobe of aedeagus, which is unique among the Sardinian species (Figures 5–6). These species form a pair of adelphotaxa very isolated from the rest of species known so far on the island, here indicated as *henroti* species group, excluding the other specialised hypogean species of Sardinia known so far (*T. elegans*, *T. onnisi*, and *T. monacha* sp. n.) treated above as *elegans* species group in the narrow sense.

The following operative and provisional key is provided to distinguish the cave dweller (deep hypogean, or troglophilic) *Typhloreicheia* species known so far in Central Eastern Sardinia:

1 Larger in size (TL: mm 2.9–3.6; L: 3.0–4.0); elytra with intervals 2–7 all having setiferous punctures, and with lateral margins serrate from the humeral angle to apex. Deep hypogean species, known from caves only **2**

– Smaller in size (TL less than 3 mm); elytra with only intervals 2–3-5–7 having setiferous punctures. Endogean but troglophilic species, occasionally found in caves **6**

2 Larger in size (TL: 3.10–3.65; L: 3.40–4.05). Median lobe of aedeagus with apical lamina very elongate, spatulate or axe-shaped distally (*henroti* species group in new sense) **3**

– Smaller in size (TL: 2.90–3.10; L: 3.00–3.40). Median lobe of aedeagus (in the two species in which it is known) with apical lamina short, rounded or sub-truncate distally (*elegans* species group in new sense) **4**

3 Larger in size (TL: 3.64 mm; L: 4.05 mm, in male holotype). Median lobe of aedeagus larger, with apical lamina wider distally (Figure 5) (Central Eastern Sardinia, Corrasi Mt.: Nurra 'e Pradu cave) .... ***ilianae* sp. n.**

– Smaller in size (TL: 3.10 – 3.65 mm; L: 3.40 – 3.86 mm). median lobe of aedeagus smaller, with apical lamina more elongate and narrower distally (Figure 6) (Central Eastern Sardinia, Dorgali: Gurennoro or Pisanu cave) .... ***henroti* Jeannel, 1957**

4 Anterior angles of both clypeus and pronotum rounded, slighly prominent in front; genae slightly convex (Central Eastern Sardinia, Seui: Is Diavolus cave) .... ***elegans* (Dodero, 1916)**

– Anterior angles of both clypeus and pronotum very prominent in front; genae very convex, inflate **5**

5 Elytra shorter, ovate, with lateral sides rounded and lateral margins with markedly prominent and numerous (23–25) teeth. Median lobe of aedeagus markedly curved, with apical lamina shorter and rounded distally (Figure 3) (Central Eastern Sardinia, Dorgali: Bue Marino cave).......... ***monacha* sp. n.**

– Elytra elongate, sub-parallel sided; lateral margins with slightly prominent and less numerous (14–16) teeth. Median lobe of aedeagus slightly curved, with apical lamina more developed and sub-truncate distally (Figure 4) (Central Eastern Sardinia: caves in the Gairo region) .... ***onnisi* Casale & Magrini, 2004**

6 Larger in size (TL: 2.31–2.50; L: 2.58–2.99). Elytra with lateral margins serrate in the basal third only. Median lobe of aedeagus with apical lamina short; endophallus with copulatory piece in the shape of twisted lamina (Central

Eastern Sardinia: Sadali, Is Janas cave; Nurallao [Nuoro]) .... ***jana* Leo, Magrini & Fancello, 2005**

– Smaller in size (TL: 1.99–2.22; L: 2.11–2.50). Elytra with lateral margins serrate from the humeral angle to apex. Median lobe of aedeagus with apical lamina markedly elongate and curved on the ventral side; endophallus with copulatory piece in the shape of triangular lamina, rounded distally and hollow at base. Central Eastern Sardinia, near Dorgali and Galtellì, in deep soil and caves .... ***pandora* (Holdhaus, 1924)**

Discussion

1. *Reicheiina*: current taxonomy, and biogeographical remarks at world scale.

As recently recalled (Casale 2009), the current distribution of Reicheiina in the Euro-Mediterranean area and the African continent is highly interesting from the biogeographical point of view: in fact, this lineage presents a markedly disjoint distribution, being represented by several genera and many species in mainland and islands of this area, and some taxa in East Africa, West Africa, South Africa and Madagascar (Jeannel 1957; Basilewsky 1980, Casale and Vigna Taglianti 1996; Balkenhol 2003, 2005; Bulirsch et al. 2005; Bulirsch and Magrini 2007).

Grebennikov et al. (2009) stressed that the discovery of supposed Reicheiina in South-Eastern and Eastern Asia (Laos, Vietnam and Japan: Balkenohl 2005) (Figure 7) revealed a large gap in their known distribution and, implicitly, challenged the monophyly of the subtribe. The same authors recalled that, besides Reicheiina, other apparently unrelated representatives of the subfamily Scaritinae show reduced or absent eyes and wings, small size and depigmentation, in correlation with their subterranean way of life, and other blind Clivinini belong to the subtribe Clivinina (as the genus *Trogloclivina* Deuve, 2003 from Papua New Guinea).

Furthermore, these authors do not consider members of the subtribe Reicheiina some taxa cited as either potentially belonging, or closely related, to the subtribe Reicheiina: the monotypic genus *Italodytes* Müller, 1938 from Apulian caves, *Syleter* Andrewes, 1941 (including Afrotropical and Oriental species), *Psilidius* Jeannel, 1957 (including Afrotropical species), *Leleuporella* Basilewsky, 1956 (including Afrotropical species and one from Sri Lanka), *Trilophus* Andrewes, 1927 (including Oriental species) and *Trilophidius* Jeannel, 1957 (including Afrotropical and Oriental species).

2. Biogeographical remarks at local scale.

Two hypotheses have been proposed to explain the origin and the exceptional specific diversity of the genus *Typhloreicheia* in Sardinia.

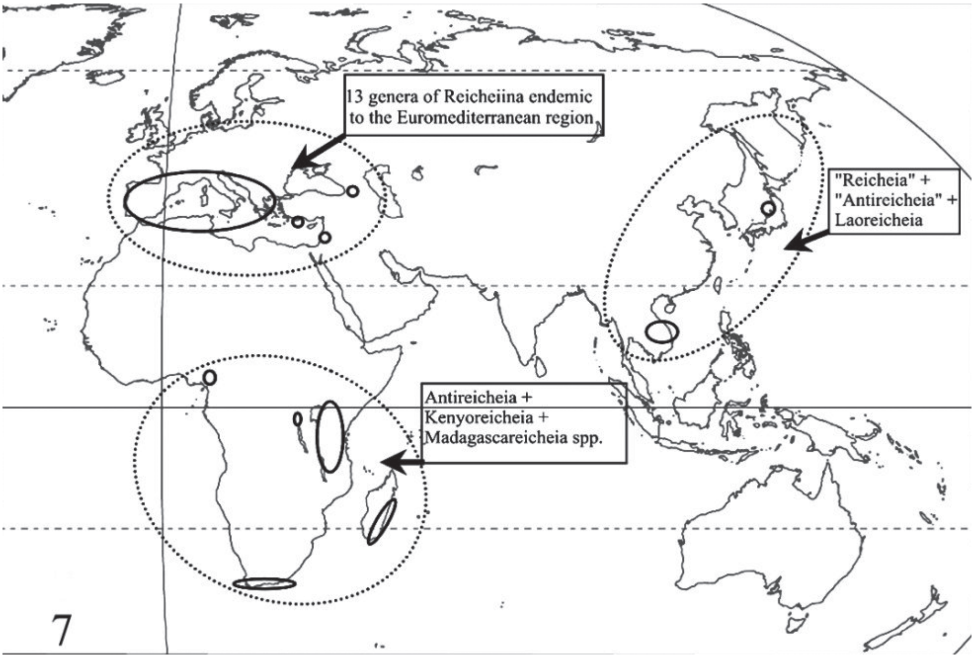


Figure 7. World distribution of the subtribe Reicheiina in the current sense.

The first hypothesis proposes at least two different, heterochronic colonisation events. The older one is represented by the common ancestor of the subgenus *Sardoreicheia* Jeannel, 1957. This subgenus was treated as synonym of *Typhloreicheia* by Casale and Vigna Taglianti (1996) and other authors, but separated again in the recent catalogues by Balkenhol (2003) and Lorenz (2005). The colonisation event originated from the Miocene tectonic drift of the Corso-Sardinian micro-plate in the Western Mediterranean (Alvarez 1972). Conversely, the more recent colonisation event of the common Apennine ancestor of *Typhloreicheia* sensu stricto occurred through land connections during the Messinian Salinity Crisis in the Mediterranen basin (Hsü et al. 1977).

This scenario should be similar to the process recently proposed by Wirta et al. (2010) concerning Scarabaeidae Scarabaeinae in Madagascar: in fact, this island has an exceptionally large fauna of more than 250 species of endemic dung beetles. Based on molecular phylogenies, the species descend from eight independent overseas colonisations, of which four have given rise to big radiations. Among them, the tribe Canthonini show three parallel radiations following the respective colonisations at 64–44 Mya.

The second hypothesis proposes that all Sardinian *Typhloreicheia* species are derived from a common Tyrrhenian, Miocene ancestor.

In other words, the question is: how many times have Reicheiina colonized the island of Sardinia? An adequate solution of this question based exclusively on morphological features is hardly possible. Involvement of molecular data might eventually help to generate complete phylogenetic hypotheses for *Typhloreicheia* and related genera and thus assist with detecting the number of colonisation events.

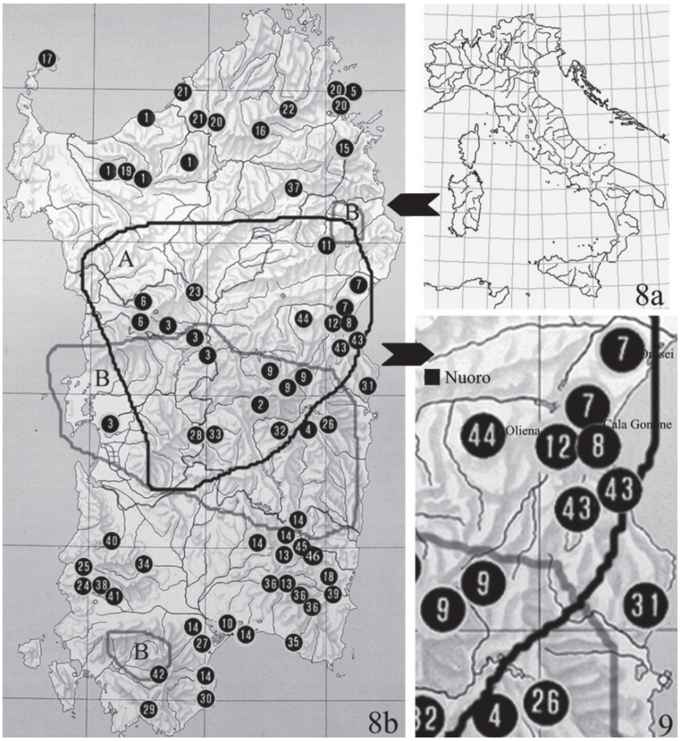
The similarities between the male genitalia of some Sardinian species and those of species of the Apennine chain, the Elba island and Sicily, supports the hypothesis of multiple colonisations of the island by different ancestors. This is further strengthened by the remarkable absence of *Typhloreicheia* species in Corsica and Baleares, where the genus is replaced by *Reicheia* Saulcy, 1863. Furthermore, the scenario in Sardinia has been complicated by the recent description of the genus *Dimorphoreicheia* Magrini, Fancello & Leo, 2003 (with two species known so far), characterised by the presence of setiferous pores on the disc of the pronotum, a feature previously thought to be peculiar to the genus *Reicheadella* Reitter, 1913, with some species distributed in the southern Balkans (Casale et al. 1998 a). Nevertheless, this highly complicated situation could be explained by any hypotheses treated below.

3. Adaptive radiation of *Typhloreicheia* in Sardinia: previous and new hypotheses compared.

Adaptive radiation might work very rapidly. Classic examples include Hawaiian silverswords and *Drosophila*, Darwin's finches on the Galápagos islands, *Anolis* lizards on Caribbean islands, and cichlids of the East African Great Lakes, among others (Givnish and Sytsma 1997; Schluter 2000; Gavrilets and Losos 2009). Gavrilets and Losos (2009) recognize two main components of adaptive radiation: the production of new species by allopatric or non-allopatric speciation, and their subsequent adaptation to a diversity of ecological niches. This may happen when an ancestral taxon finds itself in a vacant area, where resources are abundant and underutilized (e.g., islands or lakes).

The genus *Typhloreicheia* in Sardinia shows a spectacular diversity much exceeding that in all other Tyrrhenian areas (Iberian Peninsula, Baleares, Apennines, Sicily) where the genus is represented. This fact already induced Holdhaus (1924) and Jeannel (1957), even with much scarcer data to believe that "the genus should have originated in Sardinia". Some years later Magistretti (1965), in his catalogue of the carabid fauna of Italy, was able to list only 13 *Typhloreicheia* species from Sardinia, whereas they are presently 46 (see Figure 8 a, b).

Recent research in the field shows a scenario in which two, three or more sympatric *Typhloreicheia* species are present in every micro-sector of the island. Additionally, if they are living in the same area, they show different habitat choice (soil litter, deep soil, crevices, or caves, respectively), and different adaptive features to a subterranean way of life. A good example is offered by two cave-dwelling species, i.e. *T. henroti* Jeannel, 1957 and *T. monacha* sp. n., which in the Dorgali area (Central-Eastern Sardinia) co-occur with the endogean *T. doderoi* (Holdhaus, 1924) and *T. pandora* (Holdhaus, 1924). In close areas, other so-called "troglobitic" species (sampled in caves only) are reported from the Jurassic massifs of the central-eastern part of the island, where many highly specialized subterranean taxa are localized: *T. elegans* (Dodero, 1916), *T. onnisi* Casale & Magrini, 2004, and *T. ilianae* sp. n. described above (Figure 9).



Figures 8–9. 8 Geographical distribution of *Typhloreicheia* species known so far in Sardinia. Numbers in the map indicate the locality of each species, in chronological order of description. A and B, and related lines, indicate the range of the only two species with wider distribution in the island. **A** – *Typhloreicheia denticulata* (Holdhaus, 1924) sensu lato **B** – *Typhloreicheia jucunda* (Holdhaus, 1924) sensu lato; 1 – *T. raymondi* (Putzeys, 1869); 2 – *T. sardoa* (Baudi, 1891); 3 – *T. kraussei* (Reitter, 1914); 4 – *T. elegans* (Dodero, 1916); 5 – *T. parallela* (Holdhaus, 1924); 6 – *T. manto* (Holdhaus, 1924); 7 – *T. pandora* (Holdhaus, 1924); 8 – *T. doderoi* (Holdhaus, 1924); 9 – *T. monticola* (Holdhaus, 1924); 10 – *T. occulta* (Holdhaus, 1924); 11 – *T. minima* (Binaghi, 1936); 12 – *T. henroti* Jeannel, 1957; 13 – *T. fausti* Fancello, 1988; 14 – *T. valeriae* Fancello, 1988; 15 – *T. fancelloi* Magrini, 2000; 16 – *T. melonii* Magrini, 2001; 17 – *T. arganoi* Vigna Taglianti, 2001; 18 – *T. viti* Magrini & Bulirsch, 2002; 19 – *T. vignai* Magrini, 2003; 20 – *T. consortii* Magrini, 2003; 21 – *T. degiovannii* Magrini, 2003; 22 – *T. nadiae* Magrini, 2003; 23 – *T. cirocchii* Magrini, 2003; 24 – *T. angelae* Magrini, 2003; 25 – *T. leoi leoi* Magrini, 2003; 26 – *T. onnisi* Casale & Magrini, 2004; 27 – *T. laurentii* Magrini, 2004; 28 – *T. medusa* Magrini & Fancello, 2005; 29 – *T. tegulae* Leo, Magrini & Fancello, 2005; 30 – *T. exilis* Leo, Magrini & Fancello, 2005; 31 – *T. supramontis* Leo, Magrini & Fancello, 2005; 32 – *T. jana* Leo, Magrini & Fancello, 2005; 33 – *T. eleonorae* Leo, Magrini & Fancello, 2005; 34 – *T. tanit* Leo, Magrini & Fancello, 2005; 35 – *T. regina* Leo, Magrini & Fancello, 2005; 36 – *T. pellita* Leo, Magrini & Fancello, 2005; 37 – *T. rocchii* Magrini & Degiovanni, 2006; 38 – *T. holdhausi* Magrini, Fancello & Casale, 2006; 39 – *T. petriolii* Magrini & Fancello, 2007; 40 – *T. abbazzii* Magrini & Fancello, 2007; 41 – *T. leoi pilosa* Magrini & Fancello, 2007; 42 – *T. sebera* Magrini & Fancello, 2009; 43- *T. monacha* sp. n. Casale & Marcia; 44 – *T. ilianae* sp. n. Casale & Marcia; 45 – *T*. sp. n. Magrini, Marcia & Casale in litteris; 46 – T. sp. n. Magrini, Marcia & Casale in litteris (original by P. Magrini, updated with unpublished data). **9** Detail of the map of geographical distribution of *Typhloreicheia* species in Sardinia, showing the high concentration of sympatric species in the central-eastern part of the island.

Casale (2009) suggested that Reicheiina in Sardinia form a remarkably speciose and diversified group through the process of adaptive radiation. This diversity originated from one or two colonisation events (see above, paragraph 2 of Discussion). Such might be explanation of the high number of *Typhloreicheia* species in Sardinia, and their so far inexplicable relationships of the species in the adjacent territories.

Greve et al. (2010) performed an exhaustive study, based on molecular data, on the land snails of the genus *Theba* (Gastropoda: Helicidae) in the Canary Islands. They demonstrated that the main mode of diversification was intra-archipelago speciation rather than independent colonization of the islands from the mainland. The phylogenetic reconstruction inferred a Canarian origin for *Theba*. The islands, however, must have been colonized once from the mainland (North Africa or Iberian peninsula), but neither fossils nor living descendants of a continental ancestor of *Theba* have been found so far. Divergence time estimates suggested an evolution of *Theba* in the Canarian archipelago and an initial radiation during the Late Oligocene/Early Miocene. Species from Morocco are nested among species from the Canary Islands, suggesting re-colonization of the continent from the islands. If so, then re-colonization of NW Africa during the Middle Miocene led to a remarkable continental radiation, suggesting a rare example of re-colonization of the mainland from oceanic islands (Bellemain and Ricklefs 2008).

A similar process – e.g. the colonization of Sardinia by a continental *Reicheia*-like ancestor, maybe of Iberian origin through the rotation of the Corsica-Sardinia microplate (Alvarez 1972), an adaptive radiation in the island, the extinction of the colonizer on the continent, and then a re-colonization of the close, circum Mediterranean-areas through land connections during the Messinian Salinity Crisis in the Mediterranen basin (Hsü et al. 1977) cannot be excluded. In fact Reicheiina, for their peculiar distribution in the Euro-Mediterranean area, appear as a remarkably ancient lineage of Paleo-Mediterranean, Tertiary forest dweller scaritid beetles, in which remote cladogenetic events are presently documented by distribution of their relic, sometimes monotypic extant genera.

Conclusions

Available data, and discoveries in progress (including two further species not yet described, but indicated in the map of Figure 8), suggest several reasons to hypothesize that Reicheiina in Sardinia formed a remarkably diversified clade through the process of adaptive radiation.

The speciation events that produced these taxa should have been originated by isolation of small populations in micro-geographic areas, in deep soils and caves, and an exceptional extent of adaptive colonisation and diversification into a variety of soil and underground compartments and ecological niches induced by the Plio-Pleistocene climatic changes, with some cases of subsequent overlap of distributions in wet, forested phases (Casale 2009).

The hypothesis here proposed, that *Typhloreicheia* (in the current sense) radiated in Sardinia, and then re-colonized the close, circum-Mediterranean islands and mainland, remains of course a mere hypothesis, that should be tested. Unfortunately, as recalled in Introduction, the study of this group is difficult owing both to the small sizes of its representatives, and particularly the scarcity of material, some taxa being known from a few or only one specimens, so that molecular data on them – like fossils, or larval stages - are so far fully absent. Therefore, future investigations will need further, strong efforts both in the field and laboratory.

Acknowledgements

We are particularly indebted to our good friend Paolo Magrini (Florence), for providing some of the illustrations to this paper, and for data, discussion, and pleasant days in the field in Sardinia. For the loan of material, the assistance both in the field and in laboratory, and information on which the present contribution is based, we thank all those who helped us in several years of study of the subterranean Sardinian fauna: in particular, concerning the present contribution, Giuseppe Grafitti, Enrico Lana, Roberto Loru, Alessandro Molinu, Carlo Onnis, Laura Sanna and Fabio Stoch. A great acknowledgement is due to Vasily Grebennikov (Ottawa), for suggestions, corrections and improvements to the original manuscript. We thank also Stefano Birindelli for identification of terrestrial snails.

Research was in part supported by grants INTERREG 3 (Sardinia-Corsica-Tuscany), PRIN projects of the Italian Ministry of the University and Scientific Research ("Zoogeography of Mediterranean - Southern African disjoint distributions by a multimethod approach" and "The endemism in Italy"). P. Marcia has received support from Regione Sardegna through a grant co-financed with funding from the PO Sardegna FSE 2007–201 L.R.7/2007 "Promozione della ricerca scientifica e dell'innovazione tecnologica in Sardegna".

References

Alvarez W (1972) Rotation of the Corsica-Sardinia microplate. Nature Physical Science 235: 103- 105.

Balkenohl M (2003) Subfamily Scaritinae Bonelli, 1810, pp. 219–234. In: Löbl L & Smetana A (Eds), Catalogue of Palearctic Coleoptera. Vol. 1. Archostemata – Myxophaga – Adephaga. Apollo Books, Stenstrup.

Balkenohl M (2005) First record of Reicheiina species from the Oriental Region and Japan (Coleoptera, Carabidae, Scarititae, Clivinini). Coleoptera 9: 1–10.

Basilewsky P (1980) Les Reicheiina de l'Afrique du Sud (Coleoptera: Carabidae). Entomologia Generalis 6: 293–302.

Bellemain E, Ricklefs RE (2008) Are islands the end of the colonization road? Trends Ecology Evolution 23: 536–537. doi: 10.1016/j.tree.2008.05.001

Bulirsch P, Janák J, Moravec P (2005) New species and findings of Scaritinae (Coleoptera: Carabidae) from Madagascar. Studies and reports of District Museum Prague-East. Taxonomical Series 1 (1–2): 1–35.

Bulirsch P, Magrini P (2007) Descriptions of four new species and *Kenyoreicheia* gen. n. of the subtribe Reicheiina (Coleoptera: Carabidae: Scaritinae) from East Africa. Studies and reports of District Museum Prague-East. Taxonomical Series 3 (1–2): 17–30.

Casale A (1985) Note su *Typhloreicheia* italiane, con descrizione di nuovi taxa di Sicilia (Col. Carabidae, Scaritinae). Annali del Museo Civico di Storia Naturale "Giacomo Doria", Genova 85: 259–271.

Casale A (2009) Adaptive radiation in Mediterranean islands? The case of Reicheiina in Sardinia (Coleoptera, Carabidae, Scaritinae), pp. 75–88. In: Casellato S, Burighel P & Minelli A (Eds), Life and Time. The Evolution of life and its History, Cleup, Padova.

Casale A, Di Giulio A, Marcia P, Molinu A (2010) The third instar larva of *Speomolops sardous* Patrizi, 1955, a cave-dwelling molopine beetle endemic to Eastern Sardinia, with notes on its habitat (Coleoptera, Carabidae). Italian Journal of Zoology, 77 (2): 159–167. doi: 10.1080/11250000903015182

Casale A, Giachino PM, Jalžić B, Vailati D (1998a) Reicheiina nuovi o poco noti dell'area mediterranea orientale (Coleoptera Carabidae Scaritinae). Annali del Museo civico di Scienze naturali, Brescia 31: 87–104.

Casale A, Grafitti G, Lana E, Marcia P, Molinu A, Mucedda M, Onnis C, Stoch F (2008) La Grotta del Bue Marino: cinquanta anni di ricerche biospeleologiche in Sardegna. Atti XX Congresso Nazionale di Speleologia (Iglesias, 2007), Memorie dell'Istituto italiano di Speleologia, Bologna (S. II) XXI: 197–209.

Casale A, Magrini P (2004) Una nuova specie di *Typhloreicheia* del "gruppo *elegans*" della Sardegna centro-orientale, con note sulla tassonomia, sulla filogenesi e sulla distribuzione del genere in Sardegna (Coleoptera Carabidae Scaritinae). Redia 86 (2003): 47–52.

Casale A, Vigna Taglianti A (1996) Coleotteri Carabidi di Sardegna e delle piccole isole circumsarde, e loro significato biogeografico (Coleoptera, Carabidae). Biogeographia 18 (1995): 391–427.

Casale A, Vigna Taglianti A, Juberthie C (1998b) Coleoptera Carabidae. In*:* Juberthie C, Decu V (Eds) Encyclopaedia Biospeologica*,* II. Société Internationale de Biospéologie, Moulis, France, 1047–1081.

Fancello L (1988) Due nuovi Scaritini endogei della Sardegna meridionale (Coleoptera Carabidae). Bollettino della Società entomologica italiana 120: 4–10.

Gavrilets S, Losos J B (2009) Adaptive radiation: contrasting theory with data. Science 323: 732–737. doi: 10.1126/science.1157966

Giachino PM, Vailati D (2010) The subterranean environment. Hypogean life, concepts and collecting techniques. WBA Handbooks, 3, Verona, 132pp.

Givnish T, Sytsma K (1997). Molecular evolution and adaptive radiation. Cambridge University Press, New York.

Grebennikov V, Bulirsch P, Magrini P (2009) Discovery of *Antireicheia* in Cameroon with description of four new species and discussion on phylogeny and distribution of endogean Reicheiina (Coleoptera: Carabidae: Scaritinae: Clivinini). Zootaxa 2292: 1–14.

Greve C, Hutterer R, Groh K, Haase M, Misof B (2010) Evolutionary diversification of the genus *Theba* (Gastropoda: Helicidae) in space and time: A land snail conquering islands and continents. Molecular Phylogenetics and Evolution 57 (2010): 572–584. doi: 10.1016/j.ympev.2010.08.021

Holdhaus K (1924) Monographie du genre *Reicheia* Saulcy (Coleoptera Carabidae). Abeille 32: 161–220.

Hsü KJ, Montadert L, Bernouilli D, Cita MB., Erickson A, Garrison RE, Kidd RB, Melieres F, Müller C, Wright R (1977) History of the Mediterranean salinity crisis. Nature 267: 399–403. doi: 10.1038/267399a0

Jeannel R (1957) Révision des petits scaritides endogés voisins de *Reicheia* Saulcy. Revue française d'Entomologie 24: 129–212.

Leo P, Magrini P & Fancello L (2005) Materiali per lo studio delle *Typhloreicheia* della Sardegna con descrizione di nove specie nuove (Coleoptera Carabidae). Bollettino della Società entomologica italiana 137 (3): 167–203.

Liebherr JK, Will KW (1998) Inferring phylogenetic relationships within Carabidae (Insecta, Coleoptera) from characters of the female reproductive tract. In: Ball G E, Casale A, Vigna Taglianti A (Eds) Phylogeny and classification of Caraboidea (Coleoptera: Adephaga). Proceedings of a Symposium (28 August, 1996, Florence, Italy), XX International Congress of Entomology. Atti Museo regionale di Scienze naturali, Torino, 107–170.

Lorenz W (2005) Systematic list of extant ground beetles of the world (Insecta Coleoptera "Geadephaga": Trachypachidae and Carabidae. incl. Paussinae, Cicindelinae, Rhysodinae). Tutzing, iv + 530 pp.

Magistretti M (1965) Coleoptera. Cicindelidae, Carabidae. Catalogo topografico. Fauna d'Italia, 8. Calderini, Bologna, 512 pp.

Magrini P, Fancello L (2007) *Typhloreicheia* della Sardegna: descrizione di tre nuovi taxa e dati geonemici inediti (Coleoptera, Carabidae). Fragmenta entomologica 39: 161–178.

Magrini P, Fancello L, Leo P (2003) Un nuovo genere e una nuova specie di Reicheiina della Sardegna (Coleoptera Carabidae Scaritinae). Redia 84 (2001): 141–149.

Schluter D (2000**)** The ecology of adaptive radiation. Oxford University Press, Oxford.

Vigna Taglianti A (2001) I Carabidi delle isole circumsarde (Coleoptera, Carabidae). Annali del Museo civico di Storia naturale "Giacomo Doria", Genova 93 (2000): 305–428.

Vigna Taglianti A (2005) Checklist e corotipi delle specie di Carabidae della fauna italiana. Appendice B. In: Brandmayr P, Zetto T, Pizzolotto R (Eds) I Coleotteri Carabidi per la valutazione ambientale e la conservazione della biodiversità. Manuali e linee guida 34, APAT, Roma, 186–225.

Wirta H, Viljanen H, Orsini L, Montreuil O, Hanski I (2010) Three parallel radiations of Canthonini dung beetles in Madagascar. Molecular Phylogenetics and Evolution 57 (2010): 710–727. doi: 10.1016/j.ympev.2010.08.013

Zapparoli M (2009) An annotated catalogue of the epigeic and cave centipedes (Chilopoda) of Sardinia, pp. 56–168. In: Cerreti F, Mason F, Minelli S, Nardi G, Whitmore D (Eds). Research on the Terrestrial Arthropods of Sardinia (Italy). Zootaxa, 2318, 1–602.

ZooKeys 134: 33–63 (2011)
doi: 10.3897/zookeys.134.1715
www.zookeys.org

RESEARCH ARTICLE

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

A review of the genus *Serangium* Blackburn (Coleoptera, Coccinellidae) from China

Xing-Min Wang[1,2,†], Shun-Xiang Ren[1,‡], Xiao-Sheng Chen[2,§]

1 *Engineering Research Center of Biological Control, Ministry of Education, South China Agricultural University, Guangzhou, 510642, China* **2** *Institute of Zoology, Chinese Academy of Sciences, Beijing, 100101, China*

† *urn:lsid:zoobank.org:author:9A316497-BA7A-4FEC-B9F7-8E806E495D1E*
‡ *urn:lsid:zoobank.org:author:3D26C274-7182-413F-8352-453BFB99437B*
§ *urn:lsid:zoobank.org:author:BC0ABF82-220E-49B8-B849-E8CDED5C56D1*

Corresponding author: *Shunxiang* (rensxcn@yahoo.com.cn)

Academic editor: *Adam Slipinski* | Received 15 June 2011 | Accepted 12 September 2011 | Published 6 October 2011

urn:lsid:zoobank.org:pub:779DAF48-628D-46F1-9E99-4160BF53D49E

Citation: Wang X-M, Ren S-X, Chen X-S (2011) A review of the genus *Serangium* Blackburn (Coleoptera, Coccinellidae) from China. ZooKeys 134: 33–63. doi: 10.3897/zookeys.134.1715

Abstract

The genus *Serangium* Blackburn from China is reviewed. The genus *Catanella* Miyatake is removed from synonymy with *Serangium*. *S. baculum* Xiao is transferred to *Catanella*, as *C. baculum* (Xiao), **comb. n.** Twelve species of *Serangium* are described, keyed and illustrated, including eight new species, *S. magnipunctatum* Wang & Ren, **sp. n.**, *S. trimaculatum* Wang & Ren, **sp. n.**, *S. centrale* Wang & Ren, **sp. n.**, *S. leigongicus* Wang & Ren, **sp. n.**, *S. latilobum* Wang & Ren, **sp. n.**, *S. digitiforme* Wang & Ren, **sp. n.**, *S. dulongjiang* Wang, Ren & Chen, **sp. n.**, and *S. contortum* Wang & Ren, **sp. n.** *S. punctum* Miyatake is newly recorded from China.

Keywords

Coleoptera, Coccinellidae, *Serangium*, new species, China

Introduction

The genus *Serangium* was erected by Blackburn (1889) with *S. mysticum* Blackburn, 1889, from Australia as the type species. Chapin (1940) pointed out that *Serangium* and its allied genera form a coherent group, but he did not proposed a tribal name for this group. The name Serangiini was introduced by Blackwelder (1945) in his checklist and was validated by Pope (1962). The tribe Serangiini is now classified in the subfamily Microweiseinae (Ślipiński, 2007).

Serangium is the largest genus of Serangiini with 45 described species, mostly occurring in the Oriental Region (Miyatake 1994; Ślipiński and Burckhardt 2006), with 4 species known from China (Sasaji 1967; Pang and Mao 1979; Xiao and Li 1992; Pang et al. 2004; Ren et al. 2009). Recent collecting in the southern half of China has revealed several more species, which are described here. 12 species of *Serangium* from China are reviewed, described and illustrated, of which eight are new.

Materials and methods

The specimens examined were collected from China. All collected species were preserved in 85% ethanol. External morphology was observed with a dissecting stereoscope (SteREO Discovery V20, Zeiss). The following measurements were made with an ocular micrometer: total length, length from apical margin of clypeus to apex of elytra (TL); Total width, width across both elytra at widest part (TW=EW); height, take from the highest part of the beetle (TH); head width (HW); pronotal length, from the middle of anterior margin to the base of pronotum (PL); pronotal width at widest part (PW); elytral length, along the suture, from the apex to the base including the scutellum (EL). Male and female genitalia were dissected, cleared in 10% solution of NaOH by boiling for several minutes, and examined with an Olympus BX51 compound microscope.

Images were photographed with digital cameras (AxioCam HRc and Coolsnap–Pro*cf* & CRI Micro*Color), connected to the dissecting microscope. The software AxioVision Rel. 4.8 and Image–Pro Plus 5.1 were used to capture images from both cameras, and photos were cleaned up and laid out in plates with Adobe Photoshop CS 8.0.

Terminology follows Ślipiński (2007). Type specimens depositions are indicated by SCAU for South China Agriculture University, Guangzhou; and IOZ for the Institute of Zoology, Institute of Zoology, Chinese Academy of Sciences, Beijing. Other examined type specimens are from Kunming Institute of Zoology, Chinese Academy of Sciences (KIZ).

Taxonomy

Genus *Serangium* Blackburn, 1889
http://species-id.net/wiki/Serangium

Serangium Blackburn, 1889: 187, 209. Type species, monotypy: *Serangium mysticum* Blackburn, 1889.

Serangium: Sicard, 1909: 150, 151; Chapin, 1940: 268; Miyatake, 1961b: 50; Sasaji, 1971: 52; Pang & Mao, 1979: 27; Miyatake, 1994: 238; Ślipiński & Burckhardt, 2006: 39; Ślipiński, 2007: 53.

Semichnoodes Weise, 1892: 15. Type species, monotypy: *Semichnoodes kunowi* Weise, 1892. Synonymized by Weise, 1908: 13.

Catana Chapin, 1940: 266. Type species, original designation, *Catana clauseni* Chapin, 1940. Synonymized by Ślipiński & Burckhardt, 2006: 39.

Diagnostic description. Body minute, hemispherical with head in repose drawn into prothorax and closely fitting ventrally against prominent prosternal lobe (Fig. 1); dorsum glabrous, except pronotum with sparse setae, and sometimes elytral margins (Fig. 13). Head transverse, ventrally flattened with clypeal region prominent anteriorly (Fig. 2); frontoclypeus deeply emarginated around exposed antennal insertions. Mandible normal, with single apical tooth (Fig. 4); terminal maxillary palpomere always longer than wide, barrel shaped, truncate at apex (Figs 7–8). Antenna 9-segmented, antennomere 3 moderately to strongly elongate, terminal segment forming a large club which is always spatulately elongate or elongate oval and flat, apex angular (Figs 5–6).

Pronotum short, strongly transverse. Scutellum relatively large, triangular. Elytra strongly convex, usually smooth without visible punctures. Winged; wings with greatly reduced venation. Prosternum strongly prominent medially forming a broad lobe concealing mouthparts from below; prosternal process subtruncate apically, broad (Fig. 3). Epipleuron moderately narrow, incomplete, reaching 2/3 of elytra length, with clearly delimited cavities to accommodate apices of mid and hind femora. Abdomen with 5 ventrites (Fig. 10). Postcoxal line at abdominal ventrite 1 incomplete, reaching lateral margin of the ventrite, without associated pits or pores. Femora, especially profemur, broad, flat closely fitting into depressions on ventral surface protecting tibiae and tarsi from below; tarsus 4-segmented (Figs 11–12).

Male genitalia: tegmen strongly asymmetrical, parameres short or distinctly reduced with sparse setae apically (Figs 27–28). Female genitalia: ovipositor triangularly elongate, weakly sclerotised usually bearing short styli; infundibulum absent, spermatheca small and well sclerotised (Fig. 29).

Remark: *Catana* Chapin, 1940 and *Catanella* Miyatake, 1961a were synonymised with *Serangium* by Ślipiński and Burckhardt (2006) in review of the Australian Serangiini. While working on the Chinese species of Serangiini, we have examined specimens of *Catana clauseni* Chapin in China, and agreed with Ślipiński & Burckhardt's opinion that *Catana* is synonymous with *Serangium.* We have also examined many specimens of *Catanella formosana* Miyatake, 1961a and found that *Catanella*'s 8-segmented antenna and 3-segmented tarsus are constant, while male and female genitalia are also different from *Serangium*. Thus, *Catanella* should be a valid genus.

Pang et al. (2004) recorded *S. lygacum* Iablokoff-Khnzorian, 1972 from China. After our re-examination of this specimen, we conclude that it was an incorrect identification of *S. drepnicum* Xiao, 1992.

In addition, Xiao and Li (1992) described a new species *S. baculum* with 9-segmented antenna and 4-segmented tarsus. We have examined type materials of *S. baculum* and found that its antenna has 8-segments and tarsus is 3-segmented which is similar to the characters of the genus *Catanella*. Therefore we consider that *S. baculum* is wrongly placed in *Serangium* and should be moved to *Catanella* (*C. baculum* (Xiao) comb. n.)

Key to species of *Serangium* from the China

1 Terminal antennal segment spatulately elongate..**1**
– Terminal antennal segment elongate oval and flat, apex angular..................**4**
2 Dorsum uniformly dark, without spots (Fig. 13). TL: 1.60–2.08mm, TW: 1.40–1.98mm.. ***S. japonicum* Chapin**
– Dorsum dark brown to black, with spots, or dorsum red without spots **3**
3 Elytra reddish to dark brown, with a large scarlet reniform spot on each elytron (Fig. 14). Paramere 2/3 of penis guide length (Fig. 32). TL: 1.95–2.24mm, TW: 1.66–1.98mm ....***S. clauseni* (Chapin)**
– Elytra red, or red with wide black margin (Fig. 15). Paramere 2/3 of penis guide length (Fig. 38). TL: 2.09–2.18mm, TW: 1.75–1.85mm.................... ....***S. magnipunctatum* sp. n.**
4 Dorsum orange to burgundy, with at least one dark spot on suture............**5**
– Dorsum uniform dark, without spots...**7**
5 Dorsum reddish brown to burgundy, without black spots on elytral disc **6**
– Dorsum orange with black spots on each elytron (Fig. 16). TL: 2.09–2.21mm, TW: 1.75–1.88mm .... ***S. trimaculatum* sp. n.**
6 Pronotum and elytra reddish brown, with a dark spot in the middle of elytral suture (Fig. 17). TL: 2.08–2.27mm, TW: 1.88–1.98mm... ***S. centrale* sp. n.**
– Pronotum distinctly darker than elytra, elytra burgundy without spot (Fig. 18). TL: 1.58mm, TW: 1.35mm ....***S. leigongicus* sp. n.**
7 Metaventrite basal half with distinct median discrimen..............................**8**
– Metaventrite basal half without median discrimen...................................**10**
8 Punctures around median discrimen of metaventrite very large and dense, with short thick setae...**9**
– Punctures around median discrimen of metaventrite fine and sparse, with short sparse setae. Penis guide flat and elongated tongue-shaped (Fig. 71). TL: 1.98–2.11mm, TW: 1.68–1.81mm ....***S. drepnicum* Xiao**

9 Penis has a small pominence at 1/5 length (Fig. 57). Penis guide wide at basal half, sharply narrowed in middle, with a finger-shape apex (Fig. 59). TL: 2.14–2.18mm, TW: 1.91–1.96mm .... ***S. latilobum* sp. n.**

– Penis distinctly broadening at apical 1/5–2/5 length (Fig. 63). penis guide widest at base, gradually narrowing to middle, with a finger-shape apex (Fig. 65). TL: 2.14–2.21mm, TW: 1.80–1.85mm .... ***S. digitiforme* sp. n.**

10 Apex of penis rounded. Tegmen asymmetrical but simple **11**

– Apex of penis sharply pointed (Fig. 75). Tegmen asymmetrical and very complex (Fig. 77). Punctures on frons very large and dense. TL: 2.08mm, TW: 1.85mm.. ***S. punctum* Miyatake**

11 Penis is long and slender (Fig. 81). Penis guide is elongated tongue-shaped (Fig. 83). The first part of spermatheca has a strong constriction in middle (Fig. 84). TL: 2.01–2.14mm, TW: 1.68–1.81mm ....***S. dulongjiang* sp. n.**

– Penis is moderately long and stout (Fig. 87). Penis guide is contorted (Fig. 89). The first part of spermatheca has a feebly constriction in middle (Fig. 90). TL: 1.62–1.78mm, TW: 1.42–1.58mm .... ***S. contortum* sp. n.**

***Serangium japonicum* Chapin, 1940**

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

Figs 1–5, 7, 9–13, 25–29, 92

Serangium japonicum Chapin, 1940: 269; Miyatake, 1961b: 140–142; Sasaji, 1971: 55; Pang & Mao, 1979: 28; Cao, 1992: 106; Ślipiński & Burckhardt, 2006: 50; Ren et al., 2009: 40.

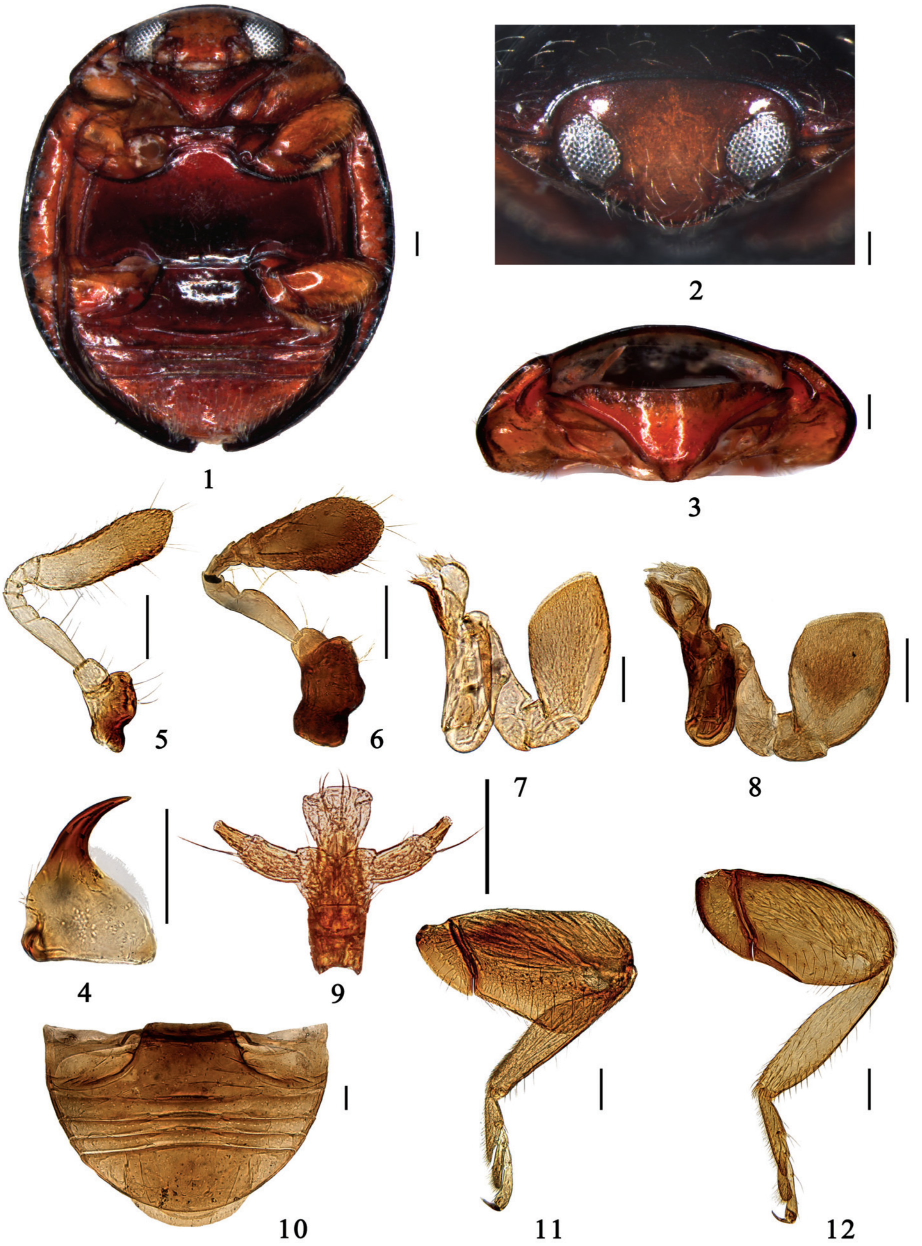
Diagnosis. This species can be identified by its completely black body with yellowish brown anterior angles of pronotum, and spatulately elongate terminal antenna segment, flattened and elongate tongue-shape penis guide in ventral view. (Fig. 28).

Description. TL: 1.60–2.08mm, TW: 1.40–1.98mm, TH: 0.82–1.02mm, TL/TW: 1.14–1.15; PL/PW: 0.52–0.53; EL/EW: 0.94–0.98.

Body minute, hemispherical, dorsum strongly convex, shiny and glabrous (Fig. 13). Dorsum uniformly black, except anterior angles of pronotum yellowish brown. Head yellowish brown. Underside reddish brown, except metaventrite dark brown. Legs yellowish brown (Fig. 1).

Head transverse and ventrally flattened, 0.40× elytral width (HW/EW=1: 2.50); punctures on frons fine and sparse, separated by 1.5–6.0 times their diameter, with short sparse setae (Fig. 2); eyes moderately large and coarsely faceted, widest interocular distance 0.45× width of head (Fig. 2). Antenna 9-segmented, terminal segment large, spatulately elongate (Fig. 5).

Pronotum short and strongly transverse, 0.58× elytral width (PW/EW=1: 1.72), densely covered in fine punctures associated with long sparse setae, punctures slightly larger than those on head, separated by 1.0–3.0 times their diameter. Punctures on



Figures 1–12. 1–5, 7, 9–12. *S. japonicum* Chapin. **1** ventral view **2** frontal view **3** prothorax **4** mandible **5** antenna **7** maxilla **9** labium **10** abdomen **11** front leg **12** hind leg; **6, 8** *S. centrale* Wang & Ren, sp. n. **6** antenna **8** maxilla. Scale bars: 0.1mm.

elytra fine and sparse, similar to those on pronotum, with a few long setae at humeral angles and a row of evenly spaced setae along margin. Prosternum shiny, glabrous and impunctate with sparse setae. Mesoventrite small, transverse, surface mat weakly furrowed, sparsely setae. Metaventrite shiny, basal half with distinctly median discrimen; punctures around median discrimen very large and dense, with short thick setae, and on other parts fine and sparse, separated by 2.0–6.0 times their diameter, with short sparse setae.

Male genitalia. Penis strongly curved in whole length, apex shortly narrowing and rounded, penis capsule indistinct (Fig. 26). Tegmen rather slender and strongly asymmetrical (Figs 27–28). Penis guide in ventral view flattened and elongate tongue-shape. Left paramere in ventral view flat and short bearing a few long setae, and right piece short but distinctly projecting, bearing a few long setae (Fig. 28). Penis guide in lateral view long and thin, almost straight, apex pointed. Right paramere in lateral view about 1/2 of penis guide (Fig. 27).

Female genitalia. Genital plate elongate triangular with a rounded apex, sparsely hairy on the apical portion, stylus rather long, bearing few setae (Fig. 29). Spermatheca divided into two parts, one of which is somewhat globular with a feeble constriction and two small pinch-like projections, the other is tubular, becoming slightly more slender distally (Fig. 29).

Specimens examined. China, Anhui: 4♂♂1♀, Guniujiang National Natural Reserve, Shitai, 29°58.97'N, 117°39.51'E, ca 490m, 24.ix.2010, Wang XM et al. leg.; **Fujian:** 6♂♂6♀♀, Fuzhou, 26°4.66'N, 119°22.05'E, ca 30m, 15.vi.1983, Tang YQ leg.; 1♂3♀♀, Shaowu, 27°20.56'N, 117°28.75'E, ca 220m, 24.viii.1984, Pang XF leg.; **Guangdong:** 4♂♂4♀♀, Gaoyao, 23°01.97'N, 112°26.41'E, ca 40m, 4.xii. 1985, Jiang N. leg.; 1♂, Shipai Country, Guangzhou, 23°7.85'N, 113°20.49'E, ca 5m, 29.vii.29, Ren SX leg.; 2♂♂2♀♀, Chenjia, Yangshan, 24°45.51'N, 112°51.68'E, ca 310m, 9.vii. 1996, Tian MY leg.; 4♂♂5♀♀, Shimentai Mountain, Yingde, 24°23.83'N, 113°17.24'E, ca 550m, 3.xi.2004, Wang XM et al. leg.; 2♂♂, campus of SCAU, 23°9.49'N, 113°21.07'E, ca 30m, viii.2008, Wang XM leg.; 1♂, Qinshuigu, Nanling Mountain, Shaoguan, 24°54.95'N, 113°6.46'E, ca 560m, 29. ix.2004, Wang XM leg.; **Guangxi:** 9♂♂10♀♀, Guilin, 25°13.93'N, 110°15.20'E, ca 300m, 23.ix.1987, Pang XF leg.; 1♀, Hongqilinchang, Shiwandashan Mountian, Shangsi, 21°54.45'N, 107°54.57'E, ca 350m, 10. xi. 2004, Lv XB leg.; 1♂, Maoershan Mountain, Guilin, 25°49.51'N, 111°01.07'E, ca 440m, 16.x. 2004, Wang XM leg.; **Guizhou:** 1♀, Huaxi, Guiyang, 26°24.60'N, 106°40.07'E, ca 1120m, 11.viii.1987, Peng XF leg.; 12♂♂17♀♀, Suoluo National Natural Preserve, Chishui, 28°26.42'N, 105°59.80'E, ca 430m, 9.viii. 1994, Tian MY leg.; 1♂1♀, Xifeng, 27°5.35'N, 106°44.59'E, ca 1100m, 9.viii.1997. Peng ZQ leg.; 2♂♂3♀♀, Dongtang, Libo, 25°17.28'N, 108°0.94'E, ca 730m, 15.x.2008, Liang JB leg.; 2♂♂, Leigongshan Moutain, Leishan, 26°22.71'N, 108°11.03'E, ca 1500m, 30.vii.1997, Peng ZQ leg.; 1♂3♀♀, Sanchahe, Libo, 25°24.53'N, 108°5.22'E, ca 730m, 19.x.2008, Liang JB leg.; **Hainan:** 2♂♂1♀, Jianfengling, 18°44.49'N, 108°51.85'E, ca 840m, 3.xi.1989, Ren SX leg.; 2♂♂, Jianfengling, 18°44.49'N, 108°51.85'E, ca 840m, ix.1995, Peng ZQ leg.; **Hubei:** 1♂1♀, Wudangshan Mountain, Shiyan, 32°24.50'N, 111°1.31'E, ca 1090m, 17.vii.1997, Peng ZQ leg.; **Hunan:** 1♂, Zhubotang, Yiyang, 28°29.07'N, 112°26.70'E, ca 50m, 18.viii.2001, Peng ZQ leg.; **Sichuan:** 2♂♂3♀♀, Zhongxian, 30°18.78'N, 107°59.80'E, ca 360m, 24.viii.1989, Ren SX leg.; 1♂1♀, Kaixian, 31°9.55'N, 108°24.26'E, ca 330m, 25.vi.1989, Ren SX leg.; 3♂♂4♀♀, Jiulidi, 30°42.80'N, 104°3.16'E, ca 500m, 27.vi.1983, Pang XF leg.; 4♂♂4♀♀, Puge, 27°35.32'N, 102°25.98'E, ca 2000m, 15.ix.2007, Wang XM leg.; 10♂♂16♀♀, Pangzhihua, 26°36.69'N, 101°35.35'E, ca 1200m, 1400m, 16.ix.2007, Wang XM leg.; 1♂1♀, Miyi, 26°50.01'N, 102°3.86'E, ca 1150m, 30.ix.2000, Peng ZQ leg.; **Zhejiang:** 4♂♂6♀♀, Cixi, 30°8.72'N, 121°18.91'E, ca 70m, 18.x.1988, Yu GY leg.; **Yunnan:** 2♂♂2♀♀, Ailaoshan, Mountain, Jingdong, 24°25.41'N, 101°3.80'E, ca 2000m, 1.x.2006, Wang XM et al. leg.; 1♂, Yingjiang, 24°36.53'N, 97°43.95'E, ca 1500m, 20.ix.2006, Wang XM leg.

Distribution. China (Anhui, Chongqing, Fujian, Guangdong, Guangxi, Guizhou, Hainan, Hubei, Hunan, Shanghai, Shaanxi, Sichuan, Taiwan, Zhejiang, Yunnan); Japan.

Serangium clauseni (Chapin, 1940)

http://species-id.net/wiki/Serangium_clauseni
Figs 14, 30–35, 92

Catana clauseni Chapin, 1940: 267; Miyatake, 1961b: 139; Ren *et al.*, 2009: 36.
Serangium clauseni: Ślipiński & Burckhardt, 2006: 50.

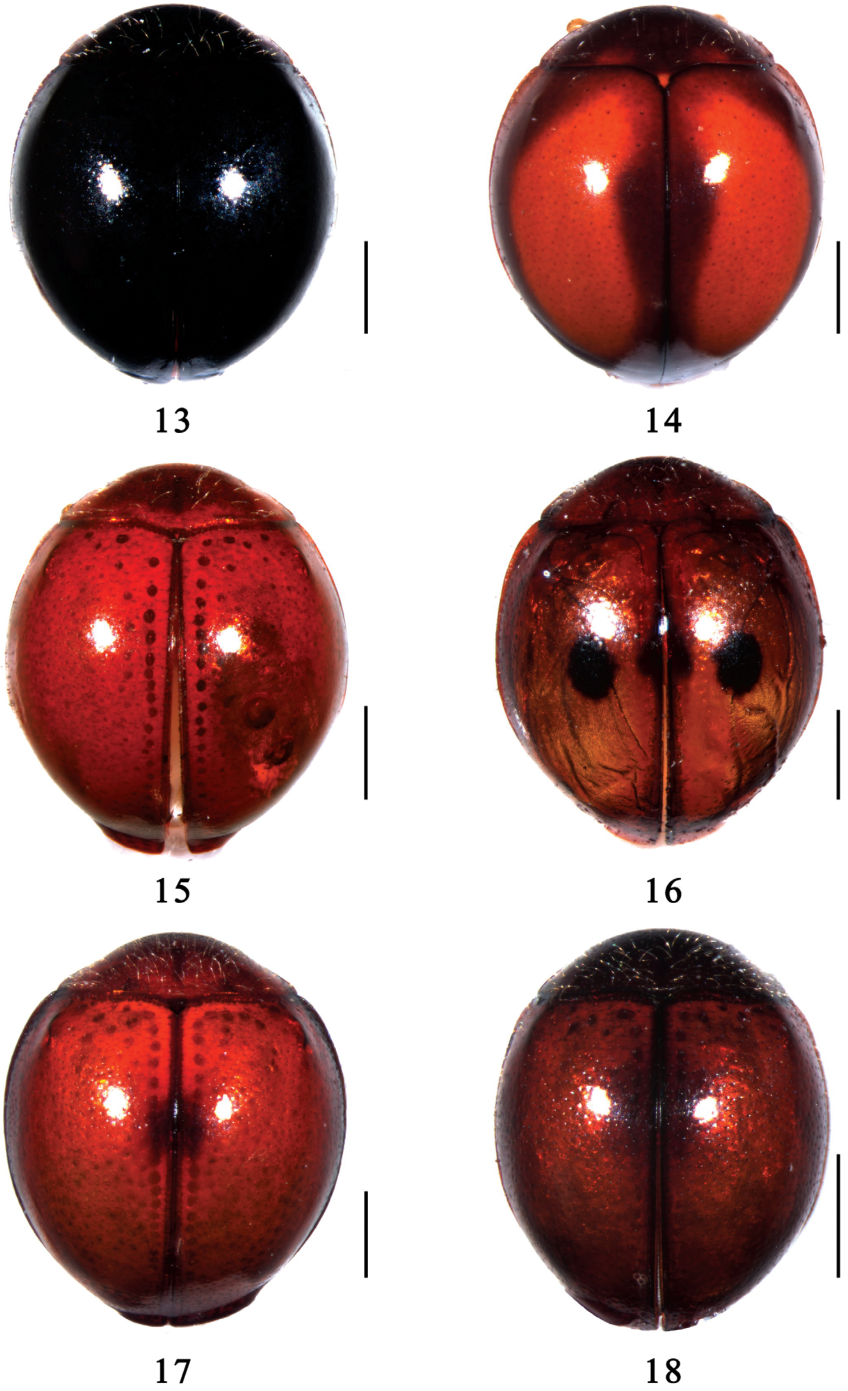
Diagnosis. This species can be identified by the unique dorsal color pattern and spatulately elongate terminal antenna segment (Fig. 14). The male genitalia are similar to *S. japonicum*, but it can be distinguished from latter as follow: penis is stout (Fig. 31), penid guide in ventral view wider than latter (Fig. 33) and right paramere in lateral view is stout and 2/3 of penid guide (Fig. 32).

Description. TL: 1.95–2.24mm, TW: 1.66–1.98mm, TH: 0.89–1.15mm, TL/TW: 1.13–1.17; PL/PW: 0.44–0.47; EL/EW: 0.93–0.95.

Body minute, hemispherical, dorsum strongly convex, shiny and glabrous (Fig. 14). Head orange to brown, pronotum reddish to dark brown, except light-colored anterior angles. Scutellum reddish to dark brown and ground color of elytra reddish to dark brown, with a large reniform spot on each elytron bright castaneous. Underside yellowish to reddish brown, except prosternum dark brown. Legs yellowish brown.

Head transverse and ventrally flattened, 0.41× elytral width (HW/EW=1: 2.45); punctures on frons moderated large, separated by 1.5–4.0 times their diameter, with short sparse setae; eyes moderately large and coarsely faceted, widest interocular distance 0.37× head width. Antenna 9-segmented, terminal segment large, spatulately elongate.

Pronotum short and strongly transverse, 0.68× elytral width (PW/EW=1: 1.46), sparsely covered in moderated large punctures associated with long sparse setae, punctures similar to those on head, separated by 2.0–6.0 times their diameter. Punctures on elytra very fine and sparse, smaller than those on pronotum, separated by 3.0–8.0



Figures 13–18. Dorsal view. **13** *S. japonicum* Chapin **14** *S. clauseni* (Chapin) **15** *S. magnipunctatum* Wang & Ren, sp. n. **16** *S. trimaculatum* Wang & Ren, sp. n. **17** *S. centrale* Wang & Ren, sp. n. **18** *S. leigongicus* Wang & Ren, sp. n. Scale bars: 0.5mm.

times their diameter, with a row of evenly spaced setae along margin. Prosternum shiny and glabrous, with sparse punctures and setae. Mesoventrite small, transverse, surface mat, weakly furrowed. Metaventrite shiny, basal half with distinctly median discrimen; punctures around median discrimen very large and dense, with short thick setae, and on other parts moderated large, sparse, separated by 2.0–5.0 times their diameter, with short sparse setae.

Male genitalia. Penis stout, strongly curved in whole length, apex narrowing and rounded, penis capsule indistinctly (Fig. 31). Tegmen slender and strongly asymmetrical (Figs 32–33). Penis guide in ventral view flattened and tongue-shape, slightly wider and shorter than *S. japonicum* (Fig. 33). Left paramere in ventral view flat and short bearing a few long setae, and right piece short but distinctly projecting, bearing a few long setae. Penis guide in lateral view thin and straight, apex pointed. Right paramere in lateral view stout, about 2/3 of penis guide (Fig. 32).

Female genitalia. Genital plate elongate triangular with a rounded apex, sparsely hairy on the apical portion, stylus rather long, bearing few setae (Fig. 35). Spermatheca divided into two parts, one of which is somewhat globular with a feeble constriction and two small pinch-like projections, the other is tubular, becoming slightly more slender distally (Fig. 34).

Specimens examined. China, Hainan: 9♂♂23♀♀, Wuzhishan, 18°47.07'N, 109°31.97'E, ca 700m, 3.v.1996, Peng ZQ leg.; 4♂♂3♀♀, Wushi, 19°8.99'N, 109°53.84'E, ca 320m, 14.vii.1999, Peng ZQ leg.

Distribution. China (Hainan).

Serangium magnipunctatum **Wang & Ren, sp. n.**

urn:lsid:zoobank.org:act:7F91655E-BBB2-4219-BAAD-7680A9E0BDE6
http://species-id.net/wiki/Serangium_magnipunctatum
Figs 15, 36–41, 92

Diagnosis. This species is similar to *S. clauseni* in general appearance and male genitalia, from which it differs in its dorsal color pattern, elytra with a few large inner punctures at basal margins and along elytral suture (Fig. 15). The male genitalia are also diagnostic: penis is slightly thinner than *S. clauseni* (Figs 31, 37), paramere about 1/3 of penis guide which is 2/3 in *S. clauseni* (Figs 32, 39).

Description. TL: 2.09–2.18mm, TW: 1.75–1.85mm, TH: 1.02–1.05mm, TL/TW: 1.18–1.20; PL/PW: 0.47–0.49; EL/EW: 0.96.

Body minute, hemispherical, dorsum strongly convex, glabrous (Fig. 15). Head yellow, pronotum reddish brown to black, except light-colored anterior angles and basal margin. Scutellum reddish brown to black. Elytra red to black, sometimes elytra black with median part red. Underside reddish brown and legs yellow.

Head transverse and ventrally flattened, 0.42× elytral width (HW/EW=1: 2.41); punctures on frons fine and conspicuous, separated by 1.5–5.0 times their diameter, with short sparse setae; eyes moderately large and coarsely faceted, widest interocular distance 0.45× head width. Antenna 9-segmented, terminal segment large, spatulately elongate.

Pronotum short and strongly transverse, 0.72× elytral width (PW/EW=1: 1.39), sparsely covered in fine punctures associated with long sparse setae, punctures smaller than those on head, separated by 2.0–4.0 times their diameter. Elytra with a few large inner punctures at basal margins and two rows of large punctures along elytral suture. Pro- and mesoventrites mat and weakly furrowed, with short sparse setae. Metaventrite shiny and glabrous, basal half with distinctly median discrimen; punctures around median discrimen large and dense, with short thick setae.

Male genitalia. Penis strongly curved in whole length, apex shortly narrowing and rounded, penis capsule indistinctly (Fig. 37). Tegmen rather slender and strongly asymmetrical (Figs 38–39). Penis guide in ventral view flattened and tongue-shape (Fig. 39). Left paramere in ventral view very short bearing a few long setae, and right piece short and stout, distinctly projecting, bearing a few long setae (Fig. 39). Penis guide in lateral view thin and straight, apex pointed. Right paramere in lateral view short, about 1/3 of penis guide (Fig. 38).

Female genitalia. Genital plate elongate triangular with a rounded apex, sparsely hairy on the apical portion, stylus long, bearing few setae (Fig. 41). Spermatheca divided into two parts, one of which is somewhat globular with a feeble constriction and two small pinch-like projections, the other is tubular, becoming slightly more slender distally (Fig. 40).

Type materials. Holotype: 1♂, **China, Yunnan:** Jiluoshan, Xishuangbanna, 21°58.78'N, 101°7.79'E, ca 1020m, 28.iv.2008, Wang XM leg. (SCAU). **Paratypes** (19): Guangxi: 1♂, Guilongshan, Napo, 23°21.63'N, 105°41.74'E, ca 880m, 4.viii.2005, Wang XM leg. (SCAU); **Yunnan:** 2♀♀, Mengxing, Mengla, 21°52.63'N, 101°27.07'E, ca 690m, 1000m, 13.v.2008, Wang XM leg. (SCAU); 4♂♂12♀♀, Lincang, 23°52.56'N, 100°5.88'E, ca 1460m, 27.viii.2005, Wang XM et al. leg. (2♂♂6♀♀ SCAU, 2♂♂6♀♀ IOZ).

Distribution. China (Guangxi, Yunnan).

Etymology. The specific epithet is formed from the Latin adjective *magnus* and *punctatus*, referring to elytra with large inside punctures.

Serangium trimaculatum Wang & Ren, sp. n.

urn:lsid:zoobank.org:act:4E8202EC-9D22-4B90-B72C-7D66DC77897A
http://species-id.net/wiki/Serangium_trimaculatum
Figs 16, 42–45, 93

Diagnosis. This is a very distinctive species having three black spots on the elytra (Fig. 16). The male genitalia are similar to *S. punctum*, but can be distinguished from latter by long left paramere and apex of penis guide (Figs 44–45).

Description. TL: 2.09–2.21mm, TW: 1.75–1.88mm, TH: 0.79–0.89mm, TL/TW: 1.18–1.20; PL/PW: 0.43–0.47; EL/EW: 0.89–0.93.

Body minute, hemispherical, dorsum strongly convex, shiny and glabrous (Fig. 16). Head orange, pronotum and scutellum orange. Elytra orange, with three black spots: two on the center of elytra and one on the middle of suture. Underside yellowish brown, except pro-, meso- and metaventrites black. Legs yellowish brown.

Head transverse and ventrally flattened, 0.38× elytral width (HW/EW=1: 2.65); punctures on frons moderated large, separated by 0.5–1.5 times their diameter, with long sparse setae; eyes moderately large and coarsely faceted, widest interocular distance 0.58× head width. Antenna 9-segmented, terminal segment large, elongate oval and flat, apex angular.

Pronotum short and strongly transverse, 0.70× elytral width (PW/EW=1: 1.43), sparsely covered in fine punctures associated with long sparse setae, punctures smaller than those on head, separated by 1.5–4.0 times their diameter. Punctures on elytra very fine and sparse, similar to those on pronotum, with a row of evenly spaced setae along margin. Prosternum glabrous, punctures fine and sparse, separated by 2.0–3.0 times their diameter, with a few short setae. Mesoventrite small, transverse, surface shiny and impunctate. Metaventrite shiny, basal half with distinctly median discrimen; punctures inconspicuous, with short sparse setae.

Male genitalia. Penis long and slender, strongly curved in whole length, apical half of siphon strongly narrowing apical, and apex very thin and sharply pointed, penis capsule broadening basally and with a distinct inner process (Fig. 43). Tegmen strongly asymmetrical and extremely complicate (Figs 44–45). Penis guide moderatedly elongate, with a finger-like apex, a small prominence at right side near the apex, bearing many distinct hairs dorsally (Fig. 45). Right lateral lobe of tegmen short, bearing dense setae. Left lateral lobe of tegmen relatively long, rounded apical without any setae (Fig. 45). Basal piece of tegmen with a long process.

Female genitalia. Unknown.

Type materials. Holotype: 1♂, **China, Sichuan:** Heizhugou Forest Park, Ebian, 29°2.51'N, 103°0.34'E, ca 1900m, 22.ix.2007, Wang XM leg. (SCAU). **Paratypes** (1): Yunnan: 1♂, Heiwadi Town, Gongshan, 27°46.48'N, 98°36.16'E, ca 2020m, 19.vii.2010, Wang XM leg. (SCAU).

Distribution. China (Sichuan, Yunnan).

Etymology. The specific epithet formed from the Latin prefixion *tri-* and noun *macula* referring to elytra with three spots.

Serangium centrale **Wang & Ren, sp. n.**

urn:lsid:zoobank.org:act:A81A7070-E1BB-46EF-AEA0-E729F5C0D775
http://species-id.net/wiki/Serangium_centrale
Figs 6, 8, 17, 46–51, 93

Diagnosis. This species is similar to *S. magnipunctatum* in general appearance, but it is easily distinguished from the latter by sharply pointed penis apex and extremely complex tegmen (Figs 37–39, 47–49). The male genitalia are similar to S. trimaculatum, but can be distinguished from latter by the shorter left paramere and the apex of penis guide (Figs 44–45, 48–49).

Description. TL: 2.08–2.27mm, TW: 1.88–1.98mm, TH: 1.09–1.15mm, TL/TW: 1.11–1.15; PL/PW: 0.51–0.52; EL/EW: 0.82–0.92.

Body minute, hemispherical, dorsum strongly convex, shiny and glabrous (Fig. 17). Head yellowish brown, pronotum reddish brown, scutellum dark brown. Elytra reddish brown, with a castaneous area in the middle of suture. Underside yellowish brown, legs yellowish brown.

Head transverse and ventrally flattened, 0.43× elytral width (HW/EW=1: 2.31); punctures on frons large, separated by 0.2–0.8 times their diameter, with sparse setae; eyes moderately large and coarsely faceted, widest interocular distance 0.54× head width. Antenna 9-segmented, terminal segment large, elongate oval and flat, apex angular (Fig. 6).

Pronotum short and strongly transverse, 0.70× elytral width (PW/EW=1: 1.43), densely covered in moderated large punctures associated with long dense setae, punctures slightly smaller than those on head, separated by 0.5–1.5 times their diameter. Punctures on elytra fine and sparse, smaller than those on pronotum, separated by 2.0–4.0 times their diameter, with a few large inside punctures at basal margins and two row of large inner punctures along elytral suture. Prosternum mat, with long dense setae. Mesoventrite small, transverse, surface mat weakly furrowed and impunctate. Metaventrite shiny and glabrous, basal half with inconspicuous median discrimen; punctures fine and sparse, separated by 2.0–4.0 times their diameter.

Male genitalia. Penis long and slender, strongly curved in whole length, apical half of siphon strongly narrowing apical, and apex very thin and sharply pointed, penis capsule broadening basally and without distinct inner and outer processes (Fig. 47). Tegmen strongly asymmetrical and extremely complicate (Figs 48–49). Penis guide relatively short with a distinctly pointed apex, a small gap at right side and a prominence at left side near the apex, bearing a tuft of setae (Fig. 49). Right lateral lobe of tegmen relatively short and wide, bearing a tuft of setae. Left lateral lobe of tegmen slightly longer and narrower than right, without any hairs (Fig. 49). Basal piece of tegmen with a long process.

Female genitalia. Genital plate elongate triangular, apical part of the plate narrow and parallel-sided with a rouned apex, stylus of the genital plate very elongate with a few long setae at its apex (Fig. 51). Spermatheca divided into two globular parts, each with a small pinch-like projection (Fig. 50).

Type materials. Holotype: 1♂, **China, Yunnan:** Dadugang, Puer, 22°22.35'N, 100°56.68'E, ca 950m, 26.iv.2008, Wang XM leg. (SCAU). **Paratypes** (2): 1♂1♀, same data as holotype (SCAU).

Distribution. China (Yunnan).

Etymology. The specific epithet formed from the Latin adjective *centrale* referring to elytra with a central dark spot.

Serangium leigongicus Wang & Ren, sp. n.

urn:lsid:zoobank.org:act:0706CBF5-A39C-4A1E-8218-117C3D6D9889
http://species-id.net/wiki/Serangium_leigongicus
Figs 18, 52–55, 93

Diagnosis. This species is similar to *S. centrale* in male genitalia, but it is easily distinguished from the latter by minute body size, slender penis, shorter penis capsule, apex of penis guide with a triangular process at left side (Figs 47–49, 53–55).

Description. TL: 1.58mm, TW: 1.35mm, TH: 0.40mm, TL/TW: 1.17; PL/PW: 0.45; EL/EW: 0.93.

Body minute, hemispherical, dorsum strongly convex, shiny and glabrous (Fig. 18). Head brown, except frons yellowish brown. Pronotum and scutellum dark brown. Elytra burgundy, with a dark area in the middle of suture. Underside dark red. Legs yellowish brown.

Head transverse and ventrally flattened, 0.44× elytral width (HW/EW=1: 2.28); punctures on frons moderated large, separated by 0.5–1.5 times their diameter, with sparse setae; eyes moderately large and coarsely faceted, widest interocular distance 0.56× head width. Antenna 9-segmented, terminal segment large, elongate oval and flat, apex angular.

Pronotum short and strongly transverse, 0.76× elytral width (PW/EW=1: 1.32), sparsely covered in fine punctures associated with moderately dense setae, punctures smaller than as those on head, separated by 1.0–3.0 times their diameter. Punctures on elytra fine, similar as those on pronotum, separated by 2.0–4.0 times their diameter, with a row of evenly spaced setae along margin. Prosternum mat, shagreened and impunctate. Mesoventrite glabrous. Metaventrite shiny and glabrous, without median discrimen; punctures fine and sparse, separated by 2.0–5.0 times their diameter, slightly larger and denser in center.

Male genitalia. Penis long and slender, strongly curved in whole length, apical half of siphon strongly narrowing apical, and apex very thin and sharply pointed, penis capsule broadening basally and with distinct inner and outer processes (Fig. 53). Tegmen strongly asymmetrical and extremely complicate (Figs 54–55). Penis guide relatively short with a distinctly pointed apex, a small triangular process at left side and a prominence at left side near the apex, bearing dense setae dorsally and ventrally (Fig. 55). Right lateral lobe of tegmen short, bearing spaesrly setae. Left lateral lobe of tegmen slightly longer than right, without any setae (Fig. 55). Basal piece of tegmen with a long process.

Female genitalia. Unknown.

Type materials. Holotype: 1♂, **China, Guizhou:** Xiaodanjiang, Leigongshan National Natural Reserve, Leishan, 26°26.53'N, 108°15.45'E, ca 1160m, 12.x.2008, Liang JB leg. (SCAU).

Distribution. China (Guizhou).

Etymology. The specific epithet is named after Leigongshan, the type locality of this ladybird.

Serangium latilobum **Wang & Ren, sp. n.**

urn:lsid:zoobank.org:act:0C2D2BE9-06F2-4DFC-AAAB-A29B8156A700
http://species-id.net/wiki/Serangium_latilobum
Figs 19, 56–61, 94

Diagnosis. This species is similar to *S. japonicum* in general appearance, but it can be distinguished from the latter by lager body size, uniform black pronotum without other color and elytra with very conspicuous swelling (Fig. 19). The male genitalia are also diagnostic: penis is moderated stout (Fig. 57), right paramere is indistinct (Fig. 58), penis guide is wide at basal half, sharply narrowed at middle with a finger-shape apex (Fig. 59).

Description. TL: 2.14–2.18mm, TW: 1.91–1.96mm, TH: 0.99–1.15mm, TL/TW: 1.11–1.12; PL/PW: 0.49–0.53; EL/EW: 0.87–0.88.

Body minute, hemispherical, dorsum strongly convex, shiny and glabrous (Fig. 19). Dorsum uniformly black. Head yellow. Underside black, except prosternum orange. Legs yellowish brown.

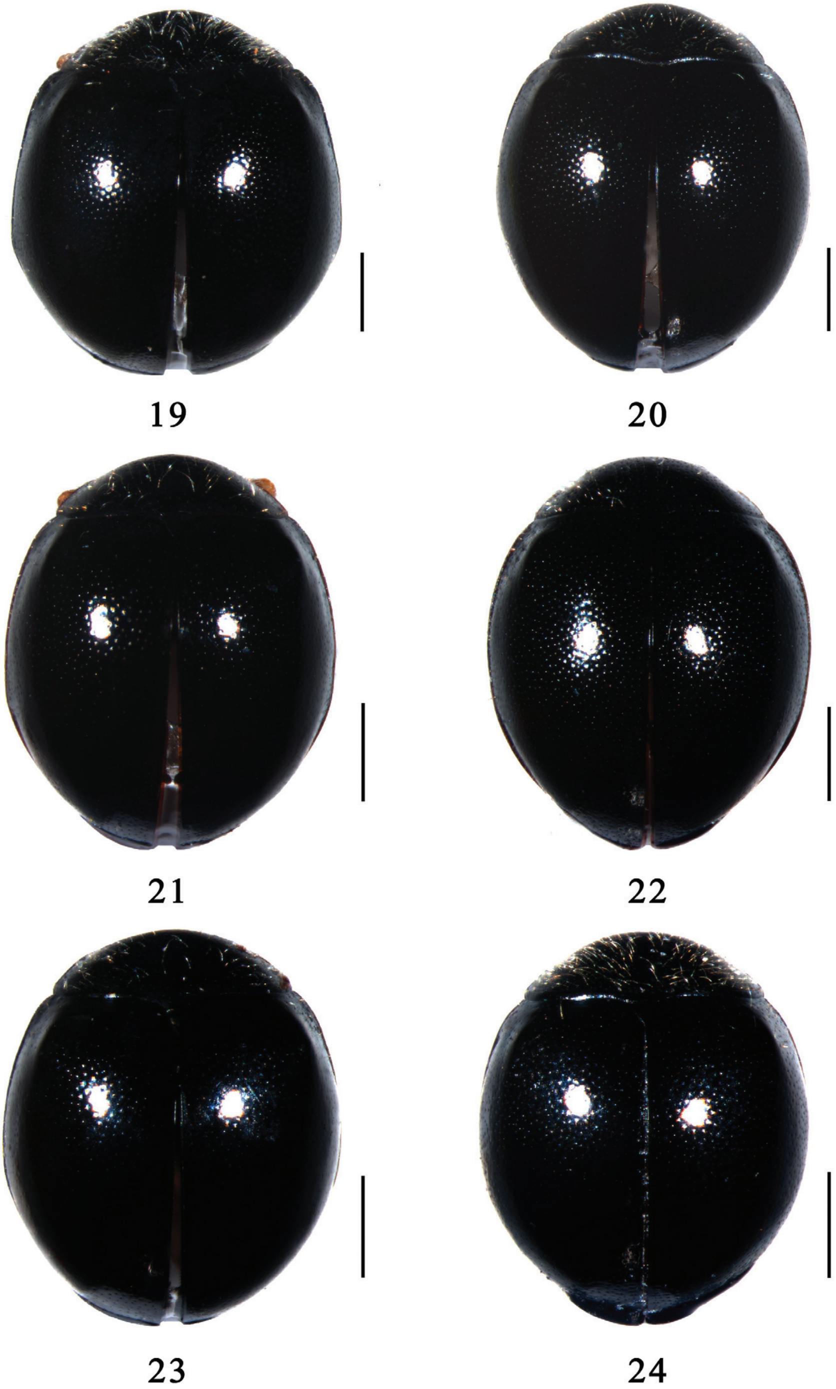
Head transverse and ventrally flattened, 0.44× elytral width (HW/EW=1: 2.29); punctures on frons fine, separated by 0.5–1.5 times their diameter, with sparse setae; eyes moderately large and coarsely faceted, widest interocular distance 0.52× head width. Antenna 9-segmented, terminal segment large, elongate oval and flat, apex angular.

Pronotum short and strongly transverse, 0.70× elytral width (PW/EW=1: 1.43), covered in fine punctures associated with long dense setae, punctures similar as those on head, separated by 1.0–2.0 times their diameter. Punctures on elytra fine and sparse, similar to those on pronotum, separated by 2.0–3.0 times their diameter, with a few long setae at humeral angles and a row of evenly spaced setae along margin. Prosternum mat, with sparse setae. Mesoventrite glabrous and impunctate, with sparse setae. Metaventrite shiny and glabrous, basal half with distinctly median discrimen; punctures around median discrimen large and dense, with short thick setae, punctures on the rest parts indistinct, with sparse setae.

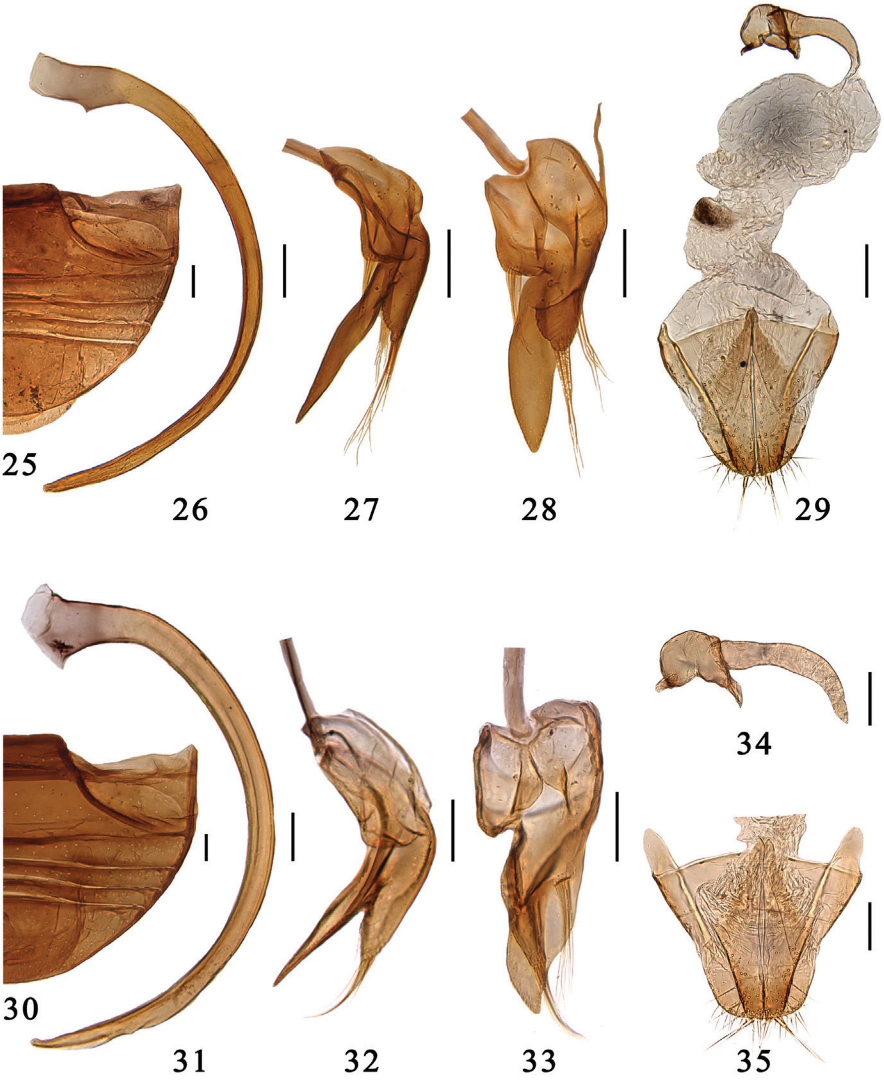
Male genitalia. Penis strongly curved in whole length, with a small prominence at 1/5, apex slightly curved, penis capsule broadening basally and with indistinct inner and outer processes (Fig. 57). Tegmen rather slender and strongly asymmetrical (Figs 58–59). Penis guide in ventral view wide at basal half, sharply narrowed at middle, then contort, forming a distinct gap in middle, apical half elongate finger-shape. Left paramere in ventral view indistinct, bearing a few long setae, and right piece very short, bearing a few long setae (Fig. 59). Penis guide in lateral view widest at base, gradually tapering to apex, basal 1/5 with a small angular prominence, apex sharply pointed (Fig. 58).

Female genitalia. Genital plate triangular with a rounded apex, slightly concaved in middle, sparsely hairy on the apical portion, stylus rather long, bearing few setae (Fig. 61). Spermatheca divided into two parts, one of which is somewhat globular with a constriction and two small pinch-like projections, the other is short tubular, becoming slightly more slender distally (Fig. 60).

Type materials. Holotype: 1♂, **China, Yunnan:** Heiwadi Town, Gongshan, [27°46.48'N, 98°36.16'E], ca 2020m, 19.vii.2010, Wang XM leg. (SCAU). **Paratypes**



Figures 19–24. Dorsal view. **19** *S. latilobum* Wang & Ren, sp. n. **20** *S. digitiforme* Wang & Ren, sp. n. **21** *S. drepnicum* Xiao **22** *S. punctum* Miyatake **23** *S. dulongjiang* Wang, Ren & Chen, sp. n.; **24** *S. contortum* Wang & Ren, sp. n. Scale bars: 0.5mm.



Figures 25–35. 25–29. *S. japonicum* Chapin. **25** abdomen **26–28** male genitalia: **26** penis **27** tegmen, lateral view **28** tegmen, ventral view **29** female genitalia. **30–35.** *S. clauseni* (Chapin). **30** abdomen **31–33** male genitalia: **31** penis **32** tegmen, lateral view **33** tegmen, ventral view. **34–35** female genitalia: **34** spermatheca **35** ovipositor. Scale bars: 0.1mm.

(28): **Yunnan:** 10♂♂17♀♀, same data as holotype (6♂♂10♀♀, SCAU; 4♂♂7♀♀, IOZ); 1♂, Gaoligongshan National Natural Reserve, Baoshan, [24°59.92'N, 99°5.03'E], ca 2000m, 19.ix.2006, Wang XM leg. (SCAU).

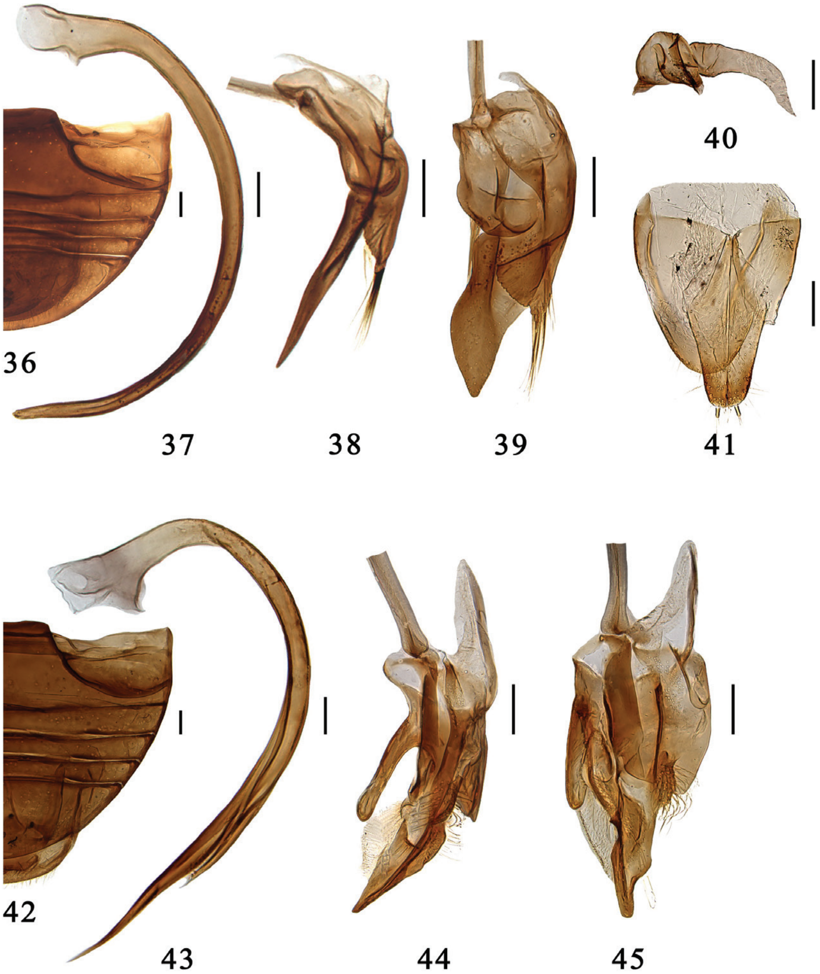
Distribution. China (Yunnan).

Etymology. The specific epithet formed from the Latin adjective *latilobus* referring to penis guide which is wide at basal half, sharply narrowed and forming a distinct gap in middle.

Serangium digitiforme Wang & Ren, sp. n.

urn:lsid:zoobank.org:act:60D8CEB6-9E49-4BA8-983F-811F1C3FF2A0
http://species-id.net/wiki/Serangium_digitiforme
Figs 20, 62–67, 94

Diagnosis. This species is very similar to *S. latilobum* in general appearance and male genitalia, but it is distinguished from the latter by penis distinctly broadening at apical 1/5–2/5, penis guide widest at base, gradually narrowing to middle (Fig. 65). In *S. latilobum*, penis only has a small pominence at 1/5 (Fig. 57), penis guide wide at basal half, sharply narrowed in middle (Fig. 59).

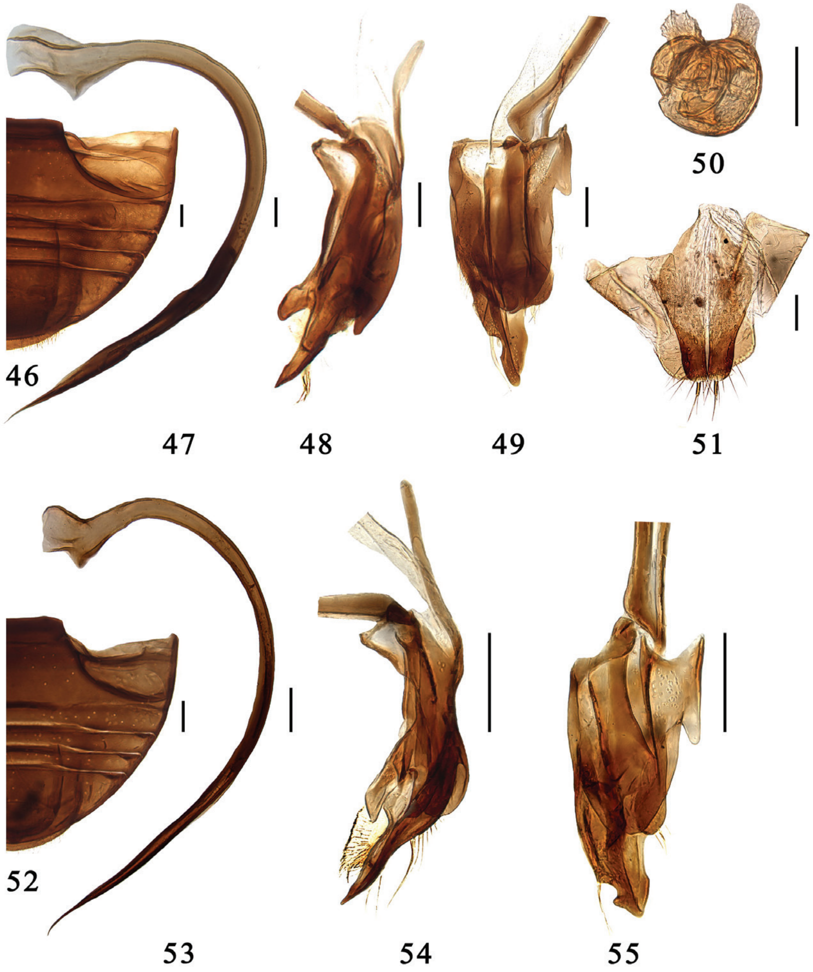


Figures 36–45. 36–41. *S. magnipunctatum* Wang & Ren, sp. n. **36** abdomen. **37–39** male genitalia: **37** penis **38** tegmen, lateral view **39** tegmen, ventral view. **40–41** female genitalia: **40** spermatheca **41** ovipositor. **42–45.** *S. trimaculatum* Wang & Ren, sp. n. **42** abdomen. **43–45** male genitalia: **43** penis **44** tegmen, lateral view **45** tegmen, ventral view. Scale bars: 0.1mm.

Description. TL: 2.14–2.21mm, TW: 1.80–1.85mm, TH: 1.01–1.05mm, TL/TW: 1.19–1.20; PL/PW: 0.46–0.48; EL/EW: 0.95–1.00.

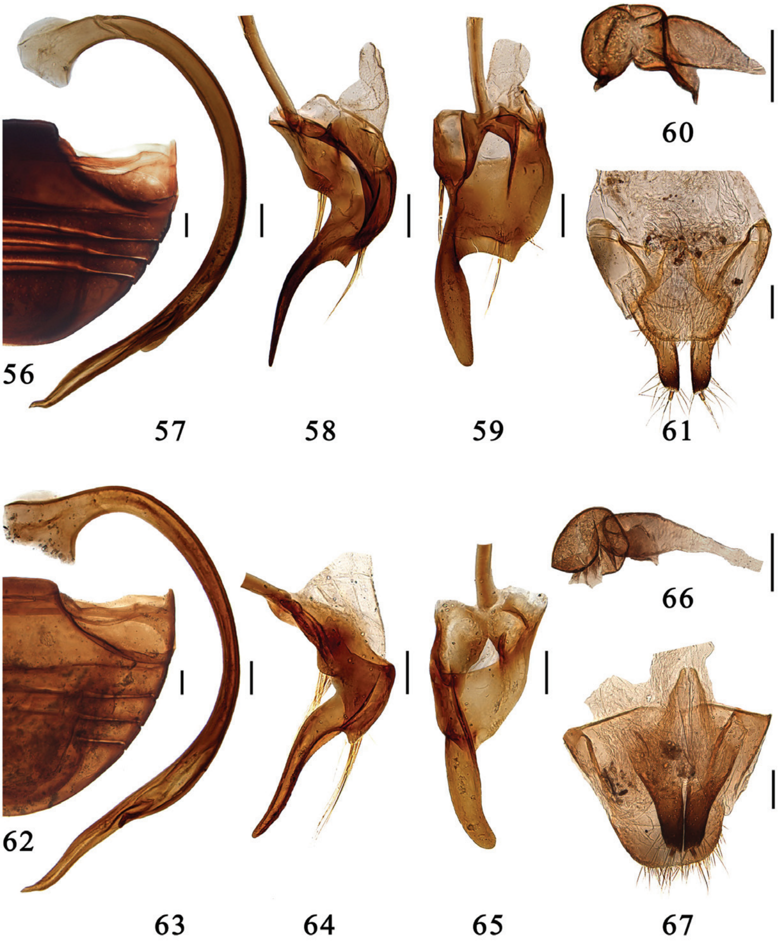
Body minute, hemispherical, dorsum strongly convex, shiny and glabrous (Fig. 20). Dorsum uniformly black. Head dark brown. Underside dark brown. Legs dark red, except tarsi yellow.

Head transverse and ventrally flattened, 0.39× elytral width (HW/EW=1: 2.60); punctures on frons fine, separated by 1.0–3.0 times their diameter, with sparse setae; eyes moderately large and coarsely faceted, widest interocular distance 0.52× head width. Antenna 9-segmented, terminal segment large, elongate oval and flat, apex angular.



Figures 46–55. 46–51. *S. centrale* Wang & Ren, sp. n. **46** abdomen. **47–49** male genitalia: **47** penis **48** tegmen, lateral view **49** tegmen, ventral view. **50–51** female genitalia: **50** spermatheca **51** ovipositor. **52–55.** *S. leigongicus* Wang & Ren, sp. n. **52** abdomen. **53–55** male genitalia: **53** penis **54** tegmen, lateral view **55** tegmen, ventral view. Scale bars: 0.1mm.

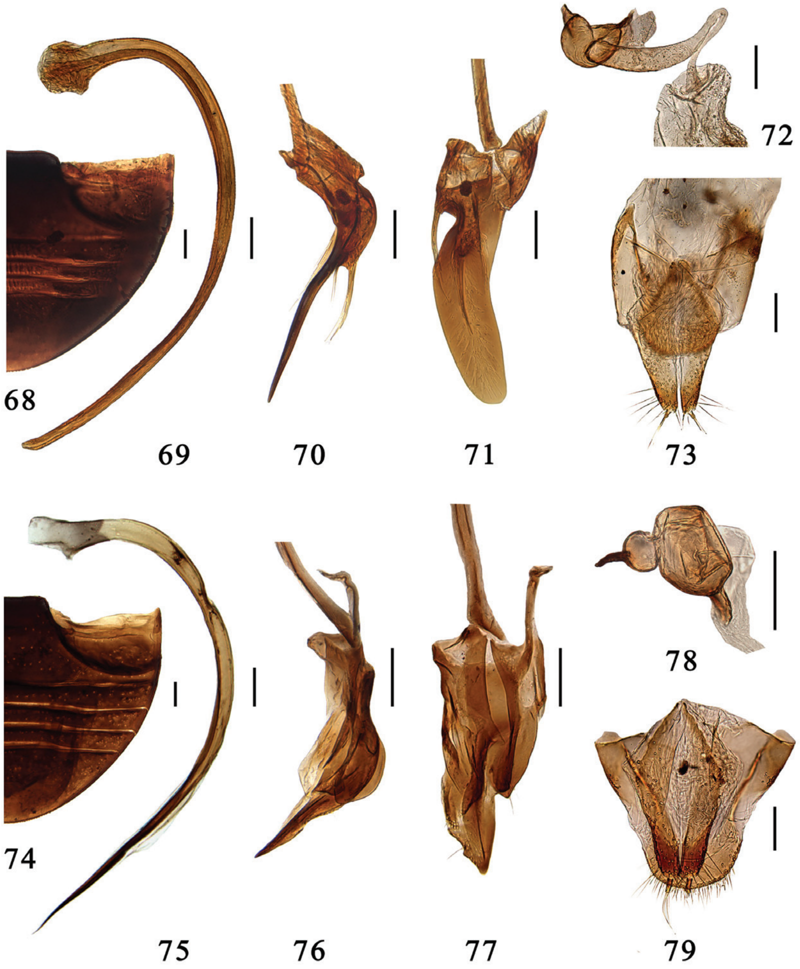
Pronotum short and strongly transverse, 0.70× elytral width (PW/EW=1: 1.43), covered in fine and dense punctures associated with moderately dense setae, similar to those on head, separated by 0.5–1.5 times their diameter. Punctures on elytra fine and sparse, slightly smaller than those on pronotum, separated by 2.0–3.0 times their diameter, with a few long setae at humeral angles and a row of evenly spaced setae along margin. Prosternum mat and shagreened, with sparse setae. Mesoventrite glabrous and impunctate, with sparse setae. Metaventrite shiny and glabrous, basal half with distinctly median discrimen; punctures around median discrimen very large and dense, with short thick setae, punctures on the rest parts moderated and sparse, separated by 2.0–4.0 times their diameter, with sparse setae.



Figures 56–67. 56–61. *S. latilobum* Wang & Ren, sp. n. **56** abdomen. **57–59** male genitalia: **57** penis **58** tegmen, lateral view **59** tegmen, ventral view. **60–61** female genitalia: **60** spermatheca **61** ovipositor. **62–67.** *S. digitiforme* Wang & Ren, sp. n. **62** abdomen. **63–65** male genitalia: **63** penis **64** tegmen, lateral view. **65** tegmen, ventral view. **66–67** female genitalia: **66** spermatheca **67** ovipositor. Scale bars: 0.1mm.

Male genitalia. Penis strongly curved in whole length, distinct distinctly broadening at 1/5–2/5, apex narrowing and slightly curved, penis capsule broadening basally and with indistinct inner and outer processes (Fig. 63). Tegmen rather slender and strongly asymmetrical (Figs 64–65). Penis guide in ventral view widest at base, strongly narrowing to middle, then contorted, apical half finger-shape. Left and right paramere in ventral view short, bearing a few long setae (Fig. 65). Penis guide in lateral view widest at base, gradually tapering to apex (Fig. 64).

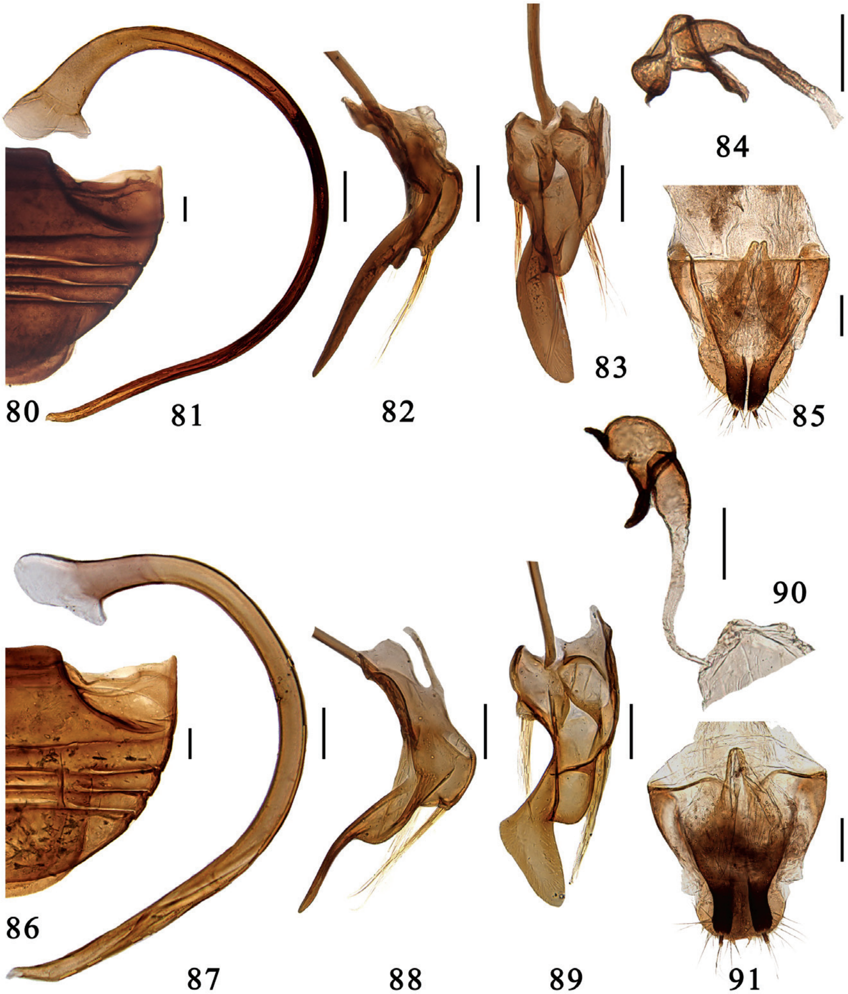
Female genitalia. Genital plate triangular with a rounded apex, slightly concaved in middle, sparsely hairy on the apical portion, stylus rather long, bearing few setae (Fig. 66). Spermatheca divided into two parts, one of which is somewhat globular with



Figures 68–79. 68–73. *S. drepnicum* Xiao. **68** abdomen; **69–71** male genitalia: **69** penis **70** tegmen, lateral view **71** tegmen, ventral view. **72–73** female genitalia: **72** spermatheca **73** ovipositor. **74–79.** *S. punctum* Miyatake **74** abdomen. **75–77** male genitalia: **75** penis **76** tegmen, lateral view **77** tegmen, ventral view. **78–79** female genitalia: **78** spermatheca **79** ovipositor. Scale bars: 0.1mm.

a constriction and two small pinch-like projections, the other is short tubular, becoming slightly more slender distally (Fig. 65).

Type materials. Holotype: 1♂, **China, Hubei:** Hongping, Shennongjia National Natural Reserve, 31°40.07'N, 110°25.73'E, ca 1830m, 19.vii.1997, Peng ZQ leg. (SCAU). **Paratypes** (6): **Hubei:** 1♂, Liujiawu, Shennongjia National Natural Reserve, 31°33.14'N, 110°21.56'E, ca 1790m, 10.vii.1989, Ren SX leg. (SCAU); **Sichuan:** 1♂, Liziping, Shimian, 28°59.75N, 102°18.04'E, ca 2000m, 26.ix.2007, Wang XM leg. (SCAU); **Guizhou:** 1♂, Lianhuaping, Leigongshan Mountain, Leishan, 26°21.89'N,



Figures 80–91. 80–85. *S. dulongjiang* Wang, Ren & Chen, sp. n. **80** abdomen. **81–83** male genitalia: **81** penis **82** tegmen, lateral view **83** tegmen, ventral view. **84–85** female genitalia: **84** spermatheca **85** ovipositor. **86–91.** *S. contortum* Wang & Ren, sp. n. **86** abdomen. **87–89** male genitalia: **87** penis **88** tegmen, lateral view **89** tegmen, ventral view. **90–91** female genitalia: **90** spermatheca **91** ovipositor. Scale bars: 0.1mm.

108°9.17'E, ca 1240m, 8.x.2008, Liang JB leg. (SCAU); 1♂, Maoping, Leigongshan Mountain, Leishan, 26°22.48'N, 108°9.85'E, ca 1410m, 8.x.2008, Liang JB leg. (SCAU); **Gansu:** 1♂1♀, Maijishan, Tianshui, 34°20.79'N, 106°0.68'E, ca 1500m, 10.viii.2008, Wang XM leg. (SCAU).

Distribution. China (Gansu, Guizhou, Hubei, Sichuan).

Etymology. The specific epithet formed from the Latin noun *digitus* and *forma*, referring to digitiform penis guide.

Serangium drepnicum Xiao, 1992

http://species-id.net/wiki/Serangium_drepnicum
Figs 21, 68–73, 94

Serangium drepnicum: Xiao & Li, 1992: 368; Ślipiński & Burckhardt, 2006: 50; Ren et al., 2009: 40.
S. lygacum: Pang et al., 2004: 66.

Diagnosis. This species is close to *S. japonicum* in general appearance and genitalia, but can be distinguished as follows by indistinctly right paramere and flat and wide penis guide (Figs 70–71).

Description. TL: 1.98–2.11mm, TW: 1.68–1.81mm, TH: 0.96–0.99mm, TL/TW: 1.16–1.18; PL/PW: 0.47–0.48; EL/EW: 0.94–0.96.

Body minute, hemispherical, dorsum strongly convex, shiny and glabrous (Fig. 21). Dorsum uniformly black. Head yellow, with basal frons black. Underside black, except prosternum orange. Legs reddish brown, except tibiae and tarsi yellow.

Head transverse and ventrally flattened, 0.41× elytral width (HW/EW=1: 2.43); punctures on frons fine, separated by 1.0–4.0 times their diameter, with sparse setae; eyes moderately large and coarsely faceted, widest interocular distance 0.48× head width. Antenna 9-segmented, terminal segment large, elongate oval and flat, apex angular.

Pronotum short and strongly transverse, 0.70× elytral width (PW/EW=1: 1.43), covered in fine punctures associated with long sparse setae, separated by 1.0–3.0 times their diameter. Punctures on elytra fine and sparse, smaller than those on pronotum, separated by 2.0–4.0 times their diameter, with a row of evenly spaced setae along margin. Prosternum mat, with sparse setae. Mesoventrite glabrous and impunctate, with sparse setae. Metaventrite shiny and glabrous, basal half with distinctly median discrimen; punctures fine and sparse, separated by 2.0–5.0 times their diameter, with short sparse setae.

Male genitalia. Penis strongly curved in whole length, apex shortly narrowing and rounded, penis capsule indistinct (Fig. 69). Tegmen rather slender and strongly asymmetrical (Figs 70–71). Penis guide in ventral view flattened and elongate tongue-shape. Left paramere in ventral view indistinct bearing a few long setae, and right piece distinctly projecting, bearing a few long setae (Fig. 71). Penis guide in lateral view long and thin, straight, apex sharply pointed (Fig. 70).

Female genitalia. Genital plate elongate triangular with a rounded apex, sparsely hairy on the apical portion, stylus long, bearing few setae (Fig. 73). Spermatheca divided into two parts, one of which is somewhat globular with a feeble constriction and two small pinch-like projections, the other is long tubular, becoming slightly more slender distally (Fig. 72).

Types. Holotype: 1♂, Hefeng, Hubei, 29°53.0'N, 110°2.38'E, ca 800m, 27.vii.1989, Xiao NN leg. (KIZ); **Paratypes:** 2♂♂, Lichuan, Hubei, 30°19.12'N, 108°55.35'E, ca 800m, 2.viii.1989, Xiao NN leg. (KIZ).

Other specimens examined. China, Fujian: 1♂1♀, Sangang, Wuyi, 26°11.89'N, 119°15.97'E, ca 380m, 16.viii.1984, Pang XF leg.; **Henan:** 2♂♂1♀, Baiyushan, Songxian, 33°40.14'N, 110°50.56'E, ca 1520m, 1375m, 14.vii.2009, Wang XM et al. Leg.; 1♂, Baotianman, Neixiang, 33°32.15'N, 111°51.38'E, ca 1030m, 6.vii.2009, Wang XM Leg.

Distribution. China (Fujian, Henan, Hubei).

Serangium punctum (Miyatake, 1963)

http://species-id.net/wiki/Serangium_punctum
Figs 22, 74–79, 95

Serangium punctum: Miyatake, 1963: 13; Sasaji, 1971: 57.
Serangium ezoense: Miyatake, 1963: 14.

Diagnosis. This species is easily recognized by frons, meso- and metaventrite with large dense punctures and the special construction of penis guide (Figs 75–77).

Description. TL: 2.08mm, TW: 1.85mm, TH: 0.92mm, TL/TW: 1.13; PL/PW: 0.45; EL/EW: 0.86.

Body minute, hemispherical, dorsum strongly convex, shiny and glabrous (Fig. 22). Dorsum uniformly black. Head black. Underside black. Legs dark brown, except tibiae and tarsi yellow.

Head transverse and ventrally flattened, 0.38× elytral width (HW/EW=1: 2.67); punctures on frons large and dense, separated by 0.5–1.0 times their diameter, with sparse setae; eyes moderately large and coarsely faceted, widest interocular distance 0.52× head width. Antenna 9-segmented, terminal segment large, elongate oval and flat, apex angular.

Pronotum short and strongly transverse, 0.71× elytral width (PW/EW=1: 1.40), evenly covered in moderately large punctures associated with long sparse setae, punctures slightly smaller than those on head, separated by 1.5–3.0 times their diameter. Punctures on elytra fine, slightly smaller than those on pronotum, separated by 2.0–4.0 times their diameter, with a few long setae at humeral angles and a row of evenly spaced setae along margin. Prosternum mat and shagreened. Meso- and metaventrites without distinctly median discrimen; punctures large and sparse, separated by 1.5–3.0 times their diameter, with sparse setae.

Male genitalia. Penis long and slender, strongly curved in whole length, apical half of siphon strongly narrowing apical, and apex very thin and sharply pointed, penis capsule broadening basally and without distinct inner and outer processes (Fig. 75). Tegmen strongly asymmetrical and extremely complicate (Figs 76–77). Penis guide moderatedly elongate, with a pointed apex, a small triangular process at left side near the apex and an angulate prominence at middle of left side, bearing sparse setae (Fig. 77). Right paramere relatively long, 1/2 of penis guide length, bearing minute setae. Left lateral lobe of tegmen slightly longer than right, flat and elongate oval without any hairs (Fig. 77). Paramere in lateral view arcuate, with a sharply pointed apex (Fig. 76). Basal piece of tegmen with a long process.

Female genitalia. Genital plate elongate triangular, apical part of the plate narrow and parallel-sided with a rouned apex, stylus of the genital plate very elongate with a few long setae at its apex (Fig. 79). Spermatheca divided into two parts, one of which is globular with a small pinch-like projection, the other nearly hemispherical, with a small pinch-like projection (Fig. 78).

Specimens examined: Gansu: 1♂, Maiji, Tianshui, 34°20.79'N, 106°0.28'E, ca 1650m, 6.viii.2009, Wang XM leg. **Guizhou:** 1♀, Xiaodanjiang, Leigongshan National Natural Reserve, Leishan, 26°26.53'N, 108°15.45'E, ca 1160m, 12.x.2008, Liang JB leg.

Distribution. China (Gansu, Guizhou) **new distribution**; Japan

Serangium dulongjiang Wang, Ren & Chen, sp. n.

urn:lsid:zoobank.org:act:B8DCED81-ACCD-4F34-9B09-AC6288CD2D87
http://species-id.net/wiki/Serangium_dulongjiang
Figs 23, 80–85, 95

Diagnosis. This species is close to *S. digitiforme* in general appearance and male genitalia, but it is distinguished from the latter as follow: penis is long and slender (Fig. 81), penis guide is elongated tongue-shaped (Fig. 83), and the first part of spermatheca has a strong constriction in middle (Fig. 84). In *S. digitiforme*, penis is moderately long and stout, distinctly broadening at apical 1/5–2/5 (Fig. 63), penis guide is finger-shaped (Fig. 65), and the first part of spermatheca has a feebly constriction in middle (Fig. 66).

Description. TL: 2.01–2.14mm, TW: 1.68–1.81mm, TH: 0.86–0.96mm, TL/TW: 1.18–1.20; PL/PW: 0.44–0.49; EL/EW: 0.96–1.00.

Body minute, hemispherical, dorsum strongly convex, shiny and glabrous (Fig. 23). Dorsum uniformly black. Head orange to dark brown. Underside black. Legs yellowish brown to dark red, except tarsi yellow.

Head transverse and ventrally flattened, 0.41× elytral width (HW/EW=1: 2.43); punctures on frons fine, separated by 1.5–2.5 times their diameter, with sparse setae; eyes moderately large and coarsely faceted, widest interocular distance 0.52× head width. Antenna 9-segmented, terminal segment large, elongate oval and flat, apex angular.

Pronotum short and strongly transverse, 0.71× elytral width (PW/EW=1: 1.42), densely covered in fine punctures associated with long dense setae, punctures similar to those on head, separated by 0.5–1.0 times their diameter. Punctures on elytra fine and sparse, similar to those on pronotum, separated by 2.0–3.0 times their diameter, with a row of evenly spaced setae along margin. Prosternum mat, with sparse setae. Mesoventrite glabrous and impunctate. Metaventrite shiny and glabrous, without distinctly median discrimen; punctures in center large and dense, with short thick setae.

Male genitalia. Penis very long and slender, strongly curved in whole length, apex shortly narrowing and rounded, penis capsule indistinct (Fig. 81). Tegmen rather slender and strongly asymmetrical (Figs 82–83). Penis guide in ventral view widest at base, gradually narrowing to middle, then strongly narrowed and contorted, apical elongate tongue-shape. Left paramere in ventral view short bearing a few long setae, and right piece short but distinctly projecting, bearing a few long setae (Fig. 83). Penis guide in lateral view long and thin, almost straight, with a angular prominence near the base, apex pointed (Fig. 82).

Female genitalia. Genital plate elongate triangular with a rounded apex, slightly concaved in middle of outer margin, apical portion with sparsely setae, stylus long, bearing few setae (Fig. 85). Spermatheca divided into two parts, one of which is somewhat globular with a strong constriction and two pinch-like projections, the other is tubular, becoming slightly more slender distally (Fig. 84).

Type materials. Holotype: 1♂, **China, Yunnan:** Longyuan Village, Dulongjiang, Gongshan, 28°1.16'N, 98°18.88'E, ca 1500m, 26.vii.2010, Wang XM leg. (SCAU). **Paratypes** (46): **Yunnan:** 7♂♂22♀♀, same data as holotype (5♂♂15♀♀, SCAU; 2♂♂7♀♀, IOZ); 1♂2♀♀, Bapo Village, Dulongjiang, Gongshan, 27°43.84'N, 98°20.71'E, ca 1390m, 1400m, 28.vii.2010, Wang XM leg. (SCAU); 1♀, Maku Village, Dulongjiang, Gongshan, 27°41.11'N, 98°18.19'E, ca 1400m, 28.vii.2010, Wang XM leg. (SCAU); 8♂♂5♀♀, Lushui, Pianma, 26°0.42'N, 98°39.46'E, ca 2300m, 10.viii.2010, Wang XM et al. leg. (5♂♂2♀♀, SCAU; 3♂♂3♀♀, IOZ).

Distribution. China (Yunnan).

Etymology. The specific epithet is named after Dulongjiang, the type locality of this ladybird.

Serangium contortum **Wang & Ren, sp. n.**

urn:lsid:zoobank.org:act:FCD37526-FC0C-4FA2-86D0-38183E3653D0
http://species-id.net/wiki/Serangium_contortum
Figs 24, 86–91, 95

Diagnosis. This species is easily recognized by its metaventrite without median discrimen and the contorted penis guide (Figs 88–89).

Description. TL: 1.62–1.78mm, TW: 1.42–1.58mm, TH: 0.69–0.96mm, TL/TW: 1.13–1.14; PL/PW: 0.48–0.49; EL/EW: 0.83–0.91.

Body minute, hemispherical, dorsum strongly convex, shiny and glabrous (Fig. 24). Dorsum uniformly black. Head yellow. Underside reddish brown, except meso- and metaventrite black. Legs yellowish brown, except femora reddish brown.

Head transverse and ventrally flattened, 0.42× elytral width (HW/EW=1: 2.40); punctures on frons moderately large, separated by 0.5–1.5 times their diameter, with sparse setae; eyes moderately large and coarsely faceted, widest interocular distance 0.53× head width. Antenna 9-segmented, terminal segment large, elongate oval and flat, apex angular.

Pronotum short and strongly transverse, 0.72× elytral width (PW/EW=1: 1.39), covered in fine inconspicuous punctures associated with long dense setae, punctures slightly smaller than those on head, separated by 1.0–1.5 times their diameter. Punctures on elytra fine and sparse, smaller than those on pronotum, separated by 2.0–3.0 times their diameter, with a row of evenly spaced setae along margin. Prosternum mat, punctures fine and inconspicuous, with sparse setae. Mesoventrite glabrous. Metaventrite shiny and glabrous, without distinctly b median discrimen; 5–6 large and dense punctures forming two cluster in the center, with short thick setae, punctures on the rest parts indistinct, with sparse setae.

Male genitalia. Penis long and stout, strongly curved in whole length, apex strongly narrowing and rounded, penis capsule indistinct (Fig. 87). Tegmen rather slender and strongly asymmetrical (Figs 88–89). Penis guide in ventral view strongly contorted in middle. Left paramere in ventral view short bearing a few long setae, and right piece short but distinctly projecting, bearing a few long setae (Fig. 89). Penis guide in lateral view wide in basal half, then sharply narrowed, apical half very thin, apex pointed (Fig. 88).

Female genitalia. Genital plate elongate triangular with a rounded apex, distinctly concaved in middle of outer margin, apical portion with sparsely setae, stylus long, bearing few setae (Fig. 91). Spermatheca divided into two parts, one of which is somewhat globular with a feeble constriction and two pinch-like projections, the other is tubular, becoming slightly more slender distally (Fig. 90).

Type materials. Holotype: 1♂, **China, Yunnan:** Heiwadi Town, Gongshan, 27°46.48'N, 98°36.16'E, ca 2020m, 19.vii.2010, Wang XM leg. (SCAU). **Paratypes** (10): **Yunnan:** 4♂♂4♀♀, same data as holotype (2♂♂2♀♀, SCAU; 2♂♂2♀♀, IOZ); **Guangxi:** 1♂, Jiuniutang, Maoershan National Natural Reserve, Guilin, 25°50.55'N, 110°22.85'E, ca 1390m, 18.x.2004, Wang XM leg. (SCAU); **Hubei:** 1♂, Wudangshan, Shiyan, 32°24.50'N, 111°1.31'E, ca 1090m, 17.vii.1997, Peng ZQ leg. (SCAU).

Distribution. China (Guangxi, Hubei, Yunnan).

Etymology. The specific epithet formed from the Latin adjective *contortus*, referring to contorted penis guide of tegmen.

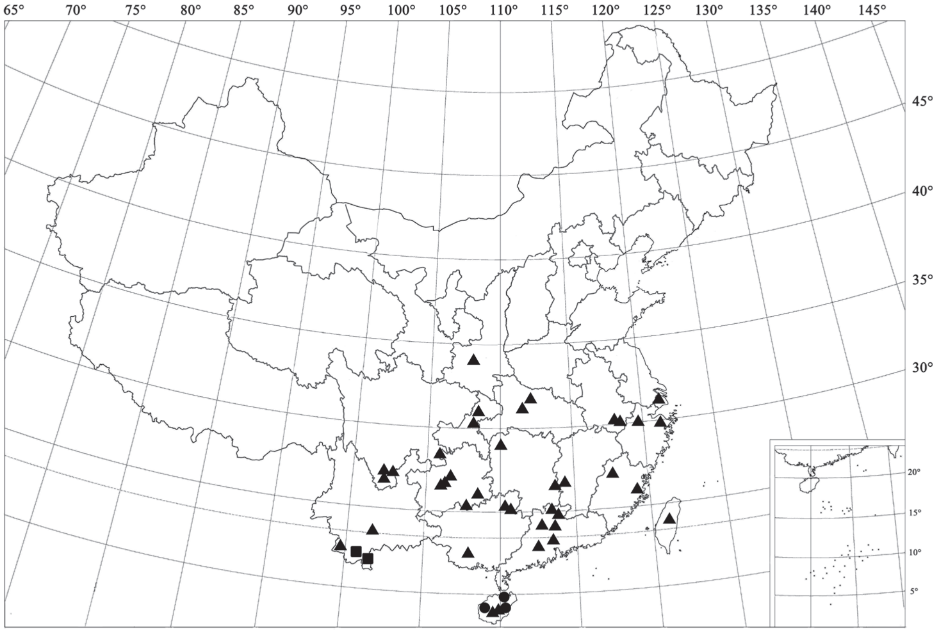


Figure 92. Distribution map. *S. japonicum* Chapin (▲); *S. clauseni* (Chapin) (●); *S. magnipunctatum* Wang & Ren, sp. n. (■).

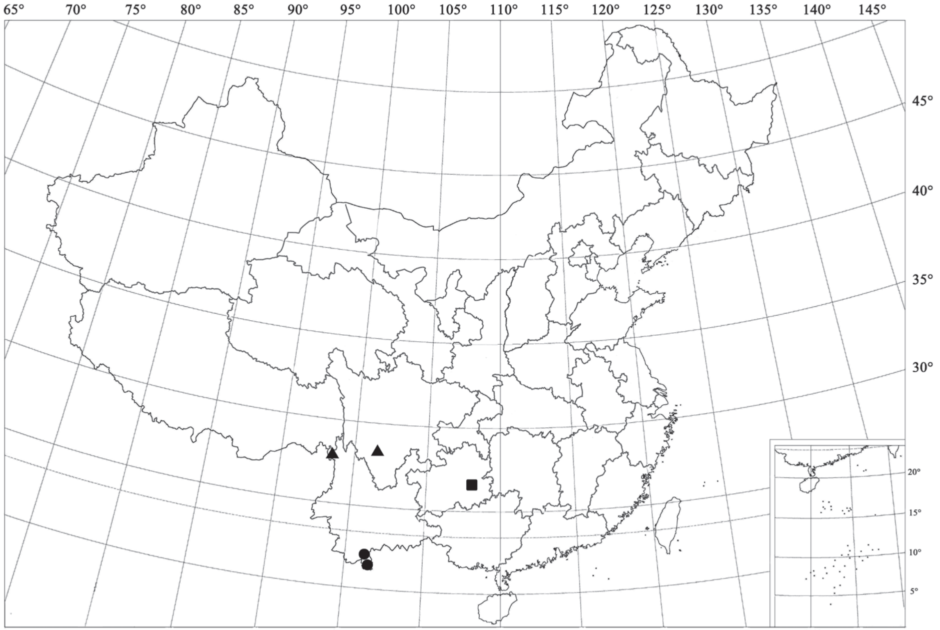


Figure 93. Distribution map. *S. trimaculatum* Wang & Ren, sp. n. (▲); *S. centrale* Wang & Ren, sp. n. (●); *S. leigongicus* Wang & Ren, sp. n. (■).

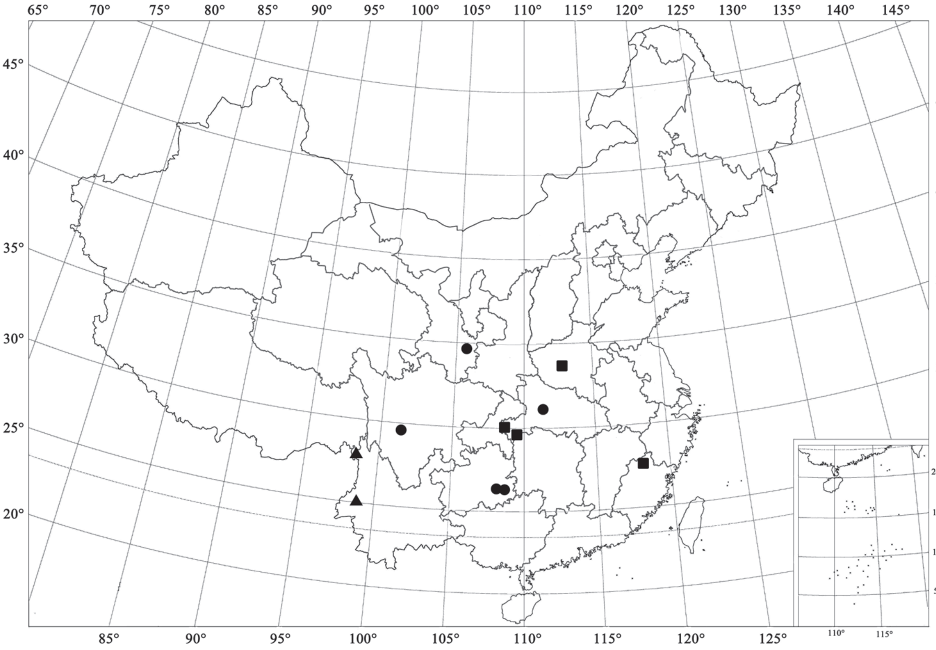


Figure 94. Distribution map. *S. latilobum* Wang & Ren, sp. n. (▲); *S. digitiforme* Wang & Ren, sp. n. (●); *S. drepnicum* Xiao (■).

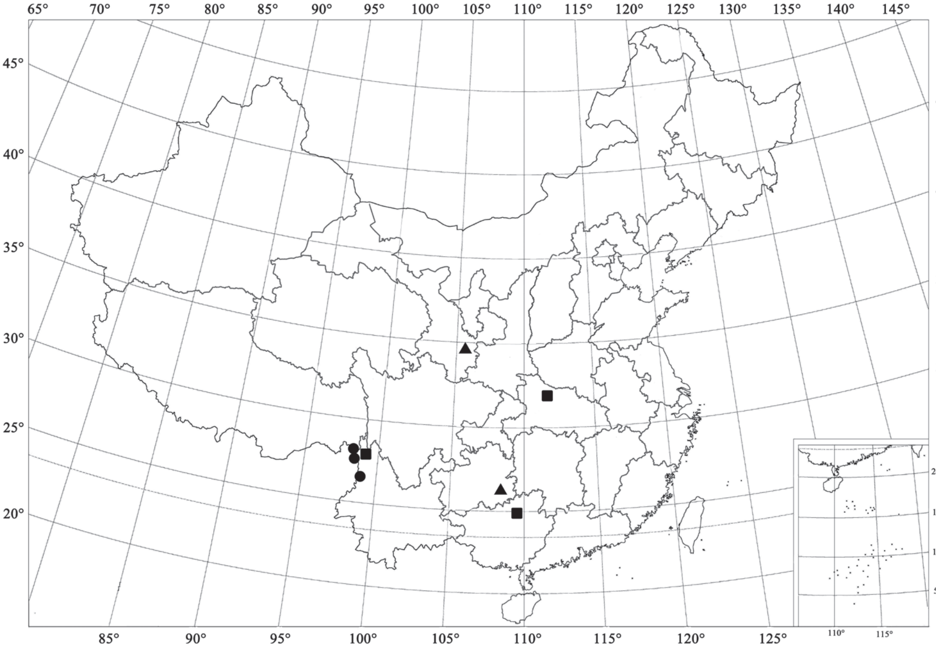


Figure 95. Distribution map. *S. punctum* Miyatake (▲); *S. dulongjiang* Wang, Ren & Chen, sp. n. (●); *S. contortum* Wang & Ren, sp. n. (■).

Acknowledgements

The authors sincerely thank Dr. Yu Guoyue (Beijing Academy of Agricultural and Forestry Science, China) and Dr. Adam Ślipiński (CSIRO Entomology, Canberra, Australia) for encouragement, suggestions and support during this research work. The research was supported by the National Natural Science Foundation of China (Nos. 2006FY120100 and 30970324).

References

Blackburn T (1889) Further notes on Australian Coleoptera, with descriptions of new species. Transactions of the Royal Society of South Australia 11: 175–214.

Blackwelder RE (1945) Checklist of the Coleopterous Insects of Mexico, Central America, the West Indies, and South America. Part 3. Smithsonian Institution United States National Museum Bulletin 185: 343–550.

Cao C, Pan Y, Wang H (1992) Coccinellidae of Yunnan. Yunnan Science & Technology Publishing House, Kunming, 242 pp. [In Chinese]

Chapin EA (1940) New genera and species of lady-beetles related to *Serangium* Blackburn (Coleoptera: Coccinellidae). Journal of the Washington Academy of Sciences 30: 263–272.

Chapin EA (1965) Coleoptera: Coccinellidae. Insects of Micronesia 16(5): 189–254.

Iablokkoff-Khnzorian SM (1972). Les type de Coccinellidae de la collection Motschulsky (Coleopteres: Coccinellidae). Nouvelle Revue d'Entomologie 2: 163–184.

Kovář I (1996) Phylogeny. In: Hodek I, Honek A (Eds) Ecology of Coccinellidae. Series Entomologica 54. Kluwer Academic Publishers, Dordrecht, 19–31.

Miyatake M (1961a) A new genus of the Coccinellidae from Japan and the Ryukyu Islands (Coleoptera). Memoirs of the College of Agriculture, Ehime University 6(2): 37–43.

Miyatake M (1961b) The East-Asian Coccinellid-beetles preserved in the California Academy of Sciences, tribe Serangiini. Memoirs of the College of Agriculture, Ehime University 6(2): 45–56.

Miyatake M (1963) Descriptions of two new species of the genus *Serangium* from Japan. Transactions of the Shikoku Entomological Society 8:13–14.

Miyatake M (1994) Revisional studies on Asian genera of the subfamily Sticholotidinae (Coleoptera: Coccinellidae). Memoirs of the College of Agriculture, Ehime University 38: 223–292.

Pang H, Ren SX, Zeng T, Pang XF (2004) Biodiversity and their utilization of Coccinellidae in China. Guangzhou (China): Science and Technology press of Guangdong, 168 pp. [In Chinese]

Pang XF, Mao JL (1979) Coleoptera: Coccinellidae II. Economic Entomology China, 14. Science Press, China, Beijing, 170pp. [In Chinese]

Pope RD (1962) A review of the Pharini (Coleoptra: Coccinellidae). Annals and Magazine of Natural History, Series 13 4: 627–640.

Ren SX, Wang XM, Pang H, Peng ZQ, Zeng T (2009). Colored Pictorial Handbook of Ladybird Beetles in China. Science Press, China, Beijing, 336pp. [In Chinese]

Sasaji H (1967) A revision of the Formosan Coccinellidae (I) the subfamily Sticholotidinae, with an establishment of a new tribe (Coleoptera). Etizenia 25: 28.

Sasaji H (1968a) Coccinellidae collected in the paddy fields of the Orient, with descriptions of new species (Coleoptera). Mushi 42: 119–132.

Sasaji H (1968b) Phylogeny of the family Coccinellidae (Coleoptera). Etizenia 35: 1–37.

Sasaji H (1971) Fauna Japonica. Coccinellidae (Insecta: Coleoptera). Academic Press Japan, Tokyo, 345pp.

Ślipiński A, Burckhardt D (2006) Revision of the Australian Coccinellidae (Coleoptera). Part 5. Tribe Serangiini. Annals Zoologici (Warsaw) 56(1): 37–58.

Ślipiński A (2007) Australian ladybird beetles (Coleoptera: Coccinellidae) their biology and classification. ABRS, Canberra (Australia), 286pp.

Sicard A (1909). Révision des Coccinellides de la faune Malgache. Annales de la Société Entomologique de France 1909: 63–165.

Weise J (1892) Kleine Beiträge zur Coccinelliden-Fauna Ost-Afrika's. Deutsche Entomologische Zeitschrift 1892: 15–16.

Weise J (1908) Die Fauna Südwest-Australiens. Ergebnisse der Hamburger südwest-australischen Forschungsreise 1905. Herausgegeben von Prof. Dr. W. Michaelsen und Dr. R. Hartmeyer. Chrysomelidae und Coccinellidae. Band II. Lieferung 1, G. Fisher, Jena. 13 pp.

Xiao NN, Li HX (1992) Coleoptera, Coccinellidae. In: Huang F (Eds) Insects of Wuling Mountains area, southwestern China. Science Press. Beijing 368–390.

ZooKeys 134: 65–82 (2011)
doi: 10.3897/zookeys.134.1653
www.zookeys.org

RESEARCH ARTICLE

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

Entedoninae wasps (Hymenoptera, Chalcidoidea, Eulophidae) associated with ants (Hymenoptera, Formicidae) in tropical America, with new species and notes on their biology

Christer Hansson[1,†], Jean-Paul Lachaud[2,3,‡], Gabriela Pérez-Lachaud[2,§]

1 *Scientific Associate of Entomology Department, the Natural History Museum, London SW7 5BD, United Kingdom* **2** *El Colegio de la Frontera Sur, Entomología Tropical, Av. Centenario Km 5.5, Chetumal 77014, Quintana Roo, Mexico* **3** *Centre de Recherches sur la Cognition Animale, CNRS-UMR 5169, Université de Toulouse UPS, 118 route de Narbonne, 31062 Toulouse Cedex 09, France*

† *urn:lsid:zoobank.org:author:EC91EABD-7115-4B05-BC80-9195C86FA55D*
‡ *urn:lsid:zoobank.org:author:B7356DAD-FB61-4F1F-B7FC-1563AFCED2A9*
§ *urn:lsid:zoobank.org:author:226D5EE2-02F7-4D72-9BDF-D9EAA0CEBCF4*

Corresponding author: *Christer Hansson* (christerdennis@gmail.com)

Academic editor: *Michael Sharkey* | Received 2 June 2011 | Accepted 2 September 2011 | Published 6 October 2011

urn:lsid:zoobank.org:pub:469CD7C7-E4E0-4BE4-98B3-F8BBCCDF3580

Citation: Hansson C, Lachaud JP, Pérez-Lachaud G (2011) Entedoninae wasps (Hymenoptera, Chalcidoidea, Eulophidae) associated with ants (Hymenoptera, Formicidae) in tropical America, with new species and notes on their biology. ZooKeys 134: 65–82. doi: 10.3897/zookeys.134.1653

Abstract

Three new species of Eulophidae associated, or presumed to be associated with ants are described: two species of *Horismenus* Walker and one species of *Microdonophagus* Schauff. Information on the biology is also included. The two *Horismenus* species are from Chiapas, Mexico. *Horismenus myrmecophagus* **sp. n.** is known only from females and is a gregarious endoparasitoid in larvae of the weaver ant *Camponotus* sp. ca. *textor*. The parasitoids pupate inside the host larva, and an average of 6.7 individuals develops per host. This is the second time a species of genus *Horismenus* is found parasitizing the brood of a formicine ant of genus *Camponotus*. *Horismenus microdonophagus* **sp. n.** is described from both males and females, and is a gregarious endoparasitoid attacking the larvae of *Microdon* sp. (Diptera: Syrphidae), a predator on ant brood found in nests of *Camponotus* sp. ca. *textor*. The new species of *Microdonophagus*, *M. tertius*, is from Costa Rica, and known only from the female. Nothing is known about its biology but since another species in same genus, *M. woodleyi* Schauff, is associated with ants through its host, *Microdon* larva (with same biology as *H. microdonophagus*), it is possible that also *M. tertius* has this association. A new distributional record for *M. woodleyi* is also reported, extending its distribution from Panama and Colombia to Brazil.

Keywords

Horismenus, *Microdonophagus*, *Camponotus*, *Microdon*, ant parasitism, myrmecophile, taxonomy

Introduction

Natural enemies of ants include dipteran, strepsipteran and hymenopteran parasitoids (for a review see Wilson (1971), Kistner (1982), Hölldobler and Wilson (1990)). Species of several families of parasitic wasps have been reported parasitizing brood or adult ants, the Eucharitidae being the only monophyletic group, at the family level, where all members are parasitoids of ants (Heraty 2002). In contrast to eucharitids, parasitization of ants by eulophids is a rare event.

Four associations involving a eulophid wasp and an ant host have been reported to date, and all are genera belonging to the subfamily Entedoninae: an unidentified gregarious parasitoid, apparently closely related to the genus *Paracrias* Ashmead (identified by Gahan), was recorded parasitizing larvae of the myrmicine *Crematogaster acuta* (Fabr.) in Guyana (Wheeler and Wheeler 1924), the prepupae of another, unidentified species of *Crematogaster* were parasitized by *Myrmokata diparoides* Bouček (Bouček 1972) in Cameroon, *Pediobius marjoriae* Kerrich was reared from cocoons of *Lepisiota* sp. (referred to as *Acantholepis* sp.) (Formicidae: Formicinae) in Uganda (Kerrich 1973), and *Horismenus floridensis* (Schauff & Bouček) (referred to as *Alachua floridensis*) was found parasitizing the pupae of *Camponotus atriceps* (F. Smith) (referred to as *C. abdominalis* Fab.) and of *C. floridanus* (Buckley) (Formicidae: Formicinae) in Florida (Schauff and Bouček 1987). Three other species of Eulophidae (the first two are Entedoninae, the third a Tetrastichinae) have been reported associated with ant nests but direct parasitism on the ant brood was not clearly established in any of these cases: *Myrmobomyia malayana* Gumovsky & Bouček with nests of an ant species of the genus *Dolichoderus* in Malaysia (Gumovsky and Bouček 2005), an unidentified species of *Horismenus* from the bivouac and refuse deposits of the army ant *Eciton burchellii* (Westwood) (Rettenmeyer et al. 2011), and an unidentified species of *Tetrastichus* from a nest of *Myrmecocystus mexicanus* Wesmael in USA (Wheeler and Wheeler 1986). Finally, two species of Entedoninae are indirectly associated with ants as they parasitize insects living in ant nests: Kerrich (1973) reported *Pediobius acraconae* Kerrich from the last instar larva of *Acracona remipedalis* Karsh (Lepidoptera: Pyralidae) living in a nest of *Crematogaster depressa* (Latreille) or *C. africana* Mayr (Formicidae: Myrmicinae) in Nigeria, and *Microdonophagus woodleyi* Schauff parasitizes larvae of *Microdon* sp. (Diptera: Syrphidae), living in nests of *Technomyrmex fulvus* (Wheeler) (referred to as *Tapinoma fulvum*) (Formicidae: Dolichoderinae) (Schauff 1986).

Here we describe two species of *Horismenus,* one parasitizing the brood of the weaver ant *Camponotus* sp. ca. *textor*, and the other parasitizing a syrphid myrmecophile associated with this ant species. A new species of *Microdonophagus* Schauff presumed to be associated with ants is also described. A new distributional record for *M. woodleyi* is provided.

Methods

Specimens for this study were either reared (*Horismenus* species) or collected manually (*Microdonophagus*), killed in alcohol, and subsequently critical point dried and mounted on cards for further studies. Observations of the specimens were made through a stereomicroscope, Nikon© SMZ 1500 with a halogen ring light as light source. The colour photos were taken with a DS-Fi1 camera mounted on the stereomicroscope and the light source for the photos was a dome light manufactured from a description on http://www.cdfa.ca.gov/. Each picture was made from several photos taken at different levels of focus, and merged using Helicon Focus©. Micrographs are from uncoated specimens analyzed in low vacuum, with a JEOL© JSM 5600 LV scanning microscope.

Morphological abbreviations and acronyms

Abbreviations for morphological terms: DE = shortest distance between eyes in frontal view; DO = diameter of median ocellus; HE = height of eye; HW = height of fore wing; LC = length of median carina on propodeum; LG = length of gaster; LM = length of marginal vein; LS = length of hind tibial spur; LT = length of hind tarsus; LW = length of fore wing, measured from base of marginal vein to apex of wing; MM = length of mesosoma; MS = malar space; OOL = distance between one posterior ocellus and eye; PM = length of postmarginal vein; POL = distance between posterior ocelli; POO = distance between posterior ocelli and occipital margin; ST = length of stigmal vein; WC = greatest width of median carina on propodeum; WH = width of head; WM = width of mouth; WT = width of thorax. For illustrations of the morphological terms see http://www.neotropicaleulophidae.com/.

Collection acronyms used are: BMNH = The Natural History Museum, London, England; CH = collection of Christer Hansson; ECO-CH-AR = Arthropod Collection El Colegio de la Frontera Sur-Chetumal, Mexico; USNM = the United States National Museum of Natural History, Washington, D.C., USA.

Taxonomy

Genus *Horismenus* Walker

There are 400 species described of the almost exclusively New World genus *Horismenus* Walker, 1843, mostly from the Neotropical region (Hansson 2009a), but only 13 have been reported from Mexico. Host records are available for 99 *Horismenus* species (Pérez and Bonet 1984, Bonet 2008, Hansson 2009a). The genus shows a wide host spectrum including lepidopteran and coleopteran leaf-miners, seed-eating bruchids and curculionids, coccids, mantispids, spider eggs, and both dipteran and hymenopteran parasitoids. Members of this genus also display a variety of life styles. Records include both primary and secondary parasitoids, solitary or gregarious species, specialist or generalist parasitoids, and as far as is known all are endoparasitoids and presumably koinobionts. The species may attack eggs, larvae, or pupae of their hosts.

Horismenus myrmecophagus **sp. n.**

urn:lsid:zoobank.org:act:CE88218A-4A94-4FD3-B87C-09C5442AA1AA
http://species-id.net/wiki/Horismenus_myrmecophagus
Figures 1, 2–6, 17, 21, 23–24

Material. HOLOTYPE female (BMNH), glued to a card, labelled "MEXICO: Chiapas, Tuxtla Chico, Rosario Izapa, 14°58'25"N 92°09'19"W, 430 m, 25.ii.2010, G. Pérez-Lachaud & J.-P. Lachaud, reared from *Camponotus* sp. ca. *textor* pupa, nest no. 2, on mandarine *(Citrus reticulata*)". PARATYPES. 1♀ with same label data as holotype (BMNH); 29♀ with same label and host data as holotype but collected from nest #3 28.ii.2010 (22♀ in BMNH, 2 ♀ in CH, 5♀ in ECO-CH-AR). Several paratypes have opaque and somewhat distorted wings due to premature killing in alcohol, i.e. before the wing membranes had hardened.

Diagnosis. Frons with interscrobal area protruding and carinate (Fig. 2); scutellum entirely reticulate, without median groove and lateral mesh–rows (Fig. 4); fore wing speculum small and closed below (Fig. 21); all coxae white; propodeum with submedian grooves strongly reticulate and with anterolateral foveae weakly indicated anteriorly (Fig. 5); propodeal callus with five setae.

The species is very similar to *H. alienus* Hansson, but differs mainly in the shape of the petiole which in *H. alienus* has a strongly raised transverse carina dorsally, but *H. myrmecophagus* has two strong and rounded projections dorsolaterally (Fig. 5); it differs also in sculpture of median propodeum: smooth in *H. alienus*, but strongly reticulate in *H. myrmecophagus* (Fig. 5).

Description. *Female*. Length of body 1.1–1.4 mm. Scape white; pedicel and flagellum pale brown. Frons golden–green with purple tinges (Fig. 23). Vertex metallic bluish–green. Mesoscutum metallic bluish–green (Fig. 24). Scutellum dark golden–purple with green tinges (Fig. 24). Propodeum dark golden–purple (Fig. 24). Legs white. Wings hyaline. Petiole dark golden–purple. Gaster dark brown with metallic purple tinges.

Antenna as in Fig. 17. Frons (Fig. 2) with part just above frontal suture with raised and weak reticulation, remaining parts with raised and strong reticulation; frontal suture V–shaped, incomplete and not reaching eyes; antennal scrobes joining frontal suture separately. Vertex (Fig. 3) with raised and strong reticulation; without a median groove. Occipital margin rounded.

Mesoscutum with raised and strong reticulation (Fig. 4); notauli indistinct. Scutellum with raised and strong reticulation (Fig. 4), without median groove and lateral mesh–rows. Dorsellum slightly concave and with raised and strong reticulation. Pro-

Figure 1. *Camponotus* sp. ca. *textor* larva parasitized by *Horismenus myrmecophagus*. *H. myrmecophagus* develops as a gregarious endoparasitoid. The ant larva has been cut open (its head is at the bottom of the picture). Several pupae of the eulophid parasitoid may be observed, some of them still inside the ant larva.

podeum with raised and strong reticulation (Fig. 5); propodeal callus with five setae. Coxae with raised and weak reticulation. Fore wing speculum small and closed below (Fig. 21); with 12 admarginal setae.

Gaster (Fig. 6) with first tergite with very weak reticulation posteriorly and laterally, otherwise smooth.

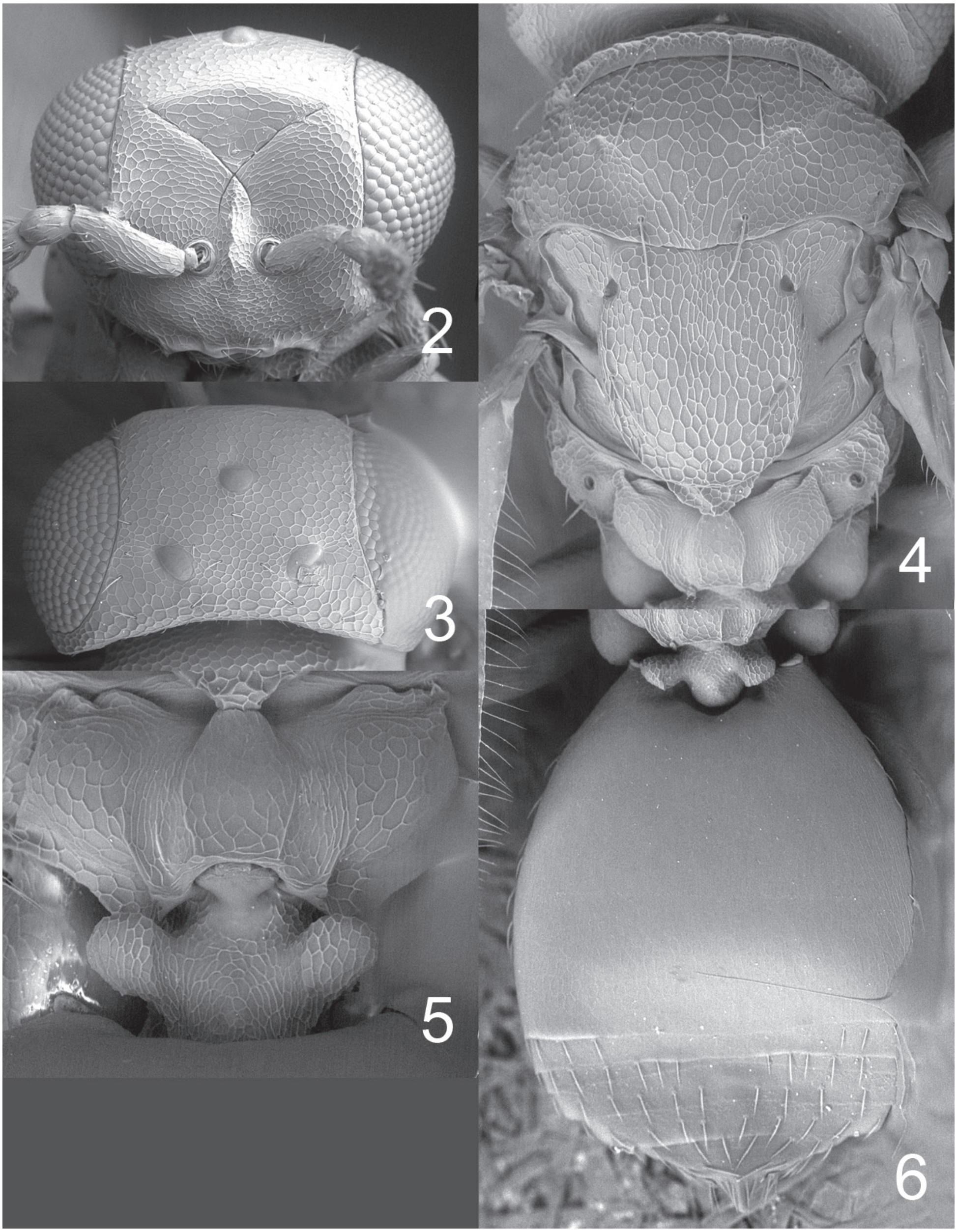
Ratios. DE/DO 6.9; WH/DE 1.9; HE/MS/WM 2.4/1.0/2.0; POL/OOL/POO 2.5/1.0/1.1; WH/WT 1.2; LW/LM/HW 1.8/1.0/1.0; PM/ST 1.4; LC/WC 1.4; WG/WC 2.0; LS/LT 0.22; MM/LG 1.0.

Male. Unknown.

Etymology. Named after the feeding habits of the larva (from the Greek *myrmecophagus* = ant eater).

Distribution. Mexico (Chiapas).

Biology. *Horismenus myrmecophagus* is a gregarious endoparasitoid of the larvae of *Camponotus* sp. ca. *textor*, a neotropical weaver ant. Parasitized host larvae spin a cocoon before their development is arrested, but no pupation occurs. Parasitized ant larvae are



Figures 2–6. *Horismenus myrmecophagus* female: **2** head in frontal view **3** vertex **4** thoracic dorsum **5** propodeum **6** gaster in dorsal view.

not modified in external form or color by the developing parasitoids, but changes in appearance were observed in the host at the end of the wasp larval development. In material preserved in alcohol, late instar larvae, pupae and teneral adults of the wasps can be readily observed inside ant larvae, within the host cocoon, but earlier developmental stages of the parasitoids could not be detected. The wasp larvae pupate inside the host larva. *Horismenus* individuals occupy almost the entire body of the host. Wasp pupae were found aligned on either part of the middle of the body of the host, their heads converging to the center, while the cephalic and caudal portions of the host larva were occupied by the host remains and the parasitoids meconia (Fig. 1). An average of 6.7 individuals developed per host (range: 4–12, mode: 7, n=27 parasitized cocoons examined). Adults emerge from the host cocoon through a unique, common hole pierced in the host larval cuticle and through the cocoon wall, but it is unknown whether adult wasps leave the nests to mate. Only females have been observed to date (all broods examined, where the sex of the parasitoid could be ascertained, were constituted by females (n=10 parasitized hosts)). The facts that only single sex broods parasitize any one host, and that only females are known, suggest that *H. myrmecophagus* is a thelythokous species. Large ant larvae (presumably queens) have never been observed to be parasitized.

Camponotus sp. ca. *textor* (until now referred to in the literature as *C. senex textor* Forel) is a common, dominant ant in shade coffee plantations in the Soconusco Region of Chiapas, Mexico (Philpott 2005). This species builds aerial nests on various native and introduced trees (*Inga* sp., *Citrus reticulata, C. sinensis*) with the silk of their larvae. Nests measure up to 40 cm in diameter, and colonies may comprise up to 30.000 individuals (Pérez-Lachaud and Lachaud, unpublished data).

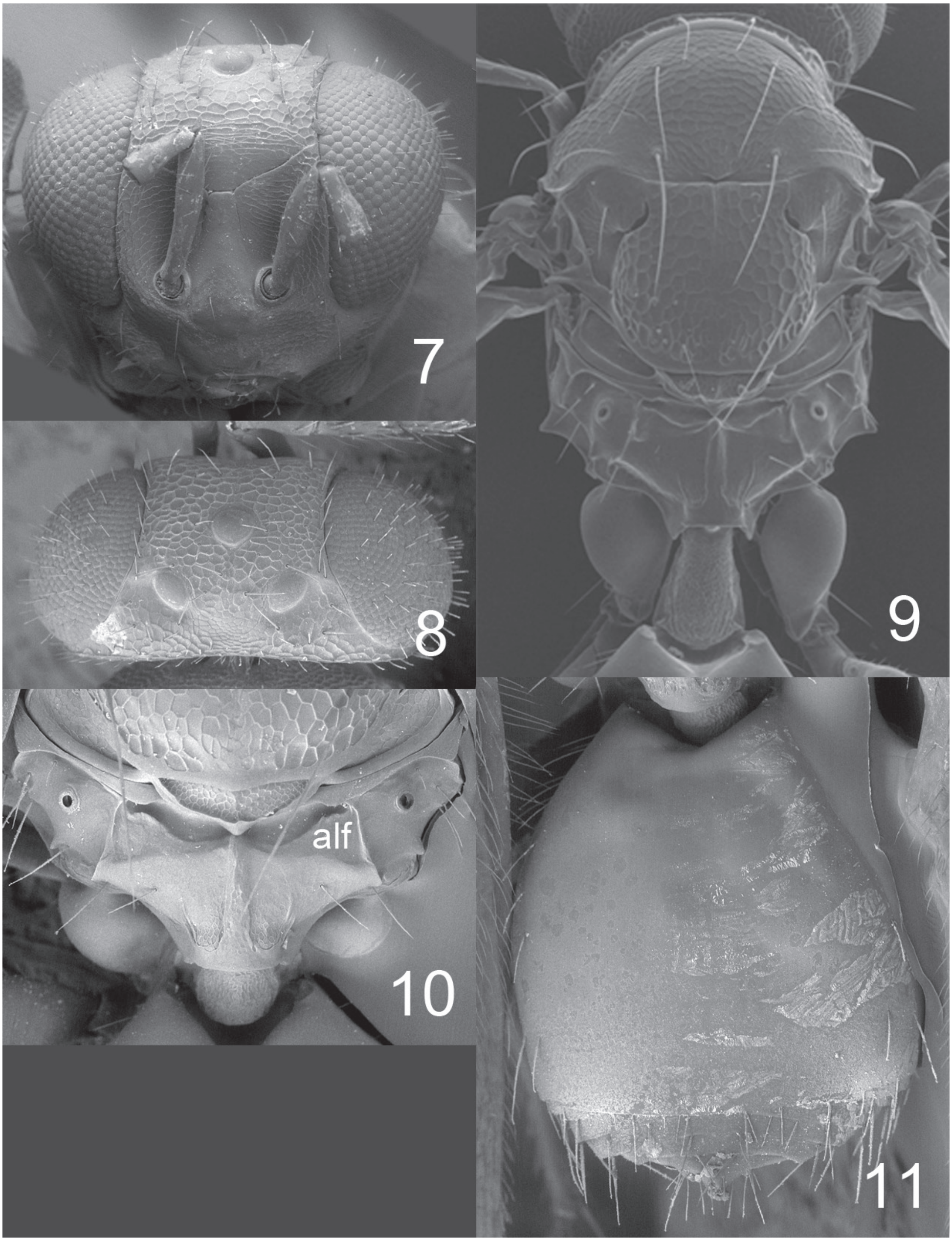
The host range of *H. myrmecophagus* is unknown. It is possible that this species may attack other ant species occupying similar niches, given that certain species of *Horismenus* are known to be polyphagous (e.g. *H. aeneicollis*, *H. apantelivorus*, *H. opsiphanis* or *H. sardus*, see Hansson 2009a), and that other ants are known to be parasitized by eulophids in the type locality (e.g. *Pachycondyla crenata* (Roger), A. de la Mora personal comment), and in French Guiana (e.g. *Camponotus* (*Dendromyrmex*) sp., G. Pérez-Lachaud and J.-P. Lachaud, unpublished data), though their identity has not been confirmed yet.

Remarks. The similar species *H. alienus* is known only from the female and its host/biology is unknown, but due to its morphological similarity to *H. myrmecophagus* it is possible that *H. alienus* is also a parasitoid of ants.

Horismenus microdonophagus sp. n.

urn:lsid:zoobank.org:act:1848E913-005D-48C1-8431-870D4FACB80F
http://species-id.net/wiki/Horismenus_microdonophagus
Figures 7–11, 18–19, 22, 25–27

Material. HOLOTYPE female (BMNH) glued to a card, labelled “MEXICO: Chiapas, Tuxtla, Chico, Rosario Izapa, 14°58’25”N 92°09’19”W, 430 m, 28.ii.2010, G. Pérez-Lachaud & J.-P. Lachaud, reared from larva of *Microdon* sp., predator inside *Camponotus* sp. ca. *textor*, nest no. 3”. PARATYPES. 10 ♀ 2♂ with same label data as holotype (4 ♀ 1♂ in BMNH, 1♀ in CH, 5♀ 1♂ in ECO-CH-AR).



Figures 7–11. *Horismenus microdonophagus* female: **7** head in frontal view **8** vertex **9** thoracic dorsum and petiole **10** propodeum **11** gaster in dorsal view. Abbreviation alf = anterolateral fovea.

Diagnosis. Fore wing speculum covered with setae (Fig. 22); scutellum transverse, 0.75X as long as wide, entirely reticulate with raised and strong reticulation and with a narrow median groove in anterior half (Fig. 9); propodeum with a median carina but without submedian grooves (Fig. 10). This species is easy to recognize through these diagnostic features.

Description. *Female*. Length 2.0 mm. Scape yellowish–brown, pedicel pale brown, flagellum dark brown. Frons dark golden–green (Fig. 25). Vertex golden–red. Mesoscutum golden–red with posterior 2/3 of midlobe metallic bluish–green (Fig. 26), to predominantly metallic bluish–green or golden–green. Scutellum golden with a median spot metallic bluish–green (Fig. 26), to predominantly metallic bluish–green. Propodeum metallic purple (Fig. 26). Coxae black to dark brown with golden–green tinges; femora, tibiae and tarsi yellowish–brown. Wings hyaline. Petiole black, shiny. Gaster metallic dark purple.

Antenna as in Fig. 18. Frons (Fig. 7) with interscrobal and clypeal areas and part just above frontal suture smooth, remaining parts with raised and strong reticulation with small meshes; frontal suture V–shaped, incomplete not reaching eyes; antennal scrobes join with frontal suture separately. Vertex (Fig. 8) with raised and strong reticulation, areas just behind posterior ocelli smooth; posterior part without median groove. Occipital margin rounded (Fig. 8).

Mesoscutum and scutellum with raised and strong reticulation (Fig. 9); notauli as indistinct impressions, forming posterior part of midlobe to an indistinct triangle. Dorsellum concave with raised and strong reticulation. Propodeum smooth (Fig. 10) or with raised and weak reticulation; median carina narrow and weak; propodeal callus with 5–7 setae and with 2–3 additional setae on median part of propodeum. Coxae smooth. Fore wing speculum absent or very small, obliterated by setae (Fig. 22); with 15 admarginal setae.

Gaster (Fig. 11) with first tergite smooth and shiny with a very weak reticulate band close to posterior margin.

Ratios. DE/DO 4.2; WH/DE 2.4; HE/MS/WM 2.7/1.0/1.4; POL/OOL/POO 3.1/1.0/1.6; WH/WT 0.9; LW/LM/HW 1.9/1.2/1.0; PM/ST 1.7; LC/WC 4.0; WG/WC 1.5; LS/LT 0.32; LP/WP 1.5; MM/LG 1.3–1.4.

Male. Length 1.6 mm. The male is similar to the female except: scape inflated (Fig. 19) and dark brown, slightly longer petiole and shorter gaster.

Ratios. HE/MS/WM 2.4/1.0/1.2; LP/WP 1.6; MM/LG 1.6.

Etymology. Named after the feeding habits of larvae (from the Greek *microdonophagus* = eater of *Microdon*).

Distribution. Mexico (Chiapas).

Biology. *Horismenus microdonophagus* is a gregarious endoparasitoid of *Microdon* larvae (Diptera: Syrphidae), a predator on the brood of *Camponotus* sp. ca. *textor*. One *Microdon* sp. larva that was about to pupate was found inside a *Camponotus* nest. From this single host 79 females and 6 males of *H. microdonophagus* emerged.

Remarks. One of the two males has the flagellum of both antennae missing, as have also some of the female paratypes, and the other male has the entire right flagellum and apical two flagellomeres of the left antenna missing. Only specimens in fair condition were included in the description, i.e. are type material. The remaining specimens were too fragmented to be included.

Genus *Microdonophagus* Schauff

This is an exclusively Neotropical genus recorded from Brazil, Colombia, Costa Rica and Panama (Schauff 1986, Hansson 2002, 2009b). It now includes three species but only in one species, *M. woodleyi*, is the biology known. This species is a gregarious endoparasitoid in larvae of *Microdon* sp. (Diptera: Syrphidae) living in nests of *Technomyrmex fulvum* (Formicidae: Dolichoderinae) (Schauff 1986). The same species also shows distinct sexual dimorphism, female being "normal" but male having several derived characters such as small eyes, reduced wings, and strongly inflated femora (Schauff 1986). Males are not known for the other two species.

Microdonophagus tertius Hansson sp. n.

urn:lsid:zoobank.org:act:5DB16050-0C5D-41AE-A2EA-6D16981D2E2C
http://species-id.net/wiki/Microdonophagus_tertius
Figures 12–16, 20, 28

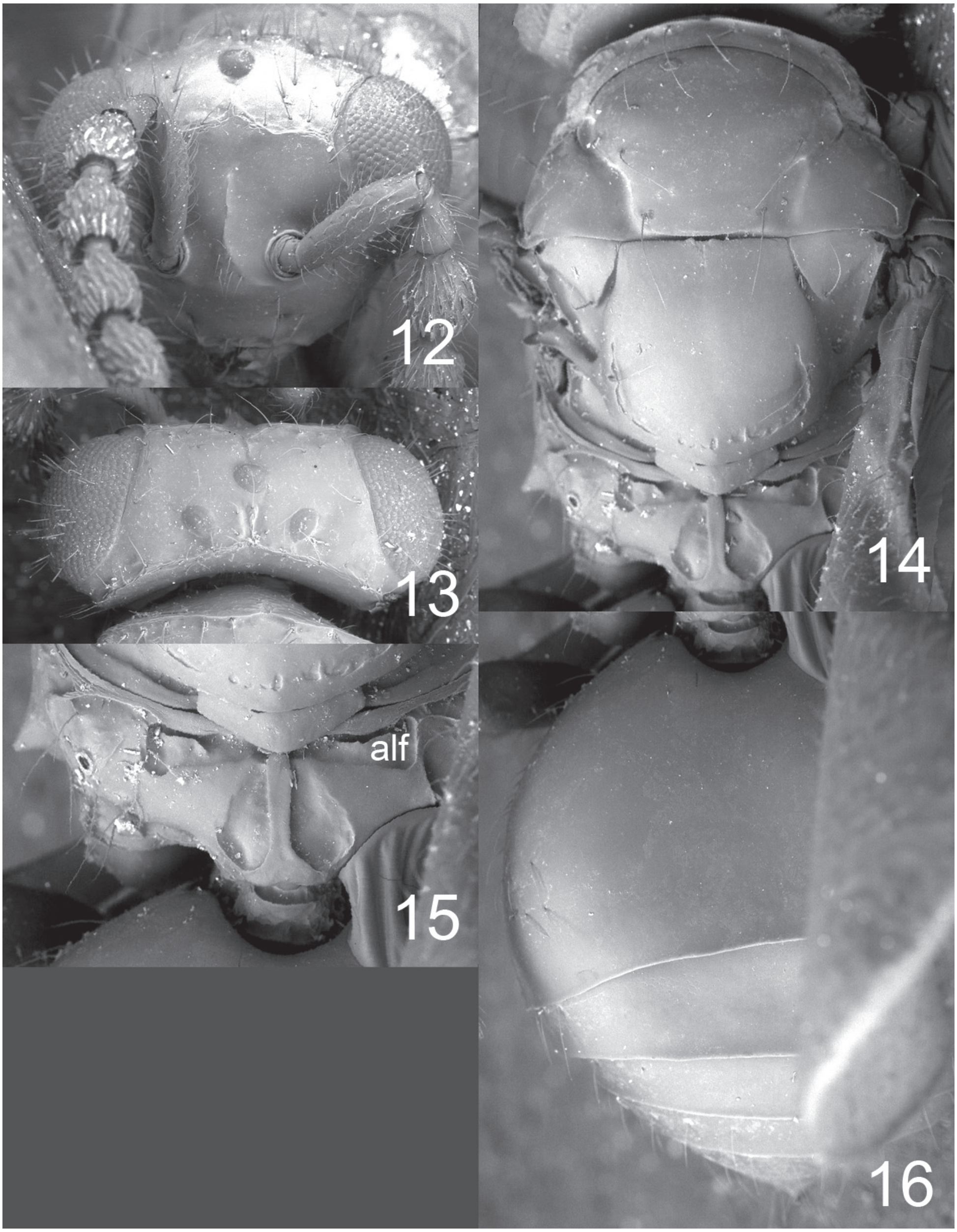
Material. HOLOTYPE female (BMNH) glued to a card, labelled "COSTA RICA, Puntarenas, Parque Nacional Corcovado, Mosokha, Quebrada Hedionda, 15.iii–15.iv.2003, Khanaki."

Diagnosis. This species is similar to *M. levis* Hansson (Hansson 2009b) in its smooth and shiny thoracic dorsum but differs from the latter in several characters: scutellum without median groove (Fig. 14); propodeum with a narrow median carina and with distinct anterolateral foveae (Fig. 15); lower mesepimeron enlarged (Fig. 28) but not as enlarged as in *M. levis* (Fig. 29).

Description. *Female*. Length 2.0 mm. Scape yellowish–brown, pedicel and flagellum pale brown. Head and body including gaster dark brown and shiny. Coxae pale brown; femora, tibiae and tarsi yellowish–brown. Wings hyaline.

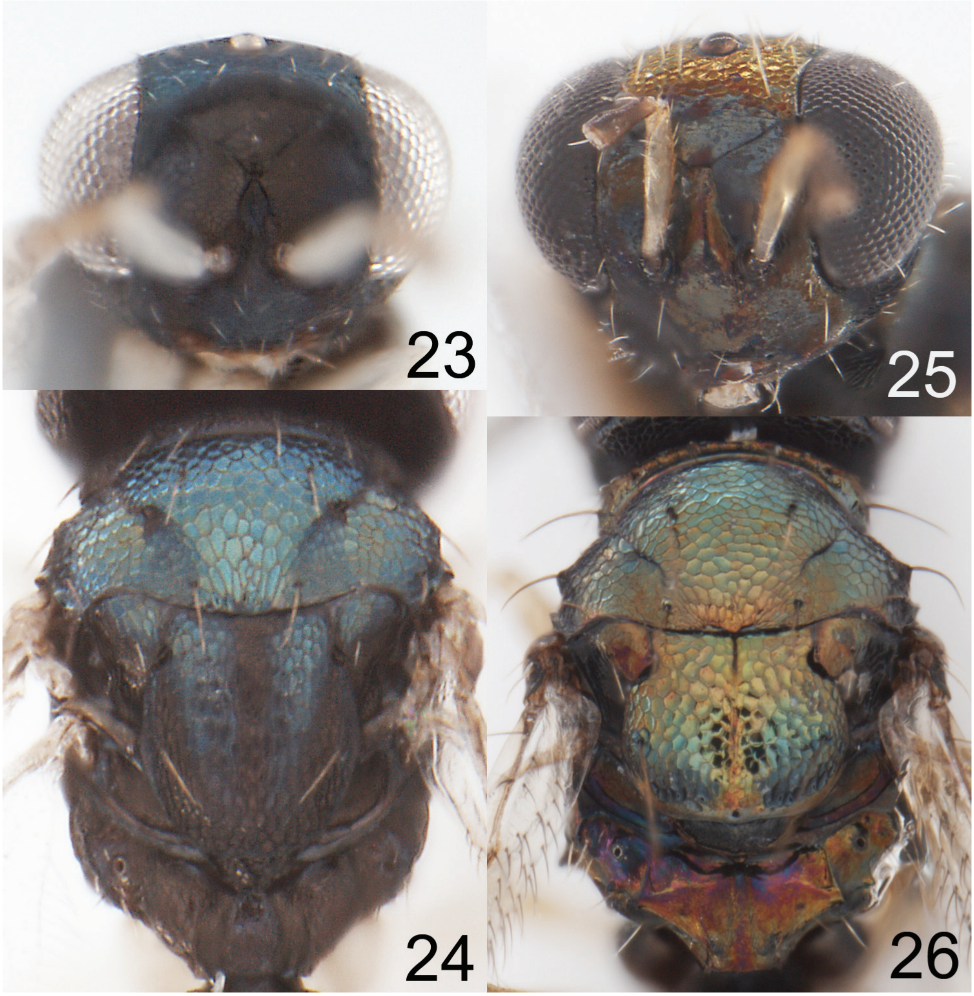
Flagellum without anelli, with three funicular segments and a two-segmented clava (Fig. 20). Frons smooth and shiny (Fig. 12), without antennal scrobes and frontal suture, with a narrow and sharp process (an interantennal crest) between toruli. Vertex smooth and shiny (Fig. 13). Occipital margin sharp (Fig. 13). Eyes with scattered long hairs (longer than in *M. levis*).

Mesoscutum smooth and shiny (Fig. 14); midlobe with two pairs of setae; notauli as distinct grooves throughout. Scutellum smooth and shiny (Fig. 14); with one pair of setae; with sublateral grooves in posterior half. Propodeum with a narrow median carina (Fig. 15); with wide sublateral grooves; with distinct anterolateral foveae; propodeal callus with about eight setae; propodeal surface smooth. Fore wing with four setae (right fore wing) and six setae (left fore wing) respectively on dorsal surface of submarginal vein; costal cell bare; speculum small and closed below; postmarginal vein not visible.



Figures 12–16. *Microdonophagus tertius* female: **12** head in frontal view **13** vertex **14** thoracic dorsum **15** propodeum **16** gaster in dorsal view. Abbreviation alf = anterolateral fovea.

Figures 17–22. 17–20 antenna in lateral view: **17** *Horismenus myrmecophagus* female **18** *H. microdonophagus* female **19** *H. microdonophagus* male (apical 2 flagellomeres missing) **20** *Microdonophagus tertius* female. **21–22** right fore wing female: **21** *H. myrmecophagus* **22** *H. microdonophagus.*



Figures 23–26. 23–24 *Horismenus myrmecophagus* female: **23** head in frontal view **24** thoracic dorsum. **25–26** *Horismenus microdonophagus* female: **25** head in frontal view **26** thoracic dorsum.

Petiole hidden behind inflated gaster but appears to be about as long as wide, dorsal surface with strong sculpture. Gaster circular; gastral tergites smooth (Fig. 16).

Ratios. HE/MS/WM 1.7/1.0/1.3; POL/OOL/POO 6.0/4.4/1.0; WH/WT 1.0; LW/LM/HW 1.7/1.0/1.0; LP/WP ca 1; MM/LG 1.0.

Male. Unknown.

Etymology. From the Latin *tertius* = third. Named for this being the third species described in the genus.

Distribution. Costa Rica.

Biology. Unknown, but possibly associated with ants, as is the type species of *Microdonophagus*, *M. woodleyi*.

Microdonophagus woodleyi Schauff

http://species-id.net/wiki/Microdonophagus_woodleyi
Figure 30

Microdonophagus woodleyi Schauff, 1986: 170–172. Holotype female in USNM.

Distribution. Brazil (new record, 1♀ from Santa Catarina, Nova Teutonia, 7.iv.1938, F. Plaumann, in BMNH), Colombia (Hansson 2002), Panama (Schauff 1986).

Identification

Horismenus and *Microdonophagus* can be identified using the matrix key to Entedoninae genera on the website http://www.neotropicaleulophidae.com/. These two genera share certain characters that indicate that they are sister-groups: multiporous plate sensilla on flagellomeres with upper surface concave; propodeum with median carina, submedian grooves and anterolateral foveae. However, they also possess characters that show that each genus is a distinct monophyletic group:

Horismenus	*Microdonophagus*
Antennal spicule with apical seta	Antennal spicule with apical peg (apomorphy)
Antennal scrobes as grooves	Antennal scrobes not visible (apomorphy)
Frontal suture as groove	Frontal suture not visible (apomorphy)
Axillar fovea present (apomorphy)	Axillar fovea missing
Lower mesepimeron normal	Lower mesepimeron enlarged (apomorphy)

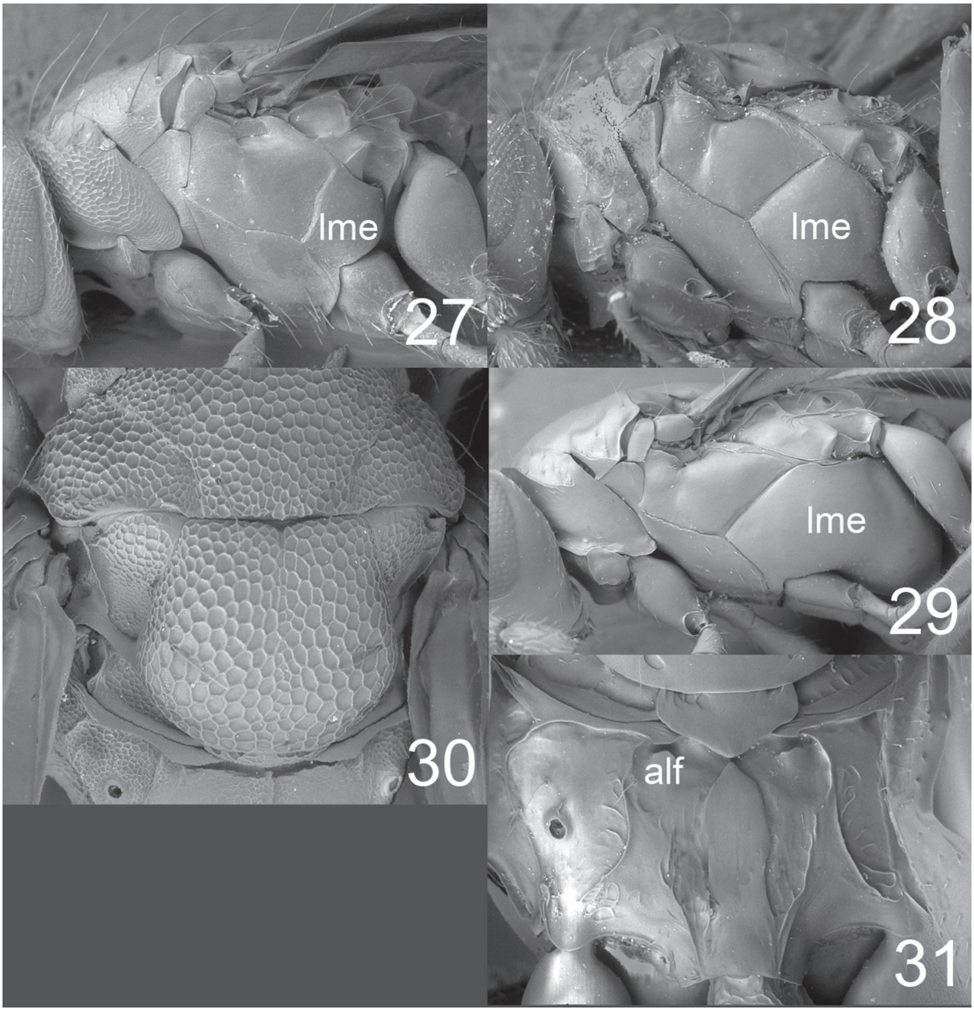
Species identification. (using modifications of the key in Hansson (2009a) below, but interactive keys on the website http://www.neotropicaleulophidae.com/, can also be used).

Horismenus myrmecophagus females run to subkey B and from there to couplet 5, first alternative, where *H. myrmecophagus* is differentiated from *H. alienus* as indicated above under diagnosis for *H. myrmecophagus*.

Horismenus microdonophagus females run to subkey D and from there to couplet 8 where the second alternative is chosen and this leads to 9a instead of 9, and then:

9a Fore wing speculum small (Fig. 22) *and* propodeum with a complete median carina (Fig. 10) .... ***H. microdonophagus* sp. n.**
– Fore wing speculum large, *or* median carina on propodeum mainly obliterated by reticulation **9**

Horismenus microdonophagus males are difficult to include in the key because the antennal clava is missing. However, the combination of strongly inflated scape, transverse scutellum that is completely reticulate, small fore wing speculum, and propo-



Figures 27–31. 27–29 mesosoma in lateral view females: **27** *Horismenus microdonophagus* **28** *Microdonophagus tertius* **29** *M. levis* Hansson **30** *M. woodleyi* Schauff, part of thoracic dorsum with scutellum. **31** *M. levis*, propodeum. Abbreviations alf = anterolateral fovea; lme = lower mesepimeron.

deum without submedian grooves make males of this species easy to recognize (true also for females).

Key to all species of *Microdonophagus*

1 Scutellum with raised and strong reticulation (Fig. 30) .... ***M. woodleyi* Schauff (female)**
– Scutellum predominantly smooth and shiny (Fig. 14)................................**2**

2 Lower mesepimeron (lme) strongly enlarged (Fig. 29); propodeum with indistinct anterolateral foveae (alf) (Fig. 31)......................... ***M. levis* Hansson**

– Lower mesepimeron (lme) smaller (Fig. 28); propodeum with distinct anterolateral foveae (alf) (Fig. 15).. ***M. tertius* sp. n.**

Discussion

Parasitization of ants is uncommon among Eulophidae and a survey of published literature showed that only four (possibly just three) eulophid genera, all Entedoninae, are recorded as parasitoids of ants. Apart from *Horismenus* (*H. floridensis* (Schauff and Bouček 1987), and *H. myrmecophagus* sp. n. (this article)), only an unidentified genus, possibly close to *Paracrias* (Wheeler and Wheeler 1924), the monotypic genus *Myrmokata* (Bouček 1972), and *Pediobius* (Kerrich 1973) have been undoubtedly associated as parasitoids of ants. The record in Wheeler and Wheeler (1924) is "apparently closely related to the genus *Paracrias* Ashmead, but I cannot identify it positively, even generically", attempt for identification and remark by A.B. Gahan. *Paracrias* spp. apparently exclusively target the order Coleoptera (Hansson 2002, Pikart et al. 2011), so *Paracrias* seems an unlikely candidate as a parasitoid of ants. The concepts of the genera *Paracrias* and *Horismenus* – which have morphological features in common (Hansson 2002) – were unclear at the time (1924) of the identification, so possibly this record actually also concerns a *Horismenus* species. Parasitism of ants is suspected but not verified for *Myrmobomyia* (Gumovsky and Bouček 2005), also an entedonine Eulophidae.

Systematic surveys of macro- and microfauna biodiversity directly within ant colonies are lacking (Hugues et al. 2008), especially in the Neotropics, and the hosts of most species of described eulophids are unknown. Parasitization of *C.* sp. ca. *textor* colonies by *H. myrmecophagus* is very low (less than 1% of ant pupae, Pérez-Lachaud and Lachaud, unpublished data). The very low prevalence of these myrmecophiles within ant nests, and the absence of targeted sampling methods to access their full biodiversity, may account for the rarity of records of eulophids associated with ants. The fact that in this single study two species of eulophids were recorded associated with ants stresses the likelihood that other eulophid species may also be associated with ants.

One hypothesized evolutionary path to parasitism of nest-building Hymenoptera, e.g. ants, by Hymenoptera parasitoids is via their non-hymenopterous symbionts, and then at some point in time a host shift has occurred (Hanson et al. in Hanson and Gauld 1995), as possibly exemplified by the two *Horismenus* species described here. We know nothing about the phylogenetic relationship between these two species but it would be interesting to know if *H. myrmecophagus* evolved after *H. microdonophagus*, thus possibly supporting this hypothesis.

Acknowledgements

We thank J.H.C. Delabie (Laboratório de Mirmecologia, CEPEC/CEPLAC, Itabuna-BA, Brazil) for confirming the identification of the ant host. We also acknowledge the Department of Biology, Lund University for the use of their SEM facility.

References

Bouček Z (1972) Descriptions of new Eulophid parasites (Hym., Chalcidoidea) from Africa and the Canary Islands. Bulletin of Entomological Research 62: 199–205. doi: 10.1017/S0007485300047647

Bonet A (2008) New hosts, host plants, and distribution records for *Horismenus* (Hymenoptera: Eulophidae) species in a bruchid beetle parasitoid guild attacking wild type *Phaseolus coccineus* and *P. vulgaris* in Central Mexico. Florida Entomologist 91: 698–701.

Gumovsky A, Bouček Z (2005) A new genus of Entedoninae from Malaysia, associated with ant nests (Hymenoptera, Eulophidae). Entomological Problems 35: 39–42.

Hanson PE, West-Eberhard MJ, Gauld ID (1995) Interspecific interactions of nesting Hymenoptera, pp. 76–88. In: Hanson PE, Gauld ID (Eds) The Hymenoptera of Costa Rica, Oxford University Press, Oxford, 893 pp.

Hansson C (2002) Eulophidae of Costa Rica, 1. Memoirs of the American Entomological Institute 67: 1–290.

Hansson C (2009a) Eulophidae of Costa Rica 3: Genus *Horismenus*. Memoirs of the American Entomological Institute 82: 1–916.

Hansson C (2009b) The genus *Microdonophagus* Schauff (Hymenoptera: Eulophidae), with description of a new species. Zootaxa 2200: 54–60.

Heraty JM (2002) A revision of the genera of Eucharitidae (Hymenoptera: Chalcidoidea) of the world. Memoirs of the American Entomological Institute 68: 1–367.

Hugues DP, Pierce NE, Boomsma JJ (2008) Social insect symbionts: evolution in homeostatic fortresses. Trends in Ecology and Evolution 23: 672–677. doi: 10.1016/j.tree.2008.07.011

Hölldobler B, Wilson EO (1990) The Ants. Springer-Verlag, Berlin-Heidelberg, 732 pp.

Kerrich GJ (1973) A revision of the tropical and subtropical species of the eulophid genus *Pediobius* Walker (Hymenoptera: Chalcidoidea). Bulletin of the British Museum (Natural History) (Entomology) 29: 115–199.

Kistner DH (1982) The social insects' bestiary, pp. 1–244. In: Hermann HR (Ed) Social Insects, vol. 3. Academic Press, New York, 459 pp.

Pérez G, Bonet A (1984) Himenópteros parasitoides de *Acanthoscelides obtectus* (Say) (Coleoptera: Bruchidae) en Tepoztlán, Morelos. Folia Entomológica Mexicana 59: 71–78.

Philpott SM (2005) Changes in arboreal ant populations following pruning of coffee shade-trees in Chiapas, Mexico. Agroforestry Systems 64: 219–224. doi: 10.1007/s10457-004-2372-2

Pikart TG, Souza GK, Costa VA, Hansson C, Zanuncio JC (2011) *Paracrias pluteus* (Hymenoptera: Eulophidae) in Brazil: new distribution and host records, and with a new host group for *Paracrias.* Zookeys 102: 77–82. doi: 10.3897/zookeys.102.1343

Rettenmeyer CW, Rettenmeyer ME, Joseph J, Berghoff SM (2011) The largest animal association centered on one species: the army ant *Eciton burchellii* and its more than 300 associates. Insectes Sociaux 58: 281–292. Supplemental material (doi: 10.1007/s00040–010–0128–8).

Schauff ME (1986) *Microdonophagus*, a new entedontine genus (Hymenoptera: Eulophidae) from Panama. Proceedings of the Entomological Society of Washington 88: 167–173.

Schauff ME, Bouček Z (1987) *Alachua floridensis*, a new genus and species of Entedoninae (Hymenoptera: Eulophidae) parasitic on the Florida carpenter ant, *Camponotus abdominalis* (Formicidae). Proceedings of the Entomological Society of Washington 89: 660–664.

Wheeler GC, Wheeler EH (1924) A new species of *Schizaspidia* (Eucharitidae), with notes on a eulophid ant parasite. Psyche 31: 49–56.

Wheeler GC, Wheeler JN (1986) The ants of Nevada. Natural History Museum of Los Angeles County, Los Angeles, 138 pp.

Wilson EO (1971) The Insect Societies. The Belknap Press of Harvard University Press, Cambridge, Mass., 548 pp.

ZooKeys 134: 83–98 (2011)
doi: 10.3897/zookeys.134.1677
www.zookeys.org

REVIEW ARTICLE

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

The indigenous honey bees of Saudi Arabia (Hymenoptera, Apidae, *Apis mellifera jemenitica* Ruttner): Their natural history and role in beekeeping

Abdulaziz S. Alqarni[1], Mohammed A. Hannan[2], Ayman A. Owayss[1], Michael S. Engel[1,3,4]

1 *Department of Plant Protection, College of Food and Agriculture Sciences, King Saud University, Riyadh 11451, PO Box 2460, KSA* **2** *Department of Environmental Sciences, University of Guelph, Guelph, Ontario, Canada N1G 2W1 Current Address: Department of Plant Protection, College of Food and Agriculture Sciences, King Saud University, Riyadh 11451, PO Box 2460, KSA* **3** *Division of Entomology, Natural History Museum, and Department of Ecology & Evolutionary Biology, 1501 Crestline Drive – Suite 140, University of Kansas, Lawrence, Kansas 66049-2811, USA* **4** *Division of Invertebrate Zoology, American Museum of Natural History, Central Park West at 79th, New York, New York 10024-5192, USA*

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

Academic editor: *Michael Ohl* | Received 8 June 2011 | Accepted 16 August 2011 | Published 6 October 2011

Citation: Alqarni AS, Hannan MA, Owayss AA, Engel MS (2011) The indigenous honey bees of Saudi Arabia (Hymenoptera, Apidae, *Apis mellifera jemenitica* Ruttner): Their natural history and role in beekeeping. ZooKeys 134: 83–98. doi: 10.3897/zookeys.134.1677

Abstract

Apis mellifera jemenitica Ruttner (= *yemenitica auctorum*: *vide* Engel 1999) has been used in apiculture throughout the Arabian Peninsula since at least 2000 BC. Existing literature demonstrates that these populations are well adapted for the harsh extremes of the region. Populations of *A. m. jemenitica* native to Saudi Arabia are far more heat tolerant than the standard races often imported from Europe. Central Saudi Arabia has the highest summer temperatures for the Arabian Peninsula, and it is in this region where only *A. m. jemenitica* survives, while other subspecies fail to persist. The indigenous race of Saudi Arabia differs from other subspecies in the region in some morphological, biological, and behavioral characteristics. Further taxonomic investigation, as well as molecular studies, is needed in order to confirm whether the Saudi indigenous bee populations represent a race distinct from *A. m. jemenitica*, or merely an ecotype of this subspecies.

Keywords

Apoidea, Anthophila, Apidae, *Apis mellifera jemenitica*, indigenous honey bee race, beekeeping, morphology, Arabian Peninsula, Saudi Arabia, natural history

Introduction

It is somewhat ironic that most domesticated animals are often overlooked for basic research into their natural history and systematics. This is certainly true for honey bees (*Apis* Linnaeus), where despite millennia of domestication and centuries of intensive biological research the systematics of the species and infraspecific varieties, along with the critical biological attributes of these populations, remains confused (e.g., *vide* Engel 1999 for an overview of the complicated taxonomic history of species of *Apis*). Naturally, we know more about honey bee biology than any other group of Apoidea but this voluminous literature exists despite the existence of significant challenges to the basic systematics, taxonomy, identification, and population variation of the more variable species such as *Apis cerana* Fabricius and *A. mellifera* Linnaeus (although significant strides are being made; e.g., Hepburn and Radloff 1998, 2011; Radloff et al. 2010, 2011; Meixner et al. 2011).

Perhaps the region most needing investigation today is the fauna of the Arabian Peninsula, along with its neighboring regions. Herein we provide a brief overview of the history of beekeeping in Saudi Arabia, research on the indigenous bee populations, and the available natural history information for these unique honey bees. It is hoped that such a review, highlighting the unique attributes of these honey bees, will further the efforts of systematic, taxonomic, ecological, and apicultural research in the region and thereby provide a stronger foundation to the melittological and apicultural communities in Saudi Arabia.

History of *Apis* and Arabian beekeeping

Today's honey bees diverged from their primitive relatives among the Electrapini, or stem-group Electrapini+Apini, perhaps as long ago as the Eocene-Oligocene transition (ca. 35 Ma) or latest Eocene (ca. 40 Ma) (Engel 1998, 2001a, 2001b, 2006; Engel et al. 2009). The earliest records of fossils definitively attributable to the genus *Apis* are from the Early Oligocene of Europe, about 35 Ma (Zeuner and Manning 1976; Engel 1998, 1999). Indeed, these earliest honey bees, such as *Apis henshawi* Cockerell and *A. vetusta* Engel superficially resemble to a large degree modern workers of *A. mellifera* L. (Engel 1998; Kotthoff et al. 2011). During the Oligocene and particularly the Miocene, honey bees exhibited significant morphological variability within populations, extended their distributions into Asia, Africa, and even the New World (Engel et al. 2009), and diversified into the principal lineages (i.e., subgenera) we recognize among modern species of *Apis* (Engel 2006; Engel et al. 2009; Kotthoff et al. 2011). By the origin of modern humans, honey bee diversification had already taken place and their varieties had well established populations and it was not long before early groups of *Homo sapiens* L. began to exploit the resources species of *Apis* had been producing for millions of years.

While beekeeping is at least 4500 years old and honey hunting (i.e., relying solely on feral colonies rather than domesticated hives and therefore not true "beekeeping") even more ancient, dating to at least 6000 BC (Galton 1971; Dams 1978; Crane 1983, 1990, 1999), the record from Arabia is not quite as extensive. In ancient Egypt beekeeping was practiced as early as 2500 BC (Crane and Graham 1985; Crane 1999) and in Greece the practice was diversified by at least the Minoan period (Crane 1999). During this early phase of beekeeping, bees were kept in earthen pots, cylinders, or logs which were placed horizontally and either hung or stacked. The history of beekeeping in the Arabian Peninsula dates back to ca. 2000 BC. An earthen painting found in Iraq depicts honey as a remedy for diseases (Crane 1983), and writers of antiquity often mentioned the riches of the beekeeping industry in the region. For example, Blinos (79 AD) noted that, "Arabia Felix wealth outperformed the whole world, as its lands had perfumed jungles, gold mines, irrigating water and produced a lot of honey and wax" (Tarcīci 1968). Similarly, Strabo (64 BC–24 AD) considered honey as one of the prominent products of "Arabia Felix", indicating in his *Geographica*, "the far western parts, towards Ethiopia, were irrigated by summer rainfall and cultivated twice a year, and honey was one of its numerous yields and was enormously abundant" (Jones 1930 [Strabo Book 16-3]). Clusters of the oldest apiaries in the region can be found in Taif, southwestern Saudi Arabia. According to apiary owners these were built in the mountain around 500 years ago (Figs 1–2). Cylinder log hives were kept in elongate cells of the rock face so as to protect them from possible attacks by rival tribes.

Early Arabic literature reveals that Arabs in the Arabian Peninsula recognized and kept bees for honey production. They called bee hives "kawarah", which means a habitation made of stalks, mud, or a wooden cavity. They also named apiaries as "masane'a", meaning "factories", which were kept at isolated sites away from human habitation (Al-Zabīdī 1888/1889). The Arabs also recognized the individual castes of the colony such as the queen (termed "the prince") and drones ("the biggest and darkest ones that stay in the nest, eat honey, and not produce it": Al-Zabīdī 1888/1889). In addition, they made detailed descriptions of swarming behavior and the various developmental stages such as eggs and larvae (Al-Zabīdī 1888/1889). Furthermore, they recognized bee plants such as *Schanginia hortensis* (Forssk. ex J.F. Gmel.) Moq. [Amaranthaceae], *Blepharis ciliaris* (L.) B.L. Burtt. [Acanthaceae], *Lavandula* spp. [Lamiaceae], *Ziziphus* spp. [Rhamnaceae], *Acacia asak* (Forssk.) Willd. [Fabaceae (a.k.a., Leguminosae)], *Acacia senegal* (L.) Willd. [Fabaceae (a.k.a., Leguminosae)], and *Anisotes trisulcus* (Forssk.) Nees [Acanthaceae]. Faith and interest in honey and honey bees increased greatly in the Arabian Peninsula after one chapter in The Holy Quran was entitled "Al-Nahl – The Bees", in which honey was mentioned as "a curative for mankind".

The modern era of beekeeping was initiated over 150 years ago. The development of the Langstroth bee hive in 1851 boosted the beekeeping industry (Langstroth 1853), and since that time significant advances have continued to be made in methods of boxing of bees, creating apiaries, observing hives, treating pathologies, &c. Some of these advances included methods of queen rearing which were restricted to a single type between 1850–1890 (Pellett 1938) but have explosively diversified over the last century, particularly with the advent of successful means of artificial insemination (Watson 1928; Laidlaw 1944; Mackensen and Roberts 1948), thereby permitting the

Figures 1–4. Bees and beekeeping in Saudi Arabia. **1** A historical apiary with traditional hives of Saudi *Apis mellifera jemenitica* Ruttner maintained over 500 years by the same family in Taif (there are many such apiaries in the area, with beekeepers maintaining these as a family tradition over numerous generations; honey from such apiaries is much costlier than those managed in Langstroth hives) **2** Entrance to a hive of *A. m. jemenitica* in Taif **3** A traditional log hive of *A. m. jemenitica* in Taif **4** Photograph showing size and other morphological differences between *A. m. jemenitica* and *A. m. carnica* Pollmann.

more rapid and effective development of novel strains, e.g., genetic lines developed bees high brood production, greater honey yields, selectivity for sugar solutions, resistance to viral diseases, etc. (e.g., Cale and Gowen 1956; Nye and Mackensen 1968; Kulinčević and Rothenbuhler 1975). Naturally, these and many other advances are employed widely in Saudi Arabia, although many traditional and often ancient beekeeping practices are simultaneously in widespread use (e.g., Figs 1–3).

Races of honey bees (*Apis mellifera*)

Engel (1999) reviewed and reported the presence of 28 races of *A. mellifera*, and 10 valid geographical races in Africa, although Meixner et al. (2011) recently have added an additional subspecies to this fauna. Table 1 provides an updated list of races of *A. mellifera*, including the area in which they occur. Not all are considered valid by all authors (e.g., Engel 2006). As has been noted by several authors for honey bees in general, the

Table 1. Summary of subspecies of *Apis mellifera* widely used in the apidological and apicultural literature and industry, arranged loosely by Ruttner's (1988) gross geographical areas (not all are considered valid biologically or taxonomically; e.g., Engel 1999, 2006).

Western Mediterranean
A.m. iberiensis Engel
A.m. intermissa Maa
= *major* Ruttner
A.m. mellifera Linnaeus
A.m. ruttneri Sheppard et al.
A.m. sahariensis Baldensperger
Irano-Ponto-Caspian East Mediterraean / Central Asia
A.m. adami Ruttner
A.m. anatoliaca Maa
A.m. caucasia Pollmann
A.m. cypria Pollmann
A.m. meda Skorikov
A.m. pomonella Sheppard & Meixner
A.m. remipes Gerstaecker
= *armeniaca* Skorikov
A.m. sossimai Engel
A.m. syriaca Buttel-Reepen
A.m. taurica Alpatov
Central Mediterranean-Southeastern Europe
A.m. carnica Pollmann
A.m. carpatica Barac
A.m. cecropia Kiesenwetter
A.m. ligustica Spinola
A.m. macedonica Ruttner
A.m. siciliana Grassi
= *sicula* Montagano
African-Arabian
A.m. adansonii Latreille
A.m. bandasii Amssalu
A.m. capensis Eschscholtz
A.m. lamarckii Cockerell
A.m. litorea Smith
A.m. monticola Smith
A.m. jemenitica Ruttner
= *nubica* Ruttner
A.m. scutellata Lepeletier de Saint Fargeau
A.m. simensis Meixner et al.
A.m. sudanensis El-Sarrag et al.
A.m. unicolor Latreille
A.m. woyigambella Amssalu

various subspecies are not discrete units and the utility of a subspecific classification has been challenged (e.g., Hepburn 2000; Hepburn and Radloff 1998, 2002, 2011; Radloff et al. 2010). It is well beyond the scope of the present review to tackle this issue but it must be noted and seriously addressed by the apidological research community.

Saudi beekeeping

Beekeeping in Saudi Arabia is a growing industry. The estimated numbers of beekeepers and bee hives are 4000 and 700,000, respectively, and they produce collectively about 3500 tons of honey per year, or about 26% of the required demand. As a result, approximately 10,000 tons of honey is imported annually from Europe, Iran, Turkey, Australia, the United States, and to a lesser extent from other countries. Accordingly, during the last couple of decades researchers have paid special attention to various aspects of beekeeping in the region, including critical investigations into honey bee races, the biology of native populations, queen rearing, bee pests and diseases, climatic impacts, as well as bee economics (e.g., El-Sarrag 1993; Al-Qahtani 1997; Al Ghamdi 1990, 2002, 2005, 2006; Alqarni 1995, 2006a, 2006b, 2010; Alqarni and Al-Atawi 2008; Alshehri 1999; Al-Kahtani 2003).

With an area of more than 2 million km^2, the climate of Saudi Arabia is relatively wide ranging, with temperature and rainfall representing the key factors influencing beekeeping activities. Temperatures start to increase in March–April and both are hot months but considered as merely transitional, whereas the period from May–August is extremely hot. Maximum temperatures during July are more than 40° C, and temperatures do not start declining until September–October, although both are still quite hot months. Temperatures range from moderate to very cold until February, with January being the coldest month of the year (sometimes around -7° C in the North). Annual rainfall ranges from a few millimeters in the Rubu–Alkhali desert to 600 mm in the mountainous areas of the Southwest. These variations in temperature force beekeepers to search for different foraging areas for their bees each year.

Taif, Baha, and Assir (mountainous regions) in the Southwest are the most suitable areas for keeping bees in Saudi Arabia (Fig. 5). These areas comprise 762,474 acres of forests with an altitude of 900–3700 m (Abu-Hassan et al. 1994). The most common species of trees are *Acacia* spp. [Fabaceae (a.k.a., Leguminosae)], *Olea europaea* subsp. *cuspidata* (Wall. & G.Don) Cif. [Oleaceae; often under the synonym *O. chrysophylla* Lam.], *Juniperus procera* Hochst. ex Endl. [Cupressaceae], *Hyphaene thebaica* (L.) Mart. [Arecaceae], and *Ziziphus spina-christi* (L.) Willd. [Rhamnaceae] (Al-Owdat et al. 1985). Temperatures in summer and winter in these regions ranges from 20°–28° C and 9°–14° C, respectively. During winter, beekeepers take their bees down to Tihama, a warm coastal region harboring several rich pollen plants that help beekeepers to increase the number of their hives through uncontrolled swarming. Since beekeepers follow traditional beekeeping methods, swarming is allowed to occur freely and

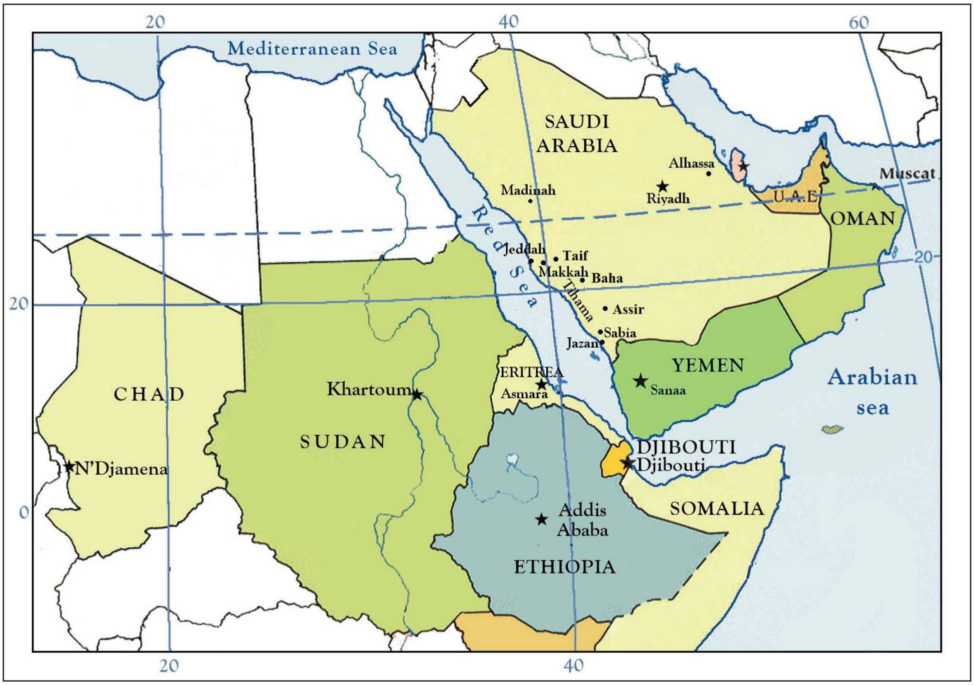


Figure 5. Distribution of *Apis mellifera jemenitica* Ruttner in the Arabian Peninsula and northeastern Africa.

more than one swarm normally leaves the hive. Unfilled traditional hives (hollow logs) marked with beeswax are distributed in the vicinity to attract swarms (Fig. 3). Other swarms are captured from trees and placed in empty hives. Most beekeepers in the Southwest perform traditional beekeeping methods, whereas Langstroth hives are used in other parts of the country. Most beekeepers perform migratory beekeeping to avoid severe weather and food deficiency. In the central region, wild nectar and pollen plants such as *Astragalus spinosus* (Forssk.) Muschl. [Fabaceae (a.k.a., Leguminosae)], *Horwoodia dicksoniae* Turrill [Brassicaceae], *Anisosciadium isosciadium* Bornm. [Apiaceae], *Citrullus colocynthis* (L.) Schrad. [Cucurbitaceae], *Achillea fragrantissima* (Forssk.) Sch. Bip. [Asteraceae (a.k.a., Compositae)], *Capparis spinosa* L. [Capparaceae], *Acacia* spp. [Fabaceae (a.k.a., Leguminosae)], and *Z. spina-christi* [Rhamnaceae] are available for bees after the rainy season, in addition to cultivated alfalfa, eucalyptus, sunflower, date palm, and some fruit trees (Alghoson 2004; Aloraydh and Alfarraj 1994). Beekeepers follow the flowering of these plants within an area of 400–500 km in diameter in the central region of the country. Some beekeepers move their bees across the country from South to West, to the Center, or to the North and vice versa. In general, the main honey plants in the country are *Acacia* spp. [Fabaceae (a.k.a., Leguminosae)] and *Z. spina-christi* [Rhamnaceae], both being found wild in all regions of Saudi Arabia. Their flowering seasons start during June and August of each year, respectively, depending on rainfall. Approximately 70% of the bees kept in Saudi Arabia are native populations of *A. m. jemenitica*, with the remainder being Carniolan (*A. m. carnica* Pollmann) or Egyptian-Carniolan hybrids (Fig. 4).

Distribution, morphology, and biology of the native honey bees of Saudi Arabia (*Apis mellifera jemenitica*)

Apis mellifera jemenitica has a wide distribution (4500 km from East to West) in tropical Africa, and in the hot desert of the Arabian Peninsula (Fig. 5), having been recorded from Chad, Ethiopia, Somalia, Sudan, Oman, Yemen, and Saudi Arabia. It is found in the areas of highest seasonal temperature as well as the zone of lowest and most irregular rainfall, regions where other honey bee races have not been able to persist (Ruttner 1976; Fletcher 1978; Radloff and Hapburn 1997; Amssalu et al. 2004; Taher et al. 2009).

Although the native Saudi honey bee is recognized as *A. m. jemenitica*, it has some significant morphological and biological differences from its conspecifics, as well as some other populations of this same race in Africa (Alqarni 1995, 2006, 2010; Al Ghamdi 1990, 2002, 2005, 2006). Ruttner (1988) placed *A. m. jemenitica* (with the unjustified change in spelling to *yemenitica*: *vide* Engel 1999) under the 'Tropical African region' as it was found between Chad and Sudan (Fig. 5). He mentioned the subspecies to be one of the major branches of *A. mellifera*, whose morphology and ecology were extreme. Alpatov (1935) and Guiglia (1964, 1968) had earlier recorded bees from Yemen but owing to a lack of morphometric data confirmation of subspecific status was not possible. In 1970, H. Peters collected in northern Yemen what he presumed to be *A. cerana indica* Fabricius but Ruttner (1976) correctly identified these bees as small individuals of *A. mellifera*, resembling otherwise sub-Saharan forms. Ruttner (1988) also noted that *A. m. jemenitica* nearly overlaps *A. cerana* Fabricius in size and setal length. Ruttner (1976) classified the race found in Sudan as *A. m. nubica* Rutter, later discovering that the same or similar form was also present in Yemen, Somalia, and Chad. As a result, he extended *A. m. jemenitica* into these regions and considered *A. m. nubica* to be a junior synonym of the former (Ruttner, 1988). In total Ruttner (1988) sampled localities across Saudi Arabia [Southwest (Sabia), middle (Riyadh), and East (Alhasaa)], Oman (Dutton et al. 1981), Yemen, Somalia, Sudan (Ruttner 1976, Rashad and El-Sarrag 1983, 1984), and Chad (Gadbin et al. 1979), and representing approximately the same latitude.

Rashad and El-Sarrag (1983, 1984) and El-Sarrag et al. (1992), after surveying 50 localities across eight Sudanese governorates, documented what they considered to be two subspecies from Sudan – *A. m. sudanensis* Sarrag et al. (from most major sections of the country) and *A. m. jemenitica* (listed at times as *A. m. nubica*, along the southern borders). The Sudanese bees were a little larger than the Saudi populations, and those from Somalia mostly resemble those of Sudan. Across all of the morphometric characteristics it was found that the populations from Saudi Arabia were the smallest, with the bees from Chad being perhaps most similar to *A. m. jemenitica* (Gadbin et al. 1979; Gadbin 1980). However, Ruttner (1988) suggested the contrary, believing *A. m. jemenitica* to be more closely allied to those populations from Somalia and Sudan.

Ruttner (1988) noted that the Saudi honey bee samples were clearly distinct (i.e., smaller, more slender, shorter setae, and more yellow in coloration), while adding that there was more homogeneity between Yemeni and Sudanese bees. This led him to be the first to consider the Saudi populations as a distinct ecotype of *A. m. jemenitica*, and the Sudanese population another, less distinctive, ecotype. Naturally, given that increased scrutiny has continued to subdivide the Ethiopian and Sudanese populations into separate subspecies, it must be wondered if the same is not valid for the native Saudi honey bees (*vide* Conclusions, *infra*).

Subsequent studies by Alqarni (1995) demonstrated significant differences in several morphological characters between Saudi *A. m. jemenitica*, the standard 'Carniolan race' (*A. m. carnica*), and their F1 hybrid cross (the 'Arabian-Carnica' honey bees) (Table 2). The native Saudi honey bees are noticeably smaller and could perhaps be classified as a race distinct from *A. m. jemenitica* (if employing the same standards applied elsewhere for honey bee subspecies; e.g., Sheppard and Meixner 2003; Amssalu 2002, 2008; Sheppard et al. 1997; Amssalu et al. 2004; Meixner et al. 2011)[1], but at least represents a noteworthy ecotype. Indeed, across a variety of biological and behavioral characters (e.g., worker brood, honey and pollen stored, foraging activity and time), the native Saudi populations of *A. m. jemenitica* performed better than *A. m. carnica* or F1 hybrids of these subspecies (e.g., Tables 3–6). The Saudi populations of *A. m. jemenitica* appear better suited than other races for survival and activity (e.g., foraging) in the extremes of the harsh Saudi environment. Alqarni (1995) also considered that the geographical proximity of the native Saudi bees (in the Abha Region) to Yemeni bees (*A. m. jemenitica* s.str.) lead to a natural intermingling between these populations. When comparing the mean values of various morphometric characters of native Saudi bees with the Yemeni populations, Alqarni (1995) noted significant differences among five characters, i.e., length and width of the forewing, width of the metabasitarsus, total length of the third and fourth metasomal terga, and the degree of yellow coloration on the third metasomal tergum. Less significant differences were found in other standard characters, e.g., length of proboscis, cubital cell index, number of hamuli on the hind wing, and slenderness of the metasoma.

Overall, Saudi *A. m. jemenitica* appears well adapted to the unique climatic conditions and their variations in the Kingdom of Saudi Arabia. For example, their rate of new queen development and foraging activities during the hot summer were significantly higher than those of other races (Alqarni 2006a, 2010). *Apis mellifera jemenitica* is also the smallest of its kind in the area but the biological significance of this size differences is presently not understood. All of the presently available data taken into

---

[1] It should be noted that given that the holotype and type series of *jemenitica* Ruttner is from Yemen, the name *jemenitica* would remain with the Yemeni populations should they be considered a separate subspecies and alternative subspecific epithets would become available or be required for the African and Saudi populations historically considered to be of the same race.

Table 2. Range and mean values (mm) of some morphometric characters of workers of native Saudi (*Apis mellifera jemenitica* Ruttner) and carniolan races (*A. m. carnica* Pollmann), and their F1 hybrid (100 workers/sample/race).

Morphometric character	*A. m. jemenitica*		*A. m. carnica*		First hybrid	
	Range	Mean	Range	Mean	Range	Mean
Flagellum length	2.32–2.64	2.47±0.01	2.58–2.84	2.70±0.01	2.52–2.77	2.64±0.01
Proboscis length	4.84–5.74	5.31±0.02	5.17–6.32	6.06±0.01	4.52–6.06	5.65±0.02
Forewing length	7.55–9.39	8.07±0.02	8.45–9.22	8.86±0.02	7.93–9-03	8.49±0.03
Forewing width	2.77–3.23	3.01±0.01	3.03–3.40	3.24±0.01	2.90–3.29	3.14±0.01
Forewing cubital index	1.43–2.67	2.10±0.03	1.75–3.33	2.81±0.04	1.75–3.00	2.39±0.04
No. of hamuli on hind wing	18.0–32.0	22.7±0.28	18.0–26.0	21.2±0.18	18.0–29.0	22.65±0.23
Metabasitarsus length	1.94–2.26	2.12±0.01	2.26–2.58	2.44±0.01	1.99–2.39	2.25±0.01
Metabasitarsus width	0.97–1.16	1.08±0.00	1.09–1.23	1.19±0.00	0.97–1.23	1.13±0.01
No. of setal rows on metabasitarsus	10.0–12.0	11.2±0.05	11.0–13.0	11.7±0.07	10.0–12.0	11.1±0.04
Length of metasomal terga III & IV	3.42–3.99	3.75±0.01	3.48–4.26	3.86±0.02	3.48–4.06	3.79±0.02
Yellow color (%) of the metasoma	40.0–75.9	59.0±0.01	0.0–55.0	6.0±0.01	0.0–56.7	29.0±0.02
Metasomal slenderness	79.2–90.7	83.78±0.00	81.3–95.6	85.69±0.01	82.2–97.5	87.5±0.00

Table 3. Monthly mean values of some biological characters of native Saudi (*Apis mellifera jemenitica* Ruttner) and carniolan (*A. m. carnica* Pollmann) colonies and their F1 hybrid during a single year (July 1992–June 1993). Different letters in the same row indicate significant differences.

Biological character	Monthly Mean Values of Colonies		
	jemenitica	*carnica*	first hybrid
Sealed worker brood areas (in^2)	415.22±54.85 a	267.27±46.74 b	451.48±71.82 a
Sealed drone brood areas (in^2)	18.95±5.17 a	7.77±2.36 b	7.90±2.24 b
Stored honey (kg)	2.33±0.20 a	2.83±0.30 a	2.76±0.29 a
Stored pollen areas (in^2)	58.14±8.36 a	29.68±5.42 b	25.69±5.46 b
No. of queen cells	2.94±1.45 a	1.55±0.49 a	3.6±1.95 a
No. of wax cups	10.81±8.21 a	6.93±3.43 a	13.41±3.88 a

consideration, it appears as though the native Saudi honey bees are an ecotype of the Yemeni race (i.e., *A. m. jemenitica* s.str.) and one that is ideal for the particular climatic regimes of the country.

Interestingly, Ruttner (1976) observed significant morphological differences among workers of the same colony in his samples across Yemeni, Sudanese, and Chadian populations, leaving him unable to explain these distinctions across the same latitude. This was also noted by El-Sarrag for honey bees sampled across eight governorates in Yemen (*vide* Alqarni 1995), which obviously did not belong to the pure Yemeni race (*A. m. jemenitica* s.str.). Migratory beekeeping and the annual import of thousands of colonies of different hybrids likely explains these observations, as the probability of pure Yemeni bees crossing with other races and hybrids must be great. Genetic studies are needed in order to determine the true frequency and effects of such hybridization in these regions. A great risk of crossing between races in different parts of Saudi Arabia is to be expected. As already mentioned, regions such as Assir, Baha, Taif, Tihama, and other parts of the country import numerous colonies from abroad. Importation is pres-

Table 4. Levels of some behavioral characters of sealed worker brood of native Saudi (*Apis mellifera jemenitica* Ruttner) and carniolan (*A. m. carnica* Pollmann) colonies and their F1 hybrid during one year (July 1992–June 1993).

Character	**Season**	**Levels given to colonies (1 degree/5 degrees)**		
		jemenitica	*carnica*	first hybrid
Hardness	Winter	1.71	1.25	1.63
	Summer	2.63	1.62	2.61
	% Variance	21.2+	12.9+	23.1+
Range	Winter	2.44	1.72	2.10
	Summer	2.88	3.20	3.40
	% Variance	8.3+	30.1+	23.2+
Arrangement	Winter	3.40	2.80	3.13
	Summer	3.30	3.20	4.20
	% Variance	1.5-	6.7+	14.6+
Grading	Winter	3.50	2.90	3.20
	Summer	3.20	3.30	3.20
	% Variance	4.5-	6.5+	0.0
Total	Winter	11.05	8.67	10.06
	Summer	12.01	11.32	13.41
General mean	"20 degrees"	11.53	10.00	11.74
Percentage		57.65	49.98	58.68

Table 5. Worker brood, honey, and pollen stored by native Saudi (*Apis mellifera jemenitica* Ruttner) and carniolan (*A. m. carnica* Pollmann) colonies and their F1 hybrid during winter (Early December 1992–Late February 1993).

Biological Character	**Month**	**Activities of Colonies**					
		jemenitica	variance	*carnica*	variance	first hybrid	*variance*
Worker brood (in^2)	Dec. Feb.	189.80 79.00	-58.4%	61.00 122.50	+50.2%	161.00 112.00	-30.4%
Stored honey (kg)	Dec. Feb.	1.64 1.14	-30.5%	2.75 0.65	-76.5%	3.17 1.01	-68.1%
Pollen (in^2)	Dec. Feb.	53.30 35.30	-33.8%	15.50 12.80	-17.4%	16.30 6.80	-58.3%

Table 6. Flight activity of native Saudi (*Apis mellifera jemenitica* Ruttner) and carniolan (*A. m. carnica* Pollmann) colonies and their F1 hybrid during Early February to Late May (1992/1993).

Observation	**Time of Activity for Colonies**		
	jemenitica	*carnica*	first hybrid
Time of 1st worker flight	5:55	5:56	5:53
Time of last worker return	18:09	17:58	18:13
Time of sunrise	6:02	**Time of sunset**	18:03
Sunrise temperature	14.5°C	**Sunset temperature**	23.5°C

ently uncontrolled and crosses between colonies are to be expected, resulting in mixed drones mating with virgin queens, something which has already been observed among Carniolan bees imported from Egypt.

Conclusion

Extensive biological, ecological, and systematic studies remain to be undertaken on honey bee populations across the Arabian Peninsula and it is hoped that this brief review will direct researchers to the limited available publications and data. Certainly a question needing further investigation is to origin and distinctiveness of the native Saudi honey bee populations and whether they are sufficiently different to warrant separate subspecific status relative to "true" *A. m. jemenitica* populations in Yemen. In particular, greater and finer geographic sampling of morphometric data is needed (as has been applied to populations and ecotypes of *A. cerana*: Radloff et al. 2010), alongside extensive DNA sequence analyses. Detailed genomic study of the samples from these regions along with such finer geographic sampling of morphometric variables will solve eventually the challenge surrounding the appropriate classification of the indigenous Saudi honey bees. Given that these subspecies and ecotypes can have profoundly different biological characters, rendering them able (or not able!) to survive in the harsh extremes of the Saudi environments, these seemingly basic questions can have a direct impact on beekeeping efforts. All of these basic investigations into Saudi bee biology will greatly aid national initiatives to strengthen the beekeeping industry and economy of the region, demonstrating once more a direct link between largely systematic research and human agriculture, health, cultural practices, and economic stability. For the moment we maintain a conservative position in regard to the status of our Saudi populations and seek to garner larger and more diverse data sources, much as has been done for near neighbors in Africa and elsewhere in Asia. The Arabian Peninsula represents a significantly open field of inquiry for apidological study.

Acknowledgements

This work was supported by King Saud University, Deanship of Scientific Research, College of Food and Agriculture Sciences Research Center. Considerable thanks are extended to Prof. Siriwat Wongsiri (Chulalongkom University, Bangkok, Thailand) for his care in reading earlier drafts of the manuscript; his comments significantly improved the final draft, as did the efforts of two reviewers. In addition, we owe special thanks to Dr. Fahad J. Alatawi for assisting with images taken in his lab, and to Mr. Hassan Badri for preparing the map.

References

Abu-Hassan AA, Alostta, ML, Mahmoud M (1994 [1414 AH (al-Hijrī)]) Natural forests in Kingdom of Saudi Arabia and its economical exploitation. Administration of Scientific Research, National Saudi Center for Science and Technology (King Abdul-Aziz's City for Sciences and Technology), Riyadh, Saudi Arabia, 182 pp.

Al Ghamdi AA (1990) Survey of honeybee diseases, pests and predators in Saudi Arabia. MPhil Thesis, University of Wales, Cardiff, United Kingdom, [xvii]+127 pp.

Al Ghamdi AA (2002) The effect of pollen supplementary feeding on some activities of honeybee colonies during summer season in Riyadh, Saudi Arabia. Saudi Journal of Biological Sciences 9(2): 85–93.

Al Ghamdi AA (2005) Comparative study between subspecies of *Apis mellifera* for egg hatching and sealed brood percentage, brood nest temperature and relative humidity. Pakistan Journal of Biological Sciences 8: 1–5.

Al Ghamdi AA (2006) Morphometrical and histological studies on some bee glands in genus *Apis* in Saudi Arabia (KSA). Bulletin of the Entomological Society of Egypt 83: 13–25.

Al-Kahtani SN (2003) Ecological studies on some activities of honeybee colonies under Al-Hassa District conditions Kingdom of Saudi Arabia. MSc Thesis, King Faisal University, Al-Hassa, Saudi Arabia, 191 pp.

Alghoson NI (2004) Bees and Honey Plants in Saudi Arabia. Alobeikan Library, Riyadh, Saudi Arabia, 184 pp. [In Arabic]

Aloraydh IA, Alfarraj SA (1994) Wild Plants in Saudi Arabia. Alhomaidhi Press, Riyadh, Saudi Arabia, 120 pp. [In Arabic]

Alpatov WW (1935) Contribution to the study of variation in the honeybee, IV. The Egyptian honeybee and its position among other bees. Byulleten Moskovskogo Obshchestva Ispytatelei Prirody, Otdel Biologicheskiy [Bulletin of the Moscow Society of Naturalists, Series Biology] 44: 284–291. [In Russian]

Al-Owdat MA, Mahmoud AA, Al-Sheikh A (1985) [1405 AH (al-Hijrī)] Botanical Geography. Deanship of Libraries, King Saud University, Riyadh, Saudi Arabia, 326 pp. [In Arabic]

Al-Qahtani MMA (1997) Factors affecting costs of production and returns of investment for beekeeping industry in Asir region, Saudi Arabia. MSc Thesis, King Saud University, Riyadh, Saudi Arabia, 194 pp.

Alqarni AS (1995) Morphometrical and biological studies of the native honeybee race *Apis mellifera* L.; the carniolan *A. m. carnica* Pollmann and their F1 hybrid. MSc Thesis, King Saud University, Riyadh, Saudi Arabia, 143 pp.

Alqarni AS (2006a) Tolerance of summer temperature in imported and indigenous honeybee *Apis mellifera* L. races in central Saudi Arabia. Saudi Journal of Biological Sciences 13(2): 123–127.

Alqarni AS (2006b) Influence of some protein diets on the longevity and some physiological conditions of honeybee *Apis mellifera* L. workers. Journal of Biological Sciences 6(4): 734–737. doi: 10.3923/jbs.2006.734.737

Alqarni AS (2010) Emergence and mating rates of *Apis mellifera* L. honeybee queens in imported and indigenous honeybee races in central Saudi Arabia. Journal of the Saudi Society for Agricultural Sciences 9(2): 105–111.

Alqarni AS, Al-Atawi FJ (2008) Use of some volatile oils as attractive agents to increase food consumption in honeybee colonies. Arab Universities Journal of Agricultural Sciences 16(1): 203–210.

Al-Shehri AZA (1999) Survey of insect pests of honey bee in the western region of KSA. MSc Thesis, King Abdul-Aziz University, Jeddah, Saudi Arabia, 138 pp.

Al-Zabīdī MR (1888/1889 [1306 AH (al-Hijrī)]) Sharh al-qāmūs al-musammā Tāj al-'Arūs [10 Volumes]. Al-Matba'a, Cairo, Egypt. [Honey bee references in volume 1, p. 381; volume 3, p. 531; volume 5, p. 432; and volume 10, p. 118].

Amssalu B (2002) Multivariate morphometric analysis and behaviour of honeybees (*Apis mellifera* L.) in southern regions of Ethiopia. PhD Dissertation, Rhodes University, Grahamstown, South Africa, xxv+332 pp.

Amssalu B (2008) *Apis mellifera Woyi-Gambella* [sic] (AB) honey bees endemic to Ethiopia. Bees for Development Journal 88: 7.

Amssalu B, Nuru A, Radloff SE, Hepburn HR (2004) Multivariate morphometric analysis of honeybees (*Apis mellifera*) in the Ethiopian region. Apidologie 35(1): 71–81. doi: 10.1051/apido:2003066

Cale GH, Jr, Gowen JW (1956) Heterosis in the honeybee (*Apis mellifera* L.). Genetics 41(2): 292–303.

Crane E (1983) The Archaeology of Beekeeping. Duckworth, London, United Kingdom, 360 pp.

Crane E (1990) Bees and Beekeeping: Science, Practice and World Resources. Cornell University Press, Ithaca, NY, xvii+614pp.

Crane E (1999) The World History of Beekeeping and Honey Hunting. Routledge, New York, NY, xxii+682 pp.

Crane E, Graham AJ (1985) Bee hives of the ancient world. Bee World 66: 23–41, 148–170.

Dams LR (1978) Bees and honey-hunting scenes in the Mesolithic rock art of eastern Spain. Bee World 59(2): 43–53.

Dutton R, Ruttner F, Berkeley A, Manley MJD (1981) Observations on the indigenous *Apis mellifera* of Oman. Journal of Apicultural Research 20(4): 201–214.

El-Sarrag MSA (1993) Studies on some factors affecting rearing of honey bee queen (*Apis mellifera* L) under Riyadh conditions. Agricultural Research Centre, King Saud University, Research Bulletin 41: 30–41.

El-Sarrag MSA, Saeed AA, Hussein MA (1992) Morphometrical study on the Sudanese honeybees. Journal of King Saud University, Agricultural Sciences 4(1) 99–108.

Engel MS (1998) Fossil honey bees and evolution in the genus *Apis* (Hymenoptera: Apidae). Apidologie 29(3): 265–281. doi: 10.1051/apido:19980306

Engel MS (1999) The taxonomy of Recent and fossil honey bees (Hymenoptera: Apidae; *Apis*). Journal of Hymenoptera Research 8(2): 165–196.

Engel MS (2001a) Monophyly and extensive extinction of advanced eusocial bees: Insights from an unexpected Eocene diversity. Proceedings of the National Academy of Sciences, USA 98(4): 1661–1664. doi: 10.1073/pnas.041600198

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

Engel MS (2006) A giant honey bee from the middle Miocene of Japan (Hymenoptera: Apidae). American Museum Novitates 3504: 1–12. doi: 10.1206/0003-0082(2006)504[0001:AGHBFT]2.0.CO;2

Engel MS, Hinojosa-Díaz IA, Rasnitsyn AP (2009) A honey bee from the Miocene of Nevada and the biogeography of *Apis* (Hymenoptera: Apidae: Apini). Proceedings of the California Academy of Sciences, Series 4 60(3): 23–38.

Fletcher DJC (1978) The African bee, *Apis mellifera adansonii*, in Africa. Annual Review of Entomology 23: 151–171. doi: 10.1146/annurev.en.23.010178.001055

Gadbin C (1980) Les plantes utilisées par les abeilles au Tchad méridionale. Apidologie 11(3): 217–254. doi: 10.1051/apido:19800304

Gadbin C, Cornuet JM, Fresnaye J (1979) Approche biométrique de la variété locale d'*Apis mellifica* L. dans le sud tchadien. Apidologie 10(2): 137–148. doi: 10.1051/apido:19790204

Galton D (1971) Survey of a Thousand Years of Beekeeping in Russia. Bee Research Association, Chalfont St. Peter, United Kingdom, 90 pp.

Guiglia D (1964) Missione 1962 del Prof. Giuseppe Scortecci nell Arabia meridionale. Hymenoptera: Tiphiidae, Vespidae, Eumenidae, Pompilidae, Sphecidae, Apidae. Atti della Società Italiana di Scienze Naturali e del Museo Civico di Storia Naturale di Milano 103(4): 305–310.

Guiglia D (1968) Missione 1965 del Prof. Giuseppe Scortecci nello Yemen (Arabia meridionale). Hymenoptera: Tiphiidae, Vespidae, Pompilidae, Sphecidae, Apidae. Atti della Società Italiana di Scienze Naturali e del Museo Civico di Storia Naturale di Milano 107(2): 159–167.

Hepburn HR (2000) Honeybee (*Apis mellifera*) classification and the confounding effects of trinomial nomenclature. In: Bitondi MMG, Hartfelder K (Eds), Anais do IV Encontro sobre Abelhas. Universidade de São Paulo, Ribeirão Preto, 188–196 [total volume xxix+[1]+363 pp.

Hepburn HR, Radloff SE (1998) Honeybees of Africa. Springer Verlag, Berlin, xv+370 pp.

Hepburn HR, Radloff SE (2002) *Apis mellifera capensis*: An essay on the subspecific classification of honeybees. Apidologie 33(2): 105–127. doi: 10.1051/apido:2002001

Hepburn HR, Radloff SE (2011) Honeybees of Asia. Springer Verlag, Berlin, xii+669 pp.

Jones HL (1930) Strabo Geography [Volume VII]: Books 15–16 [Loeb Classical Library No. 241]. Heinemann, London, UK, 400 pp.

Kotthoff U, Wappler T, Engel MS (2011) Miocene honey bees from the Randeck Maar of southwestern Germany (Hymenoptera, Apidae). ZooKeys 96: 11–37. doi: 10.3897/zookeys.96.752

Kulinčević JM, Rothenbuhler WC (1975) Selection for resistance and susceptibility to hairless-black syndrome in the honeybee. Journal of Invertebrate Pathology 25(3): 289–295. doi: 10.1016/0022-2011(75)90084-1

Laidlaw HH, Jr (1944) Artificial insemination of the queen bee, *Apis mellifera* L.: Morphological basis and results. Journal of Morphology 74(3): 429–465. doi: 10.1002/jmor.1050740307

Langstroth LL (1853) Langstroth on the Hive and the Honey-bee: A Bee-keeper's Manual. Hopkins, Bridgman, and Co., Northampton, MA, xvi+384 pp.

Mackensen O, Roberts WC (1948) A Manual for the Artificial Insemination of Queen Bees. United States Department of Agriculture, Agricultural Research Administration, Bureau of Entomology and Plant Quarantine [ET-250], Washington DC, 33 pp.

Meixner MD, Leta MA, Koeniger N, Fuchs S (2011) The honey bees of Ethiopia represent a new subspecies of *Apis mellifera – Apis mellifera simensis* n. ssp. Apidologie 42(3): 425-437.

Nye WP, Mackensen O (1968) Selective breeding of honeybees for alfalfa pollen: Fifth generation and backcrosses. Journal of Apicultural Research 7: 21–27. doi: 10.1007/s13592-011-0007-y

Pellett FC (1938) History of American Beekeeping. Collegiate Press, Ames, IA, ix+213 pp.

Radloff SE, Hepburn HR (1997) Multivariate analysis of honeybees, *Apis mellifera* Linnaeus (Hymenoptera: Apidae), of the Horn of Africa. African Entomology 5(1–2): 57–64.

Radloff SE, Hepburn C, Hepburn HR, Fuchs S, Hadisoesilo S, Tan K, Engel MS, Kuznetsov V (2010) Population structure and classification of *Apis cerana*. Apidologie 41(6) 589–601. doi: 10.1051/apido/2010008

Radloff SE, Hepburn HR, Engel MS (2011) The Asian species of *Apis*. In: Hepburn HR, Radloff SE (Eds) Honeybees of Asia. Springer Verlag, Berlin, 1–22 [total volume xii+669 pp.] doi: 10.1007/978-3-642-16422-4_1

Rashad SE, El-Sarrag MS (1983) Some characters of the Sudanese honeybee *Apis mellifera* L. In: Mehrotra KN (Ed) Proceedings, 2nd International Conference on Apiculture in Tropical Climates. Indian Agricultural Research Institute, New Delhi, India, 301–309 [total volume xxiv+728 pp.]. [Note: often the 1980 abstracts volume is erroneously cited for this article: Second International Conference on Apiculture in Tropical Climates, February 29-March 8, 1980: Abstracts of Papers. International Conference on Apiculture in Tropical Climates, New Delhi, India, iv+98 pp.]

Rashad SE, El-Sarrag MS (1984) Beekeeping in Sudan: Two morphometrical studies on the Sudanese honeybees. Unpublished MS, International Bee Research Association, Cardiff, United Kingdom. [*vide etiam* Rashad SE, El-Sarrag MS (1978) Beekeeping in Sudan. Bee World 59(3): 105–111.]

Ruttner F (1976) Les races d'abeilles de l'Afrique. XXV Congrés International d'Apiculture, Grenoble 1976: 347–367.

Ruttner F (1988) Biogeography and Taxonomy of Honeybees. Springer, Berlin, Germany, xii+284 pp.

Sheppard WS, Meixner MD (2003) *Apis mellifera pomonella*, a new honey bee subspecies from Central Asia. Apidologie 34(4): 367–375. doi: 10.1051/apido:2003037

Sheppard WS, Arias MC, Grech A, Meixner MD (1997) *Apis mellifera ruttneri*, a new honey bee subspecies from Malta. Apidologie 28(5): 287–293. doi: 10.1051/apido:19970505

Taher S, Fuchs S, Moritz RFA (2009). Morphological studies of honeybees (*Apis mellifera*) from Libya. Apidologie 40(2): 97–105. doi: 10.1051/apido/2008068

Tarcīci A (1965) al-Yaman wa Ḥaḍārat al-ʻArab maʼ Dirāsah Jughrāfiyah Kāmilah [Yemen and Arab Civilization, with a Complete Geographical Study]. Dār Maktabat al-Ḥayāt, Beirut, Lebanon, 319 pp. [In Arabic]

Watson LR (1928) Controlled mating in honeybees. Quarterly Review of Biology 3(3): 377–390. doi: 10.1086/394310

Zeuner FE, Manning FJ (1976) A monograph on fossil bees (Hymenoptera: Apoidea). Bulletin of the British Museum (Natural History), Geology 27(3): 149–268.