

A new species of *Dystacta* Saussure, 1871 from Nyungwe National Park, Rwanda (Insecta, Mantodea, Dystactinae)

Riley Tedrow^{1,2,†}, Kabanguka Nathan^{3,‡}, Nasasira Richard^{3,§}, Gavin J Svenson^{1,2,|}

1 Department of Invertebrate Zoology, Cleveland Museum of Natural History, 1 Wade Oval Drive, Cleveland, Ohio, USA **2** Department of Biology, Case Western Reserve University, 10900 Euclid Avenue, Cleveland, Ohio, USA **3** Kitabi College of Conservation and Environmental Management (KCCCEM), C/O Rwanda Development Board, P.O Box 330 Huye, Kigali, Rwanda

† <http://zoobank.org/A5C8FE87-A1DD-48FB-B6C8-013FC6D738CF>

‡ <http://zoobank.org/52B1BF63-4F97-43DE-B0F7-05E13C7A5A0D>

§ <http://zoobank.org/CA2824C7-3664-4BB2-9032-8E8917433F19>

| <http://zoobank.org/C33233D2-1A14-4D3B-AB4A-205551D77223>

Corresponding author: Gavin J Svenson (gsvenson@cmnh.org)

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Abstract

A recent targeted entomological survey in the Republic of Rwanda has produced two conspecific male and female specimens of an undescribed species of praying mantis (Mantodea). The specimens were collected in Nyungwe National Park in May of 2013. The species is closest morphologically to *Dystacta alticeps* (Schaum, 1853). Therefore, a new species is described, *Dystacta tigrifrutex* **sp. n.**, along with the first instar nymphs and ootheca. In addition, the previously monotypic genus *Dystacta* Saussure, 1871 is re-described to provide a broader definition of the genus group. Habitus images, measurement data, a key to species, natural history information, and locality data are provided.

Keywords

Mantodea, praying mantis, *Dystacta*, Afrotropical, taxonomy, new species

Introduction

The order Mantodea is a diverse group of predatory insects known as praying mantises. The group is comprised of approximately 2,500 described species (Ehrmann 2002) with a vast array of morphological and behavioral adaptations. Although the order has received much more taxonomic attention in recent years (see Rivera 2010), it has long been a neglected order of insects with strong potential for new species discovery (e.g. Svenson 2014).

During a preliminary survey of insects in Nyungwe National Park (NNP) in southwestern Rwanda, a single male and single female of an unknown species of praying mantis were collected (Fig. 1). The male was attracted to a metal halide light system and was found on the ground near the trap. The female was found in close proximity to the light walking through ground vegetation. It was not clear if the female was attracted to the light, but the male is assumed to have flown in specifically to the light. The collecting site was in a high altitude location within NNP (~2,500 m) in montane forest. The weather was cool (~15 °C) with intermittent rain.

After a thorough examination of the new specimens, we determined them to be representative of an undescribed species belonging to the monotypic genus *Dystacta* Saussure, 1871. Although distinct from the only other species in the genus, *D. alticeps* (Schaum, 1853), our new species shares a number of similarities justifying its inclusion within the genus. Originally described by Saussure to contain a single species, *D. paradoxa* Saussure, 1871, that was later synonymized with *Mantis alticeps* Schaum, 1853 (now within *Dystacta*), four additional species have been described within *Dystacta*, three being later synonymized with *D. alticeps* and the other moved to a different genus (see below). Considering the broad range of *D. alticeps* with records in Angola, Botswana, Congo, Malawi, Mozambique, Namibia, South Africa, Tanzania, and Zimbabwe (Ehrmann 2002), it is not surprising that synonymies have been described. *Dystacta* is classified within the tribe Dystactini with seven other genera (Ehrmann 2002). Svenson and Whiting (2009) and Yager and Svenson (2008) recovered the tribe within a diverse assemblage including species of Amelinae, Chroicopterinae, and Hapalomantinae, a result strongly supported by molecular data.

We now describe the new species using male and female specimens as well as characterize the ootheca and first instar nymphs. In addition, because *Dystacta* was originally described based on a single species and the description was too narrow and reflected only the variability within *D. alticeps*, we redescribe the genus herein to provide a more accurate set of characters for the genus-group.

Methods

Region sampled

Nyungwe National Park is Africa's largest protected mountain rainforest, covering about 970 km² of pristine habitat. The forest is located in the Albertine Rift, a series

of mountain ranges stretching from the Rwenzori mountains in western Uganda to the Lendu Plateau in eastern Congo. The park resides in the southwestern portion of Rwanda. The rainy season for Nyungwe lasts from September to May, and the dry season from June to August (Kaplin 2013). Nyungwe has an average minimum temperature of 10.9 degrees Celsius and an average maximum temperature of 19.6 degrees Celsius. The forest is complex and diverse, supporting a variety of soil types that allow for tall forests and dry ridges with short trees and thickets. Bamboo covers most of the southeastern part of the park, but open herbaceous areas, flooded forests, and marshes are also scattered throughout (Plumptre et al. 2002). The forest elevation ranges from 1,600–2,950 meters and it receives rain in excess of 2000 mm per year (<http://nyungwepark.com/nyungwe/the-park/>).

Collection and preparation

A metal halide light trapping system was utilized at night to attract insects. The system is composed of tent poles holding up a white curtain in a vertical position. A copper “T” sits perpendicularly atop the center of the apparatus. A metal halide bulb is affixed to each end of the horizontal line of the “T”. These bulbs are supported by individual light ballasts and powered by either an outlet or a small portable generator. Insects are attracted to the light and land upon the white curtain. Specimens were placed in vials directly from the curtain. These lights typically attract flying and nonflying insects to the perimeter of the light apparatus, and a scan often produces many more specimens collected via sweep net or hand.

The male and female were kept alive in cubical screen enclosures to monitor their behavior and capture live habitus images. The male died within 12 hours of captivity. The female produced a single ootheca that was incubated in a humid container in order to procure first instar nymphs. The female lived in captivity for two weeks then had to be euthanized for transport back to the United States. The female was preserved in ethanol and later pinned due to her large abdomen that may have spoiled in the field or during transport. The male was field pinned after a leg was preserved in ethanol for future genetic work (tissue sample deposited in the Cleveland Museum of Natural History).

Descriptive conventions and character systems

The species treatment within this study provides a brief diagnosis, new natural history observations, and verbal character descriptions stemming from the anterior surface of the head, the dorsal surface of the pronotum, the prothoracic leg, the wings, and the abdomen. The verbal descriptions are provided for the male and female as well as the ootheca and the first instar nymphs. Description of ootheca is modeled after Breland and Dobson (1947). Foreleg spine nomenclature follows Wieland (2008, 2013) where diagrams of arrangements can be viewed.

Measurements Specimens were measured using a Leica M165C stereo-microscope and an IC80 HD coaxial video camera using the live measurements module of the Leica Application Suite (LAS). All measurements presented in this study are in millimeters. A total of 21 measurement classes were captured including:

1. *Body length* = length of body from central ocelli to posterior tip of wing or abdomen (intraspecifically variable measurement, primarily for general size estimation).
2. *Forewing length* = from proximal margin of axillary sclerites to distal tip of the discoidal region.
3. *Hindwing length* = from proximal margin of axillary sclerites to distal tip of the discoidal region.
4. *Pronotum length* = from anterior margin to posterior margin.
5. *Prozone length* = anterior margin of pronotum to center of supra-coxal sulcus.
6. *Pronotum width* = from lateral margins at the widest point, the supra-coxal bulge.
7. *Pronotum narrow width* = from lateral margins of the pronotum at narrowest region of metazone.
8. *Head width* = from lateral margins of the eyes at widest point.
9. *Head vertex to clypeus* = from the vertex of the head at center to the lower margin of the frons and upper margin of clypeus.
10. *Frons width* = from lateral margins of frons, inferior to the antennal insertions, at the widest point.
11. *Frons height* = from upper margin abutting central ocellus to lower margin abutting clypeus.
12. *Prothoracic femur length* = from proximal margin abutting trochanter to distal margin of genicular lobe.
13. *Mesothoracic femur length* = from most proximal margin abutting trochanter to the distal side of the terminal spine insertion site.
14. *Mesothoracic tibia length* = from most proximal groove near joint with the femur to the distal side of the terminal spine insertion site.
15. *Mesothoracic tarsus length* = from proximal joint to the apex of the unguis curve.
16. *Metathoracic femur length* = from most proximal margin abutting trochanter to the distal side of the terminal spine insertion site.
17. *Metathoracic tibia length* = from most proximal groove near joint with the femur to the distal side of the terminal spine insertion site.
18. *Metathoracic tarsus length* = from proximal joint to the apex of the unguis curve.
19. *Anteroventral femoral spine count* = all inner marginal ridge spines and two proximal near marginal spines, but excluding the genicular spine.
20. *Anteroventral tibial spine count* = all inner marginal ridge spines, but excluding the distal terminal spur.
21. *Posteroventral tibial spine count* = all outer marginal ridge spines, but excluding the distal terminal spur.

The measurement of total body length was taken from the central ocellus to tip of posterior margin of abdomen or wing, which produced a measure only useful for general assessment of body size rather than species description. Since head position, abdominal expansion, and wing position are all variable, total body length should only be used as a rough measure class to initially discriminate between the small and large praying mantis species when performing identifications.

Imaging Live habitus images were captured with a Canon Powershot SX10 IS with accompanying Canon Speedlite 430EX II flash units. High resolution images of the types, the pronotum, and head images were captured using a Passport Storm© system (Visionary Digital™, 2012), which includes a Stackshot z-stepper, a Canon 5D SLR, macro lenses (50mm, 100mm, and MP-E 65mm), three Speedlight 580EX II flash units, and an associated computer running Canon utility and Adobe Lightroom 3.6 software. The z-stepper was controlled through Zerene Stacker 1.04 and images were processed using the P-Max protocol. All images were captured over an 18% grey card background for white balance standards. Images were processed in Adobe Photoshop CS6 Extended to adjust levels, contrast, exposure, sharpness, and add scale bars. Minor adjustments were made using the stamp tool to correct background aberrations and to remove distracting debris. Plates were constructed using Adobe Illustrator CS6. Habitus images of the types can be viewed online at <http://specimens.mantodearesearch.com>.

Taxonomic placement

Afrotropical distributed species classified within Amelinae, Chroicopterinae, and Dystactinae (*sensu* Ehrmann 2002) were compared with the male and female of the undescribed species (*D. tigrifrutex* sp. n.) discovered in NNP. In addition, available keys by Giglio-Tos (1927) and Kaltenbach (1998) were used to recover genus level identification. Both methods proved that the new taxon had the greatest affinities with *Dystacta alticeps* (Schaum, 1853), and should be included within the monotypic genus *Dystacta* Saussure, 1871. The holotype female of *D. alticeps* was examined and compared with the female specimen from NNP and though they are remarkably similar, they are unique (for reference, the imaged type of the junior synonym, *Paracilnia ornatipennis* Beier, 1935, can be seen at <http://specimens.mantodearesearch.com>). In addition, a close comparison with holotype of *Pseudodystacta braueri* Karney, 1908, another very similar species that was previously included within *Dystacta* (see below), revealed key differences. For example, *D. tigrifrutex* has a much more elongate pronotum and a greater constriction in the metazone following the supra-coxal dilation than seen in *P. braueri*; the male wings are densely ciliated along the anterior margin and in the costal region while not densely ciliated in *P. braueri*; the medial and cubital veins of the male forewing are divergent and widely spread in *D. tigrifrutex* while closer together and near parallel in *P. braueri*; the female is apterous while *P. braueri* females have very short and rounded wings with blunt ends; and finally, the females have two large tubercles near the posterior margin of the pronotum that are not present in *P. braueri*.

Many characters easily define *D. alticeps* and *D. tigrifrutex* as congeneric including: dense ciliation along the anterior margin and in the costal region of the forewings; the medial and cubital veins of the forewings are divergent and widely spread; a vertex that is slightly curved in males and strongly curved in females; the male antennae ciliated and medium to long; the female antennae short; the wings of the male partially opaque, extending well beyond the abdomen; the wings of females not fully developed; the forefemora with 12–13 anteroventral femoral spines; the foretibiae with 10–11 anteroventral tibial spines; and the supra-anal plate transverse. However, since *Dystacta* is monotypic, we have determined that its current description primarily reflects *D. alticeps* and required a more broad description to include the new species.

***Dystacta* Saussure, 1871**

<http://species-id.net/wiki/Dystacta>

Dystacta: Saussure 1871: 455; Stål 1877: 51; Westwood 1889: 17; Kirby 1904: 226; Giglio-Tos 1927: 206; Beier 1935: 21; Beier 1964: 947; Beier 1968: 10; Ehrmann 2002: 124; Otte and Spearman 2005: 30.

Genus-type. *Dystacta paradoxa* Saussure, 1871 (by monotypy). The genus-type is currently the junior synonym of *Mantis alticeps* Schaum, 1853.

Taxonomic history. Henri de Saussure created the genus *Dystacta* in 1871 (pg. 445) for a male specimen collected by M. Brunner de Wattenwyl in South Africa, *D. paradoxa* Saussure, 1871. Later, Westwood (1889: 17) included *Mantis alticeps* Schaum, 1853 (pg. 113) within *Dystacta* (it should be noted that the date of Schaum's description of *M. alticeps* is incorrect in Otte and Spearman (2005) as they list it as 1852). Kirby (1904: 226) later synonymized *D. paradoxa* Saussure, 1871, with *Mantis alticeps* Schaum, 1853. Four more species were subsequently described, three were eventually synonymized with *Mantis alticeps* by Beier (1935: *Polyspilota marmorata* Schulthess, 1899 and *Dystacta stali* Karny, 1908) and Kaltenbach (1996: *Paracilnia ornatipennis* Beier, 1935). The fourth, *D. braueri* Karney, 1908, was removed from *Dystacta* and fixed as the type species of a new genus, *Pseudodystacta*, erected by Kaltenbach (1996). Therefore, *Dystacta* has always effectively been monotypic until now. The genus and included species, particularly *D. alticeps*, have been included in various taxonomic works and checklists throughout the 1900's.

Redescription. Male. *Body*: Ochre to dark brown with black markings; head lacking projections, the antennae simple; the pronotum almost spade-like with a strong supra-coxal dilation; the wings smoky grey or brown, extending beyond the abdomen; the meso- and metathoracic legs of a similar length; the abdomen tubular.

Head: Transverse, eyes slightly exophthalmic; the vertex rounded or slightly rounded, the parietal sutures present. Juxta-ocular protuberances absent. Ocelli large, protruding from small cuticular mounds, but the region between all three slightly raised with a triangular shape; the lateral ocelli oriented outward; the region around the

raised ocelli and below the frontal suture depressed. The clypeus transverse, the upper margin convex; the lower margin slightly concave. Labrum rounded. The flagellomeres of the antennae mostly pale in the basal half, transitioning to a darker coloration on the distal end of the antennae. Anterior surface of head mostly pale or ochre with dark speckling across the surface; frons ochre with dark splotches of black, a transverse black band just below the antennae extends laterally across the anterior surface of the eyes; the clypeus ochre with dark markings; labrum ochre, occasionally with darker markings; mandibles ochre; vertex ochre with dark splotches or banding; maxillary palpi ochre with a darkened terminal segment.

Thorax: Longer than wide, with an expanded supra-coxal bulge; dorsal surface smooth. Medial region of prozone peaked, sloping to the anterior margins; medium length with margins gradually tapering anteriorly to a rounded anterior margin; the margins smooth, but with setae present. Metazone with two tubercles positioned on each side of the medial line just anterior to the posterior margin, a raised carina oriented anterolaterally, extending to the lateral margins of the metazone. Metazone with concave lateral margins tapering posteriorly until two thirds from the supra-coxal bulge, then widening to the posterior margin; margins smooth, but with setae present; the dorsal surface of the metazone not depressed. Ochre with faint black markings. Prosternum with or without a complex black and whitish pattern (Fig. 2); if present, a transverse black band anteriorly and a curved black band posteriorly, the posterior half of the medial region whitish colored, the anterior half with a trapezoidal shape of brown surrounded by a thin black band, the trapezoid reaching the lateral margins. The wings elongate, extending well beyond the terminus of the abdomen. Forewings opaque; setae along the anterior margin, the costal region densely ciliated, the discoidal region ciliated or not; the discoidal region smoky brown or grey with dark splotches; the veins more pigmented than surrounding cell colors; the medial and cubital veins are divergent and widely spread. Hindwings with setae along anterior margin; mostly matching coloration of forewing; the wings extending beyond the abdomen.

Prothoracic Legs: Femur shape normal with a straight dorsal margin; spines robust, pale proximally and black distally; femoral groove to accommodate the tibial spur in the proximal half; the posterior surface smooth; 4 discoidal spines. Posterior surface of femur ochre with black stippling; setae dispersed across a pale ventral surface. The discoidal spines robust, the third from the base very large and robust, twice the length of the second and fourth. Anteroventral femoral spines alternating between short and long, the longer spines of similar length and the shorter spines of similar length; posteroventral femoral spines all of the same length; the posterior and anterior genicular spines small, but robust. Tibia with sparse or dense setae along the dorsal margin and on the posterior, anterior and ventral surfaces; anterior and posterior surfaces ochre with darker markings. Posteroventral tibial spines of similar length, except for the most distal spine being larger than the others; anteroventral tibial spines gradually increase in length from the most proximal to the most distal spine. Forecoxae mostly smooth with setae interspersed throughout, a few tubercles present along the margins, but none are robust as seen in females.

Meso- and Metathoracic Legs: Femora with ventral (posterior) carina well developed; dorsal (anterior) carina absent; surface with numerous small, fine setae; darkly speckled with black markings. Coxae with numerous black markings speckling the surface. Tibia round, covered with setae. Tarsi with ample setae.

Abdomen: Smooth, tubular with brownish to black coloration; the surface with numerous setae across the surface. Tergites rounded at the postero-lateral margins. Supra-anal plate transverse, with a rounded terminus. Cerci with ample setae, round, tapering to a point.

Female. *Body:* Medium; ochre to dark brown with black markings; a highly convex head; the pronotum almost spade-like with strong supra-coxal dilation; the wings reduced or absent; the meso- and metathoracic legs of a similar length; the abdomen broad and elliptical.

Head: Transverse, eyes not particularly exophthalmic; vertex highly convex, the parietal sutures present; juxta-ocular protuberances absent. Frontal suture faint, but forming dorsally oriented curve. Ocelli absent or vestigial, but lenses not visible; a carina connecting former ocellar locations that connects all three and forms a U; region within the U and below the frontal suture depressed. Frons transverse with an angled carina below the antennae, meeting medially with a raised point. Clypeus transverse, the upper margin convex, the lateral margins tapering to a rounded distal terminus; surface with a medial, transverse carina. Labrum rounded with a darkened distal terminus. Antennal flagellomeres pale basally and fading to black toward the distal end; setae present. Anterior surface of head mostly pale or ochre with tiny dark speckling across the surface; labial palpi ochre, maxillary palpi ochre, sometimes with black markings.

Thorax: Longer than wide, with an expanded supra-coxal bulge; dorsal surface with uneven tiny depressions and scattered black tubercles. Prozone with medial region of prozone peaked, sloping to the lateral margins. Metazone with uneven sculpting across the surface. Margins of the prozone convex, tapering sharply to a narrowed, rounded anterior margin; margins of metazone strongly convex, tapering to a narrow constriction medially before widening to the posterior margin. Tubercles present on the margins of the prozone; a few large tubercles present on the margins of the metazone. The supra-coxal sulcus strongly defined and sweeping anteriorly prior to the expanded lateral margins at the supra-coxal bulge. Prosternum with or without a complex black and whitish pattern (Fig. 2); if present, a transverse black band anteriorly and a curved black band posteriorly, the posterior half of the medial region whitish colored, the anterior half with a trapezoidal shape of brown surrounded by a thin black band, the trapezoid reaching the lateral margins. Wings reduced or absent.

Prothoracic Legs: The femur squat, almost forming a triangle; spines robust, pale proximally and black distally; femoral groove to accommodate the tibial spur proximal to the middle. The posterior surface of the femur with a marginal carina; dorsal margin narrowing; the posterior surface with numerous small tubercles; 4 discoidal spines. The ventral surface of the femur pale with numerous tubercles medially distal to the discoidal spines, the tubercles continue just proximal to the discoidal spines until the junction with the trochanter; the discoidal spines robust, the third from the base very large and robust. The anterior surface of the femur mostly pale with some black mark-

ing. Tibia robust with rare, fine setae on the surface and near the lateral margins of the ventral surface; posterior surface pale with some black markings; ventral surface ochre and lustrous; posteroventral and anteroventral tibial spines gradually becoming longer from the proximal to the distal end. Coxae with tubercles and setae across the surface, the dorsal margin with setae and a few strong tubercles; the anterior surface mostly ochre with some black markings, the distal lobes ochre.

Meso- and Metathoracic Legs: Femora with ventral (posterior) carina well developed; dorsal (anterior) carina absent; surface with numerous small, fine setae. Coxae with numerous black markings speckling the surface. Tibia round, covered with setae. Tarsi short with ample setae.

Abdomen: Very broad, elliptical, the widest being the middle. Fine setae disperse across the dorsal and ventral surfaces; each tergite with a medial keel, more pronounced anteriorly. Tergites rounded at the posterolateral margins. Supra-anal plate transverse, with a rounded terminus. The ovipositor enlarged and broad, projecting far beyond the distal margin of the supra-anal plate and the cerci. Cerci round, tapering to a point.

Key to species

- 1 Male and female large in size (observed range 44–56 mm). Forewings of male with setae, some robust, along anterior margin; the surface of the costal region ciliated; the discoidal region smooth, not ciliated. Male and female with distinct pattern on the prosternum (Fig. 2A). Female brachypterous. Male foretibiae with 9–10 posteroventral spines. Male forefemora with 13 anteroventral spines ***alticeps* (Schaum, 1853)**
- 1' Male and female small in size (observed range 19–34 mm). Forewings of male with dense setae along anterior margin; the surface of the costal and discoidal regions tightly ciliated. Male and female prosternum ochre with dark brown speckling that becomes more dense posteriorly (Fig. 2B). Female apterous. Male foretibiae with 7–8 posteroventral spines. Male forefemora with 12 anteroventral spines ***tigrifrutex* sp. n.**

Dystacta alticeps (Schaum, 1853)

Mantis alticeps: Schaum 1853: 777; Schaum 1862: 113.

Cardioptera alticeps: Saussure 1871: 211.

Dystacta alticeps: Westwood 1889: 17; Krauss 1901: 284; Kirby 1904: 226; Karny 1908: 371; Rehn 1912: 112; Werner 1923: 118; Giglio-Tos 1927: 207; Beier 1935: 21; Kaltenbach 1996: 239; Lombardo 1997: 73; Kaltenbach 1998: 19; Ehrmann 2002: 124; Otte and Spearman 2005: 31.

= *Dystacta paradoxa:* Saussure 1871: 447; Saussure 1872: 80; Stål 1877: 51; Westwood 1889: 17; Kirby 1899: 347 [SYN of *D. alticeps*]; Ehrmann 2002: 124 [SYN]; Otte and Spearman 2005: 31 [SYN].

- = *Polyspilota marmorata*: Schulthess 1899: 192; Kirby 1904: 241; Beier 1935: 21 [SYN of *M. alticeps*]; Ehrmann 2002: 124 [SYN]; Otte and Spearman 2005: 31 [SYN].
- = *Paracilnia ornatipennis*: Beier 1935: 102; Kaltenbach 1996: 239 [SYN of *M. alticeps*]; Ehrmann 2002: 124 [SYN]; Otte and Spearman 2005: 31 [SYN].
- = *Dystacta stali*: Karny 1908: 371; Beier 1935: 21 [SYN of *M. alticeps*]; Ehrmann 2002: 124 [SYN]; Otte and Spearman 2005: 31 [SYN].

Repository. Holotype Female. Museum für Naturkunde der Humboldt-Universität, Berlin, Germany.

***Dystacta tigrifrutex* Tedrow & Svenson, sp. n.**

<http://zoobank.org/BA908752-636F-4B12-9510-A54E75E9B2B9>

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

Repository. Holotype Male (CLEV GSMC004381). Allotype Female (CLEV GSMC004420). The Cleveland Museum of Natural History, Cleveland, OH, USA

Holotype and Allotype labels: Pinned. Rwanda, Nyungwe National Park, -2.478121, 29.200055, 2446 m, 4–9 May 2013, Coll: R. Tedrow & G.J. Svenson.

Natural history. Based on the collecting location on the ground for both the male and the female and the fact that the female is apterous, we presume that the species utilizes a low vegetation or forest floor habitat. This would be consistent with morphologically similar species in Africa (Chroicopterinae), Asia (some Amelinae) and South America (some Thespinae). The female walks nimbly through vegetation and uses her forelegs periodically, pausing and moving them similar to boxing mantises (species of *Hestiasula*). The male took flight readily and was difficult to observe and expired quickly in captivity.

Diagnosis. Male brown with elongate wings. The easiest way to distinguish *D. tigrifrutex* from *D. alticeps* is the distinct black and whitish pattern on the prosternum of *D. alticeps* (Fig. 2A) while *D. tigrifrutex* has a speckled pattern on the prosternum (Fig. 2B). In addition, the presence of tight ciliation on the discoidal region of the forewings of male *D. tigrifrutex* compared with the smooth surface seen in *D. alticeps*. Females are apterous in *D. tigrifrutex* and brachypterous in *D. alticeps*.

Description. Male. Holotype (Figs 1A, 3A–B). Body length 34.72; forewing length 28.2; hindwing length 27.16; pronotum length 4.65; prozone length 1.77; pronotum width 2.11; pronotum narrow width 1.03; head width 3.46; head vertex to clypeus 1.53; frons width 1.27; frons height 0.595; prothD. *tigrifrutex* D. *tigrifrutex* oracic femur length 5.19; mesothoracic femur length 5.46; mesothoracic tibia length 4.59; mesothoracic tarsus length 3.85; metathoracic femur length 6.48; metathoracic tibia length 7.26; metathoracic tarsus length 5.30; anteroventral femoral spine count R12/L12; posteroventral femoral spine count R4/L4; anteroventral tibial spine count R11/L10; posteroventral tibial spine count R7/L8.

A DK cyclopean ear present on the ventral surface of the metathorax (see Yager and Svenson 2008 for description of the DK form).

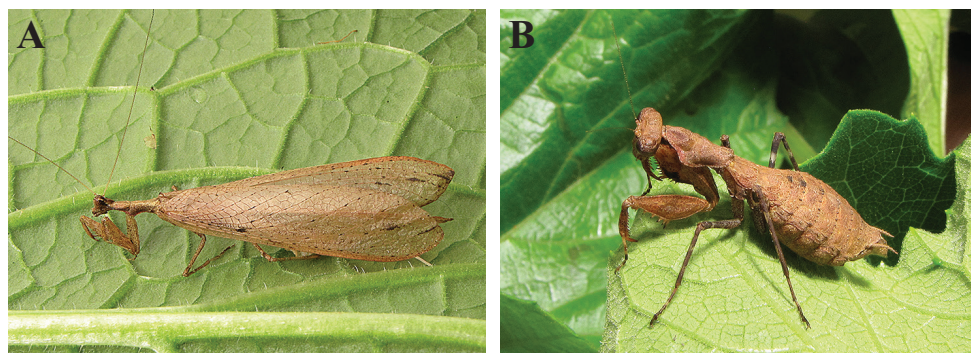


Figure 1. *Dystacta tigrifrutex* sp. n., live habitus: **A** holotype male (GSMC004381) **B** allotype female (GSMC004420).

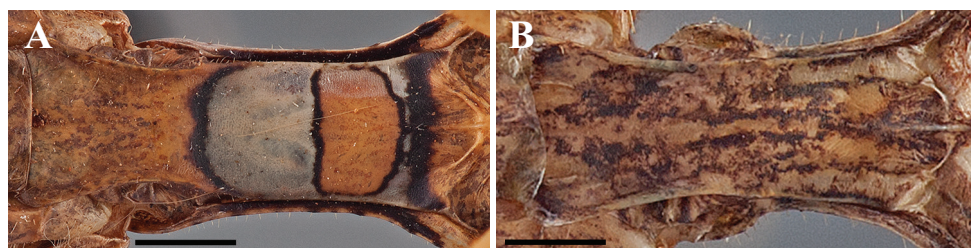


Figure 2. *Dystacta* male prosternum (scale bar = 1 mm), posterior margin on the left: **A** *Dystacta alticeps* Schaum, 1853 **B** *Dystacta tigrifrutex* sp. n.

Head (Fig. 4A): Transverse, eyes slightly exophthalmic; the vertex rounded, the parietal sutures present; juxta-ocular protuberances absent. Frontal suture faint with a medial carina forming a continuous arc. Ocelli large, protruding on small cuticular mounds, but the region between all three slightly raised, with a triangular shape; the lateral ocelli oriented outward; the region around the raised ocelli and below the frontal suture depressed. Clypeus transverse, the upper margin convex, the lateral margins tapering; surface with moderate sculpting; the lower margin of the clypeus slightly concave. Labrum rounded. Antennae with a mostly pale pedicel and scape, but both with small black marks; the flagellomeres mostly pale in the basal half, transitioning to black on the distal end of the antennae, the setae dark colored, with 4-5 setae on each flagellomere. Anterior surface of head mostly pale or ochre with tiny dark speckling across the surface; frons ochre with dark splotches of black, a transverse black band just below the antennae extends laterally across the anterior surface of the eyes; the clypeus ochre with dark splotches of black; labrum ochre with black splotches, with ochre mandibles; vertex ochre with black splotches; raised area around ocelli black. Maxillary palpi ochre with black spots with the terminal segment black on one side.

Pronotum (Figs 2B, 5A): Longer than wide, with an expanded supra-coxal bulge; dorsal surface smooth. Prozone with two angled carina oriented anterolateral from the supra-coxal sulcus; medial region of prozone peaked, sloping steeply to the anterior

margins; medium length with margins gradually tapering anteriorly to a rounded anterior margin; the margins smooth, but with setae present. Metazone with two small depressions posterior to the supra-coxal sulcus; two large and prominent tubercles positioned on each side of the medial line just anterior to the posterior margin, a raised carina oriented anterolaterally, extending to the lateral margins of the metazone. Metazone with concave lateral margins tapering posteriorly until two thirds from the supra-coxal bulge, then widening to the posterior margin; margins smooth, but with setae present; the dorsal surface of the metazone not depressed. Ochre with faint black spots and more opaque black lines laterally. Prosternum ochre with dark brown speckling that becomes more dense posteriorly.

Forelegs: Femur shape normal with a straight dorsal margin; spines robust, pale proximally and black distally; femoral groove to accommodate the tibial spur in the proximal half; the posterior surface smooth; 4 discoidal spines. Posterior surface of femur ochre with black stippling; anterior surface ochre with black speckling that is more concentrated along the outer margins; ventral surface with a black band between the second most proximal and third most proximal posteroventral spines as well as a black band extending half way from the most distal posteroventral spine to the genicular spine; setae dispersed across a pale ventral surface. The discoidal spines robust, the third from the base very large and robust, twice the length of the second and fourth. Anteroventral femoral spines 1, 3, 5, 7, 9–11 short, but of similar length to each other; anteroventral femoral spines 2, 4, 6, 8 long, but of similar length to each other; posteroventral femoral spines all of the same length; the posterior and anterior genicular spines small, but robust. Tibia with numerous setae along the dorsal margin and on the posterior, anterior and ventral surfaces; anterior and posterior surfaces ochre with black stippling; posterior external surface ochre with groups of dense black stippling, occasionally with a black stippled line beginning at the base of the tibio-femoral joint to about a quarter of the way to the distal end to the tibia. Posteroventral tibial spines 1–6 of similar length, the distal spine 7 larger than the others; anteroventral tibial spines gradually increase in length from the most proximal to the most distal spine. Forecoxae mostly smooth with setae interspersed throughout, a few tubercles present along the margins, but none are robust as seen in females.

Meso- and Metathoracic Legs: Femora with pronounced ventral (posterior) carina; dorsal (anterior) carina faint. The femora, tibiae and tarsi with dense setae. Femora mostly pale with a number of black bands near the distal terminus on the posterior surface, the most pronounced running just dorsal to the ventral carina; anterior surface with a number of black bands along the ventral carina. Tibia pale with a number of faint black marks, some appearing as bands. Tarsi short; the first three tarsal segments are light proximally and have a dark spot on the distal end, the remaining segments black; mesotarsi and metatarsi with the first segment shorter than the remaining segments combined.

Wings: Elongate, extending well beyond the terminus of the abdomen. Forewing slender, the costal region narrow and opaque brown; dense setae along the anterior margin; the entire surface tightly ciliated; the discoidal region smoky grey with few

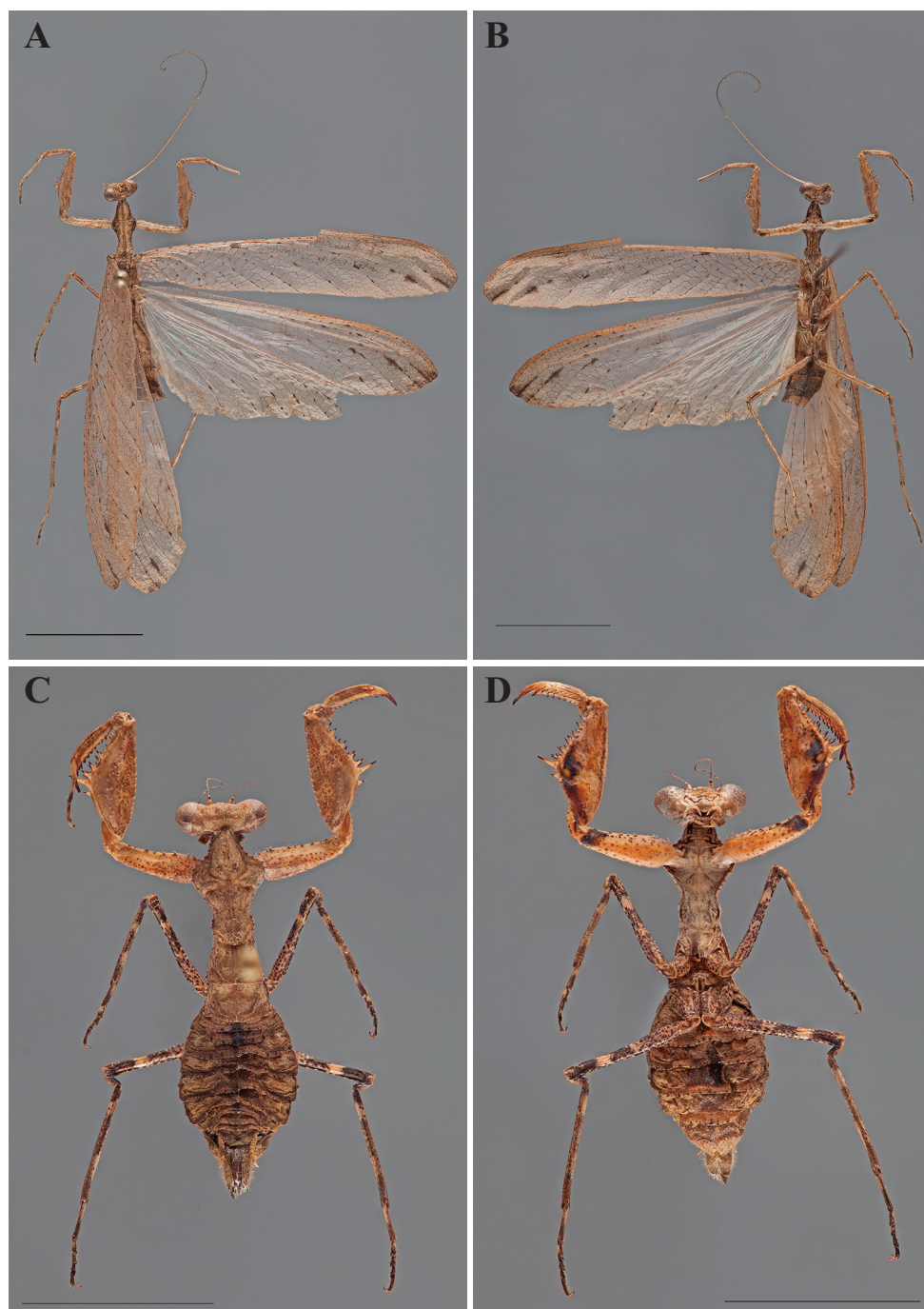


Figure 3. *Dystacta tigrifrutex* sp. n., pinned habitus (scale bar = 1 cm). Holotype male (GSMC004381): **A** dorsal **B** ventral. Allotype female (GSMC004420): **C** dorsal **D** ventral.

dark splotches, three or four in the distal half; the veins more pigmented than surrounding cell colors, but small black sections disperse across all veins and occasionally along the major wing veins, increasing in frequency moving toward the distal terminus. Hindwings with setae along anterior margin, the surface tightly ciliated; matching coloration of forewing, but the costal region translucent grey in the proximal half, fading to opaque brown in the distal half; black marks along the distal terminus of the discoidal region; the terminus of the discoidal region projecting well beyond the margin of the anal region, the wing appearing highly elongate.

Abdomen: Smooth, tubular with brown and black coloration. A black medial line on the ventral surface that is contiguous across sternites; the posterior half of sternites fading from brown to black; the surface with numerous setae. Tergites rounded at the postero-lateral margins. Supra-anal plate and cerci not known since the posterior half was detached and carried away by opportunistic ants when drying.

Genital Complex: Due to specimen damage, the genitalia are absent.

Female. Allotype (Figs 1B, 3C–D). Female was preserved in ethanol and later pinned, causing some deformation in the abdomen. Body length 19.82; pronotum length 5.89; prozone length 2.56; pronotum width 3.83; pronotum narrow width 1.83; head width 4.83; head vertex to clypeus 3.72; frons width 1.87; frons height 1.10; prothoracic femur length 6.61; mesothoracic femur length 5.46; mesothoracic tibia length 4.82; mesothoracic tarsus length 3.91; metathoracic femur length 6.18; metathoracic tibia length 7.10; metathoracic tarsus length 4.73; anteroventral femoral spine count R12/L11; posteroventral femoral spine count R4/L4; anteroventral tibial spine count R11/L11; posteroventral tibial spine count R9/L9.

A DO cyclopean ear present on the ventral surface of the metathorax (see Yager and Svenson 2008 for description of the DO form).

Head (Fig. 4B): Slightly transverse, eyes not particularly exophthalmic; vertex highly convex, the parietal sutures present; juxta-ocular protuberances absent. Frontal suture faint, but a forming dorsally oriented curved. Ocelli absent or vestigial, but lenses not visible; a carina connecting former ocellar locations connecting all three and forming a U; region within the U and below the frontal suture depressed. Frons transverse with an angled carina below the antennae, meeting medially with a raised point. Clypeus transverse, the upper margin convex, the lateral margins tapering to a rounded distal terminus; surface with a medial, transverse carina. Labrum rounded with a darkened distal terminus. Antennae with a mostly pale pedicel that has a black band distally; scape black, flagellomeres pale basally and fading to black within 10 antennomeres; setae sparse basally, becoming more dense distally. Anterior surface of head mostly pale or ochre with tiny dark speckling across the surface; frons with a transverse black band just below the antennae; labial palpi ochre, maxillary palpi ochre then with a black spot on both sides of the terminal segment.

Pronotum (Fig. 5B): Longer than wide, with an expanded supra-coxal bulge; dorsal surface with uneven tiny depressions and scattered black tubercles. Prozone with two angled carina oriented anterolateral from the supra-coxal sulcus; medial region of prozone peaked, sloping steeply to the lateral margins. Metazone with uneven sculpting across

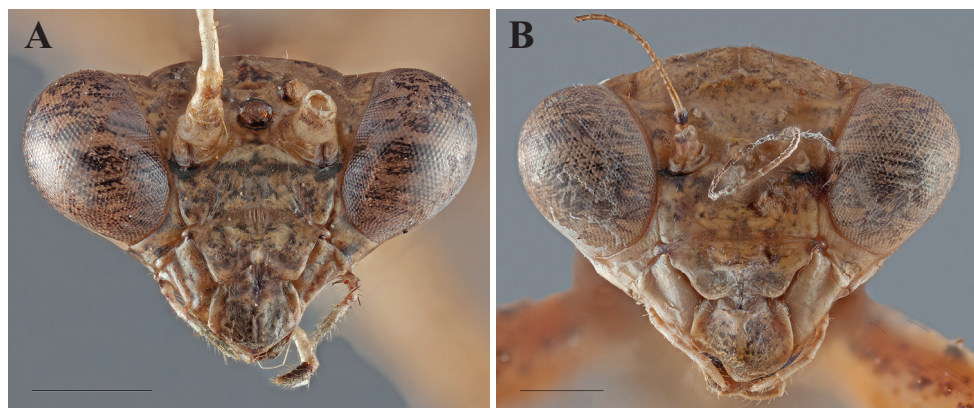


Figure 4. *Dystacta tigrifrutex* sp. n., head from the anterior perspective (scale bar = 1 mm): **A** holotype male **B** allotype female.

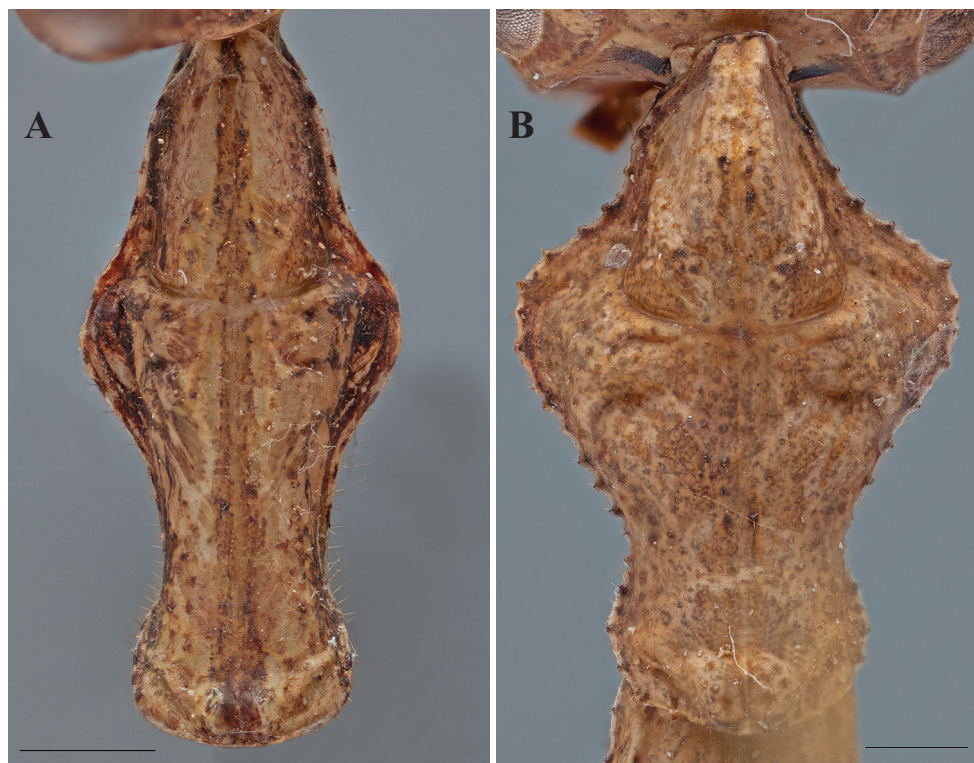


Figure 5. *Dystacta tigrifrutex* sp. n., pronotum from the dorsal perspective (scale bar = 1 mm): **A** holotype male **B** allotype female.

the surface, two depressions posterior to the supra-coxal sulcus; two large and prominent tubercles positioned on each side of the medial line just anterior to the posterior margin. Margins of the prozone convex, tapering sharply to a narrowed, rounded anterior margin;

margins of metazone strongly convex, tapering to a narrow constriction medially before widening to the posterior margin. Small, blunt tubercles present on the margins of the prozone; a few large tubercles present on the margins of the metazone, diagonally pointed setae protruding from the posterior side of the lateral half of the tubercle. The supra-coxal sulcus strongly defined and sweeping anteriorly prior to the expanded lateral margins at the supra-coxal bulge. Metazone provides the lateral expansion at the supra-coxal bulge; the dorsal surface flat, but bulging over the lateral margins in the anterior half. Prosteronum ochre with dark brown speckling that becomes more dense posteriorly.

Forelegs: The femur squat, almost forming a triangle; spines robust, pale basally and black distally; femoral groove to accommodate the tibial spur just proximal to the middle. The posterior surface of the femur with a marginal carina; dorsal margin narrowing, almost lamellar along the slightly convex margin; dorsal margin with small tubercles that give rise to small hairs; the posterior surface with numerous small tubercles; 4 discoidal spines. The ventral surface of the femur pale with numerous tubercles medially distal to the discoidal spines, each giving rise to a long hair, tubercles continue just proximal to the discoidal spines until the junction with the trochanter; the discoidal spines robust, the third from the base very large and robust. The anterior surface of the femur mostly pale, but with black markings along the ventral margin anterior and posterior to the femoral groove, the groove itself pale; black speckling across the surface. Anteroventral femoral spines (proximal to distal) 2, 4, 6, 8, 12 long, but of similar length to each other, spines 1, 3, 5, 7, 9–11 short, but of similar length to each other; posteroventral femoral spines all of similar length; the posterior and anterior genicular spines small, but robust. Tibia robust with rare, fine setae on the surface and near the lateral margins of the ventral surface; posterior surface ochre with black stippling, ventral surface ochre and lustrous; posteroventral and anteroventral tibial spines gradually becoming longer from the proximal to the distal end. Coxae with tubercles and setae across the surface, the dorsal margin with setae and a few strong tubercles; the anterior surface mostly ochre with small black spots, a large black marking near the distal margin, the distal lobes ochre.

Meso- and Metathoracic Legs: Femora with ventral (posterior) carina well developed; dorsal (anterior) carina absent; surface with numerous small, fine setae; darkly speckled with black markings, sparse proximally, becoming more dense distally, but with a pale band in the distal half. Coxae with numerous black markings speckling the surface. Tibia round, covered with setae; mostly black with two pale bands, one in the proximal half and the other in the distal half. Tarsi short with ample setae; mostly black with the first three tarsal segments are light proximally and darken toward the distal end, the remaining segments black; mesotarsi and metatarsi with the first segment shorter than the remaining segments combined.

Wings: Apterous with no visible vestiges.

Abdomen (Fig. 6A–B): Very broad, elliptical, the widest being the middle. Tergites and sternites with small, black tubercles along the posterior margins; fine setae disperse across dorsal and ventral surface; each tergite with a medial keel, more pronounced anteriorly. Described from the ethanol preserved specimen, plates 2,3,4, and 5 with

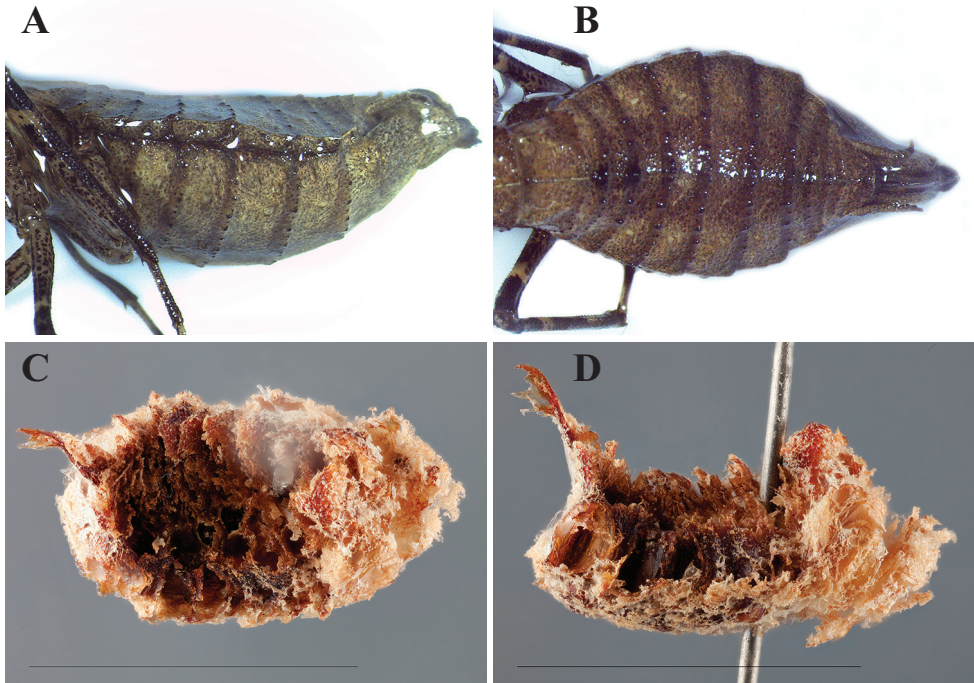


Figure 6. *Dystacta tigrifrutex* sp. n. Allotype female abdomen preserved in ethanol: **A** lateral **B** dorsal. Ootheca (scale bar = 1 cm): **C** dorsal **D** lateral.

small carinae near the lateral margin forming a 45 degree angle with the distal margins of their respective segments, the carinae highest at the margin and descending medially at approximately a 45 degree angle. Tergites rounded at the postero-lateral margins. Supra-anal plate transverse, evenly rounded terminus. The ovipositor enlarged and broad, projecting far beyond the distal margin of the supra-anal plate and the cerci. Cerci round, tapering to a point.

Nymphs. *First Instar.* Length 3.89; pronotum length 1.21; prozone length 0.52; pronotum width 0.73; pronotum narrow width 0.43; head width 1.39; prothoracic femur length 1.61; mesothoracic femur length 1.38; mesothoracic tibia length 1.28; mesothoracic tarsus length 1.23; metathoracic femur length 1.89; metathoracic tibia length 1.79; metathoracic tarsus length 1.29; anteroventral femoral spine count R12/L12; posteroventral femoral spine count R4/L4; anteroventral tibial spine count R10/L10; posteroventral tibial spine count R8/L8.

Head: Transverse, eyes exophthalmic; vertex highly convex, parietal sutures present; juxta-ocular protuberances absent. Frontal suture forming a dorsally oriented curve. Ocelli not fully developed; the anterior ocellus raised; the location of the lateral ocelli marked by yellow bumps, connected by a U-shaped carina; the region within the U and below the frontal suture slightly depressed. Frons transverse with an angled carina below the antennae, meeting medially with a slightly raised point. Clypeus transverse, the upper margin convex, the lateral margins tapering; surface with a medial,

transverse carina. Labrum rounded with a darkened distal terminus. Antennae with a faded black pedicel; scape pale with black splotching; flagellomeres pale basally and fading to black within four antennomeres; setae very sparse basally, becoming slightly more dense distally. Anterior surface of head dark brown with light brown spots; a pale ring formed around the circumference of the antennal insertion sites and a pale arc formed between the eyes posterior to the ocelli. Labial and maxillary palpi segments black basally with a distal light brown terminus.

Pronotum: Longer than wide, with an expanded supra-coxal bulge; dorsal surface smooth. Prozone with a strongly peaked medial region, sloping steeply to the lateral margins. Metazone smooth with a continuation of the peaked region of the prozone sloping steeply to the lateral margins; two small bumps are found on either side of the midline at the distal end of the metazone.

Forelegs: The femur squat, nearly triangular; spines robust with a blackish-brown coloration; femoral groove to accommodate the tibial spur proximal to the middle. The posterior surface of the femur with a marginal carina; dorsal margin narrowing, almost lamellar along the slightly convex margin; dorsal margin with small tubercles that give rise to small hairs. The ventral surface blackish-brown with occasional tubercles giving rise to small hairs; the discoidal spines robust, the third from the base very large and robust. Anterior surface of femora blackish-brown; the groove blackish-brown as well. Anteroventral femoral spines (proximal to distal) 2, 4, 6, 8, 12 are long and of similar length to each other while spines 1, 3, 5, 7, 9–11 are short and of similar length to each other; posteroventral femoral spines all of similar length; the posterior and anterior genicular spines small, but robust. Tibia robust with several setae on the anterior surface and near the lateral margins of the ventral surface; posterior surface ochre; posteroventral and anteroventral tibial spines gradually becoming longer from the proximal to the distal end. Coxae smooth; the surface ochre with blackish-brown spots and a blackish-brown band at the distal end; the distal lobes ochre.

Meso- and Metathoracic Legs: Femora with ventral (posterior) carina; dorsal (anterior) carina absent; surface with numerous small, fine setae; ochre with faint, small brown spots and three wide, faint brown bands. Coxae ochre. Tibia round, covered with setae of varying size; dark brown with four sand colored bands. Tarsi short and covered with setae; black and blackish-brown in color; mesotarsi and metatarsi with the first segment shorter than the remaining segments combined.

Abdomen: Broad, elliptical, widest in the middle. Tergites with a medial keel, more pronounced anteriorly. Setae occurring on the lateral margins projecting laterally. Tergites rounded at the postero-lateral margins. Supra-anal plate transverse. Cerci round and short, tapering to a point.

Ootheca (Fig. 6C–D). *Measurements*. Length 11.12; width 6.40; height 5.24; perimeter (dorsal perspective) 33.87; perimeter (from lateral perspective) 43.23. From the dorsal perspective, the ootheca appears elliptical, with a distinct dorsal point on the posterior end where the egg-case laying terminated. The ootheca is convex ventrally and concave dorsally from the lateral perspective. The anterior end is larger than the remainder of the ootheca, which is consistent in girth with the exception of the terminal dorsal

point. Large egg chambers can be seen in rows perpendicular to the top and bottom of the egg-case. The emergence area takes up the majority of the dorsal surface. There is very little air space, the egg chambers extending nearly to the perimeter of the oothecae. The interior of the ootheca is a dark to light reddish brown with a foam textured light brown cast covering the external surface. The method of attachment for this species appears to be smooth vertical surfaces, with no apparent ventral circlet at the point of attachment. This hypothesis is based off the observation of a single specimen that laid its ootheca on the side wall of a mesh cube container in which it was temporarily held (the flexible surface may have influenced the convexity of the ventral surface). The cube contained several twigs at various angles as well as leaves.

Etymology. The word *tigrifrutex* is derived from the latin word *tigris* (meaning tiger) and the latin word *frutex* (meaning bush). This name was crafted to reflect the behavior of the female, whose morphology suggests that she is adapted for hunting prey close to the ground and in the undergrowth.

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References

- Beier M (1935) Mantodea, Fam. Mantidae, Subfam. Mantinae. Genera Insectorum de P. Wytsman 203 Fascicule, 154 pp.

- Beier M (1964) Blattopteroidea-Mantodea. In: Bronn HG (Ed) H. G. Bronn's Klassen und Ordnungen des Tierreichs. III. Abt.: Insecta-Arthropoda. Akademie Verlagsges., 5. Lfg., 5(6): 850–970.
- Beier M (1968) Mantodea. In: Helmcke JG, Starck D, Wermuth H (Eds) Handbuch der Zoologie. 12, Teil 2/12, 4(2), Walter de Gruyter & Co., Berlin, 47 pp.
- Breland OP, Dobson JW (1947) Specificity of Mantid Oothecae. *Annals of The Entomological Society of America* 40(4): 557–575
- Ehrmann R (2002) Mantodea: Gottesanbeterinnen der Welt. Natur und Tier – Verlag GmbH, Münster, 519 pp.
- Giglio-Tos E (1927) Mantidae. Das Tierreich. Walter de Gruyter & Co., Berlin, 707 pp.
- Kaltenbach AP (1996) Unterlagen für eine Monographie der Mantodea des südlichen Afrika: 1.-Artenbestand, geographische Verbreitung und Ausbreitungsgrenzen (Insecta: Mantodea). *Annalen des Naturhistorischen Museums in Wien* 98(B): 193–346.
- Kaltenbach AP (1998) Unterlagen für eine Monographie der Mantodea des südlichen Afrika: 2.-Bestimmungstabellen für die höheren Taxa, Nachträge zum Artenbestand. *Annalen des Naturhistorischen Museum in Wien* 100(B): 19–59.
- Kaplin B (2013) Nyungwe National Park. Antioch University New England. Web Sept. 2013. http://www.antiochne.edu/nyungwe/forest_facts/
- Karny HH (1908) Orthoptera (I.) Blattaeformia Oothecaria. In: Schultze L (Ed) Zoologische und anthropologische Ergebnisse einer Forschungsreise im westlichen und zentralen Südafrika. *Denkschrift Gesellschaft zu Jena* 13: 355–376.
- Kirby WF (1899) On a collection of Mantidae from the Transvaal & c. fromed by Mr. W. L. Distant. *The Annals and Magazine of Natural History* 4: 344–353. doi: 10.1080/00222939908678211
- Kirby WF (1904) A synonymic Catalogue of Orthoptera. I. Orthoptera Euplexoptera, Cursoria et Gressoria). Vol. 1. British Museum, Nat. Hist., London, 501 pp.
- Krauss HA (1901) Beiträge zur Kenntnis der Orthopteren Deutsch-Südwestafrikas. *Verhandlungen der Zoologisch-Botanischen Gesellschaft in Wien* 51: 281–293.
- Lombardo F (1997) New and little known Mantodea from Eastern and Central Southern Africa. *Journal of Orthoptera Research* 6: 69–81. doi: 10.2307/3503537
- Nyungwe Nziza: Nyungwe forest <http://nyungwepark.com/nyungwe/the-park/>
- Otte D, Spearman L (2005) Mantida Species File. *Catalog of the Mantids of the World*. Association of Insect Diversity, Philadelphia, 489 pp.
- Plumptre AJ, Masozera M, Fashing PJ, McNeillage A, Ewango C, Kaplin BA, Liengola I (2002) Biodiversity Surveys of the Nyungwe Forest Reserve in S.W. Rwanda. *Wildlife Conservation Society Working Papers* No. 18.
- Rehn JAG (1912) On some African Mantidae and Phasmidae in the Collection of the Deutsches Entomologisches Museum. *Archiv für Naturgeschichte* 78(6): 106–126.
- Rivera J (2010) A historical review of praying mantid taxonomy and systematics in the Neotropical Region: State of knowledge and recent advances (Insecta: Mantodea). *Zootaxa* 2638: 44–64.
- Saussure H de (1871) *Mélanges Orthoptérologiques*. IV. Mantides. *Mémoires de la Société de Physique et d'Histoire Naturelle de Genève* 21: 1–337.

- Saussure H de (1872) *Mélanges Orthoptérologiques*. IV Fascicule. Mantides et Blattides. *Mémoires de la Société de Physique et d'Histoire Naturelle de Genève* 23(1): 1–165.
- Schaum HR (1853) Bericht über die zur Bekanntmachung geeigneten Verhandlungen der Königlich Preussischen Akademie der Wissenschaften zu Berlin (1853): 775–780
- Schaum HR (1862) Zoologie, Insecten, Orthoptera, Geradflüger, Mantidae. In: Peters WCH (Ed) *Naturwissenschaftliche Reise nach Mossambique auf Befehl seiner Majestät des Königs Friedrich Wilhelm IV in den Jahren 1842 bis 1848 ausgeführt*. George Reimer, Berlin, 5: 112–116.
- Schulthess A von (1899) La Faune Entomologique de Delago. II. Orthoptères. *Bulletin de la Société vaudoise des Sciences Naturelles* 35: 191–215.
- Stål C (1877) *Systema Mantodeorum*. Essai d'une systematisation nouvelle des Mantodées. *Bihang till Kongl. Svenska vetenskaps-akademiens handlingar* 4(10): 1–91.
- Svenson GJ (2014) Revision of the Neotropical bark mantis genus *Liturgusa* Saussure, 1869 (Insecta, Mantodea, Liturgusini). *ZooKeys* 390: 1–214. doi: 10.3897/zookeys.390.6661
- Svenson GJ, Whiting MF (2009) Reconstructing the Origins of Praying Mantises (Dictyoptera, Mantodea): the roles of Gondwanan vicariance and morphological convergence. *Cladistics* 25: 468–514. doi: 10.1111/j.1096-0031.2009.00263.x
- Werner F (1923) Mantodea und Phamodea. In: Michaelsen W. *Beiträge zur Kenntnis der Fauna Deutsch-Südwest-Afrikas* 2: 105–132.
- Westwood JO (1889) *Revisio Insectorum Familiae Mantidarum, speciebus novis aut minus cognitis descriptis et delineatis*. Gurney and Jackson, London, 55 pp.
- Wieland F (2008) The genus *Metallyticus* reviewed (Insecta: Mantodea). *Species, Phylogeny and Evolution* 1(2): 147–170.
- Wieland F (2013) The phylogenetic systems of Mantodea (Insecta: Dictyoptera). *Species, Phylogeny and Evolution* 3.1: 3–222.
- Yager DD, Svenson GJ (2008) Patterns of Praying Mantis Auditory System Evolution Based on Morphological, Molecular, Neurophysiological, and Behavioral Data. *Biological Journal of the Linnaean Society* 94: 541–568. doi: 10.1111/j.1095-8312.2008.00996.x

A review of the microgastropod genus *Systemostoma* Bavay & Dautzenberg, 1908 and a new subterranean species from China (Gastropoda, Pulmonata, Hypselostomatidae)

Adrienne Jochum^{1,†}, Rajko Slapnik^{2,‡}, Marian Kampschulte^{3,§},
Gunhild Martels^{3,¶}, Markus Heneka^{4,¶}, Barna Páll-Gergely^{5,#}

1 Department of Community Ecology, Institute of Ecology and Evolution, Baltzerstrasse 6, University of Bern, CH-3012 Bern, Switzerland **2** Drnovškova pot 2, Mekinje, 1240 Kamnik, Slovenia **3** Universitätsklinikum Gießen und Marburg GmbH–Standort Gießen, Zentrum für Radiology, Abteilung für Radiologie, Klinik-Str. 33, 35385 Gießen, Germany **4** RjL Micro & Analytic GmbH, Im Entenfang 11, 76689 Karlsdorf-Neuthard, Germany **5** Department of Biology, Shinshu University, Matsumoto 390-8621, Japan

[†] <http://zoobank.org/0A945916-C4FE-424A-8D0F-6FABA2BF289B>

[‡] <http://zoobank.org/09E86269-966B-49E6-AB92-31B66968DC0D>

[§] <http://zoobank.org/9E955DE5-576F-4793-BADA-0F92EF4C3015>

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[#] <http://zoobank.org/31E196E9-5A51-4295-9A36-D5DA689502B7>

Corresponding author: Barna Páll-Gergely (pallgergely2@gmail.com)

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Abstract

A review of the microgastropod genus *Systemostoma* is provided. Thai and Malaysian species are transferred to a new genus, *Angustopila* (type species: *Systemostoma tamlod* Panha & Burch 1999). A new subterranean *Angustopila* species is described here. Conchologically, the new species is most similar to the cave-dwelling, Thai *A. tamlod* (Panha & Burch, 1999). One Thai species (*Systemostoma edentata*) is transferred to the genus *Hypselostoma*. Vietnamese members remain in the genus *Tonkinospira* (nomen novum) for *Systemostoma* Bavay & Dautzenberg 1908 (non *Systemostoma* Marsson 1887). A comprehensive map of former *Systemostoma* species is presented. SEM and NanoCT images, including a video of *A. huoyani* **sp. n.** internal shell morphology, pro-

vide novel perspectives of the shells of *Angustopila* and of the scarcely known Vietnamese *Tonkinospira* species. The biology of these snails is not yet known but collection localities suggest a troglomorphic ecology.

Keywords

Taxonomy, subterranean snail, Pupillidae, Vertiginidae, conservation, cave-dwelling species

Introduction

Microgastropods are less than 5 mm in size and represent the majority of worldwide tropical land snail diversity. They are restricted to specific microhabitats such as limestone rock surfaces or caves, have limited active dispersal ability and thus, frequently demonstrate high local endemism. Due to their small size and high degree of endemism, our knowledge of the taxonomy and ecology of microgastropod taxa such as the hypselostomatid genus *Systemostoma* is limited. Consequently, very little is known about tiny species and thus, the complex systematics of most tropical microgastropod groups is based on conchological characters only.

The microgastropod genus *Systemostoma* was established as a subgenus of *Helix* by Bavay and Dautzenberg (1908) for two Vietnamese species described in the same paper, namely *Helix (Systemostoma) pulverea* and *H. (S.) pauperrima*. The diagnosis of *Systemostoma* however, was given in another paper published a year later (Bavay and Dautzenberg 1909). The third Vietnamese species was described as *Systemostoma defixa* Bavay & Dautzenberg (1912). After these descriptions, *Systemostoma* remained in the dark for almost four decades. Jaekel (1950) described *Angustopila depressa* from the debris of an unknown Tonkinese (Northern Vietnam) tropical river. Therefore, knowledge of the distribution and ecology of this species is lacking. More recently, four species of *Systemostoma* were described from Thailand, namely *S. concava* and *S. elevata* by Thompson and Upatham (1997) and *S. edentata* and *S. tamlod* by Panha and Burch (1999). The genus was also reported from Malaysia, but the systematic position of the Malaysian samples is not yet clarified. Although Benthem-Jutting's (1949) figure of "*Hypselostoma laidlawi*" (Fig. 9) and her *Paraboysidia neglecta* (Benthem-Jutting, 1961) are similar and represent the same species according to her explanation, these illustrations likely show two different species (see Panha and Burch 1999).

The classification of *Systemostoma* is problematic. Together with the suspected, closely related genera (e.g. *Acinolaemus* Thompson & Upatham, 1997, *Anauchen* Pilsbry, 1917, *Boysidia* Ancey, 1881, *Hypselostoma* Benson, 1856, *Krobylos* Panha & Burch, 1999, *Gyliotrachela* Tomlin, 1930), *Systemostoma* is sometimes classified within Pupillidae (e.g. Panha and Burch 1999) or Vertiginidae (e.g. Thompson and Upatham 1997). These related genera are classified within Hypselostomatidae by Schileyko (1998). After examining the type species of the genus, Schileyko (1998) concluded that unlike these other genera, *Systemostoma* probably does not belong to Hypselostomatidae, but rather, likely belongs to Helicodiscidae because of the characteristic spiral sculpture. Later, Schileyko postulated that the genus is possibly related to *Aulacospira* as considered by

Pilsbry (1917) or to *Pupisoma* (Valloniidae) (Schileyko 2011). Before the description of the Thai species, previous diagnoses (Bavay and Dautzenberg 1909, Pilsbry 1917, Zilch 1959) described the genus as a taxon lacking apertural dentition. Thompson and Upatham (1997) claimed that *Systemostoma* species bear no teeth and that a low fold may be present on the parietal wall. Moreover, they described the sculpture as “dense mesh of very fine granular reticulation superimposed upon which are fine spiral threads. Spiral sculpture may be present or absent on the protoconch”. Thompson and Upatham (1997) hypothesized a close relationship between *Systemostoma* and *Acinolaemus* based on the likely, homologous parietal lamella and similar protoconch sculpture.

All *Systemostoma* have a relatively simple shell compared to the other members of the family Hypselostomatidae, whose shells usually have oddly coiled shapes and multiple apertural denticles. Still, *Systemostoma* species show a high diversity in general shell shape, aperture shape and dentition and shell sculpture. *Systemostoma* seems to represent a “collection bin” taxon for species possessing few or no denticles. The reduction of the apertural teeth however, could have evolved independently in different evolutionary lineages. In this case, congeners may well have been classified/lumped within one genus but systematically belong to at least three genera. In the following, we describe a new, subterranean species from China, present an overview of all former *Systemostoma* species, describe a new genus for Thai, Malaysian and the new Chinese species, transfer *S. edentata* to the genus *Hypselostoma* and assign a new name (*Tonkinospira*) to the Vietnamese species because the name *Systemostoma* (non *Systemostoma* Marsson 1887) is preoccupied. We present SEM and Nano-CT images of shells of the new species and the scarcely known Vietnamese members of the genus.

Material and methods

Abbreviations

RBINS	Royal Belgian Institute of Natural Sciences (Brussels, Belgium)
SMF	Senckenberg Forschungsinstitut und Naturmuseum (Frankfurt am Main, Germany)
MCSMNH	Malacological collection of the Slovenian Museum of Natural History (Ljubljana, Slovenia)
SMNS	Staatliches Museum für Naturkunde Stuttgart (Stuttgart, Germany)

Image acquisition

SEM: One paratype of *Angustopila huoyani* sp. n. was mounted on an aluminium stub, gold-palladium sputtered using the Edwards Kniese Sputter Coater S150B (Marburg, Germany) and subsequently scanned on the CamScan CS 24 scanning electron microscope (Dortmund, Germany). Specimens of *Tonkinospira* nom. n. were non-coated

and imaged with the Zeiss EVO LS15 scanning electron microscope (Jena, Germany) using the Variable Pressure (VP) mode.

Micro-CT: *Tonkinospira* nom. n. species were imaged using a nano-computed tomography system (nano-CT), manufactured and developed by Bruker-Micro-CT/SkyScan (SkyScan 2011, Kontich, Belgium) at the Department of Experimental Radiology, Justus-Liebig University Biomedical Research Center Seltersberg (BFS), Giessen, Germany. The scanner is based on a nanofocus tube generating X-rays in cone-beam geometry. Briefly, the system contains an open pumped type X-ray source, a LaB6 cathode and a transmission anode consisting of a tungsten-coated beryllium window. Enhanced edge sharpness is gained by a high-focussed X-ray spot of 300 nm side length (see Langheinrich et al. (2010) for more details). Specimens of *Tonkinospira* nom. n. were mounted on a computer-controlled stage. They were then scanned 180° around their vertical axis in rotation steps of 0.2° at 80 kV tube voltage and 120 µA tube current. Reconstruction of cross sectional images was performed using a modified Feldkamp cone-beam reconstruction algorithm. Image resolution of the cross sectional images was 1 µm isotropic voxel side length with a grey scale resolution of 8 bit. The video of *Angustopila huoyani* sp. n. was created using a SkyScan 1172 scanner at RJL Micro & Analytic GmbH, Karlsdorf-Neuthard, Germany. The scanner is equipped with a sealed micro focus x-ray source and a 11 Mpx CCD detector. The specimen was scanned with 4 µm voxel size in rotation steps of 0.6° at 59 kV tube voltage and 167 µA tube current. Reconstruction with cross sectional images followed the same aforementioned, cone-beam reconstruction algorithm. Image resolution of the cross sectional images was 4 µm isotropic voxel side length with a grey scale resolution of 8 bit. The animated video was generated using a direct volume rendering method implemented in the software CTvox.

Digital images: *Angustopila huoyani* sp. n. was photographed using a Kontron-Elektronik-ProgRes-3012 microscope camera (Jena, Germany) and a Leitz MZ12 stereomicroscope.

Taxonomy

Family Hypselostomatidae Zilch 1959

Genus *Angustopila* Jochum, Slapnik & Páll-Gergely, gen. n.

<http://zoobank.org/2DD2207C-8C0E-46F0-A1D3-12F480F105BD>

<http://species-id.net/wiki/Angustopila>

Type species. *Systemostoma tamlod* Panha & Burch 1999.

Diagnosis. *Angustopila* gen. n. is characterized by a very small, smooth, conical shell with regular, moderately increasing whorls. The body whorl sometimes extends beyond the penultimate whorl in profile. The sculpture of the protoconch is usually ornamented by spiral and radial lines resulting in a powdery, reticulated surface. The protoconch is slightly recessed into the second whorl. Aperture slightly or not adnate, with usually one or two denticles, peristome slightly reflexed.

Etymology. The name derives from the combination of the Latin *angustus* (= narrow) and *pila* (= pillar, column). Gender: feminine.

Remarks. *Angustopila* gen. n. differs from *Tonkinospira* nom. n. (former Vietnamese *Systemostoma*) by smaller shell size, more elevated spire, slightly reflexed apertural rim and general dentition present within the aperture. *Acinolaemus* usually has more teeth and a turban-like shell. *Krobylos* species have angulated whorls, lack spiral lines on the shell and possess a relatively large, toothless, adnate aperture.

Distribution. The genus is known from Thailand and Malaysia. The Chinese *Angustopila huoyani* sp. n. is located very distant, almost 1500 km from the northern Thai localities.

***Angustopila concava* (Thompson & Upatham, 1997)**

Systemostoma concava Thompson & Upatham, 1997: Bulletin of the Florida Museum of Natural History, 39 (7): 231–232, Fig. 32–38. [“Thailand, Nakhon Ratchasima Province, limestone hill 3.4 km west of Ban Mu Si, 380 m altitude (14°32.0'N, 101°22.5'E)”]

Systemostoma concava – Panha and Burch 2005: Malacological Review, 37/38: 118–119, Fig. 101.

***Angustopila elevata* (Thompson & Upatham, 1997)**

Systemostoma elevata Thompson & Upatham, 1997: Bulletin of the Florida Museum of Natural History, 39 (7): 232–233, Fig. 39–43. [“Thailand, Chiang Mae Province, Doi Chiang Dao (Mountain), 7 km west of Chiang Dao; 600 m altitude (19°24.3'N, 98°54.2'E)”]

Systemostoma elevata – Panha and Burch 2005: Malacological Review, 37/38: 120–121, Fig. 103.

***Angustopila huoyani* Jochum, Slapnik & Páll-Gergely, sp. n.**

<http://zoobank.org/2101F700-9723-422F-B70B-F8D0C2D20345>

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

Figure 4–5, Video 1

Type material. China, Hunan, Longshan (龙山县), Huoyan (火焰), Feihu Dong (飞虎洞), (29°12.53'N, 109°18.37'E, 550 m alt.), soil, leg. Verovnik, 13.04.1997, MCSMNH 50312/1 (holotype), MCSMNH 50312/2–9 (8 paratypes).

Diagnosis. A tiny, thin-shelled conical snail with very deep and narrow umbilicus, 5 shouldered whorls and two apertural denticles (parietal and palatal).

Description. Shell thin, greyish white, semi opaque; conical, widest at its base, with a homogeneous powdery superficial texture and regularly increasing, shouldered whorls



Video 1. Micro-CT Video of *Angustopila huoyani* sp. n. Video: Markus Heneka.

Video available for download in full resolution from http://www.pensoft.net/J_FILES/1/articles/7488/export.php_files/Jochum_Video_1.avi

separated by deep suture; smooth with no notable spiral or radial sculpture. It is characterized by very fine irregular axial lamellae and reticulating microgranules producing the powdery superficial texture; protoconch shows reticulating granules and recognisable radial lines only at the upper part of the first whorl; aperture semi-circular, slightly oblique from ventral view; peristome very slightly thickened and reflexed; parietal callus adnate (attached to the penultimate whorl); aperture with two well-developed but short denticles, one on the parietal and the other on the palatal side; umbilicus very deep and narrow.

Measurements. See Table 1.

Differential diagnosis. *Tonkinospira defixa*, *T. pulverea*, *T. pauperrima* and *T. depressa* are much larger than the new species, have reticulated sculpture and lack denticles in the aperture. Moreover, *T. defixa* has a more depressed spire, fewer whorls, wider umbilicus and slightly keeled body whorl; *T. pulverea* has fewer whorls, a comparatively larger aperture, somewhat keeled, wider body whorl and its umbilicus is partly closed by the apertural margin; *T. pauperrima* shows increased bulging in whorl configuration; *T. depressa* has a lower spire, slightly keeled body whorl and a large aperture without denticles. *Hypselostoma* (?) *edentata* also lacks denticles in the aperture and possesses a very wide, laterally compressed body whorl. *A. tamlod*, the most similar species, is slightly smaller, has fewer whorls, wider umbilicus and obvious spiral

Table 1. Shell measurements (mm) for *Angustopila huoyani* sp. n. from the type locality. SH - shell height, SW - shell width, AH - aperture height, AW - aperture width, SW/SH×100 - shell width shared with shell height and multiplied 100, AW/AH×100 – aperture width shared with aperture height and multiplied 100).

SH	SW	AH	AW	SW/SH×100	AW/AH×100	specimen
1.09	0.87	0.33	0.43	80	133.33	Holotype
1.13	0.91	0.41	0.43	80.77	105.26	Paratype
1.09	0.89	0.35	0.41	82	118.75	Paratype
1.13	0.91	0.39	0.41	80.77	105.55	Paratype
1.20	0.96	0.43	0.43	80	100	Paratype
1.22	41641	0.39	0.46	83.93	116.66	Paratype
1.09	0.89	0.35	0.39	82	112.5	Paratype
1.09	0.91	0.33	0.39	84	120	Paratype
1.30	0.89	0.39	0.37	68.33	94.44	Paratype

Table 2. Average. minimum value (min). maximum value (max). variance of values (var) and standard deviation of a set of values (stdev) for *Angustopila huoyani* sp. n. N = 30.

	SH	SW	AH	AW	SW/SH×100	AW/AH×100
Average	1.17	0.94	0.37	0.43	80.09	114.20
Min	1.04	0.85	0.33	0.37	68.33	94.44
Max	1.30	1.04	0.43	0.46	87.50	133.33
Var	0.0058	0.0031	0.0008	0.0007	15.4080	79.0895
stdev	0.0765	0.0560	0.0288	0.0288	3.9253	8.8932

striation on the teleoconch. *A. concava* has a much wider body whorl than that of *A. huoyani*, has weaker apertural denticles and prominent spiral sculpture. *A. elevata* has no denticles in the aperture and possesses a wider umbilicus and spirally striated shell. *A. neglecta* (see also notes under that species) has a wider umbilicus and more rapidly growing whorls, resulting in a comparatively wider body whorl than in the new species. *A. neglecta* also has spiral lines on the shell and its sinulus is wider. Shell characters and ecological information of all *Angustopila* species are presented in Table 3.

Etymology. The new species is named after the Gorges of Huoyan, where the type locality is located.

Distribution. The new species is known from the type locality only.

Ecology. The new species is known only from the Feihu Dong (“Cave of the Wind Tiger”). *A. huoyani* were culled from samples of rocky-loamy substrate collected in the entrance corridor of the cave. It is highly likely that the distribution of *A. huoyani* sp. n. is restricted to this cave only.

Conservational status. Our knowledge of the biogeography of the genus is very limited. However, we assume that most *Angustopila*, especially the cave-dwelling species, are narrow-range endemics. Since extreme endemism always makes species vulnerable to human encroachment, this species warrants conservation priority. Currently, no direct threats are known.

Table 3. The most important morphological traits and ecological information for *Angustopila huoyani* sp. n. and its congeners extracted from the literature.

	<i>concava</i>	<i>elevata</i>	<i>huoyani</i> sp. n.	<i>neglecta</i>	<i>tamlod</i>
Shell colour	greyish white	light gray	greyish white	white	white
Teleoconch sculpture	spiral threads; weak growth wrinkles	spiral threads; weak growth wrinkles	very fine irregular axial lamellae, reticulating microgranules	spiral threads; growth wrinkles	spiral threads
Protoconch sculpture	spiral/ reticulated	reticulating granules	reticulating granules	not described	not decribed
Aperture shape/ peristome	kidney-shaped, oblique	ovate, oblique	semi-circular, oblique	ovate	semi-circular
Aperture dentition	angular, upper palatal, parietal	dentition lacking	parietal, palatal	angular, upper palatal, weak basal	parietal, palatal
Umbilicus	narrow	narrow	very narrow	relatively wide	very narrow
Whorl number	4.6–5.3	4.2–4.3	5.3	4.5	4.75
Shell height (mm)	1.02–1.21	0.92–0.99	1.04–1.3	1.2–1.8	0.9–1.0
Ecology	leaf litter & limestone talus	leaf litter & limestone talus	cave	cave (?)	cave

Angustopila neglecta (van Benthem-Jutting, 1961)

Hypselostoma laidlawi – Benthem Jutting ? 1949 : Bulletin of the Raffles Museum, 21: 19, Fig. 9.
Paraboyssidia neglecta van Benthem Jutting 1961: Bulletin of the Raffles Museum, 26: 36, Plate 8, Fig. 2a. [“Biserat Caves, State of Jalor” and “Gua Che Yatin, Ulu Tembeling, Pahang”]
“*Hypselostoma laidlawi*” (referring to the figure in Benthem-Jutting (1949) as probably *Systemostoma* species) – Panha and Burch 1999: Walkerana, 10 (24): 125.

Remarks. Although the specimen on Benthem Jutting’s (1949) figure is similar, it probably is not conspecific to her other figure (Benthem Jutting 1961). See detailed explanation in Panha and Burch (1999).

Angustopila tamlod (Panha & Burch, 1999)

Systemostoma tamlod Panha & Burch, 1999: Walkerana 10 (24): 118–121, Fig. 3. [“Lod Cave, Pang Ma Pa District, Mae Hong Son Province, 19°29'36"N, 98°17'18"E and 10°34'03"N, 98°16'41"E, 800 meters elevation (CUIZM, Ver 025), Thailand. All specimens were collected inside the cave, almost two kilometres from the entrance.”]

Genus *Hypselostoma* Benson 1856

<http://species-id.net/wiki/Hypselostoma>

Hypselostoma Benson 1856b, The Annals and Magazine of Natural History, ser. 2, no. 17: 342. (nom. n. for *Tanystoma* Benson 1856a, non Latreille 1829).

Type species. *Tanystoma tuberiferum* Benson 1856 by monotypy.

Remarks. *Systemostoma edentata* Panha & Burch, 1999 differs from all former, Thai *Systemostoma* species by the relatively large, toothless, adnate aperture. It is probably a toothless member of a hypselostomatid genus other than former *Systemostoma*. Here, *S. edentata* is placed within the genus *Hypselostoma* because its similarity with *H. panhai* Burch & Tongkerd 2002. *H. panhai* is not a typical member of the genus *Hypselostoma* in terms of shell characters, but was placed into this genus based on molecular data of Tongkerd et al. (2004).

***Hypselostoma* (?) *edentata* (Panha & Burch, 1999)**

Systemostoma edentatum Panha & Burch, 1999: Walkerana, 10 (24): 121–124, Fig. 4 a–d. [“Tampahat National Park, Phrae Province, 18°36'20"N, 99°53'49"E, 650 meters elevation (CUISM, Ver 022), Thailand”]

Systemostoma edentata – Panha and Burch 2005: Malacological Review, 37/38: 119–120, Fig. 102.

Genus *Tonkinospira* Jochum, Slapnik & Páll-Gergely, nom. n.

Systemostoma Bavay & Dautzenberg, 1908: Journal de Conchyliologie, 56: 243.

Systemostoma – Bavay and Dautzenberg 1909: Journal de Conchyliologie, 57: 196. (diagnosis).

Remarks. The name *Systemostoma* Bavay & Dautzenberg, 1908 is preoccupied (non *Systemostoma* Marsson 1887, Bryozoa). Therefore, *Tonkinospira* Jochum, Slapnik & Páll-Gergely nom. n. is proposed as replacement.

Type species. *Helix* (*Systemostoma*) *pauperrima* Bavay & Dautzenberg, 1908 by subsequent designation (Pilsbry 1917).

Diagnosis. A genus of small, conical or depressed-conical species with regularly growing, rounded or angulated whorls. The sculpture is characterized by spiral lines on both the protoconch and the teleoconch, decussated by irregular radial lines resulting in a reticulated surface structure. The aperture is toothless, adnate or slightly adnate and shows a sharp peristome.

Etymology. The new name is established by the fusion of Tonkin (northern Vietnam, the area of distribution) and the Latin spira (a coil, twist). Gender: feminine.

Remarks. *Tonkinospira* differs from *Krobylos* by the increased degree of angulation of the whorls and the lack of spiral lines on the teleoconch. For differences with *Angustopila* gen. n., see above.

The systematic position of the genus is questionable. It most probably belongs to the family Hypselostomatidae, but its relationship with other families such as Helicodiscidae (see Schileyko 1998) or Valloniidae (see Schileyko 2011) cannot be excluded.

Distribution. So far, the genus is reported from Northern Vietnam only.

***Tonkinospira defixa* (Bavay & Dautzenberg, 1912)**

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

Figure 1

Systemostoma defixa Bavay & Dautzenberg 1912: Journal de Conchyliologie, 60: 22–23, Plate 1, Fig. 18–19. [“Île de la Table, baie d’Along”].

Systemostoma defixa – Pilsbry 1917: Manual of Conchology...: 226, Plate 38, Figs 15–16.

Material examined. *Systemostoma defixa* (Bavay & Dautzenberg, 1912) (2 specimens), RBINS Dautzenberg Collection reg. nr. IG 10591 (tray 844), probably syntypes.

Remarks. The whole shell, including the protoconch, is covered with regular, very fine spiral threads. The spiral lines are decussated with rather irregular radial lines, creating a reticulated surface.

***Tonkinospira depressa* (Jaekel 1950)**

Systemostoma depressa Jaekel 1950: Archiv für Molluskenkunde, 79: 15–16, Plate 1, Fig. 1. [from river debris, no type locality specified].

***Tonkinospira pauperrima* (Bavay & Dautzenberg, 1908)**

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

Figure 2

Helix (*Systemostoma*) *pauperrima* Bavay & Dautzenberg 1908: Journal de Conchyliologie, 56: 243–244. [“Phu-Quoc-Oaï”].

Helix (*Systemostoma*) *pauperrima* – Bavay and Dautzenberg 1909: Journal de Conchyliologie, 57: 195–196, Plate 8, Fig. 4–6. [“Trouvé à Phu-Quoc-Oaï, parmi les détritits coquilliers”]

Systemostoma pauperrima – Pilsbry 1917: Manual of Conchology...: 225–226, Plate 38, Figs 3–5.

Systemostoma pauperrima – Schileyko *Ruthenica* 1998: Supplement 2(2): 165, Fig. 202.

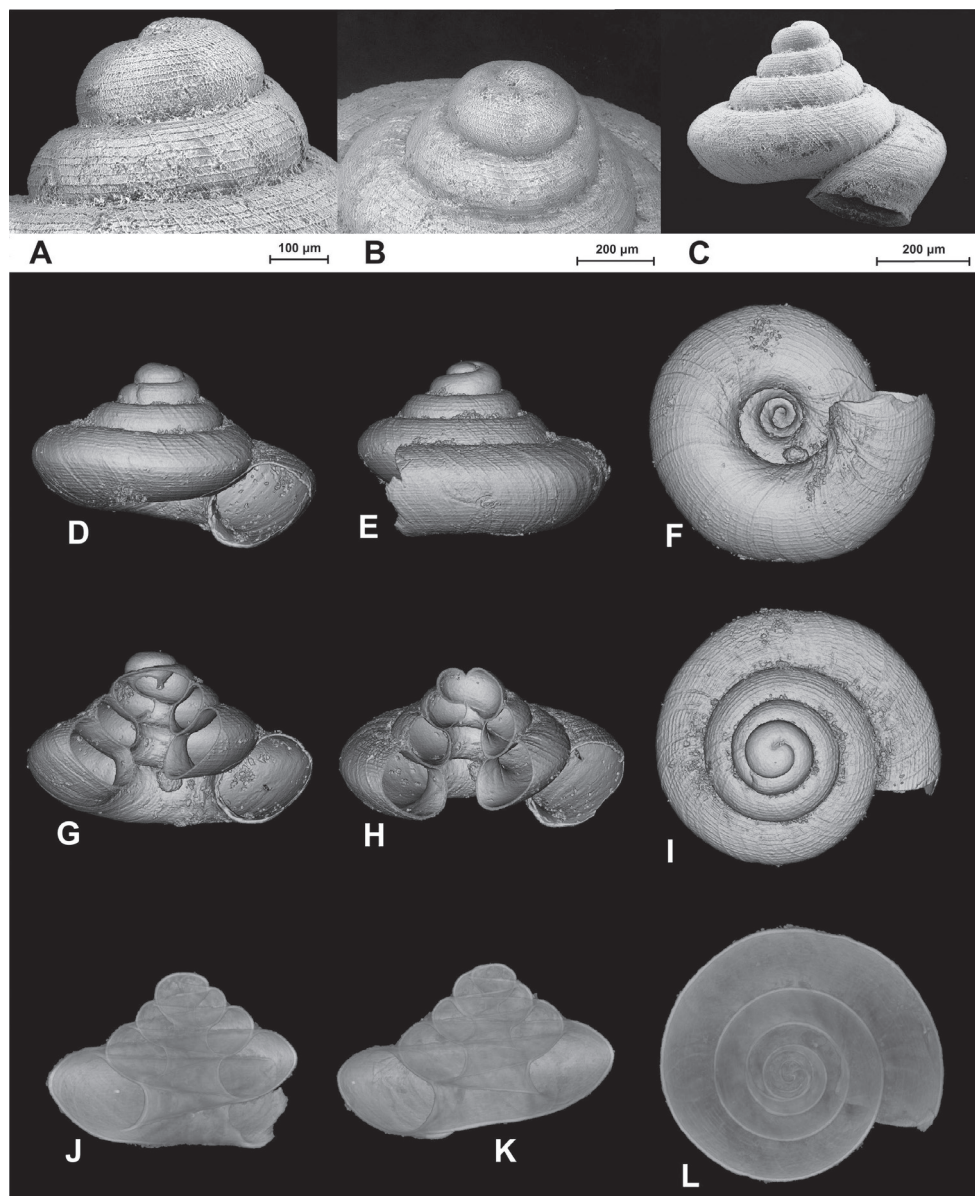


Figure 1. SEM (A–C) and Nano-CT Volume Compositing 3D (D–I) and Nano-CT Summed Voxel Projection images (J–L) of *Tonkinospira defixa* (Bavay & Dautzenberg, 1912). RBINS Dautzenberg Collection reg. nr. IG 10591 (tray 844). Type locality material. Photos: SEM: Suzanne Leidenroth (SMNS). Nano-CT: Gunhild Martels.

Material examined. *Helix* (*Systemostoma*) *pauperrima* (Bavay & Dautzenberg, 1908) (1 specimen). RBINS Dautzenberg Collection reg. nr. IG 10591 (tray 844), probably syntype.

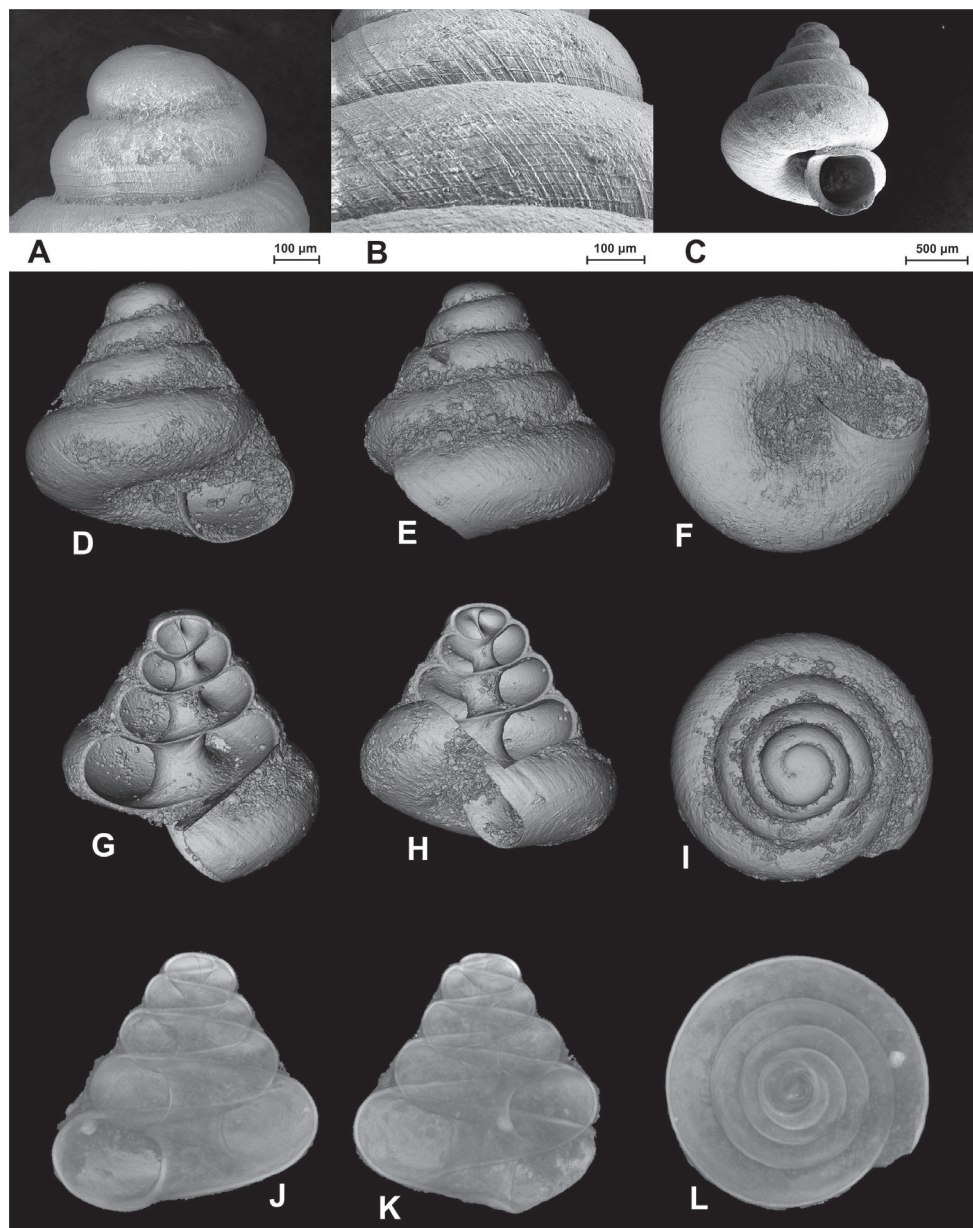


Figure 2. SEM (A–C) and Nano-CT Volume Compositing 3D (D–I) and Nano-CT Summed Voxel Projection images (J–L) of *Tonkinospira pauperrima* (Bavay & Dautzenberg, 1908). RBINS Dautzenberg Collection reg. nr. IG 10591 (tray 844). Type locality material. Photos: SEM: Suzanne Leidenroth (SMNS). Nano-CT: Gunhild Martels.

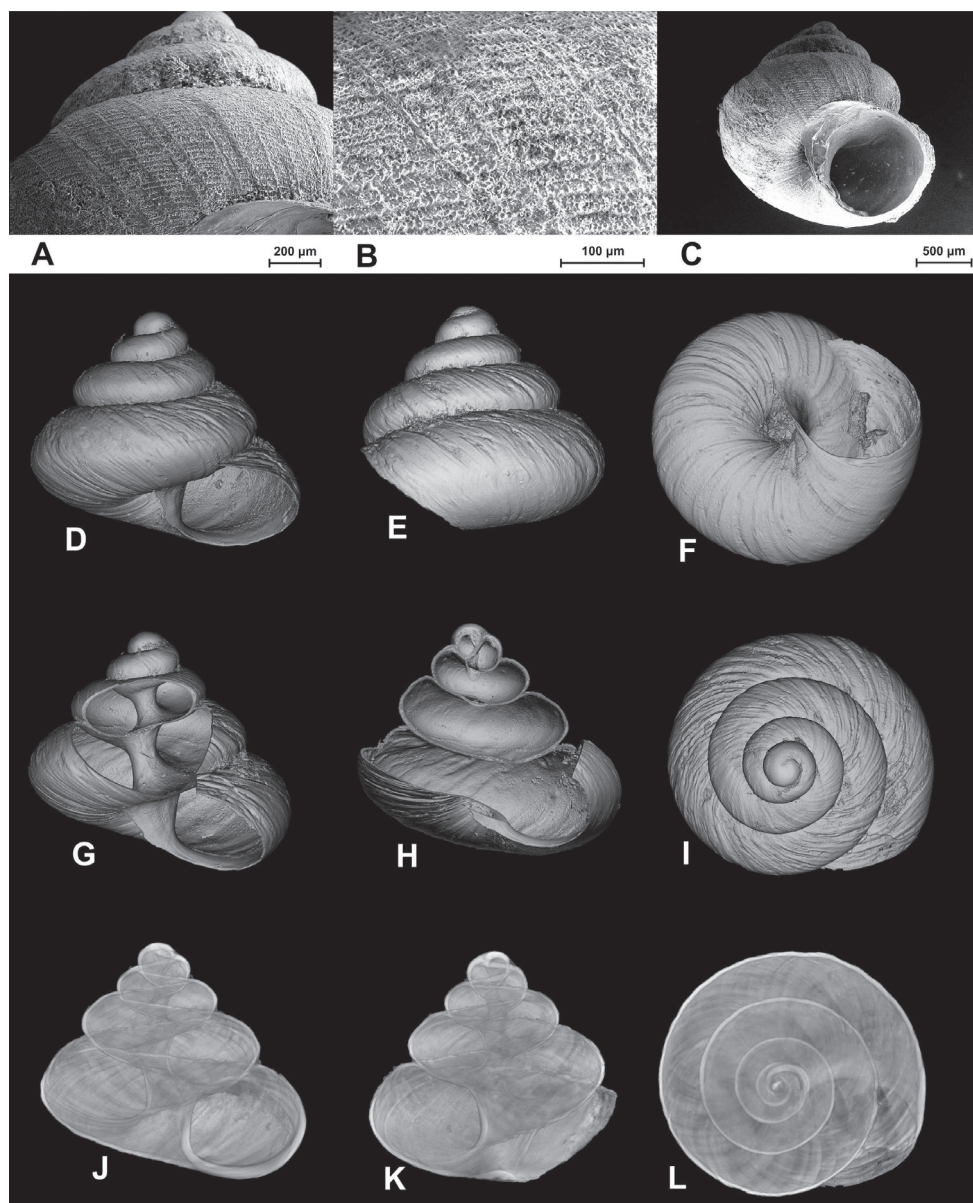


Figure 3. SEM (A–C) and Nano-CT Volume Compositing 3D (D–I) and Nano-CT Summed Voxel Projection images (J–L) of *Tonkinospira pulvereae* (Bavay & Dautzenberg, 1908). RBINS Dautzenberg Collection reg. nr. IG 10591 (tray 844). Type locality material. Photos: SEM: Suzanne Leidenroth (SMNS). Nano-CT: Gunhild Martels.

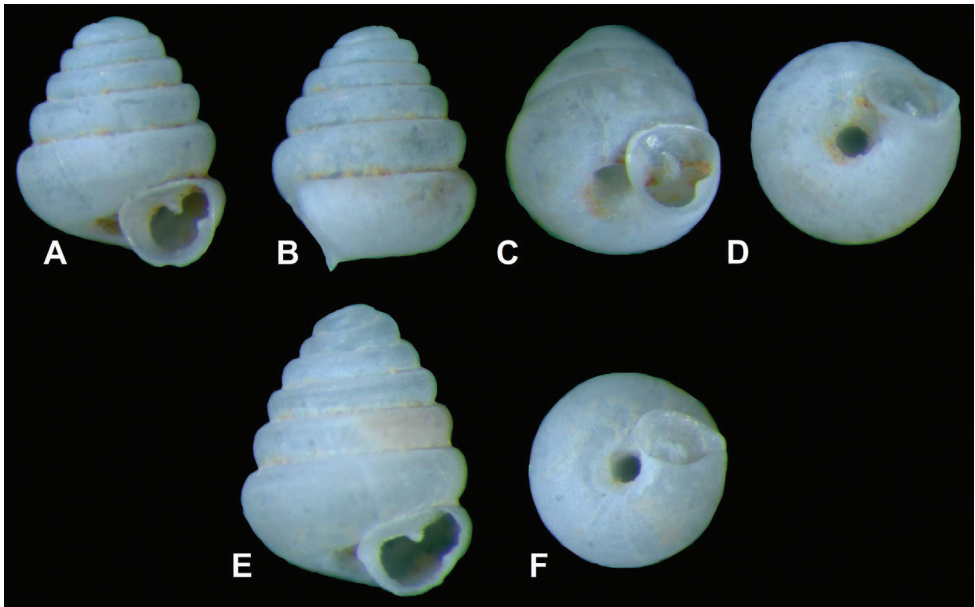


Figure 4. Holotype (A–D) and paratype (E–F) specimens of *Angustopila huoyani* sp. n. China, Hunan (湖南省), Xiangxi (湘西土家族苗族自治州), Longshan (龙山县), Huoyan (火焰), Feihu Dong (飞虎洞), (ca. 29°12.53'N, 109°18.37'E), soil, leg. Verovnik, 13.04.1997. Photos: Sigrid Hof (SMF).

Remarks. The whole shell, including the protoconch is covered with regular, extremely fine spiral threads. The number of threads increases from the apex towards the aperture. The spiral lines are decussated with irregular radial lines, resulting in a reticulated surface.

***Tonkinospira pulvere* (Bavay & Dautzenberg, 1908)**

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

Figure 3

Helix (*Systemostoma*) *pulvere* Bavay & Dautzenberg, 1908: Journal de Conchyliologie, 56: 243. [“Phu-Quoc-Oai”].

Helix (*Systemostoma*) *pulvere* – Bavay and Dautzenberg 1909: Journal de Conchyliologie, 57: 194–195, Plate 8, Fig. 7–9. [“Vit sur les rochers de Phu-Quoc-Oai”]

Systemostoma pulvere – Pilsbry 1917: Manual of Conchology...: 225, Plate 38, Figs 10–12.

Material examined. *Helix* (*Systemostoma*) *pulvere* Bavay & Dautzenberg, 1908 (1 specimen), RBINS Dautzenberg Collection reg. nr. IG 10591 (tray 844), probably syntype.

Remarks. The teleoconch shows rather regular, very fine spiral threads. These spiral lines are more numerous than in the other two examined species. The spiral lines are decussated. Irregular, impressed varices occur at intervals across the whorls. At higher magnification, the shell shows a highly flocculent texture.

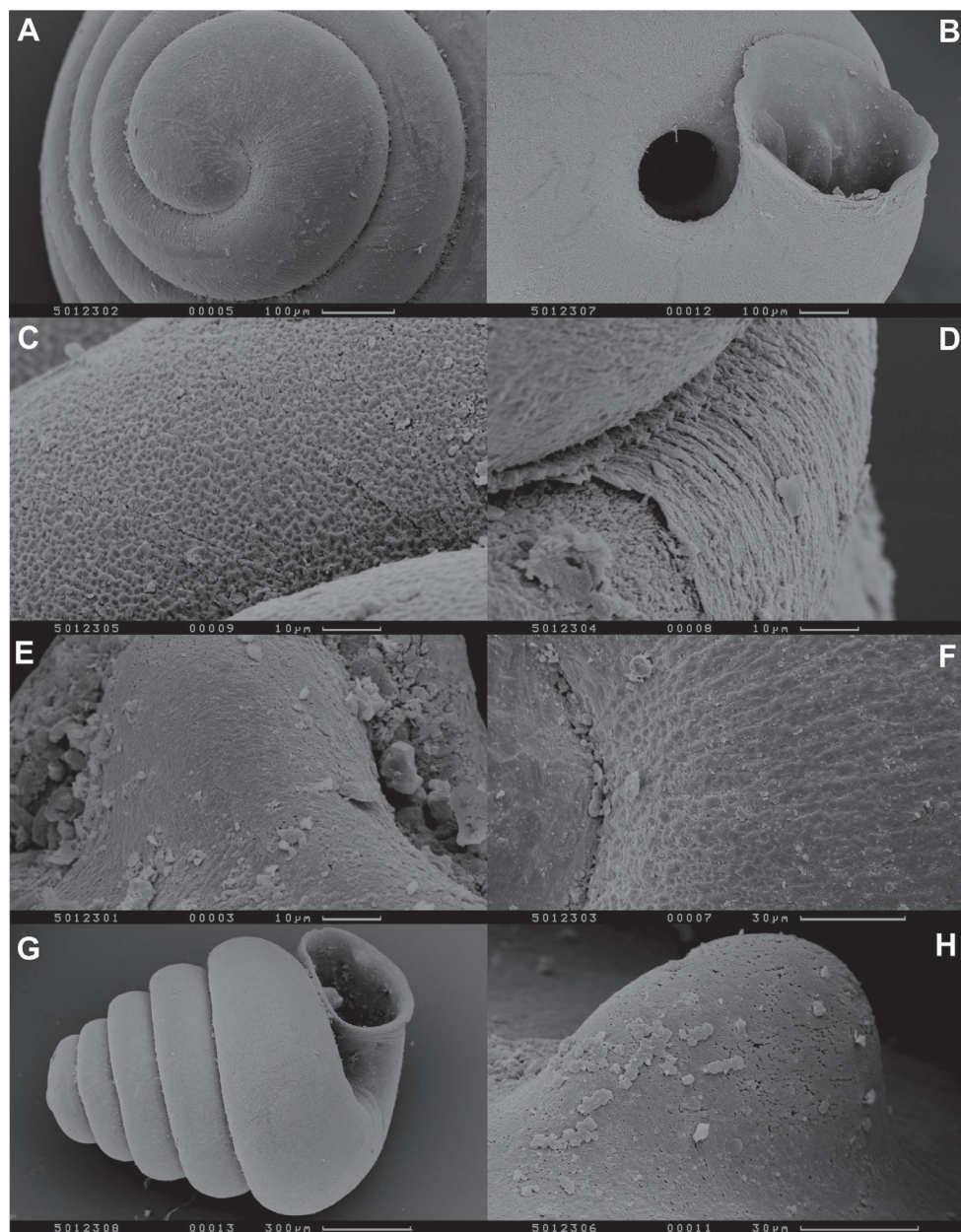


Figure 5. SEM images of *Angustopila huoyani* sp. n. paratype. Same data as in Fig. 4. **A** protoconch **B** umbilicus and adnate aperture **C** reticulating microgranules on whorls **D** fine axial lamellae **E** palatal denticle **F** reticulation on protoconch **G** shell profile **H** parietal callus. Photos: Yaron Malkowsky (SMF).

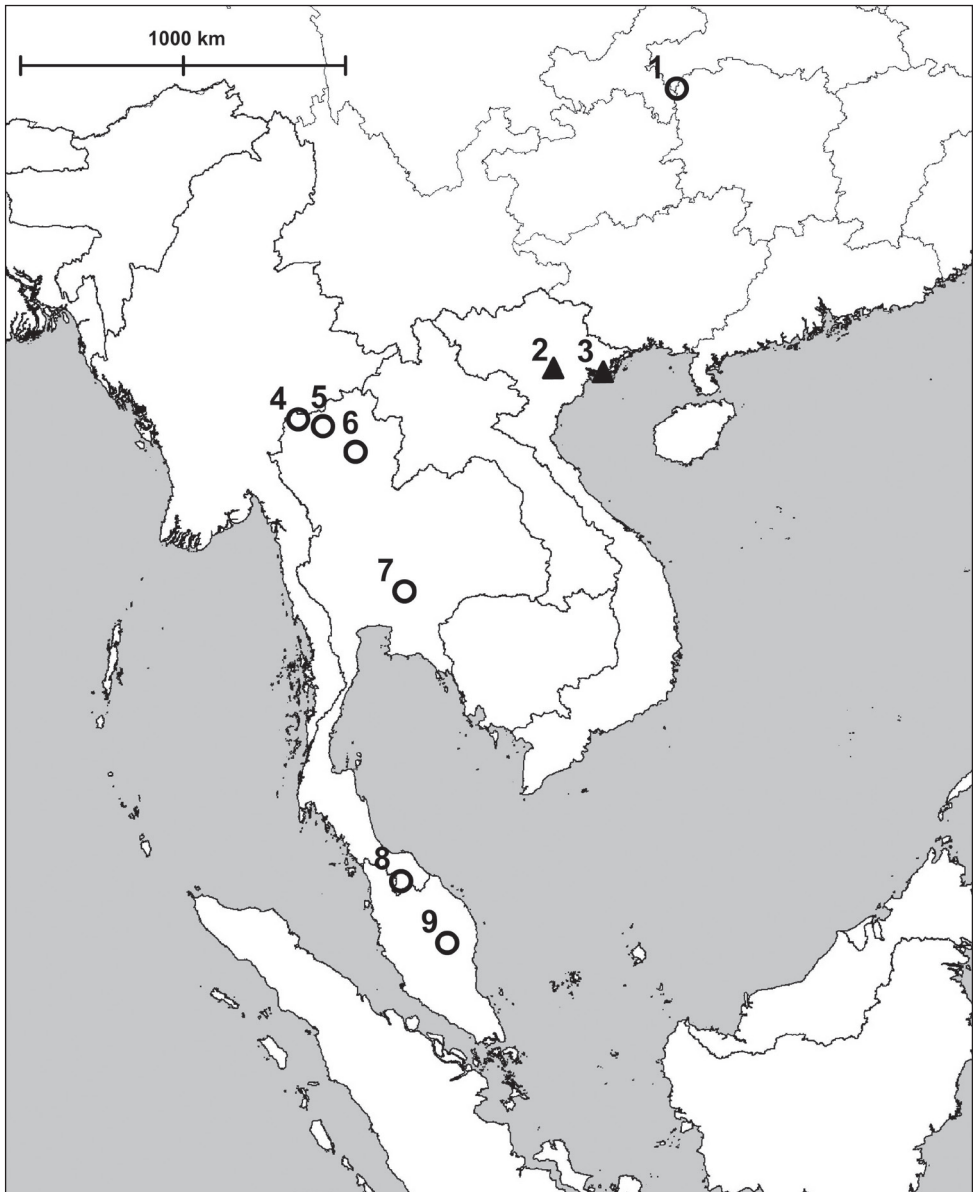


Figure 6. Map showing the localities of *Angustopila* gen. n. (empty circle) *Tonkinospira* nom. n. (filled triangle) and species. **1** *Angustopila huoyani* sp. n. **2** *Tonkinospira pauperrima* (Bavay & Dautzenberg, 1908) and *T. pulvereae* (Bavay & Dautzenberg, 1908) **3** *T. defixa* (Bavay & Dautzenberg, 1912) **4** *A. tam-lod* (Panha & Burch, 1999) **5** *A. elevata* (Thompson & Upatham, 1997) **6** *A. edentata* (Panha & Burch, 1999) **7** *A. concava* (Thompson & Upatham, 1997) **8, 9** *A. neglecta* (van Benthem-Jutting, 1961).

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References

- Ancey CF (1881) Descriptions de Mollusques Terrestres Nouveaux. Le Naturaliste Vol 1, no. 47: 373–374. <http://biodiversitylibrary.org/item/105816#page/373/mode/1up>
- Bavay A, Dautzenberg Ph (1908) Molluscorum Terrestrium Tonkinorum Diagnoses. Journal de Conchyliologie 56: 229–251. <http://biodiversitylibrary.org/item/55061#page/269/mode/1up>
- Bavay A, Dautzenberg Ph (1909) Description de Coquilles Nouvelles de l'Indo-Chine. Journal de Conchyliologie 57: 163–206.
- Bavay A, Dautzenberg Ph (1912) Description de Coquilles Nouvelles de l'Indo-Chine. Journal de Conchyliologie 60: 1–54. <http://biodiversitylibrary.org/item/55204#page/15/mode/1up>
- Bentham Jutting WSS van (1949) The Malayan species of *Boysidia*, *Paraboysidia*, *Hypselostoma*, and *Gyliotrachela* (Gastropoda, Pulmonata, Vertiginidae) with a catalogue of all the species hitherto described. Bulletin of the Raffles Museum 21: 5–49.
- Bentham Jutting WSS van (1961) Additional new Species and new Localities of the Family Veriginidae and the Genera *Oophana* and *Opisthostoma* from Malaya. Bulletin of the Raffles Museum 26: 34–48.
- Benson WH (1856a) Description of *Tanystoma tuberiferum*, a Burmese form related to the genus *Anostoma* of Lamarck. The Annals and Magazine of Natural History ser. 2, no. 17: 129–131. <http://biodiversitylibrary.org/item/19391#page/153/mode/1up>
- Benson WH (1856b) Remarks on the genera *Tanystoma*, *Nematura*, and *Anaulus*. The Annals and Magazine of Natural History ser. 2, no. 17: 342–343. <http://biodiversitylibrary.org/item/19391#page/379/mode/1up>
- Jaekel SH (1950) Die Mollusken eines tropischen Flußgenistes aus Tonkin. Archiv für Molluskenkunde 79: 15–20.

- Langheinrich AC, Yeniguen M, Ostendorf A, Marhoffer S, Dierkes C, Gerlach von S, Nedelmann M, Kampschulte M, Bachmann G, Stolz E, Geriets T (2010) In vitro evaluation of the sinus sagittalis superior thrombosis model in the rat using 3D micro- and nanocomputed tomography. *Neuroradiology* 52: 815–821. doi: 10.1007/s00234-009-0617-5
- Marsson TF (1887) Die Bryozoen der weissen Schreibkreide der Insel Rügen. *Paläontologische Abhandlungen* 4: 1–122.
- Panha S, Burch JB (1999) New taxa of Pupillidae (Pulmonata: Stylommatophora) from Thailand. *Walkerana* 10 (24): 113–134. <http://molluskconservation.org/WALKERANA/Vol10/walkerana%20vol10%20no24%201-134.PDF>
- Panha S, Burch JB (2005) An introduction to the microsnails of Thailand. *Malacological Review* 37/38: 1–155.
- Pilsbry HA (1916–1918) *Manual of Conchology, Second Series: Pulmonata, Vol. 24, Pupillidae (Gastrocoptinae)*. Conchological Department, Academy of Natural Sciences of Philadelphia, Philadelphia, 380 pp, plates 1–50. <http://biodiversitylibrary.org/item/16727#page/51mode/1up>
- Schileyko AA (1998) *Treatise on Recent terrestrial pulmonate molluscs. Part 2. Gastrocoptidae, Hypselostomatidae, Vertiginidae, Truncatellinidae, Pachynodidae, Enidae, Sagdidae*. *Ruthenica Supplement* 2(2): 129–261.
- Schileyko AA (2011) Check-list of land pulmonate molluscs of Vietnam (Gastropoda: Stylommatophora). *Ruthenica* 21(1): 1–68. http://www.ruthenica.com/documents/vol21_Schileyko_1-68.pdf
- Tomlin JR le B (1929–1931) Some preoccupied generic names. *Proceedings of the Malacological Society of London* 18: 255–256, 258; 19: 174–175.
- Thompson FG, Upatham S (1997) Vertiginid land snails from Thailand (Gastropoda, Pulmonata, Pupilloidea). *Bulletin of the Florida Museum of Natural History* 39(7): 221–245. <http://ufdc.ufl.edu/UF00095785/>
- Tongkerd P, Lee T, Panha S, Burch JB, O' Foighil D (2004) Molecular phylogeny of certain Thai gastrocoptine micro land snails (Stylommatophora: Pupillidae) inferred from mitochondrial and nuclear ribosomal DNA sequences. *Journal of Molluscan Studies* 70: 139–147. doi: 10.1093/mollus/70.2.139, <http://mollus.oxfordjournals.org/content/70/2/139.full.pdf+html>

Calcaridorylaimus castaneae sp. n. (Nematoda, Dorylaimidae) from Bulgaria with an identification key to the species of the genus

Sevdan Nedelchev^{1,†}, Milka Elshishka^{2,‡}, Stela Lazarova^{2,§},
Georgi Radoslavov^{2,||}, Peter Hristov^{2,¶}, Vlada Peneva^{2,#}

1 Faculty of Biology, University of Sofia, Bd. "Dragan Tzankov" 8, 1421 Sofia, Bulgaria **2** Institute of Biodiversity and Ecosystem Research, Bulgarian Academy of Sciences, 2 Gagarin Street, 1113 Sofia, Bulgaria

[†] <http://zoobank.org/9BDC2CA1-9183-40A5-94D0-F7FD7CD16275>

[‡] <http://zoobank.org/79DCEFF6-47EB-41DF-ABE3-69213F54806B>

[§] <http://zoobank.org/83C802AD-6631-4008-8E2E-3B8F3ACA1F5C>

^{||} <http://zoobank.org/415009FF-DE2E-4A02-83D4-66125561AFA7>

[¶] <http://zoobank.org/4C865CC6-DED3-4DCE-AAA1-71A51922752B>

[#] <http://zoobank.org/D066DD81-0D99-4117-835C-34CD35BE6F41>

Corresponding author: Vlada Peneva (vpeneva@ecolab.bas.bg)

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Abstract

An unknown species belonging to the genus *Calcaridorylaimus* Andrassy, 1986 was collected from the litter of broadleaf forests dominated by *Castanea sativa* Mill. and mixed with *Quercus daleschampii* Ten. and *Fagus sylvatica* L. on Belasitsa Mountain, south-western Bulgaria. *Calcaridorylaimus castaneae* sp. n. is characterised by its long body (1.4–2.1 mm), lip region practically not offset, vulva transverse, short odontostyle (14.5–16 µm) and tail (75.5–110.5 µm, $c=14.7$ –23.6; $c'=2.9$ –4.4) in females and 38–46 µm long spicules with small spur before their distant end in males. It is most similar to *C. andrassyi* Ahmad & Shaheen, 2004, but differs in having transverse vs pore-like vulva and shorter spicules (38–46 µm vs 52–57 µm). An identification key to the species of the genus *Calcaridorylaimus* is proposed. Phylogenetic analyses were performed on 18S and D2–D3 expansion domains of 28S rRNA genes by Neighbor-Joining, Maximum Likelihood and Bayesian Inference methods. The phylograms inferred from 18S sequences showed closest relationships

of the new species with some species belonging to the genus *Mesodorylaimus*. However, insufficient molecular data for members of both genera do not allow the phylogenetic relationships of *Calcaridorylaimus* and the new species described herein to be elucidated.

Keywords

Taxonomy, morphology, 18S and D2-D3 rRNA genes, compendium

Introduction

During an ecological study of chestnut forests on Belasitsa Mountain (2003–2005) an undescribed species belonging to the genus *Calcaridorylaimus* Andr ssy, 1986 was recovered. The genus *Calcaridorylaimus* is represented by nine species worldwide: *C. calcarifer* Andr ssy, 1986, *C. promissus* Andr ssy, 1986, *C. ruwenzorii* (De Coninck, 1935) Andr ssy, 1986, *C. signatus* (Loof, 1975) Andr ssy, 1986, *C. simillimus* Andr ssy, 1986, *C. sirgeli* Heyns & Meyer, 1995, *C. arcticus* Gagarin, 1997, *C. andrassyi* Ahmad & Shaheen, 2004 and *C. beatus* Andr ssy, 2011. The genus is distributed mainly in the southern hemisphere: three species occur in Africa, two in South America and one each in Antarctic, Central America, and Europe, and *C. promissus* was recorded from Australia and Alaska, North America (Andr ssy 1986, 2003) (Fig. 1). The most characteristic features of these species are the shapes and structures of the spicules which are provided with a small spur before the distal tip. The new species is described based on both morphological and molecular data.

Materials and methods

Sample collection

The litter samples were collected in 2003 by the last author (VP) from three sites on Belasitsa Mountain representing different types of broadleaf forests dominated by *Castanea sativa* Mill. mixed with *Quercus daleshampii* Ten. and *Fagus sylvatica* L. (Forest Management Plan database, sub-compartments 104g, 140b and 146a). Subsequently, on 17.10.2012 new litter samples were collected by Dr Michaela Ilieva from one of these sites, sub-compartment 140b, in order to obtain fresh material for molecular studies. Nematodes were recovered from the litter using the Baermann funnel method. They were killed by heat (65  C), fixed in TAF (Triethanolamine-formalin, Courtney et al. 1955), and processed to anhydrous glycerine (Seinhorst 1959). Drawings were prepared using an Amplival 30-G048b and a drawing tube PA-6Y42. Photographs were taken using an Axio Imager M2-Carl Zeiss compound microscope equipped with a digital camera (ProgRes C7) and specialised software (CapturePro Software 2.8). Measurements were made using an Olympus BX41 light

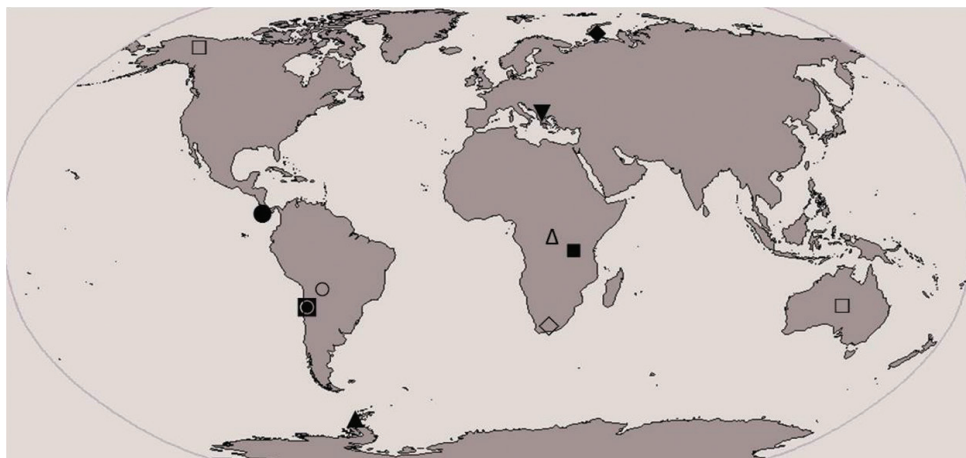


Figure 1. Distribution of *Calcaridorylaimus* spp. (■ *C. calcarifer*, ● *C. andrassyi*, ◆ *C. arcticus*, □ *C. promissus*, ▲ *C. signatus*, ○ *C. simillimus*, ◇ *C. sirgeli*, △ *C. ruwenzorii*, ◼ *C. beatus*, ▼ *C. castaneae* sp. n.).

microscope, a digitising tablet (CalComp Drawing Board III, GTCO CalCom Peripherals, Scottsdale, AZ, USA), and computer programme Digitrak 1.0f (Philip Smith, Scottish Crop Research Institute, Dundee, UK).

DNA extraction, amplification and sequencing

Genomic DNA was extracted from two female and two male worms using a standard nematode digestion protocol (Holterman et al. 2006). Two overlapping fragments of 18S rRNA genes (~1600 bp) were amplified from each specimen using primer sets 988F (5'-CTC AAA GAT TAA GCC ATG C-3') and 1912R (5'-TTT ACG GTC AGA ACT AGG G -3') for the first fragment, and 1813F (5'-CTG CGT GAG AGG TGA AAT-3', 2646R 5'-GCT ACC TTG TTA CGA CTT TT-3') for the second fragment (Holterman et al. 2006). The D2/D3 expansion segments of the 28S rRNA gene (~900 bp) were additionally amplified from all specimens using the primers D2A (5'-ACA AGT ACC GTG AGG GAA AGT TG-3') and D3B (5'-TCG GAA GGA ACC AGC TAC TA-3') (De Ley et al. 1999). Each PCR reaction was performed under the following conditions: initial denaturation 94 °C for 5 min; 40 cycles (denaturation 94 °C for 30 sec; primer annealing 50 °C for 30 sec; extension 72 °C for 1 min), and final extension 72 °C for 10 min. PCR products were visualized on 1% agarose gel with GreenSafe (NZYtech) under visible and UV light. Fragment size was determined using GeneRuler™ 100 bp Ladder Plus (Ferments, Thermo Scientific). The amplified products were sequenced by Eurofins MWG Operon.

Sequence and phylogenetic analysis

The sequences of the new species have been deposited in GenBank with the accession numbers KF717497 and KF717498 for the 18S and the D2-D3 rRNA genes, respectively. A BLAST (Basic Local Alignment Search Tool) search at NCBI (National Center for Biotechnology Information) was performed using the obtained sequences as queries to confirm their nematode origin and to identify the most closely related nematode sequences. The sequences revealing a similarity up to 97% and 85% with nematodes from various Dorylaimida families were included in the phylogenetic analyses of 18S and D2-D3 regions, respectively (Griffiths et al. 2006; Holterman et al. 2006; Meldal et al. 2007; Lesaulnier et al. 2008; Pedram et al. 2010; Pedram et al. 2011; Álvarez-Ortega and Peña-Santiago 2012a; 2012b; Donn et al. 2012; Álvarez-Ortega et al. 2013). The Multiple Sequence Alignments (MSA) of both datasets were performed using the Clustal Omega tool (Sievers et al. 2011) via the EBI webserver: <http://www.ebi.ac.uk/Tools/msa/clustalw2/>. Subsequently, the MSAs were manually optimised and trimmed using MEGA 5 (Tamura et al. 2011). *Eudorylaimus* sp. (family Qudsianematidae) was used as an outgroup taxon for both 18S and D2-D3 rDNA sequence datasets (accession numbers AY284800 and AY593037, respectively; Holterman et al. 2008). The phylogenetic reconstructions of three datasets D2-D3, complete and partial 18S rDNA were performed using Neighbor Joining (NJ), Maximum Likelihood (ML) and the Bayesian Inference (BI) algorithms and implemented in MEGA 5.0 and MrBayes v. 3.2.1 (Huelsenbeck and Ronquist 2001, Tamura et al. 2011, Ronquist et al. 2012). The NJ phylogenetic inferences were performed under the following settings: Maximum Composite Likelihood method for computing evolutionary distances; Gamma distributed rates among sites, estimated values set up to 0.3429 (D2-D3) and 0.05 (18S rDNA); 2000 bootstrap replications. A total of 755 and 1593 positions in the final datasets were used for both analyses, respectively. General Time Reversible model (GTR) plus Gamma distribution rates (G) and 1000 bootstrap replications were used as ML analyses settings for all datasets. The Bayesian MCMC tree searches were conducted using MrBayes 3.2.1. Each analysis was run for 10, 000, 000 generations with a sample frequency of 1000 generations. The first 25% of the chains discarded as burning and the remaining 75% trees kept to summarise the tree topology, branch lengths, and posterior probabilities (PP) of branch support. The evolutionary models for nucleotide substitutions were set up as for ML analyses. Convergence diagnostic values were calculated every 1000 generations with a predefined stop value equal to 0.01. A single strict consensus tree was visualised using FigTree v1.4.0 graphical viewer (<http://tree.bio.ed.ac.uk/software/figtree/>). Posterior probabilities values of ≥ 0.80 (BI) and bootstrap values of ≥ 70 (NJ and ML) were considered as credible support values for nodes.

Taxonomy

Calcaridorylaimus castaneae sp. n.

<http://zoobank.org/9BF1D302-1986-47C5-B0D8-2F5DC75BD6D2>

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

Figs 2–6

Measurements. See Table 1.

Description. *Female.* Body slender, more or less curved ventrally. Cuticle ca 2 μm at anterior part of neck, 3 μm thick at midbody, 4.5–5.5 μm at postanal region; outer layer with fine transverse striae. Lateral chord ca 1/4 of body width. Three dorsal, two ventral and three lateral pores are observed in the spear area. Lip region practically not offset, lip region width ca 20% of its height. Lips partly fused, labial papillae slightly protruding. Body at proximal end of pharynx 3–4 times the width of the lip region diameter. Amphidial aperture 5–6 μm wide or about half the lip region width. Odontostyle 1.2–1.3 times the lip region diameter, aperture occupying 35–40% of its length. Odontophore simple 1.3–1.7 times odontostyle length. Guiding ring at 8.5–9 μm from anterior end. Nerve ring surrounding the pharynx at 36–39% of neck length from head end. Hemizonid and conspicuous excretory pore observed in the nerve ring region. Pharyngeal characters (five females and five males): pharynx beginning to widen at 56–60% and attaining its full width at 61–64% of neck length from anterior end. DO (for terminology see Loof and Coomans 1970) lying near the point where the pharynx attains its full width; DO–DN 8–13 μm . The two S_1N lying at a small distance behind the middle of the distance DN– S_2N , the anterior one (S_1N_1) smaller, ca 2 μm diam; S_1N_2 comparatively large and distinct, 3–4 μm diam. DN nucleolus 4–4.5 μm diam.; S_2N 2–3 μm diam. (DN> S_1N_2 > S_2N). Locations (%):

DO=60–64	S_1N_1 =78–81	S_2N =91–92	K=73–84
DN=62–66	S_1N_2 =82–85	S_2O =93–95	K'=78–85
DO–DN=2.2–3.8	S_1N_1 – S_1N_2 =2.9–4.8.		

Cardia conoid, variable in length, microvilli visible only here. Genital system didelphic-amphidelphic, ovaries reflexed, reaching rarely the vulva level. Oviducts and ovaries very long compared to uteri. Uteri not differentiated, short, anterior 96–125 μm and posterior 95–135 μm long, in one female with no sperm inside the genital system uteri shorter, 83 μm each, sphincter between uterus and *pars dilatata oviductus* well developed. Sperm present in uteri and *pars dilatata oviductus*. Synchronous uterine eggs 1–3, measuring 72–78 \times 32–44 μm . Vulva transverse. Vagina extending to 60–70% inwards: *pars proximalis* 9–13 μm wide, 14.5–19.5 μm long, *pars refringens* more or less rounded trapezoid, 10–12.5 μm wide, 4–6 μm deep; *pars distalis* approx. 1.5 μm (terminology following De Ley et al. 1993). Peculiar tongue-like valve present at intestine-prerectum junction. Rectum 1.3–1.5, prerectum 3–4 times anal body width long, respectively. Tail first conoid, then more or less uniformly tapering to a

Table 1. Morphometrics of *Calcaridorylaimus castaneae* sp. n., females and males, from Belasitsa Mountain. All measurements, unless indicated otherwise, in μm and in the form: mean \pm SD (range).

Habitat	Mixed broadleaf forest					Chestnut forest	
Locality and year of collection	140b 2003			140b 2012		104g 2003	
Characters	Holotype	Paratypes					
		Females	Males	Females	Males	Females	Males
n		40	20	10	10	18	12
L (mm)	1.7	1.7±0.11 (1.5–2.0)	1.6±0.08 (1.4–1.8)	1.6±0.2 (1.4–1.8)	1.6±0.1 (1.4–1.8)	1.6±0.15 (1.4–2.1)	1.5±0.06 (1.4–1.6)
a	35.7	36.6±2.4 (32.5–42.7)	37.9±2.3 (33.3–42.2)	35.7±2.1 (32.2–38.7)	40.0±2.3 (37.0–44.3)	38.4±1.4 (35.7–40.6)	38.1±2.0 (34.0–41.6)
b	4.9	5.0±0.3 (4.5–5.7)	4.7±0.2 (4.4–5.1)	5.1±0.2 (4.8–5.6)	5.1±0.4 (4.7–6.0)	4.9±0.3 (4.4–5.5)	4.6±0.2 (4.3–5.0)
c	19.4	18.8±0.4 (16.0–22.0)	74.4±7.4 (63.8–89.7)	18.3±1.4 (16.8–21.0)	66.7±6.9 (53.7–73.2)	18.5±2.3 (14.7–23.6)	72.2±7.0 (61.4–83.5)
c'	3.9	3.6±0.4 (2.9–4.4)	0.76±0.06 (0.67–0.84)	3.5±0.4 (3.0–4.0)	0.84±0.06 (0.77–0.95)	3.6±0.3 (2.9–4.2)	0.76±0.06 (0.68–0.87)
V/T %	50.7	51.6±1.7 (47.9–54.8)	66.3±3.2 (60–72)	51.2±1.6 (49–54)	59.5±2.5 (56–62.5)	51.0±2.3 (46.5–54.5)	62.8±4.3 (54–70)
G1%	17	18.4±1.7 (14–22.6)	-	19.1±1.0 (18.1–20.7)	-	17.8±2.1 (13.8–21.7)	-
G2%	16	18.3±2.3 (14.1–24.4)	-	18.2±1.0 (16.6–19.1)	-	18.7±3 (14.5–26.5)	-
Odontostyle	14.5	15.0±0.4 (14.5–16)	15.1±0.25 (14.5–16)	15.1±0.2 (14.9–15.4)	14.9±0.4 (14–15)	15.0±0.2 (14.5–15)	15±0.3 (14.5–16)
Odontophore	26	24.8±2.2 (20–29)	22.9±1.5 (21–27)	21.6±2.1 (20–26)	23.7±4.0 (20–28)	27.2±1.6 (24–30)	25.6±1.7 (23–28)
Spear	41	39.8±2.2 (35–43)	37.7±1.2 (35.5–41.5)	36.8±2.0 (35–41)	38.6±4.2 (34–43)	41±1.4 (38–44)	40.7±1.6 (38–43)
Neck length	346	342±13.2 (310–366)	338.6±8.8 (318–352)	319.3±27.3 (272.5–352)	315±31.4 (242–340)	335.8±17 (306–376)	336±11.9 (310–352)
Cardia length	19	19±1.8 (16–24)	19±2.1 (16–24)	33.3±7.0 (22–41)	29.6±5.8 (24–39)	18.5±2.4 (15–25)	19.9±3.8 (14.5–26)
Body width at: lip region	12	12.3±0.3 (12–12.5)	12.3±0.3 (12–12.5)	12.4±0.5 (12–13)	12.5±0.5 (12–13)	12.3±0.4 (12–13)	12.5±0.19 (12–13)
mid-body	48	46.8±4.7 (39.5–55)	42.8±2.3 (37–47)	45.2±2.2 (41–48)	40.1±2.7 (35–44.5)	42±4.7 (37–58)	40.7±2.2 (37–45)
anus	22	24.9±1.8 (22–30)	28.8±0.9 (27–30)	25.7±1.1 (24.5–28.5)	28.7±1.7 (25–30.5)	24.8±1.3 (23–27)	28.5±1.0 (27–30)
Lateral chord	12	12.7±1.8 (10.5–18)	10.1±1.3 (8–12.5)	12.8±1.1 (11–15)	10.4±1.4 (9–13)	12.2±1.2 (10.5–16)	10±0.9 (8.5–12)
Prerectum	89	89.4±11 (68–117)	184±17.2 (132–207)	89.5±19.1 (64–104.5)	155.5±24.6 (130–200)	76.6±9.3 (60–96)	165.4±10 (145–176)
Rectum	41	37±2.4 (30–41)	41±2.1 (37.5–44)	34.5±4.2 (30–40.5)	40.3±3.3 (34–43)	39.6±1.4 (37–41)	43.8±1.5 (41–46)
Tail	88	90.9±7.1 (76–110)	22.1±1.8 (19–25)	88.7±8.5 (75.5–103)	24.3±2.6 (20–28)	90.1±9 (78–110.5)	21.6±2.3 (18–26)
Spicules	-	-	43±1 (41–45)	-	43.6±2.9 (38–46)	-	43.5±2 (39.5–45)
T-distance anterior end of anterior testis-cloaca (mm)	-	-	1.1±0.1 (0.9–1.3)	-	0.96±0.11 (0.86–1.11)	-	1.0±0.1 (0.8–1.15)

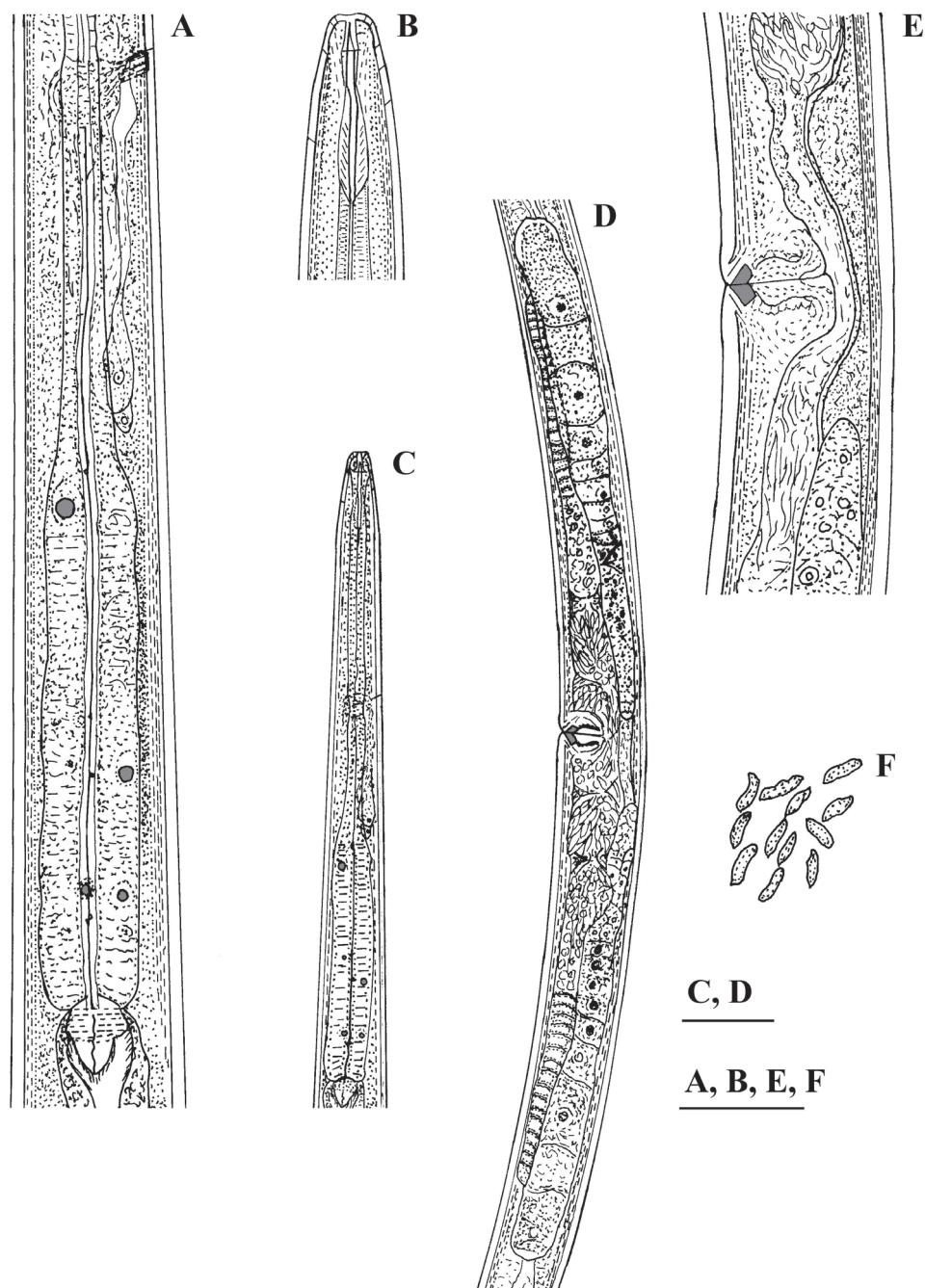


Figure 2. *Calcaridorylaimus castaneae* sp. n. Female: **A** Pharyngeal gland nuclei **B** Anterior region **C** Pharyngeal region **D** Genital system **E** Vulval region **F** Sperm cells in uterus. Scale bars: **A, B, E, F** – 30 µm; **C, D** – 50 µm.

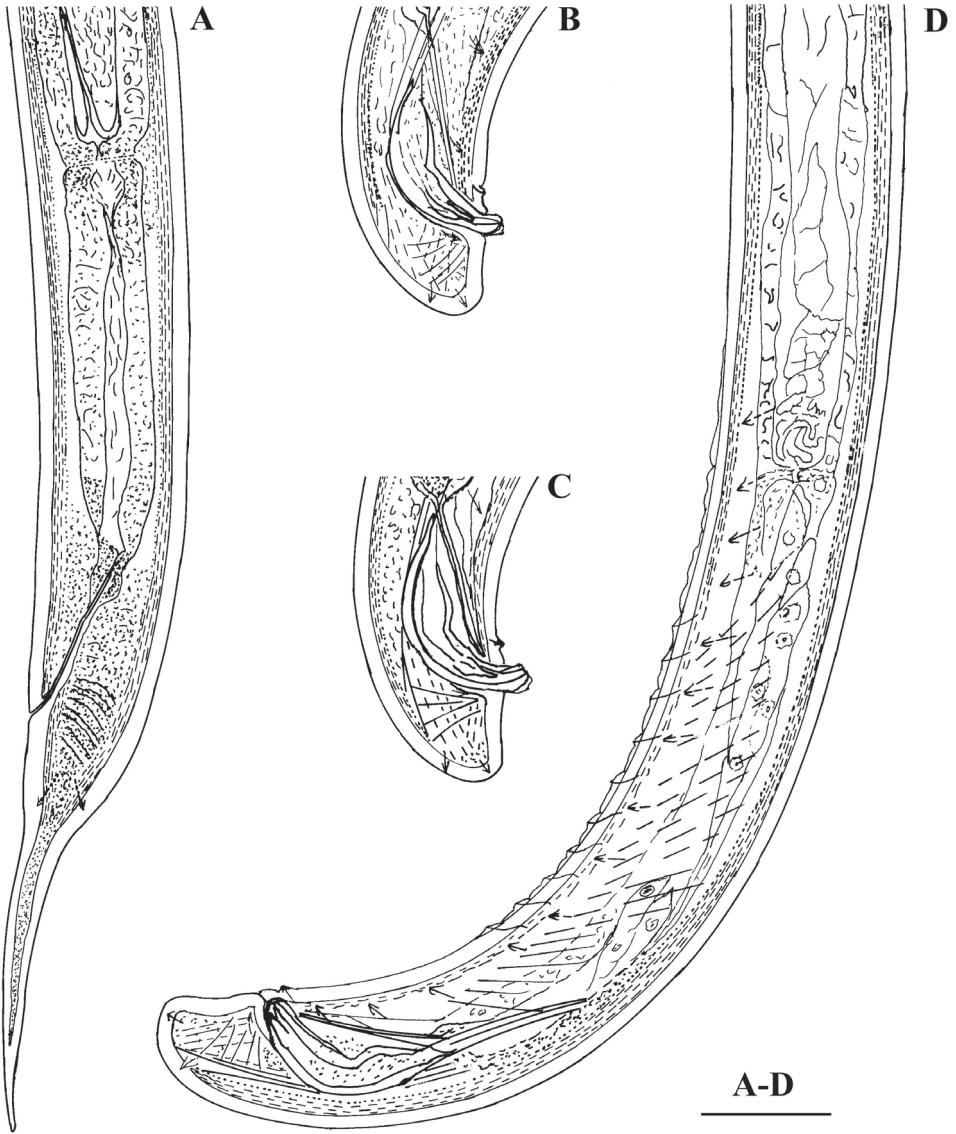


Figure 3. *Calcaridorylaimus castaneae* sp. n. Female: **A** Posterior region. Male: **B, C** Extruded spicules with supplements **D** Posterior region. Scale bar: **A–D** – 30 µm.

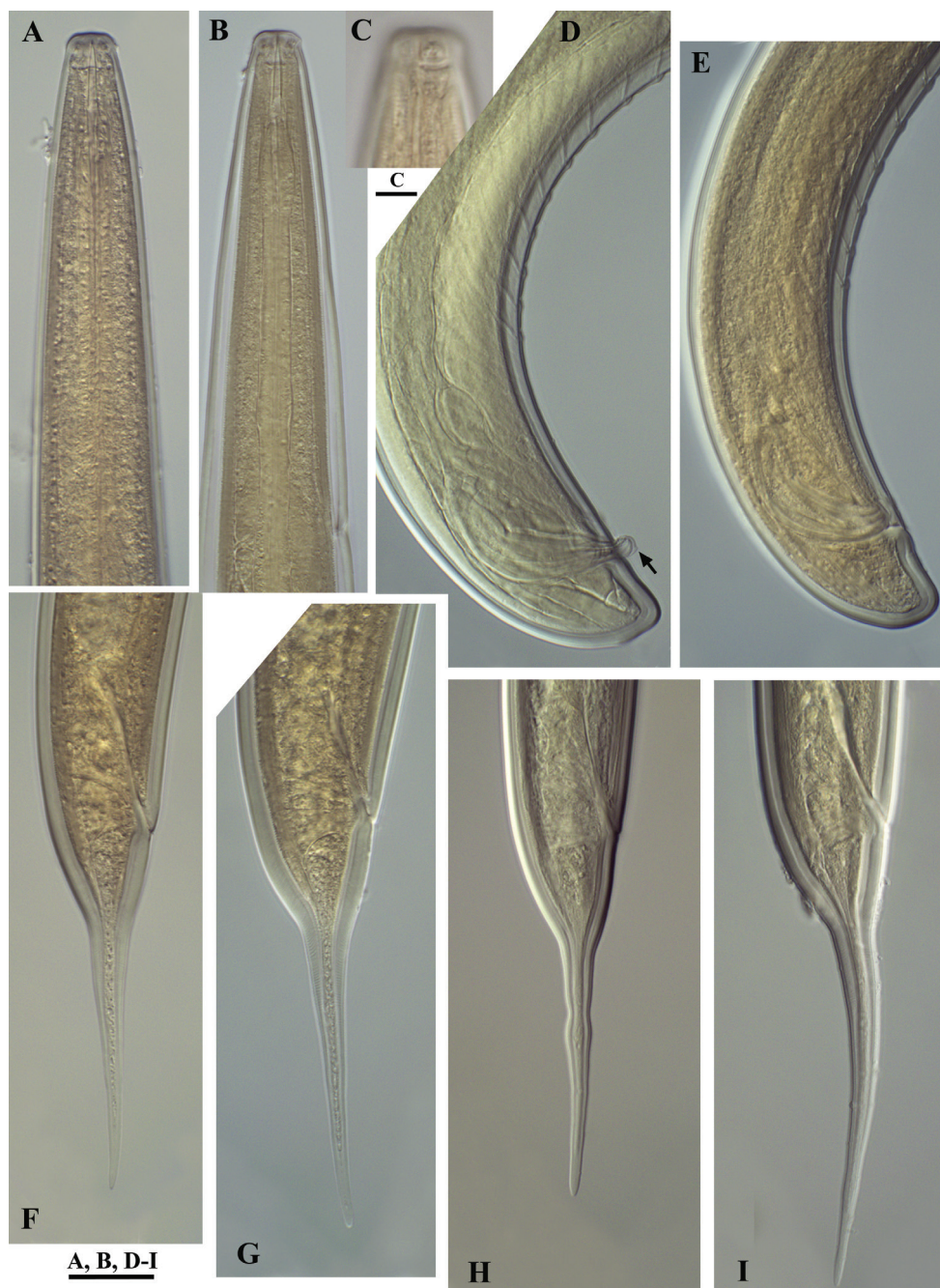


Figure 4. *Calcaridorylaimus castaneae* sp. n. Female: **A** Anterior end **C** Amphid **F–I** Tail shapes Male **B** Anterior end **D** Posterior end with extruded spicules, arrow indicating the spur **E** Posterior end. Scale bars: **A, B, D–I** – 20 µm; **C** – 6 µm.

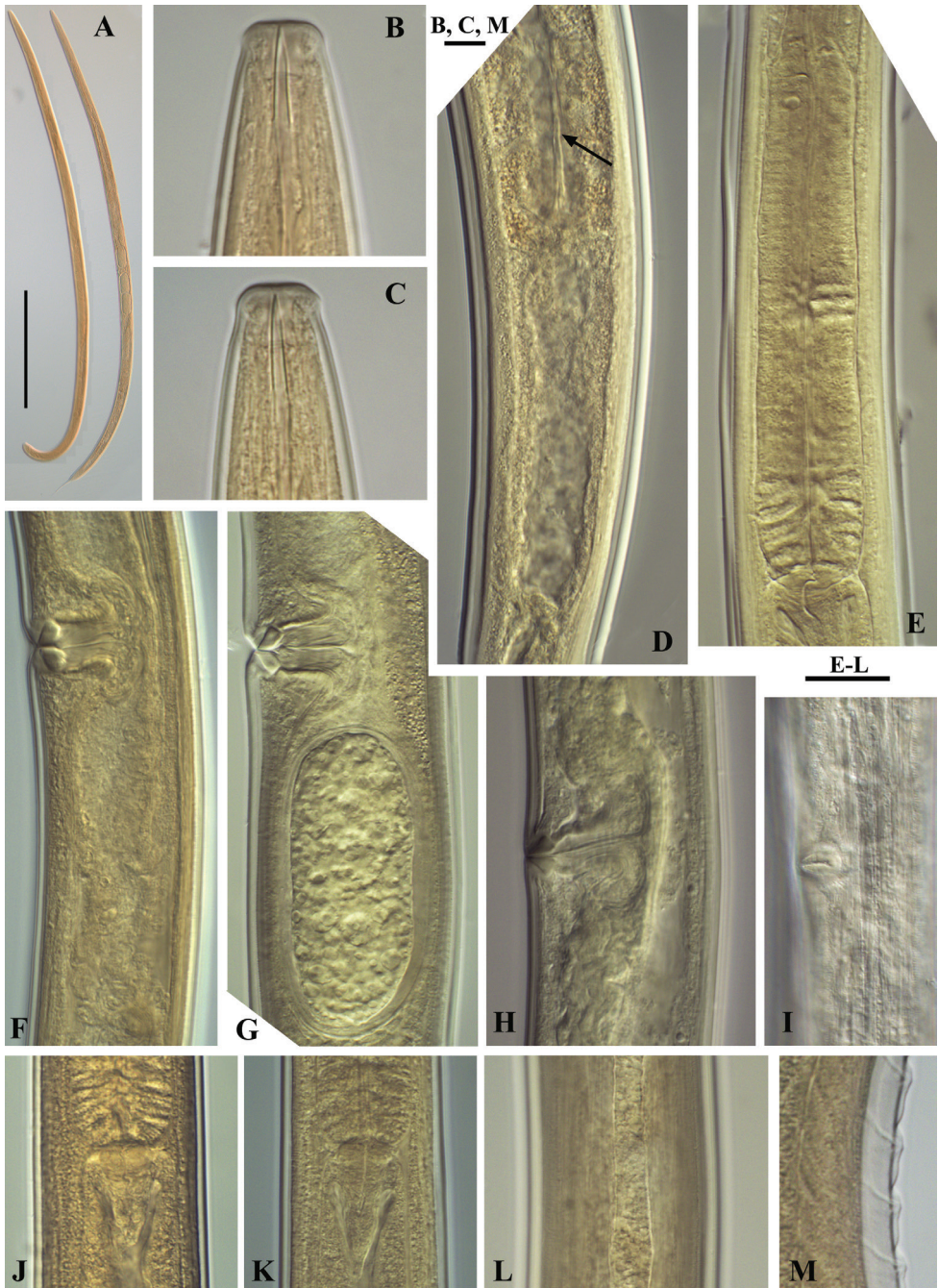


Figure 5. *Calcaridorylaimus castaneae* sp. n. *Female*: **A** Entire body **B** Lip region **D** Prerectum, arrow pointing tongue-like valve **E** Pharyngeal bulb **F** Vulval region with posterior uterus **G** Vulval region with egg in posterior uterus **H**, **I** Vulval region **J** Cardia **L** Lateral field. *Male*: **A** Entire body **C** Lip region **K** Cardia **M** Supplements. Scale bars: **A** – 200 µm; **B**, **C**, **M** – 6 µm; **E**–**L** – 20 µm.

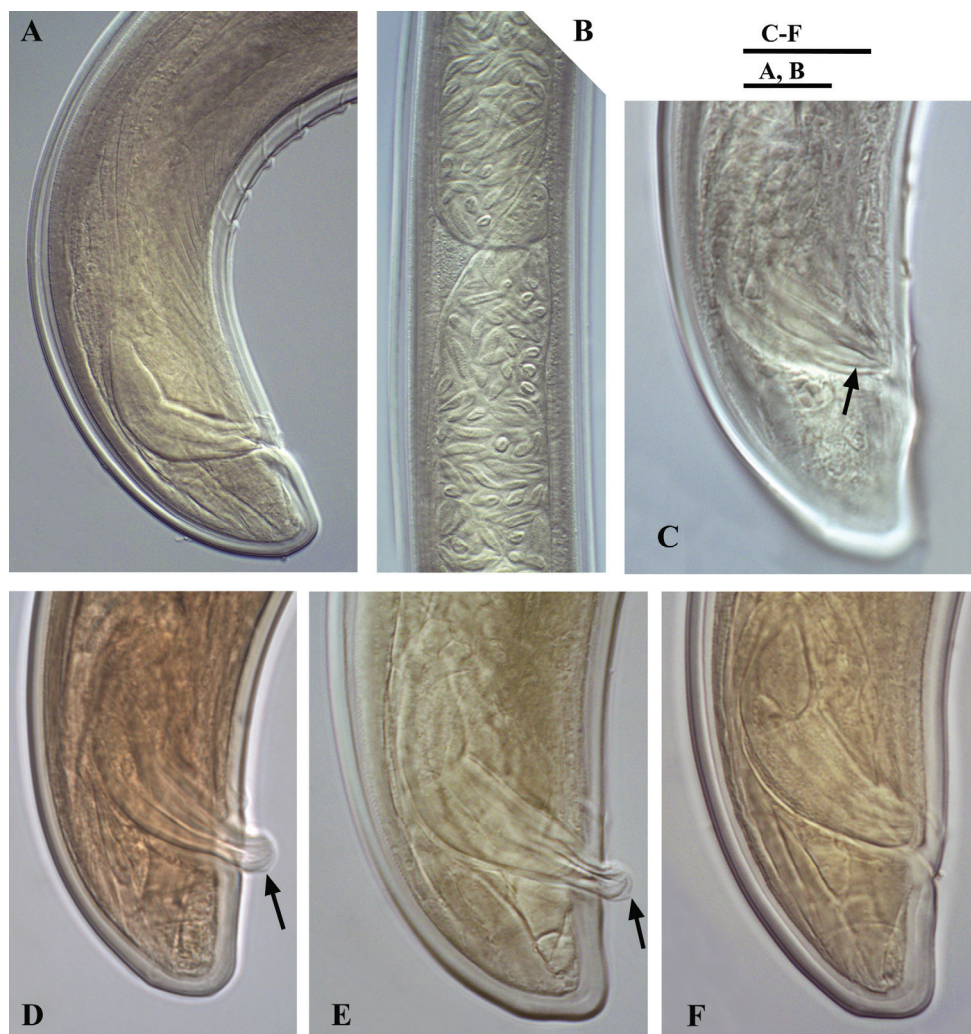


Figure 6. *Calcaridorylaimus castaneae* sp. n. Male: **A** Posterior end **B** Sperm cells in testis **C–F** Spicular region **C** Lateral piece of spicules **D, E** Extruded spicules, arrows pointing the spur **F** Spicules in the body. Scale bars: **A, B** – 20 μ m; **C–F** – 18 μ m.

narrowly rounded terminus. Posterior part of tail usually slightly curved dorsally. Two pairs of caudal pores, one subventral, other subdorsal.

Male. General morphology similar to that of female, body curved ventrally in J-shape when fixed. Genital system diorchic, testes opposed, well developed. Spicules dorylaimoid, with double contour on dorsal arm, 1.3–1.6 times the corresponding body diameter long; ventral arm smaller than dorsal. A spur present dorsally before the distal tip, distinctly visible in extruded spicules. Lateral guiding pieces 9–11 μ m long or ca. 23 % spicule length. In addition to adcloacal pair seven to twelve (mostly nine or ten), regularly spaced ventromedian supplements present (9 supplements in 8 specimens; 10 suppl. – in 7, and 7, 8

and 12 each in one specimen). Prerectum 4.5–7.5 times the corresponding body diameter long, extending 0.7–1.8 body widths anterior to the supplement series. Tail dorsally conoid and broadly rounded. One subdorsal and one subterminal pair of caudal pores.

Differential diagnosis and relationships. *Calcaridorylaimus castaneae* sp. n. differs from all species in the genus by a combination of the following characters: long body (1.4–2.1 mm), lip region practically not offset, short odontostyle (14.5–16 μ m in females and 14–16 μ m in males) and short female tail (75.5–110.5 μ m, $c=14.7$ –23.6; $c'=2.9$ –4.4); vulva transverse, 38–46 μ m long spicules with spur before its distal end. The new species is most similar to *C. andrassyi* from which it can be differentiated by having transverse vulva vs pore-like and shorter spicules (38–46 μ m vs 52–57 μ m). Further, *C. castaneae* differs from *C. ruwenzorii* by having shorter odontostyle (14.5–16 μ m vs 19.5–25 μ m), and tail (75.5–110.5 μ m vs 160 μ m, higher c ($c=14.7$ –23.6 vs $c=10$) and lower c' ($c'=2.9$ –4.4 vs 7) values in females. It can be differentiated from *C. arcticus*, *C. beatus*, *C. calcarifer* and *C. signatus* by having different vulva shape (transverse vs longitudinal) and shorter spicules (38–46 μ m vs 57–67 μ m; 48–55 μ m; 52–54 μ m and 72 μ m). From *C. sirgeli* it differs by having transverse vulva vs pore-like, higher c ($c=14.7$ –23.6 vs $c=9.7$ –11.3) and lower c' ($c'=2.9$ –4.4 vs $c'=5.3$ –6.7) values. Finally, *C. castaneae* differs from *C. promissus* and *C. simillimus* by having longer odontostyle (14.5–16 μ m vs 13 μ m and 11 μ m) and shorter tail (75.5–110.5 μ m vs 158–178 μ m and 175 μ m).

Presence of the conspicuous excretory pore observed in *C. castaneae* is unusual for members of Dorylaimida, however, similar structure has been mentioned only for two *Longidorus* species, namely *L. macrosoma* Hooper, 1961 and *L. carniolensis* Širca et al., 2011 (Aboul-Eid 1969, Širca et al. 2011) and for several *Mesodorylaimus* species origination from Antarctica – *M. chipevi* Nedelchev & Peneva, 2000, *M. antarcticus* Nedelchev & Peneva, 2000, *M. masleni* Nedelchev & Peneva, 2000, *M. imperator* Loof, 1975 (Nedelchev and Peneva 2000).

Type locality and plant association. Belasitsa Mountain, south-western Bulgaria, litter from old broadleaf forest (100–140 years) dominated by *C. sativa*, mixed with *Q. daleschampii* and *F. sylvatica*. Site is located in the vicinity of Belasitsa hut, N41°22'12"; E23°11'12" (sub-compartment 140b). Second locality: young sweet chestnut forest (30–40 years old) near Belasitsa village (sub-compartment 104g).

Type material. Holotype and 80 paratype females and 47 males deposited in the nematode collection of the Institute of Biodiversity and Ecosystem Research, Sofia, Bulgaria. Other paratypes deposited as follows: four females and two males in the Nematode Collection of the Foodland Environment Research Agency, Sand Hutton, UK (former Rothamsted Nematode Collection); three females and three males in the USDA Nematode Collection, Beltsville, Maryland, USA; two females and two males in the Riverside Nematode Collection, University of California, Riverside, USA; four females, and four males in the Wageningen Nematode Collection (WANECO), Wageningen, the Netherlands; four females and three males in the Nematode Collection of the Zoology Museum of the Ghent University, Belgium.

Etymology. The scientific name is derived from the generic name of dominant tree species, the sweet chestnut tree (*Castanea*) in the forest where this nematode was found.

Table 2. Main morphological and morphometrical data of Calcaridorylaimus species, habitat type and distribution.

Species	Body length (mm)	a	c	c'	V%	Odontostyle	Lip region width	Tail	Vulva shape	Spicule length	Supplements	Habitat	Distribution	References
<i>C. andrusyi</i> ♀ ♂	1.8 (1.7–1.9)	44 (42–46)	15 (14–16)	4.4 (4.1–4.7)	49 (48–52)	15 (15–16)	12 (11.5–12)	113 (105–120)	P	54 (52–57)	10	forest	Costa Rica	Ahmad and Shaheen 2004
	1.5 (1.5–1.6)	39 (34–45)	78 (76–81)	0.66 (0.6–0.7)		15	12 (11.5–12.5)	20 (18.5–21.5)						
<i>C. arcticus</i>	1.6–2.3	24–34	13–16	3.5–5.8	49–53.4	14–17	15–17	139 (120–171)	L			aquatic, fresh-water	Russian Arctic	Gagarin 1997
	1.84–2.24	24–34	53–75	0.6–0.7		14–17	15–17	36 (29–48)		63 (57–67)	10–12			
<i>C. boatus</i>	1.28–1.30 1.36–1.48	24–29 28–33	19–23 57–72	2.2–2.4 0.6–0.8	51–52	15–16	14–15	60–68	L	48–55	13–14	Moist grassy soil, 4500 m asl	Chile	Andrássy 2011
<i>C. calcarifer</i>	1.18–1.30 0.95–1.07	30–32 26–28	7.8–10.3 45–46	6–8 0.7–0.8	49–52	13–14	10–12	115–167 21–23	L	52–54	8–9	rain forest soil	Republic of Congo	Andrássy 1986
<i>C. castaneae</i> sp. n.	1.4–2.1 1.4–1.8	32.2–42.7 33.3–44.3	16.0–23.6 53.7–89.7	2.9–4.4 0.7–0.95	46.5–54.8	14.5–16 14–16	12–13 12–13	75.5–110.5 18–28	T	38–46	7–12	broadleaf forest, litter	Bulgaria	Present study
<i>C. promissus</i>	1.28–1.37 1.02–1.10	36–38 28–30	7.7–8.4 47–57	8.4–9.0 0.8–0.9	45–47	13	10–11	158–178 18–22	T	50–53	10–13	wet moss from a rock, forest	Australia	Andrássy 1986
<i>**C. promissus</i>	1.6–1.65 1.55	34–37 35	9–11 90	7–8 ?	50–51	14–15	?–	150–160 ?	?	50	9–11	moss from swampy soil	Alaska	Andrássy 2003
<i>C. ruenzarii</i>	1.6 1.3–1.5	32 35–40	10 44–74	7	47	19.5–25	12–14	160	?	44	7–8		Republic of Congo	de Coninck 1935
<i>C. signatus</i>	1.3–1.7 1.7	25–33 29	12.0–18.0 61	2.9–4.2 0.6*	49–56 –	16–18 17	14*	100* 24*	L	72	12	wet moss	Antarctic	Loof 1975
<i>C. similimus</i>	1.3 1.14	43 33	7.4 90	11 0.7	50	11.5	9.5–10	175 12	T	45	11	<i>Stipa</i> sp., near lake Titikaka	Bolivia	Andrássy 1986
<i>C. sirgeli</i>	1.34 (1.1–1.5)	33.2 (30–36)	10.6 (9.7–11.3)	6.1 (5.3–6.7)	53.4 (52–56)	13.6 (12–15)	11.5 (10–12.5)	127 (105–148)	P	42.4 (39–45)	6–9	moist soil under fynbos and mosses	South Africa	Heyns and Meyer 1995

Shape of vulva: **L** – longitudinal; **P** – pore like; **T** – transverse; when average values are present ranges in parentheses; * from the drawing; ** *C. promissus* from Alaska (Andrássy 2003) was not included in a subsequent paper by the same author (Andrássy 2011); since most of the characters deviate substantially from the original description, probably this population belongs to another species.

Key to species of *Calcaridorylaimus*

1	Odontostyle 19.5–25 μm long.....	<i>C. ruwenzorii</i>
–	Odontostyle shorter, ≤ 17 μm	2
2	$c' = 11$	<i>C. simillimus</i>
–	$c' < 9$	3
3	$c' = 2.2\text{--}2.4$	<i>C. beatus</i>
–	$c' \geq 2.9$	4
4	$c \leq 11$	5
–	$c > 11$	7
5	$V = 45\text{--}47$, supplements 10–13	<i>C. promissus</i>
–	$V > 49$, supplements 6–9	6
6	Vulva longitudinal, spicules 52–54 μm	<i>C. calcarifer</i>
–	Vulva pore-like, spicules 39–45 μm	<i>C. sirgeli</i>
7	Lip region 14–17 μm wide, vulva longitudinal	8
–	Lip region 11–13 μm wide, vulva not longitudinal	9
8	Tail 120–171 μm long, $L = 1.6\text{--}2.27$, spicules 57–67.....	<i>C. arcticus</i>
–	Tail 100 μm long, $L = 1.3\text{--}1.7$, spicules 72.....	<i>C. signatus</i>
9	Vulva pore-like, spicules 52–57	<i>C. andrassyi</i>
–	Vulva transverse, spicules 38–46.....	<i>C. castaneae</i>

Phylogenetic relationships of *Calcaridorylaimus castaneae* based on partial 28S and 18S rDNA sequences

The sequences of D2-D3 expansion domains of 28S and 18S ribosomal DNA from two female and two male nematodes have been processed. No inter-individual variability within both domains have been observed, thus only two consensus sequences for each of the genes (787 and 1699 bp long) have been submitted to GenBank (accession numbers KF717498 and KF717497). A BLAST search for D2-D3 region showed highest similarity (88%) to the sequence of *Labronema vulvapapillatum* clone 2 (AY592997, Holterman et al. 2008) while the 18S rDNA showed 99% similarity (4–6 nucleotide differences) to the sequences of *Mesodorylaimus bastiani* (AJ966488) from France (Meldal et al. 2007) and two sequences of unidentified species from environmental samples from Scotland (AJ875133 and JN049666) (Griffiths et al. 2006, Donn et al. 2012).

The phylogenetic analyses based on 18S rDNA and D2-D3 of 28S rDNA sequences from various dorylaimid species with the highest matches of the BLAST search (up to 97% and 85%, respectively) were aligned along with our sequence. The phylograms obtained by NJ, ML and BI methods showed similar topology and differed only in the positions of poorly supported clades. The BI trees (Figs 7 and 8) with posterior probabilities higher than 0.8 and NJ-ML trees with bootstrap values above 70% are presented (Figs 9 and 10). The new species has clustered in a well-supported

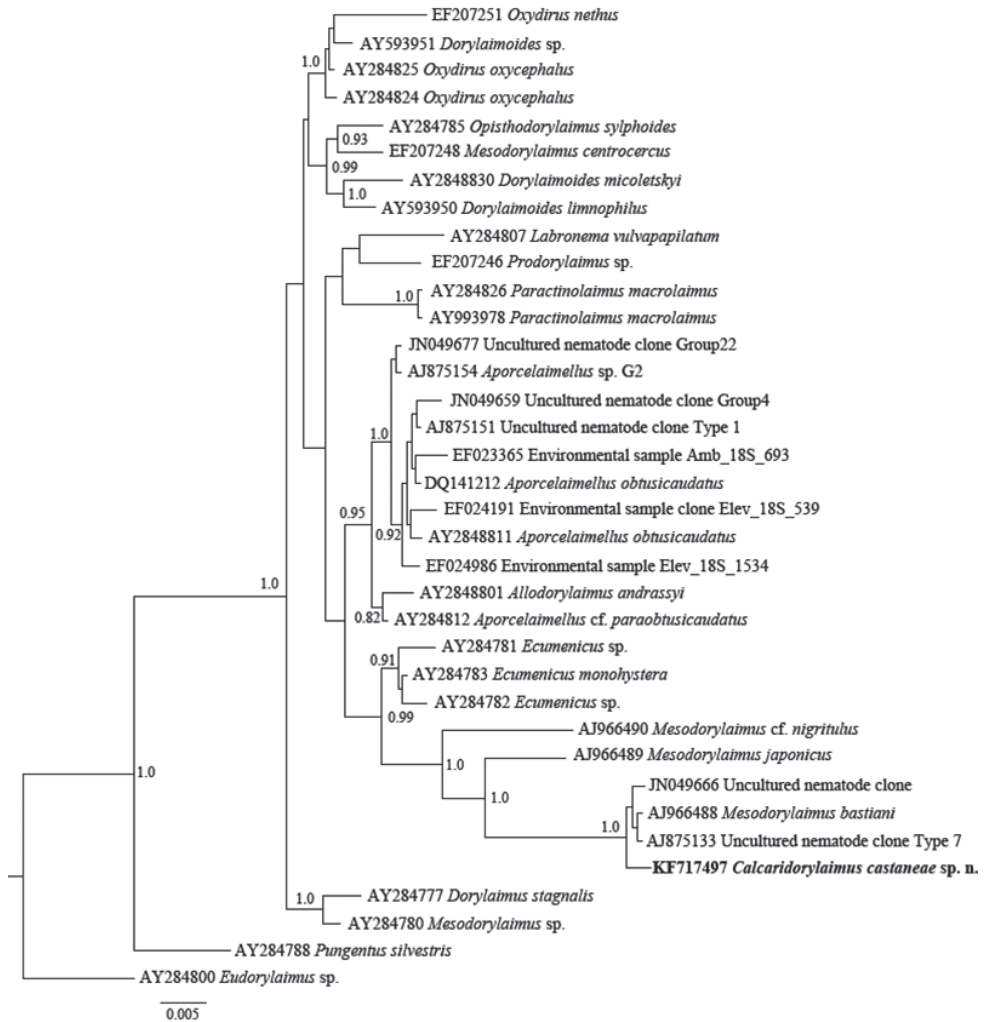


Figure 7. Phylogenetic relationships of *Calcaridorylaimus castaneae* sp. n. and its closest species for 18S rRNA gene. Bayesian Inference strict consensus tree acquired under GTR+G model. Posterior probabilities higher than 0.8 are presented.

group with several *Mesodorylaimus* spp. (*M. bastiani* (Bütschli, 1873), *M. japonicus* (Cobb in Thorne and Swanger, 1936) and *M. cf. nigriritulus* (Schneider, 1937)) and two unidentified nematodes from environmental samples in the 18S rDNA phylogenetic reconstructions (Figs 7 and 9); and to more distantly related species from various dorylaimid genera and families (*Prodorylaimus*, *Labronema*, *Nevadanema*, *Paractinolaimus*) in the partial D2-D3 LSU reconstructions (Figs 8 and 10).

The genus *Calcaridorylaimus* was erected by Andrassy (1986) to accommodate a few species having different shapes and structures of spicules from those of *Mesodorylaimus*, with the males and females being practically indistinguishable. The phylograms inferred from

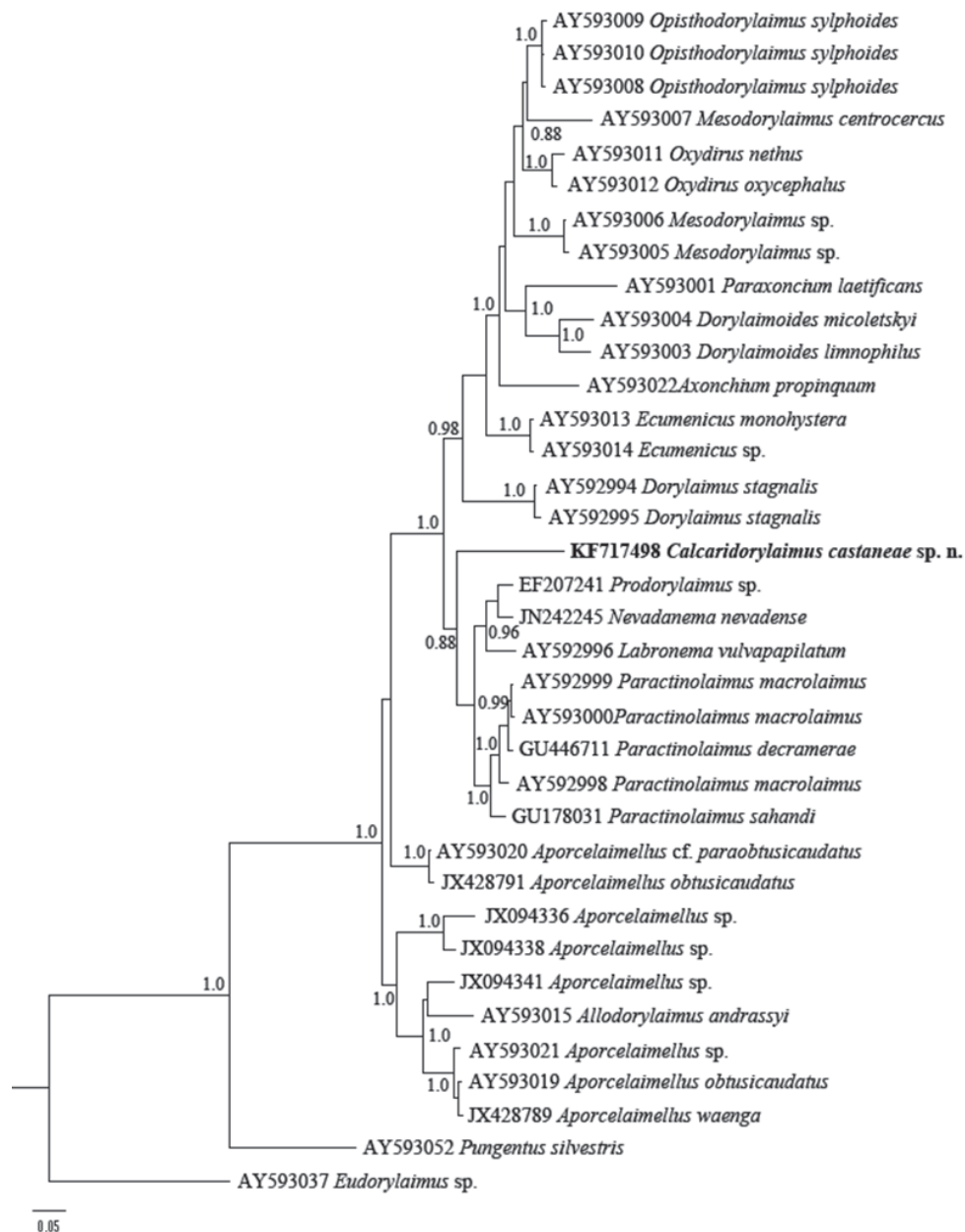


Figure 8. Phylogenetic relationships of *Calcaridorylaimus castaneae* sp. n. and its closest species for D2-D3 expansion segments of the 28S rRNA gene. Bayesian Inference strict consensus tree acquired under GTR+G model. Posterior probabilities higher than 0.8 are presented.



Figure 9. Phylogenetic relationships of *Calcaridorylaimus castaneae* sp. n. and its closest species for 18S rRNA gene. Tree acquired with Neighbor Joining and Maximum Likelihood (GTR+G model) methods. Bootstrap values higher than 70% are presented.

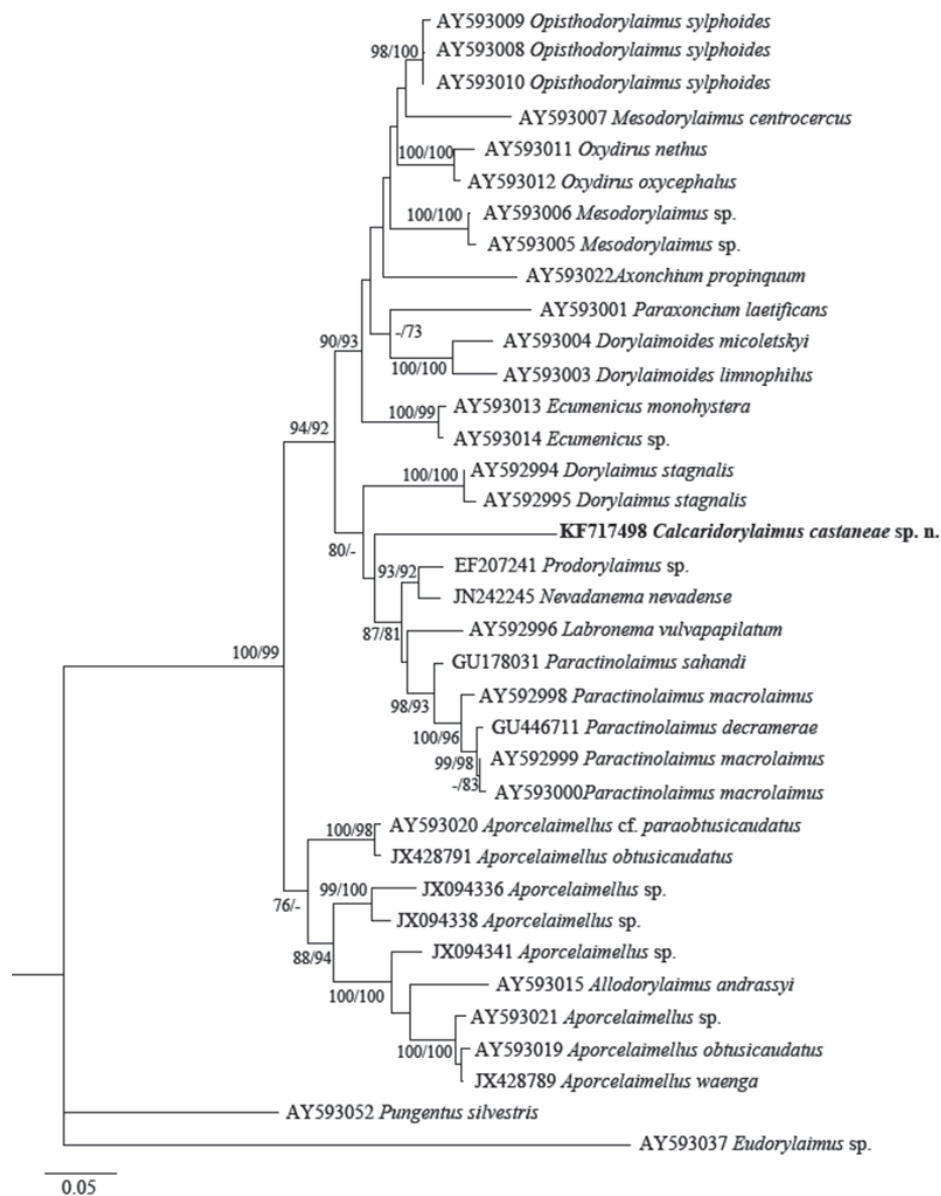


Figure 10. Phylogenetic relationships of *Calcaridorylaimus castaneae* sp. n. and its closest species for D2–D3 expansion segments of the 28S rRNA gene. Tree acquired with Neighbor Joining and Maximum Likelihood (GTR+G model) methods. Bootstrap values higher than 70% are presented.

18S sequences showed the closest relationships of *C. castaneae* with some members of the latter genus; however, the insufficiency of molecular data complementary to detailed morphological studies of species belonging to both genera does not allow the elucidation of evolutionary relationships among them and the position of the new species herein described.

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References

- About-Eid HZ (1969) Histological anatomy of the excretory and reproductive systems of *Longidorus macrosoma*. *Nematologica* 15: 437–450. doi: 10.1163/187529269X00777
- Ahmad W, Shaheen A (2004) Five new and two known species of the family Dorylaimidae (Nematoda:Dorylaimida) from Costa Rica. *Nematology* 6: 567–587. doi: 10.1163/1568541042665232
- Álvarez-Ortega S, Peña-Santiago R (2012a) Nematodes of the order Dorylaimida from Andalucía Oriental, Spain. *Nevadanema nevadense* gen. n., sp. n. (Qudsianematidae) from Sierra Nevada National Park. *Nematology* 14: 249–264. doi: 10.1163/138855411X589309
- Álvarez-Ortega S, Peña-Santiago R (2012b) Studies on the genus *Aporcelaimellus* Heyns, 1965 (Dorylaimida, Aporcelaimidae). Morphological and molecular characterization of Iberian *A. obtusicaudatus* (Bastian, 1865) Altherr, 1968, with an updated diagnosis of the species. *Journal of Nematode Morphology and Systematics* 15: 103–126.
- Álvarez-Ortega S, Abolafia J, Peña-Santiago R (2013) Studies on the genus *Aporcelaimellus* Heyns, 1965 (Dorylaimida: Aporcelaimidae). Four typical species with simple uterus from Southern Iberian Peninsula. *Zootaxa* 3613: 36–60. doi: 10.11646/zootaxa.3613.1.2
- Andrássy I (1986) The genus *Mesodorylaimus* and its relatives (Nematoda: Dorylaimidae). *Acta Zoologica Hungarica* 32: 207–261.
- Andrássy I (2003) New and rare nematodes from Alaska. Five species of the order Dorylaimida. *Journal of Nematode Morphology and Systematics* 5(2002): 163–181.
- Andrássy I (2011) Two new nematode species of the subfamily Mesodorylaiminae (Dorylaimidae) from Chile. *International Journal of Nematology* 21: 130–138.
- Courtney WD, Pooley D, Miller VL (1955) TAF, an improved fixative in nematode technique. *Plant Disease Reporter* 39: 570–571.
- De Coninck A (1935) Contribution à la connaissance de Nématodes libres du Congo Belge. I. Les Nématodes libres des marais de la Nyamuamba (Ruwendzori) et des sources chaudes du Mont Banze (Lac Kivu). *Revue de Zoologie et de Botanique Africaines* 26: 211–232 and 249–326.
- De Ley P, Loof PAA, Coomans A (1993) Terrestrial nematodes from the Galapagos Archipelago 2: Redescription of *Aporcelaimellus obtusicaudatus* (Bastian, 1865) Altherr, 1968, with

- review of similar species and a nomenclature for the vagina in Dorylaimida (Nematoda). Bulletin de l'Institut Royal des Sciences Naturelles de Belgique, Biologie 63: 13–34.
- De Ley P, Félix MA, Frisse LM, Nadler SA, Sternberg PW, Thomas WK (1999) Molecular and morphological characterisation of two reproductively isolated species with mirror-image anatomy (Nematoda: Cephalobidae). Nematology 1: 591–612. doi: 10.1163/156854199508559
- Donn S, Neilson R, Griffiths BS, Daniell TJ (2012) A novel molecular approach for rapid assessment of soil nematode assemblages - variation, validation and potential applications. Methods in Ecology and Evolution 3: 12–23. doi: 10.1111/j.2041-210X.2011.00145.x
- Gagarin V (1997) Free-living nematode fauna of fresh-waters bodies of Novaya Zemlya Archipelago. Biologiya vnutrennikh vod 3: 33–40. [In Russian]
- Griffiths BS, Donn S, Neilson R, Daniell TJ (2006) Molecular sequencing and morphological analysis of a nematode community. Applied Soil Ecology 32: 325–337. doi: 10.1016/j.apsoil.2005.07.006
- Heyns J, Meyer AJ (1995) New and little known Laimyodorinae species from Fynbos in the south-western Cape (Nematoda: Dorylaimidae). South African Journal of Zoology 30: 50–56.
- Hooper D (1961) A redescription of *Longidorus elongatus* (de Man, 1876) Thorne & Swanger, 1936 (Nematoda, Dorylaimidae), and description of five new species of Longidorus from Great Britain. Nematologica 6: 237–257.
- Holterman M, Wurff AVD, Elsen SVD, Megen HV, Bongers T, Holovachov O, Bakker J, Helder J (2006) Phylum-wide analysis of SSU rDNA reveals deep phylogenetic relationships among nematodes and accelerated evolution toward crown clades. Molecular Biology and Evolution 23: 1792–1800. doi: 10.1093/molbev/msl044
- Holterman M, Rybczyk K, Van den Elsen S, Van Megen H, Mooyman P, Peña-Santiago R, Bongers T, Bakker J, Helder J (2008) A ribosomal DNA-based framework for the detection and quantification of stress-sensitive nematode families in terrestrial habitats. Molecular Ecology Resources 8: 23–34. doi: 10.1111/j.1471-8286.2007.01963.x
- Huelsenbeck JP, Ronquist F (2001) Bayes MR: Bayesian inference of phylogeny. Bioinformatics 17: 754–755. doi: 10.1093/bioinformatics/17.8.754
- Lesaulnier C, Papamichail D, McCorkle S, Ollivier B, Skiena S, Taghavi S, Zak D, van der Lelie D (2008) Elevated atmospheric CO₂ affects soil microbial diversity associated with trembling aspen. Environmental Microbiology 10: 926–941. doi: 10.1111/j.1462-2920.2007.01512.x
- Loof PAA (1975) Dorylaimoidea from some subantarctic islands. Nematologica 21: 219–255. doi: 10.1163/187529275X00581
- Loof PAA, Coomans A (1970) On the development and location of the oesophageal gland nuclei in the Dorylaimina. Proceedings of the IX International Nematology Symposium (Warsaw, 1967): 79–161.
- Meldal BH, Debenham NJ, De Ley P, De Ley IT, Vanfleteren JR, Vierstraete AR, Bert W, Boronie G, Moens T, Tyler PA, Austen MC, Blaxter ML, Rogers AD, Lambshhead PJ (2007) An improved molecular phylogeny of the Nematoda with special emphasis on marine taxa. Molecular Phylogenetics and Evolution 42: 622–636. doi: 10.1016/j.ympev.2006.08.025

- Nedelchev S, Peneva V (2000) Description of three new species of the genus *Mesodorylaimus* Andr ssy, 1959 (Nematoda: Dorylaimidae) from Livingston Island, Antarctica, with notes on *M. imperator* Loof, 1975. Russian Journal of Nematology 8: 161–172.
- Pedram M, Niknam G, Vinciguerra MT, Ye W, Robbins RT (2010) Description of *Paractinolaimus decraemerae* sp. n. and redescription of *P. parietinus* Eroshenko, 1977 (Dorylaimida: Actinolaimidae) from northwest Iran. International Journal of Nematology 20: 169–178.
- Pedram M, Niknam G, Vinciguerra MT, Ye W, Robbins RT (2011) Morphological and molecular characterization of *Paractinolaimus sahandi* n. sp. (Nematoda: Actinolaimidae) from the Sahand Mountains in Iran. Journal of Helminthology 85: 276–282. doi: 10.1017/S0022149X10000556
- Ronquist F, Teslenko M, van der Mark P, Ayres DL, Darling A, H hna S, Larget B, Liu L, Suchard MA, Huelsenbeck JP (2012) MrBayes 3.2: Efficient Bayesian Phylogenetic Inference and Model Choice Across a Large Model Space. Systematic Biology 61: 539–542. doi: 10.1093/sysbio/sys029
- Seinhorst JW (1959) A rapid method for the transfer of nematodes from fixative to anhydrous glycerin. Nematologica 4: 67–69. doi: 10.1017/S0022149X10000556
- Sievers F, Wilm A, Dineen DG, Gibson TJ, Karplus K, Li W, Lopez R, McWilliam H, Remmert M, S ding J, Thompson JD, Higgins DG (2011) Fast, scalable generation of high-quality protein multiple sequence alignments using Clustal Omega. Molecular Systems Biology 7: 539. doi: 10.1038/msb.2011.75
-  irca S, Urek G, Lazarova S, Elshishka M, Peneva V (2011) *Longidorus carniolensis* sp. n. (Nematoda, Longidoridae) from vineyard soil in Slovenia. ZooKeys 141: 1–27. doi: 10.3897/zookeys.141.1906
- Tamura K, Peterson D, Peterson N, Stecher G, Nei M, Kumar S (2011) MEGA5: Molecular evolutionary genetics analysis using Maximum Likelihood, Evolutionary Distance, and Maximum Parsimony methods. Molecular Biology and Evolution 28: 2731–2739. doi: 10.1093/molbev/msr121

Taxonomic notes on the genus *Eupoa* Żabka, 1985 (Arachnida, Araneae, Salticidae)

Dmitri V. Logunov^{1,†}, Yuri M. Marusik^{2,3,‡}

1 The Manchester Museum, The University of Manchester, Oxford Road, Manchester M13 9PL, UK **2** Institute for Biological Problems of the North FEB RAS, Portovaya Str. 18, Magadan 68500, Russia **3** Zoological Museum, University of Turku, FI-20014 Turku, Finland

† <http://zoobank.org/0692E80C-BF14-471A-8692-E6B37FC8C75D>

‡ <http://zoobank.org/F215BA2C-5072-4CBF-BA1A-5CCBE1626B08>

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

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Abstract

The south-east Asian genus *Eupoa* is redescribed and diagnosed. Seven new species are diagnosed, described and illustrated: *E. daklak* **sp. n.** (♀) from Viet-Nam; *E. lehtineni* **sp. n.** (♂♀) from India, Thailand and Viet-Nam; *E. lobli* **sp. n.** (♂) from Malaysia; *E. pappi* **sp. n.** (♂) from Thailand; *E. pulchella* **sp. n.** (♂) from Thailand; *E. schwendingeri* **sp. n.** (♂♀) from Thailand; and *E. thailandica* **sp. n.** (♂♀) from Thailand. *Eupoa prima* Żabka, 1985 and *E. yunnanensis* Peng & Kim, 1997 are redescribed and illustrated on the basis of type and/or newly collected materials. The female of *E. yunnanensis* Peng & Kim, 1997 is found and described for the first time.

Keywords

SE Asia, jumping spiders, Aranei, *Eupoa*, new species, (re)descriptions

Introduction

The genus *Eupoa* Żabka, 1985 was described to accommodate a single species *E. prima* Żabka, 1985 from northern Viet-Nam (Żabka 1985). For more than 10 years the genus had been considered monotypic until three more species were described by Peng and Kim (1997) from China (Hainan and Yunnan provinces): *E. liaoi* Peng & Li, 2006; *E. maculata* Peng & Kim, 1997 and *E. yunnanensis* Peng & Kim, 1997. Later, three more species were described from China: *E. liaoi* Peng & Li, 2006 from Hainan province (Peng and Li 2006) and *E. jingwei* Maddison & Zhang, 2007 and *E. nezha* Maddison & Zhang, 2007 from Guangxi (Maddison et al. 2007). Two of the *Eupoa* species described from Hainan (*E. liaoi* and *E. maculata*) have recently been transferred to other genera (Zhou and Li 2013a). Thus, to date a total of five valid species has been described in the genus *Eupoa*: one from northern Viet-Nam and four from south-eastern regions of China (Yunnan, Guangxi and Hainan).

By their general appearance, members of the genus *Eupoa* are superficially similar to those of *Neon* Simon, 1876. Both groups are small to very small spiders, with males having the swollen and relatively large palps for the size of the spiders (Figs 42–43, 86, 90). Both *Eupoa* and *Neon* are typical dwellers of forest leaf litter. However, the conformation of male copulatory organs in *Eupoa* is much more complex leaving no doubts that both genera are not related. The phylogenetic relationships of *Eupoa* remain poorly resolved, although the genus is indeed a basal salticid; see below under ‘Diagnosis and Affinities’.

The aim of the present paper is twofold: (1) to provide a comprehensive description of the genus *Eupoa* on the basis on newly collected materials; and (2) to describe seven new species from various regions of SE Asia.

Material and methods

A total of 42 adult museum specimens belonging to nine species has been examined. The material studied in this paper was borrowed from the following museums: HNHM = Hungarian Natural History Museum, Budapest, Hungary (curator: Dr T. Szuts); MHNG = Museum d’Histoire Naturelle, Geneve, Switzerland (curator: Dr P. Schwendinger); SMFM = Naturmuseum und Forschungsinstitut Senckenberg, Frankfurt am Main, Germany (curator: Dr P. Jäger and Ms J. Altmann); ZMTU = Zoological Museum, Turku University, Turku, Finland (curator: Mr S. Koponen); ZMUM = Zoological Museum of the Moscow State University, Moscow, Russia (curator: Dr K. G. Mikhailov).

Digital photographs were taken using an Olympus E-520 camera attached to an Olympus SZX16 stereomicroscope, and prepared using CombineZP image stacking software. Photographs were taken with the specimens secured in dishes with paraffin on bottom. SEM microphotographs were made by means of a JEOL JSM-5200 in the Zoological Museum, University of Turku. Epigynes were cleared in a 10% KOH solution.

Abbreviations used in the text and figures are as follows: *Eyes*: AME – anterior median eye, ALE – anterior lateral eye, PME – posterior median eye, PLE – posterior lateral eye. *Copulatory organs*: CTA – compound terminal apophysis; E – embolus; ID – insemination ducts; MA – median apophysis; PA – patellar apophysis; R – receptacle; TA – tegular apophysis; TbA – tibial apophysis. *Leg segments*: Fm – femur, Pt – patella, Tb – tibia, Mt – metatarsus, Tr – tarsus. *Position of leg spines*: d – dorsal, pr – prolateral, rt – retrolateral, v – ventral. For the leg spination the system adopted is that used by Ono (1988). The sequence of leg segments in measurement data is as follows: femur + patella + tibia + metatarsus + tarsus. All measurements are in mm.

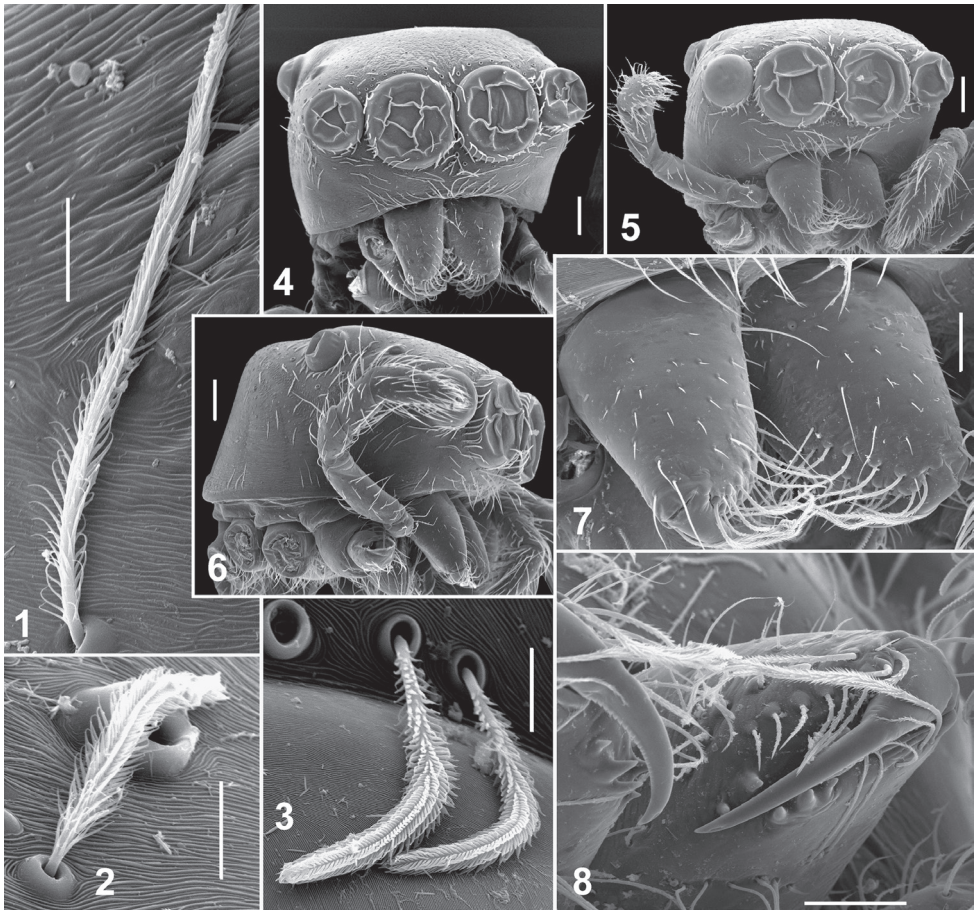
Taxonomy

Genus *Eupoa* Żabka, 1985

<http://species-id.net/wiki/Eupoa>

Eupoa Żabka, 1985: 220. Type species: *Eupoa prima* Żabka, 1985; by monotypy.

Description. Small to very small spiders ranging from about 1.65 to 2.45 mm in length. Sexes similar in general body form; sexual dimorphism is poorly marked and can be seen in the following characters: dorsal scutum presents in males (absent in females), body coloration in males is slightly darker or more contrastingly coloured, anterior and posterior pairs of spinnerets are of contrasting colours in males (brown/dark grey *vs.* yellow; e.g., *E. prima*, *E. yunnanensis*), and legs I and II in males are often with no spines or just with 2/3 pairs of ventral spines on metatarsi (always with spines on tibiae and metatarsi in females; e.g., *E. schwendingeri* sp. n., *E. yunnanensis*). *Carapace*: rather high, with abruptly declining, practically vertical thoracic part (Figs 6, 59, 90); sparsely covered with white elongated pinnate scales (Figs 1–3); fovea absent (Figs 73, 75); lateral sides of carapace, near ALEs, with vertical rows of skin structures (50–60 in a group) looking like either as rounded or elongated smooth bare patches, slightly risen above the surrounding skin (Figs 20, 22), or as flat elongated patches with what looks like several micro-pustules situated on them (Fig. 18); similar bare skin structures occur on leg patellae (see below; Figs 20–21). *Eyes*: in three rows, with large black areas around eyes (Figs 42–46, 58–59); anterior eye row wider in both sexes, so the quadrangle is as an inverted trapezium; second row midway between ALE and PLE; quadrangle length 52–66% of carapace length. *Chlypeus*: narrow, about 17–47% of AME diameter (from frontal view; Figs 4–5), visibly backward sloping (Figs 6, 59). *Chelicerae*: small and vertical (Figs 4–5, 7; promargin with two small teeth; retromargin with three small teeth (Fig. 8). *Maxillae*: slightly convergent; usual shape. *Labium*: transverse-ovoid. *Sternum*: as inverted cone with swollen lateral sides (Figs 30, 72, 76). *Pedichel*: short, in live specimens not visible in dorsal view. *Abdomen*: elongate, covered with elongated pinnate scales (Fig. 32); dorsal scutum present in males; colour markings on dorsum simple, either

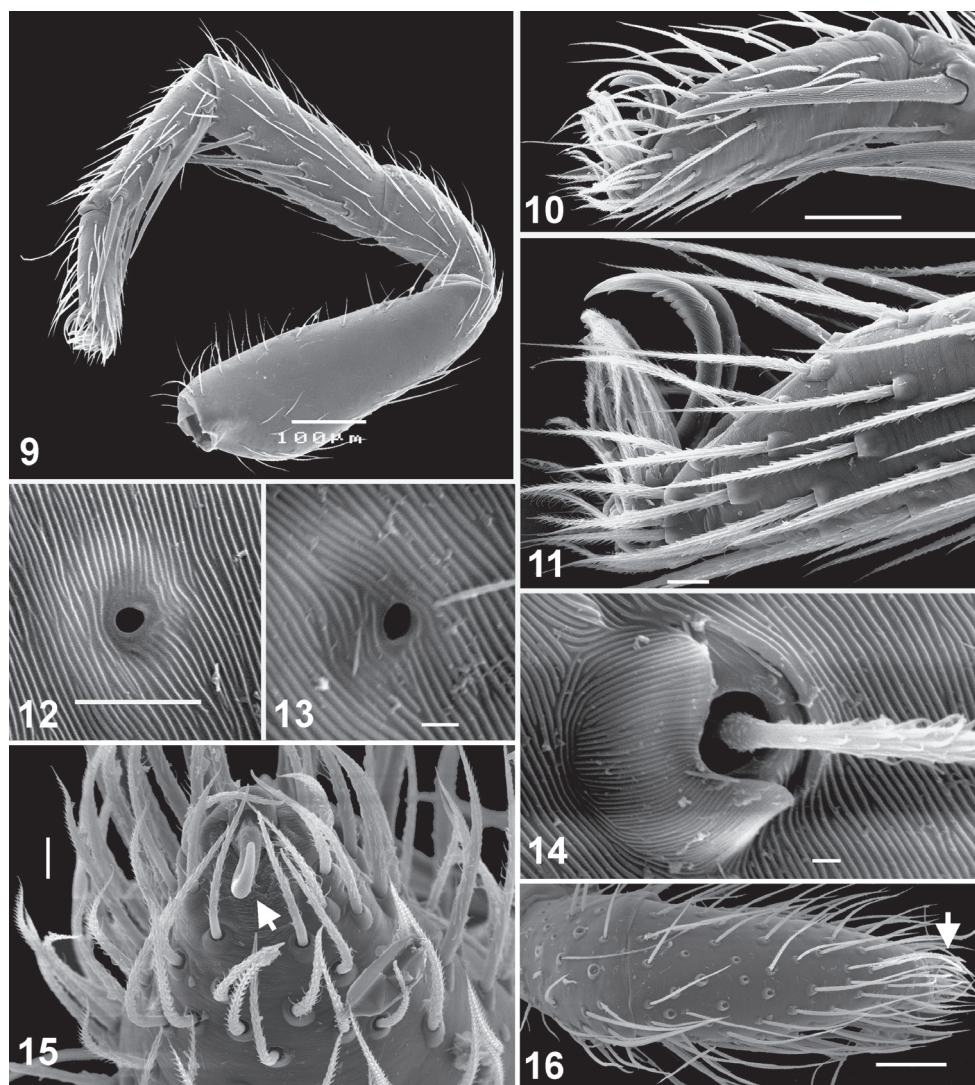


Figures 1–8. Somatic characters of *Eupoa lehtineni* sp. n. **1–3** plumose scales on female carapace. **4** male carapace, frontal view **5** female carapace, frontal view **6** ditto, lateral view **7** female chelicerae, frontal view **8** female fang and cheliceral teeth. Scale bars: 10 μ m (**1–3**), 50 μ m (**7–8**), 0.1 mm (**4–6**).

consisting of a median yellow stripe (Figs 41, 43, 45) or two rows of spots with a pair of largest spots at the rear of dorsum (Figs 85–86). *Book-lung covers*: usual shape, not sclerotized. *Spinnerets*: posterior pair almost two times longer than anterior pair (Figs 31–32). *Legs*: subequally developed (Fig. 9); legs I in males usually with dark brown longitudinal stripes; trichobothrial bases relatively flat and striated (Fig. 14); tarsal organ as a rounded or ovoid pit (Figs 12–13); tarsal claws narrow, with poorly developed teeth (Figs 10–11); skin structures of two kinds present anteriorly on the dorsal surface of leg patellae, situated in a longitudinal row of about 20–30 pores (arrowed in Figs 19, 21, 23–24): structures of the first kind represents flat elongated and smooth bare patches with what looks like several micro-pustules situated on them (Figs 17, 24); structures of the second kind look like a rounded or elongated or circular smooth bare patch, slightly risen above the surrounding skin (Figs 21;

similar bare structures occur on the carapace, see above, Figs 20, 22), these structures resemble the second kind of skin pores described in *Neon* (Logunov 1998: figs 7, 11). *Leg formula*: IV,I,III,II in both sexes, rare IV,I,II,III in females. *Leg spination*: in males legs I and II are often spineless (or with a few spines on Mt I: v 2–2–2ap); in females Tb I v 2–2–2ap, Tb II pr and rt 0–1–0, v 1–1/0 and Mt I and II v 2–2–2ap; in both sexes Tb III and IV usually pr and rt 0–1–0 (or 0–1). *Female palp*: general form; with an apical claw (arrowed in Figs 15–16). *Male palp*: swollen and relatively large for the size of the spiders (Figs 42–43); femur of usual shape, except for *E. prima* (Figs 80–83), shorter than cymbium; patella swollen, with one (Figs 61, 70, 84, etc.) or two (Fig. 80) apophyses that sometimes are as long as the femur (*E. prima*; Fig. 80) or poorly-developed and inconspicuous (*E. lehtineni* sp. n.; Fig. 50), or sometimes bifid (Figs 96, 126); tibia shorter than patella, with one or two tibial apophyses (Figs 49, 59, 116, etc.) that sometimes are poorly-developed (*E. prima*; Figs 81, 84) or covered with long hairs (*E. thailandica* sp. n.; Fig. 111); cymbium well-developed, sometimes with bunches of white hairs at its basis (e.g., in *E. thailandica* sp. n.; Figs 106–107); tegulum well-developed (sometimes on one side of the bulb only; e.g., in *E. pappi* sp. n.; Figs 70–71) and usually with regular apophysis (Figs 52, 60, etc.), which sometimes poorly-developed (e.g., in *E. schwendingeri* sp. n.; Fig. 98) or even absent (e.g., in *E. pulchella* sp. n.; Figs 91–96); median apophysis present (Figs 49, 83, etc.), but sometimes poorly-developed (e.g., in *E. pappi* sp. n.; Figs 67–68); compound terminal apophysis present and situated inside the apical cavity of tegulum, either thin and long (Figs 52, 61) or strong, with a longitudinal groove on its anterior edge (e.g., in *E. pappi* sp. n. or *E. thailandica* sp. n.; Figs 66–68, 109); embolus usually very long and coiled, making 1.5–2 revolutions, with its terminal end resting on top of the cymbium (Figs 36, 51, 62), or can be short (Fig. 94) and even fingerlike and apically bifurcated in some species (*E. yunnanensis*; Fig. 125). *Female copulatory organs*: simple, with a pair of copulatory openings that usually spaced up from each other and poorly visible on the epigynal plate; epigynal plate flat (Figs 29, 48, 100) or sometimes with a central shallow atrium (*E. yunnanensis*; Fig. 127), usually covered with long light hairs (Figs 39–40); insemination ducts relatively short, directed to each other (Fig. 101; see also Žabka (1985: fig. 169) or being subparallel (Figs 53, 118); receptacles rounded or bean-shaped, usually much stronger sclerotized than insemination ducts (Figs 53, 118, 128); in most species receptacles and fertilization ducts are situated at the posterior end of the vulva (near the epigastric furrow), but sometimes lie at its anterior end (*E. lehtineni* sp. n.; Figs 53–54).

Diagnosis and affinities. Of the described salticid genera, *Eupoa* is closest to *Corusca* Zhou & Li, 2013 (10 species) and *Sinoinsula* Zhou & Li, 2013 (12 species) known from Hainan Island of China (Zhou and Li 2013a, b). *Eupoa* can vaguely be distinguished from *Corusca* by the presence of patellar apophysis in the males (except for *C. viriosa* Zhou & Li, 2013 and *C. wuzhishanensis* Zhou & Li, 2013) and the paired copulatory openings in the females. This is why none of the new species described in this paper has been assigned to *Corusca*, even *Eupoa lehtineni* sp. n. and *Eupoa lobli* sp. n. of which the conformation of male copulatory organs is very similar



Figures 9–16. Somatic characters of *Eupoa lehtineni* sp. n. (9–11, 13–16) and *E. thailandica* sp. n. (12). 9 female leg I, median view 10 female tarsus I, lateral view 11 female tarsus III, lateral view 12–13 tarsal organ on female tarsus I, dorsal view 14 trichobotrial base, female tarsus I, dorsal view 15–16 female palp and the claw at its tip (arrowed). Scale bars: 1 μ m (13–14), 5 μ m (12), 10 μ m (11, 15), 50 μ m (10, 16), 0.1 mm (9).

to that of the *Corusca* species. *Eupoa* can be distinguished from *Sinoinsula* by the conformation of copulatory organs in the males: viz., the presence of median apophysis and, more importantly, by the apical/medio-lateral origin of the embolus (prolateral in *Sinoinsula*). Nevertheless, despite the aforementioned differences it is likely that the three genera are not only closely related but could even be treated as one, under the name of *Eupoa*. The original differential diagnoses of *Corusca* and *Sinoinsula* (see

Zhou and Li 2013a) were purely based on a few characters of the copulatory organs, some of which vary (e.g., the presence/absence of the patellar, tegular or compound terminal apophyses), whereas somatic morphology was largely neglected. It seems that at least the limits of *Corusca* are unclear and can be reconsidered in the future. In the opinion of one of us (DL), the genera *Corusca* and *Sinoinsula* would be better considered the subgenera of *Eupoa* (*s. lato*), unless additional reliable diagnostic characters in somatic morphology were found. However, no synonymy is being made at this time. This problem is outside the scope of the present paper and will be considered in more detail in the future.

The phylogenetic relationships of *Eupoa* remain poorly resolved. On the basis of two morphological characters (presence of the median apophysis and a tarsal claw in the female palp; Figs 15–16) and molecular data, Maddison et al. (2007) argued that the genus *Eupoa* is a basal salticid of which phylogenetic placement lies outside the Salticoidea, and even outside the Spartaeinae (as it lacks a recognised tegular furrow; *sensu* Wijesinghe 1992). Obviously, further studies are required to resolve the correct phylogenetic placement of *Eupoa*.

Composition. Currently, 12 species are included in *Eupoa* (Platnick 2014; present data).

Distribution. *Eupoa* seems to be restricted to the Oriental Region, for all the described species thereof as well as those of two closely related genera, *Corusca* and *Sinoinsula*, are restricted to SE Asia (Żabka 1985; Peng and Kim 1997; Maddison et al. 2007; Zhou and Li 2013a; present data).

Descriptions

Eupoa daklak sp. n.

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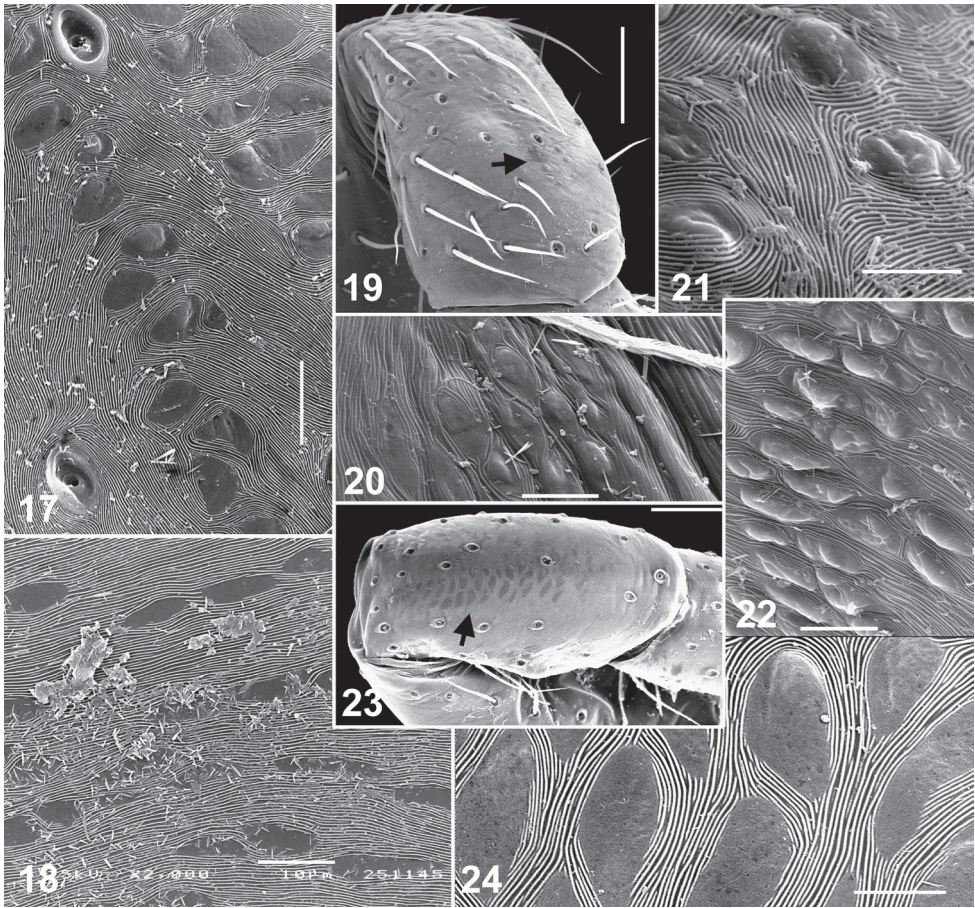
Figs 33–35

Type. Holotype ♀ (ZMUM) from Viet-Nam, Dak Lak Prov., c. 25 km SSW of Buon Ma Thuot (c. 12°26'48"N, 107°58'E), Dak Linh, 500 m a.s.l., 28–29.04.1986, L.N. Medvedev & S.I. Golovatch.

Etymology. The species epithet is a noun taken in apposition of the type locality: Daklak province of Viet-Nam.

Diagnosis. The central shallow depression of the epigyne of *E. daklak* sp. n. (Fig. 33) is unique among all the *Eupoa* species known to us. The male of *E. daklak* sp. n. remains unknown.

Comments. Although this species is described on the basis of a single female, it is highly unlikely that it could belong to one of the three other new species described below on the basis of males (*E. lobli* sp. n. from Malaysia; *E. pappi* sp. n. and *E. pulchella* sp. n. from Thailand). All *Eupoa* species, as well as those of two closely related



Figures 17–24. Skin structures of *Eupoa lehtineni* sp. n. (17, 19–22) and *E. thailandica* sp. n. (18, 23, 24). 17 male patella I, dorsal view 18, 20, 22 female carapace, lateral view 19, 21, 23–24 female patella I, dorsal view. Scale bars: 5 μ m (21, 24), 10 μ m (17–18, 20, 22), 50 μ m (19, 23).

genera (*Corusca* and *Sinoinsula*), are litter-dwellers, with most of them (except for *E. lehtineni* sp. n.) having small, local ranges. For instance, 22 distinct species of *Corusca* and *Sinoinsula* were recently described from Hainan Island of China alone (Zhou and Li 2013a, b). Therefore, it is safe to conclude that this and three other *Eupoa* species that are described herein on the basis of a single sex from very distant localities indeed belong to different species. Finally, there is no technical way to match this female with one of the males, unless they were collected together.

Distribution. The type locality only.

Description. MALE unknown.

FEMALE. Measurements. Carapace 0.89 long, 0.76 wide and 0.49 high at PLE. Ocular area 0.59 long, 0.77 wide anteriorly and 0.71 wide posteriorly. Diameter of AME 0.24. Clypeus height 0.07, chelicera length 0.29. Abdomen 1.06

long, 0.89 wide. Length of leg segments: I: $0.47 + 0.22 + 0.29 + 0.29 + 0.19$; II: $0.41 + 0.19 + 0.23 + 0.23 + 0.19$; III: $0.39 + 0.17 + 0.26 + 0.27 + 0.19$; IV: $0.61 + 0.23 + 0.43 + 0.34 + 0.23$. *Leg spination*. Leg I: Tb v 2-2-2ap; Mt v 2-2-2ap. Leg II: Tb v 2-2; Mt v 2-2-2ap. Leg III: Tb pr and rt 0-1-0; Mt pr 1-1ap, rt and v 1-0. Leg IV: Tb pr and rt 0-1-0; Mt pr 1-0-2ap, rt 1-0-1ap, v 1-0. *Coloration* (Fig. 35). Carapace yellow-brown, with brownish radial veins on thorax and yellow eye field. Blackened around eyes. Clypeus naked, yellow, with a brown marginal line. Sternum, maxillae, labium and chelicerae yellow, tinged with brown. All abdomen brownish yellowish, without a colour pattern. Book-lung covers yellow, tinged with brown. Spinnerets: anterior pair brownish, posterior pair pale yellow. All legs yellow, with poorly marked brownish patches at segment joints. Palps: femora and patellae brownish, metatarsi and tarsi yellow. Epigyne and vulva as in Figs 33–34: epigynal plate as a rounded shallow depression; insemination ducts thin and transparent; pear-shaped receptacles are close to each other, meeting up along the median line.

***Eupoa lehtineni* sp. n.**

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

Figs 1–11, 13–17, 19–22, 25–32, 36–54

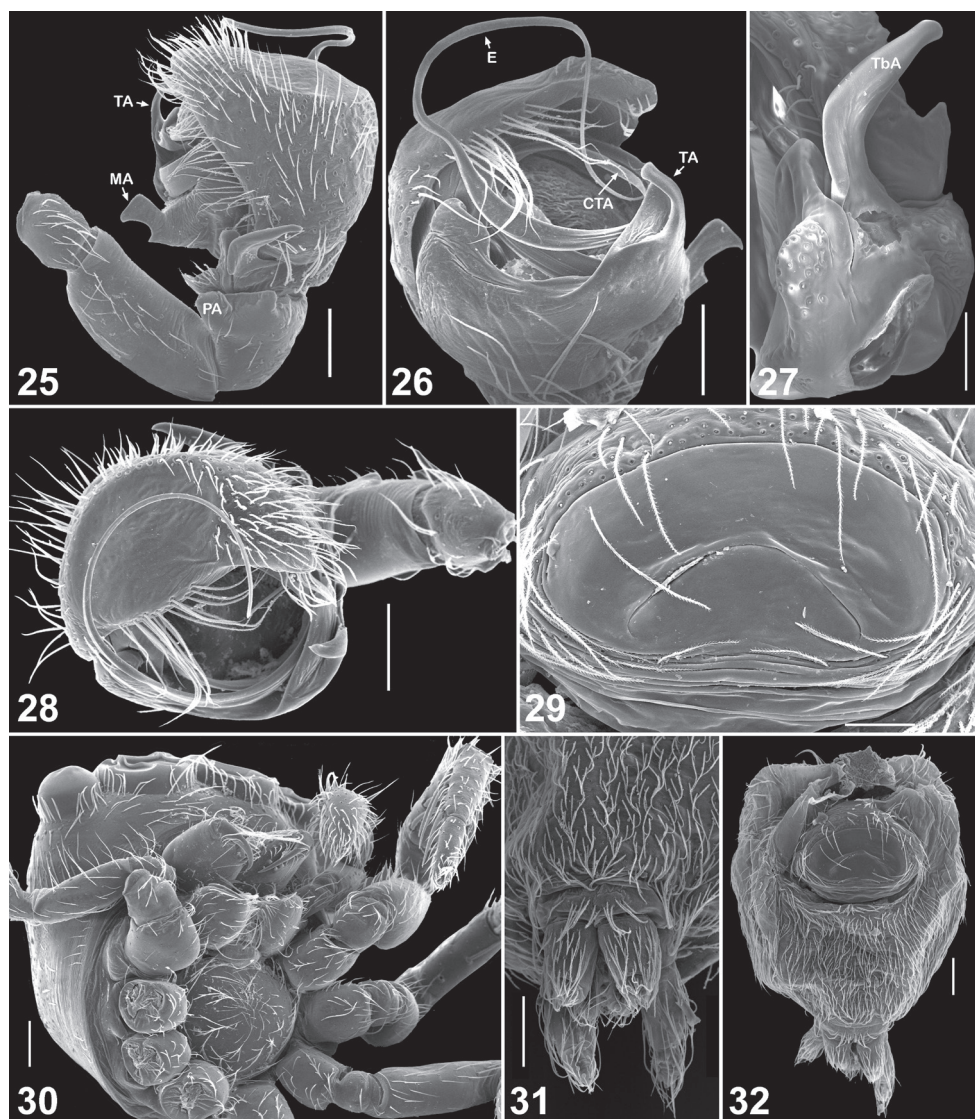
Types. Holotype ♂ (ZMTU) from India, Meghalaya, East Khasi Hills, Umran, river-side forest, 1200 m a.s.l., 4.05.1979, P.T. Lehtinen.

Paratypes: INDIA: 2♂5♀ (ZMTU), together with the holotype. – THAILAND: 3♂5♀ (MHNG, one male without abdomen and palp), Trat Prov., Ko Chang, west side ($12^{\circ}03'N$, $102^{\circ}18'E$), WINKLER-extraction in secondary forest with primary spots (AS-T-5), 50–200 m a.s.l., 3–23.12.1999, A. Schultz; 1♀ (MHNG), Kanchanaburi Prov., Sai Yok Distr., Sai Yok National Park, near HQ, 100 m a.s.l., 21.07.1987, P.J. Schwendinger. – VIET-NAM: 1♀ (ZMUM), Dong Nai Prov., Vinh Cuu Dist., Vinh Cuu Nature Reserve (= Ma Da Forest), c. 6 km N of Ba Hao Vil. ($c.11^{\circ}19'N$, $107^{\circ}05'E$), 80 m a.s.l. (sample-5), 10.05.1995, T. Sergeeva; 1♀ (ZMUM), same locality (sample-11), 6.06.1995, T. Sergeeva.

Etymology. The species is named in honour of our colleague and friend, Dr Pekka Lehtinen (Turku, Finland), who collected the holotype.

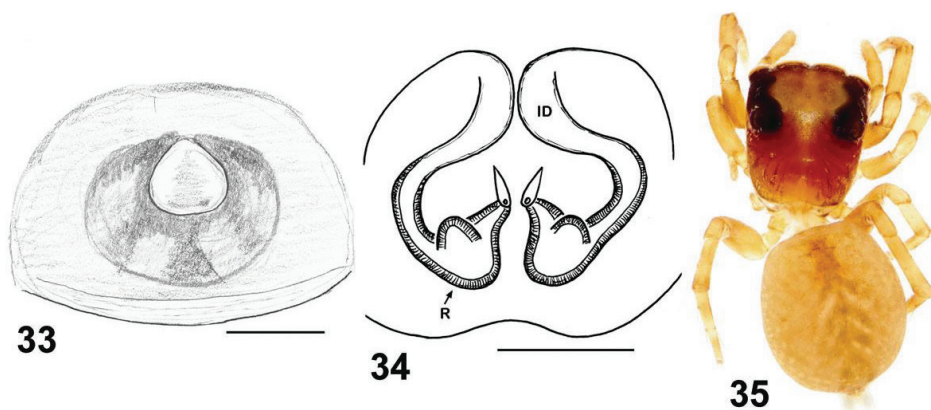
Diagnosis. By the conformation of the large, round tegulum, the tibial apophysis and the thin compound terminal apophysis that is hidden in the apical cavity of tegulum (Figs 26, 52), the male of *E. lehtineni* sp. n. is most similar to that of *E. lobli* sp. n. (Figs 60–62), but can easily be distinguished by the shape of tegular and median apophyses. The female of *E. lehtineni* sp. n. has the easily recognizable triangle epigynal plate (Figs 29, 39–40) and the mutual arrangement and shape of receptacles (Figs 53–54).

Distribution. From eastern India, south-eastward to Thailand and southern Viet-Nam (present data).

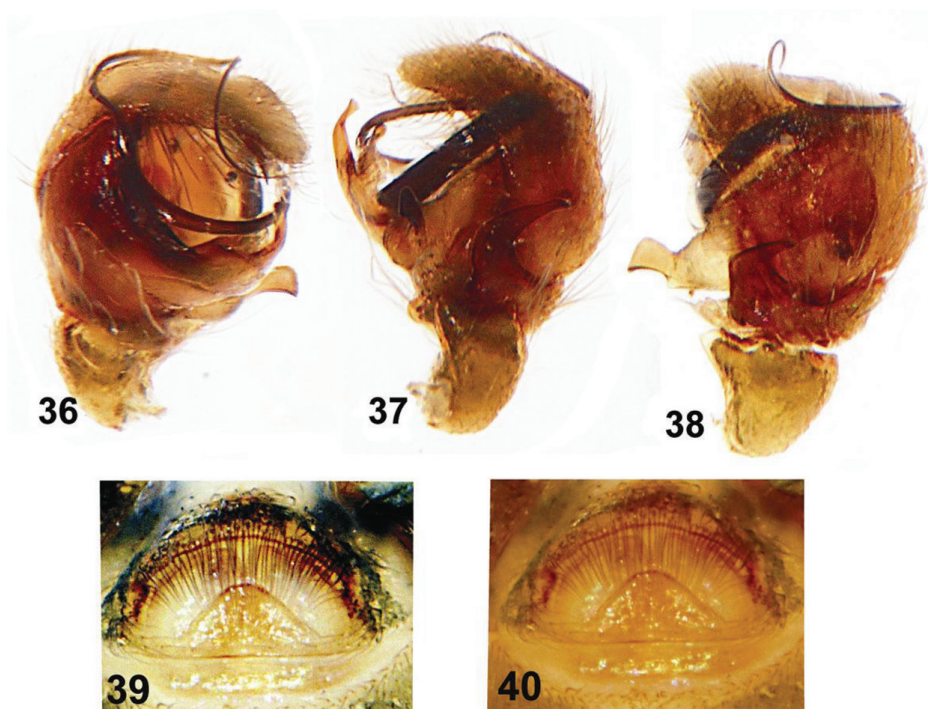


Figures 25–32. Copulatory organs and somatic characters of *Eupoa lehtineni* sp. n. **25** male palp, retrolateral view **26** ditto, median view **27** male tibial apophysis, retrolateral view **28** male palp, apical view **29** epigyne, ventral view **30** female carapace, ventral view **31** female spinnerets, ventral view **32** female abdomen, ventral view. Abbreviations as explained in ‘Material and methods’. Scale bars: 50 μ m (**27**, **29**), 0.1 mm (**25–26**, **28**, **30–32**).

Description. MALE (from Thailand: Ko Chang). *Measurements.* Carapace 0.94 long, 0.79 wide and 0.51 high at PLE. Ocular area 0.61 long, 0.79 wide anteriorly and 0.77 wide posteriorly. Diameter of AME 0.24. Clypeus height 0.06, chelicera length 0.29. Abdomen 0.76 long, 0.58 wide. Length of leg segments: I: 0.44 + 0.22 + 0.30 + 0.26 + 0.16; II: 0.40 + 0.21 + 0.21 + 0.24 + 0.19; III: 0.38 + 0.18 + 0.22 + 0.27 +

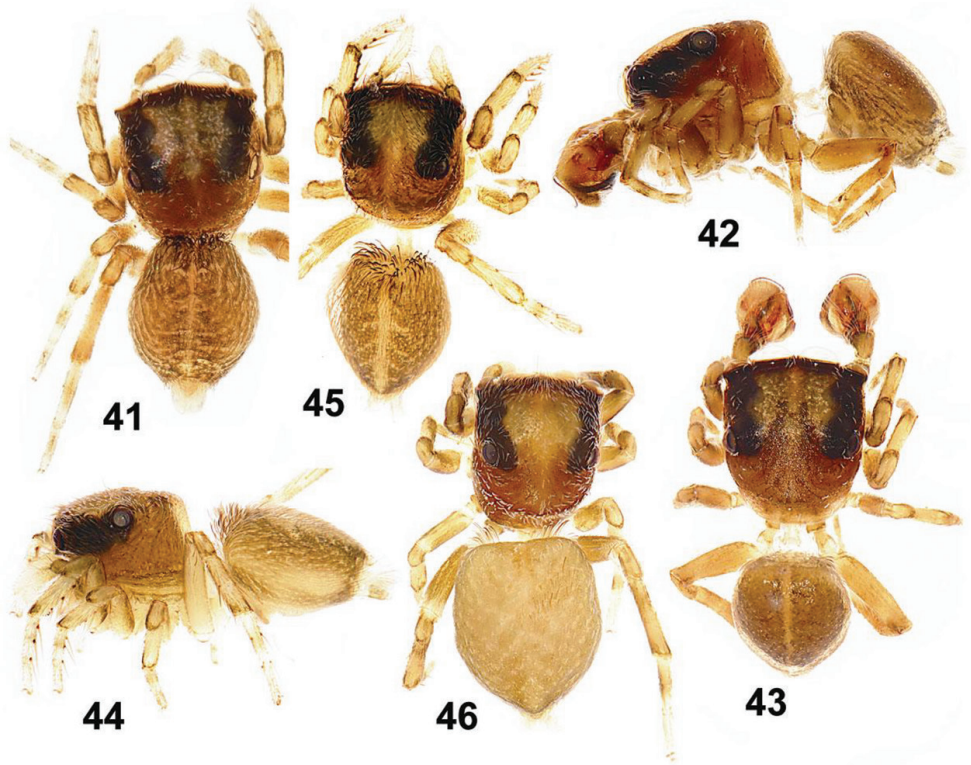


Figures 33–35. Copulatory organs and somatic characters of *Eupoa daklak* sp. n. **33** epigyne, ventral view **34** vulva, dorsal view **35** female body, dorsal view. Abbreviations as explained in 'Material and methods'. Scale bars: 0.1 mm.



Figures 36–40. Copulatory organs of *Eupoa lehtineni* sp. n. from India. **36** male palp, median view **37–38** ditto, retrolateral view **39–40** epigyne, ventral view.

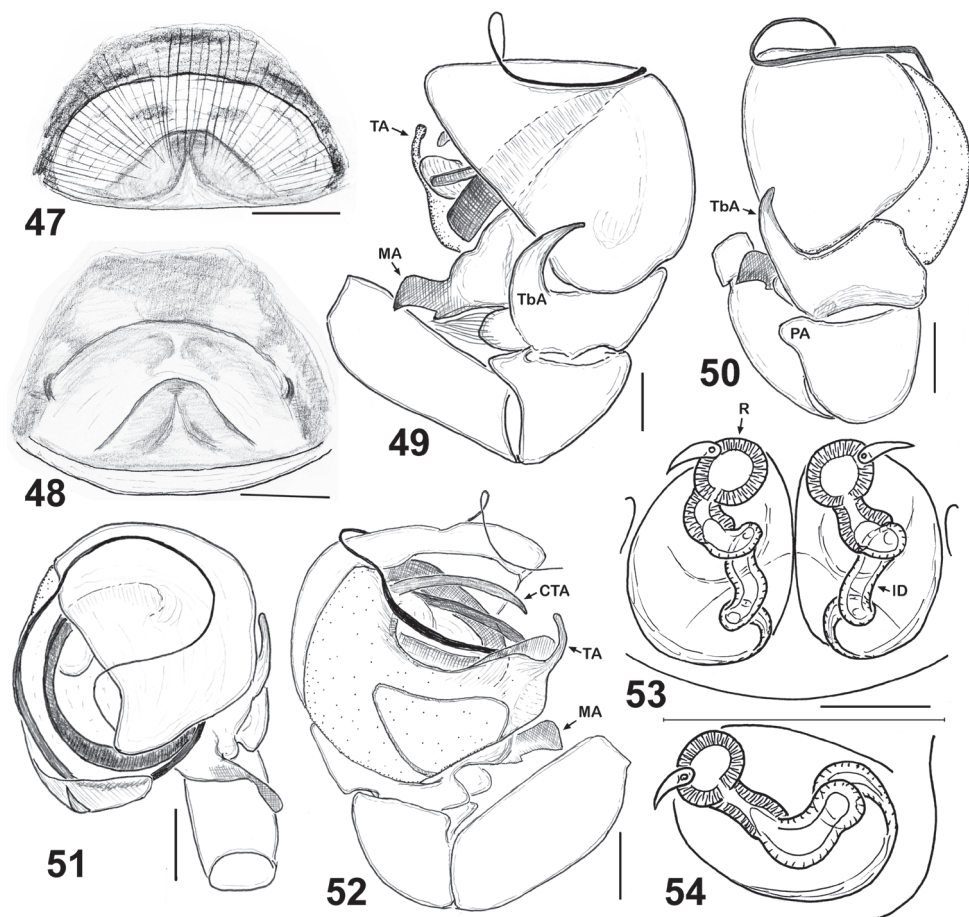
0.20; IV: 0.59 + 0.23 + 0.41 + 0.30 + 0.23. *Leg spination.* Leg I: Mt v 2-2-2ap. Leg II with no spines. Leg III: Tb pr and rt 0-1-0. Leg IV: Tb pr and rt 0-1-0; Mt pr and rt 0-1-1-ap. *Coloration* (Figs 42–43). Carapace light grey-brown, with grey-yellow eye



Figures 41–46. General appearance of *Eupoa lehtineni* sp. n. **41, 45–46** females, dorsal view **42** male, lateral view **43** ditto, dorsal view **44** female, lateral view. Specimens: **41–43** – India; **44–46** – Viet-Nam.

field and with poorly visible dark brown radial veins on thorax. Blackened around eyes. Clypeus naked, yellow-brown. Sternum light grey-brown. Maxillae, labium and chelicerae grey-yellow. Abdomen light grey-brown, dorsum completely covered with large scutum and with a thin longitudinal, medial yellow line. Book-lung covers light grey-brown. Spinnerets: anterior pair grey brownish, posterior pair yellow. All legs grey-yellow, with dark brown patches at segment joints, but patellae, tibiae and metatarsi I pro-ventrally with dark brown longitudinal stripe. Palp grey-yellow, its structure as in Figs 25–28, 36–38, 49–52: patellar apophysis short and obtuse; tibial apophysis blade-shaped, bent dorsad; tegulum well-developed, apically with prominent, hook-shaped regular apophysis; median apophysis massive, directed ventrad; compound terminal apophysis thin and long, situated inside the apical cavity of tegulum; embolus coiled, making two revolutions, with its terminal end resting on top of the cymbium.

FEMALE (from Viet-Nam: Dong-Nai). *Measurements*. Carapace 0.93 long, 0.73 wide and 0.51 high at PLE. Ocular area 0.59 long, 0.75 wide anteriorly and 0.71 wide posteriorly. Diameter of AME 0.24. Clypeus height 0.06, chelicera length 0.33. Abdomen 0.89 long, 0.71 wide. Length of leg segments: I: 0.49 + 0.26 + 0.31 + 0.31 + 0.21; II: 0.39 + 0.21 + 0.23 + 0.26 + 0.18; III: 0.39 + 0.17 + 0.24 + 0.31 + 0.21; IV:



Figures 47–54. Copulatory organs of *Eupoa lehtineni* sp. n. **47–48** epigyne, ventral view **49** male palp, retrolateral view **50** ditto, dorsal view **51** ditto, apical view **52** ditto, median view **53–54** vulva, dorsal view. Abbreviations as explained in ‘Material and methods’. Specimens: **49–53** – India; **47–48, 54** – Viet-Nam. Scale bars: 50 μ m (**27, 29**), 0.1 mm (**25–26, 28, 30–32**).

0.63 + 0.23 + 0.49 + 0.37 + 0.23. *Leg spination*. Leg I: Tb v 2-2-2ap; Mt v 2-2-2ap. Leg II: Tb pr 0-1-0, v 1-1; Mt v 2-2-2ap. Leg III: Tb pr 0-1-0, Mt pr 1-1ap, rt 1ap. Leg IV: Tb pr and v 0-1-0; Mt pr 2-0-2ap, rt 1-0-1ap. *Coloration* (Figs 41, 44–46). Carapace pale brown, with yellow eye field and a thin longitudinal median line on thorax. Blackened around eyes. The entire carapace covered (not very densely) with white and transparent elongated scales. Clypeus naked, brown-yellow. Sternum yellow, tinged with brown. Maxillae, labium and chelicerae pale yellow. Abdomen: dorsum light brown, with a longitudinal medial yellow line; sides light brown, each with a wide yellow stripe; venter yellow. Anterior edge of carapace with a bunch of long brownish hairs. Book-lung covers yellow. Spinnerets: anterior pair brownish, posterior pair pale yellow. All legs yellow, with brownish (semi)rings at segment joints,

but femora, patellae and tibiae I pro-ventrally with dark brown stripe. Palps: femora and patellae light brown, metatarsi and tarsi yellow. Epigyne and vulva as in Figs 29, 39–40, 47–48, 53–54: epigynal plate triangular, with obtuse tip directed anteriorly, covered with long whitish hairs; insemination ducts relatively short, subparallel and directed anteriorly; receptacles relatively small and rounded; receptacles and fertilization ducts situated in the anterior part of vulva.

***Eupoa lobli* sp. n.**

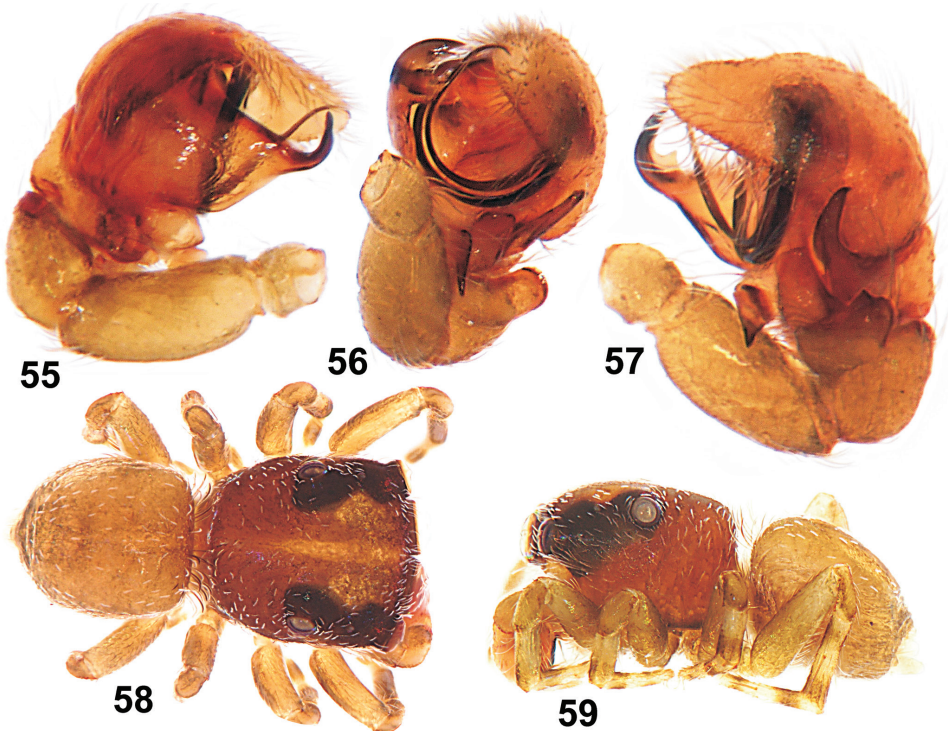
<http://zoobank.org/C5D9756D-9195-4014-A068-939D89C19F09>

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

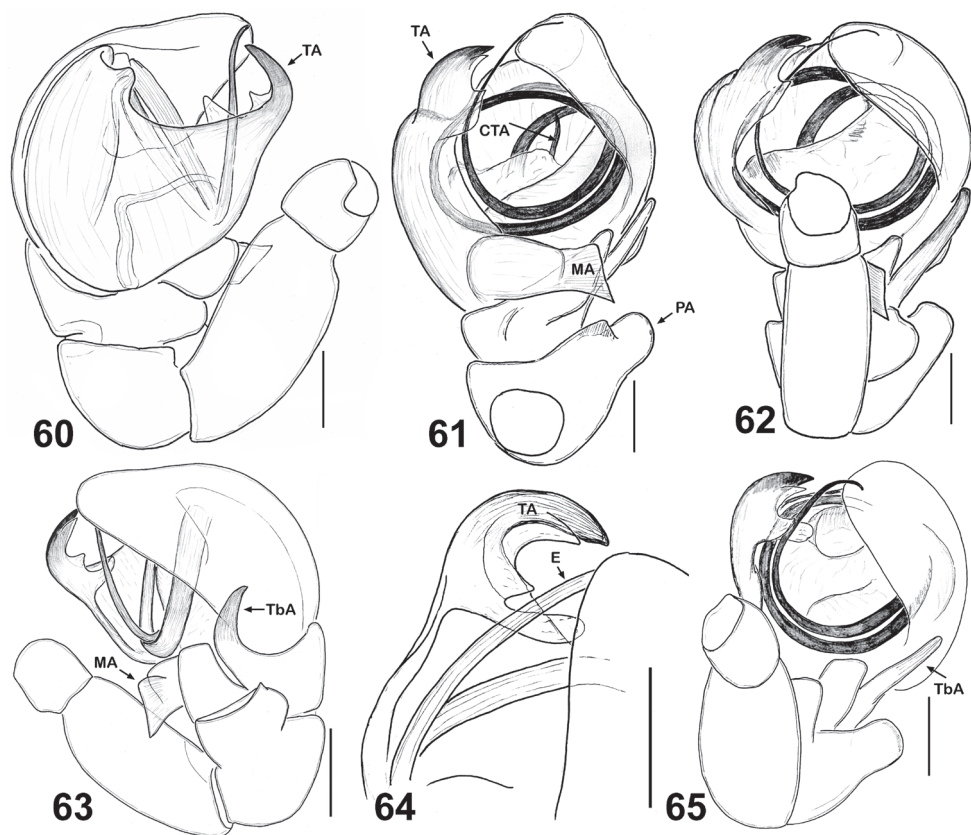
Figs 55–65

Type. MALAYSIA: 1♂ (MHNG, both palps detached), West Malaysia, Pahang, Cameron Highlands, 1520 m a.s.l., trail 14, Bukit Mentiga (tamisage), 23.03.1993, I. Löbl & F. Calame.

Etymology. The species is named after the famous coleopterist, Dr. Ivan Löbl (Geneva, Switzerland), who collected the holotype.



Figures 55–59. Copulatory organs and somatic characters of *Eupoa lobli* sp. n. (the holotype). **55** male palp, median view **56** ditto, apical view **57** ditto, retrolateral view **58** male general appearance, dorsal view **59** ditto, lateral view.



Figures 60–65. Copulatory organs of *Eupoa lobli* sp. n. (the holotype). **60** male palp, median view **61–62, 65** ditto, ventral view **63** ditto, retrolateral view **64** tegular apophysis, retrolateral view. Abbreviations as explained in 'Material and methods'. Scale bars: 0.1 mm.

Diagnosis. The male of *E. lobli* sp. n. is most similar to that of *E. lehtineni* sp. n., but can easily be distinguished by the shape of tegular and median apophyses (cf. Figs 60–61 and 52). The female of *E. lobli* sp. n. remains unknown.

Distribution. The type locality only.

Description. MALE. *Measurements.* Carapace 0.93 long, 0.74 wide and 0.51 high at PLE. Ocular area 0.54 long, 0.74 wide anteriorly and 0.67 wide posteriorly. Diameter of AME 0.23. Clypeus height 0.11, chelicera length 0.23. Abdomen 0.71 long, 0.64 wide. Length of leg segments: I: $0.46 + 0.21 + 0.31 + 0.29 + 0.21$; II: $0.38 + 0.23 + 0.22 + 0.26 + 0.20$; III: $0.37 + 0.19 + 0.21 + 0.22 + 0.20$; IV: $0.64 + 0.22 + 0.39 + 0.31 + 0.25$. *Leg spination.* Leg I: Tb v 0-1-0; Mt v 2-2-2ap. Leg II with no spines. Leg III: Tb rt 1-0. Leg IV: Tb pr and rt 0-1-0; Mt pr 1-0-1ap, rt 1-0-2ap. *Coloration* (Figs 58–59). Carapace light brown, sparsely covered with white elongated scales; eye field with a median yellow stripe. Blackened around

eyes. Clypeus naked, yellow. Sternum, maxillae and labium yellow brownish. Abdomen light brown, with no colour pattern; dorsum completely covered with scutum. Book-lung covers light brown. Spinnerets: anterior pair brownish, posterior pair pale yellow. All legs yellow, with brownish patches at segment joints, but tibiae I and II pro-ventrally with dark brown longitudinal stripe. Palps brownish yellow, their structure as in Figs 55–57, 60–65: patellar apophysis short and wide, as if cut on its tip; tibial apophysis claw like, blade-shaped and directed dorsad; tegulum well-developed, with prominent, wide tegular apophysis apically possessing three hook-shaped, obtuse teeth; median apophysis massive, directed latero-ventrad; compound terminal apophysis relatively short and thin, hidden inside the cavity formed by cymbium and tegulum; embolus coiled, making two revolutions, with its tip resting on top of the cymbium.

FEMALE unknown.

***Eupoa pappi* sp. n.**

<http://zoobank.org/72FED4F4-8221-4D13-9ABE-726088FDF2A5>

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

Figs 66–71

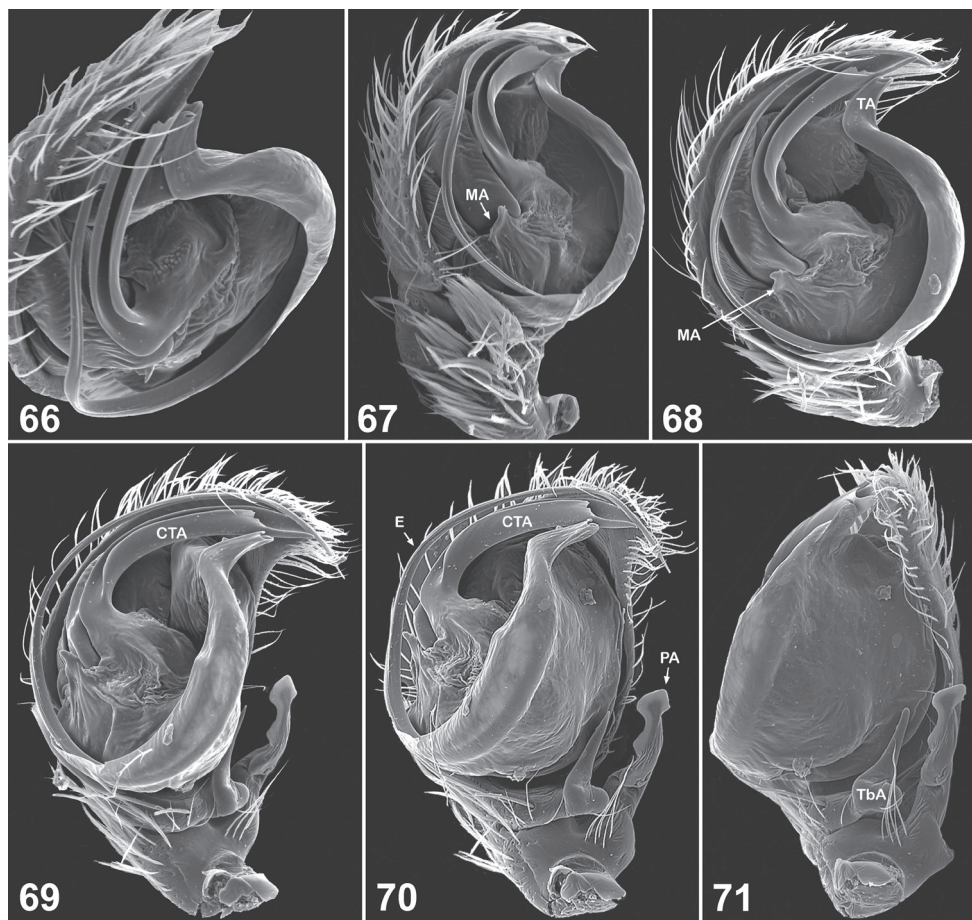
Type. Holotype ♂ (HNHM) from Thailand Trang Prov., Thung Khai Botanic Garden, primary lowland rainforest, 12.11.2004, L. Papp & M. Földvári.

Etymology. The species is named after Dr. László Papp (Budapest, Hungary), who collected the holotype.

Diagnosis. By having the massive compound terminal apophysis with a deep longitudinal groove on its apical edge (Fig. 67), the male of *E. pappi* sp. n. is most similar to that of *E. thailandica* sp. n. (Figs 109, 115), from which it differs in having the larger open cavity of tegulum and the shape of tegular and compound terminal apophyses. The female of *E. pappi* sp. n. remains unknown.

Distribution. The type locality only.

Description. MALE (one palp missing). *Measurements.* Carapace 0.93 long, 0.75 wide and 0.60 high at PLE. Ocular area 0.60 long, 0.80 wide anteriorly and 0.63 wide posteriorly. Diameter of AME 0.23. Clypeus height 0.10, chelicera length 0.28. Abdomen 0.88 long, 0.63 wide. Length of leg segments: I: 0.55 + 0.24 + 0.40 + 0.39 + 0.20; II: 0.49 + 0.21 + 0.29 + 0.29 + 0.17; III: 0.48 + 0.33 + 0.34 + 0.35 + 0.23; IV: 0.78 + 0.28 + 0.53 + 0.43 + 0.28. *Leg spination.* Leg I: Mt v 2-2ap. Leg II and III: no spines. Leg IV: Tb pr and rt 0-1-0; Mt pr and rt 1-1ap. *Coloration.* Carapace light yellow, with brownish margins. Eye field brownish, blackened around eyes. Clypeus naked, yellowish brownish. Sternum, maxillae, labium and chelicerae light yellow. Abdomen: dorsum yellow, with dark grey longitudinal lateral bands and two round, large dark grey spots in its rear part; venter yellow. Book-lung covers yellow. Spinnerets: anterior pair yellow, posterior pair dark grey.



Figures 66–71. Copulatory organs of *Eupoa pappi* sp. n. (the holotype). **66** male palp, apical view **67–68** ditto, median view **69** ditto, ventral view **70–71** ditto, retrolateral view. Abbreviations as explained in ‘Material and methods’.

All legs yellow, but patellae IV with brownish sides. Palps: femora yellow, remaining segments brownish yellow. Palpal structure as in Figs 66–71: patellar apophysis long, reaching almost a half of the cymbial length; tibia with a median bunch of thick white hairs; tibial apophysis sharpened at its tip directed anteriorly and with a wide, rounded base; tegulum flat and developed on its pro-lateral side only; tegular apophysis situated on the apical end of tegulum and bent laterad; median apophysis poorly developed, seen as a short triangle process at the base of compound terminal apophysis (but separated from it by membrane); compound terminal apophysis massive, with a deep longitudinal groove on its apical edge; embolus whip-shaped, making one revolution.

FEMALE unknown.

***Eupoa prima* Žabka, 1985**

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

Figs 72–84

Eupoa prima Žabka, 1985: 220, figs 161–169 (D♂♀).

Types. Holotype ♂ (ZMTU) from Viet-Nam, Bac Thai, Bach Tong, Duong Quang (apparently, Bach Thong Distr., Bac Kan Prov.), jungle slope, 900 m a.s.l., 17.10.1978, P.T. Lehtinen.

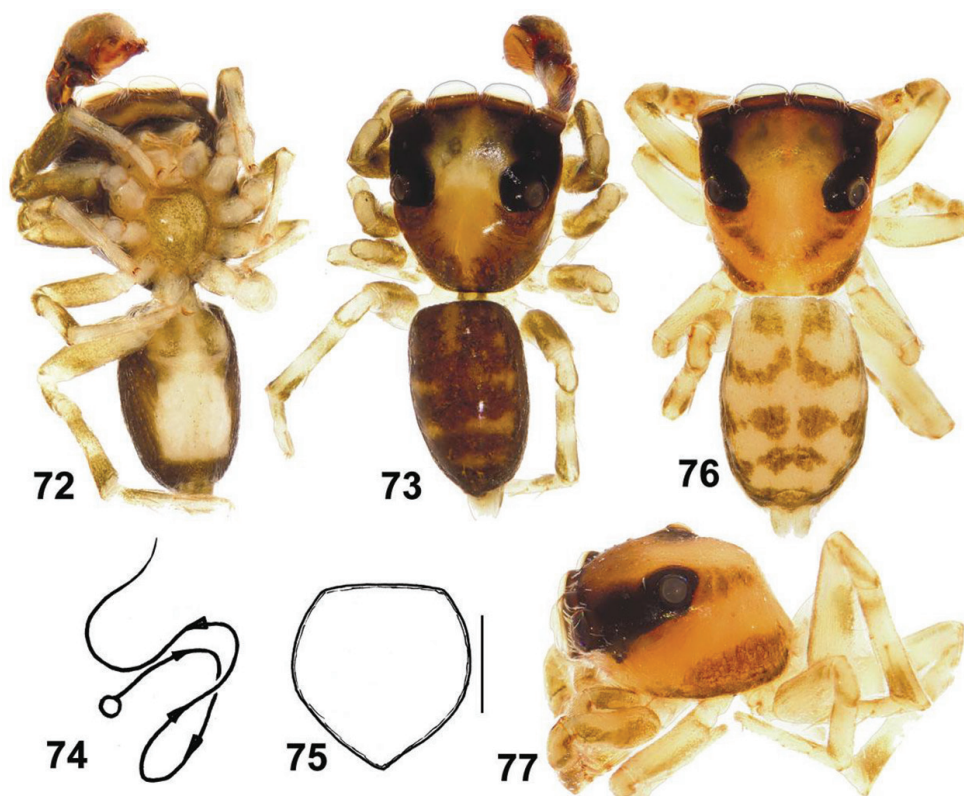
Paratypes: VIET-NAM: 1♂1♀ (ZMTU; epigyne missing), together with the holotype; 1♀ 5juv. (HNHM; epigyne missing), c. 5 km E of Lao Cai town, 200 m a.s.l., sieving forest litter, 1971, Topál-Matskásl.

Diagnosis. Both sexes of *E. prima* are most similar to those of *E. jingwei* and *E. nezha* known from Guangxi province of China; three species seem to form a natural species group. Males of all three species can easily be separated by the shape of tegular and patellar apophyses; cf. Figs 80–84 with figs 1–3, 8–10 in Maddison et al. (2007). Females of these three species cannot be readily distinguished now as they have the virtually identical conformation of their epigynes; cf. fig. 167 in Žabka (1985) and Figs 7, 13 in Maddison et al. (2007), whereas the vulvas of *E. jingwei* and *E. nezha* has not been studied and illustrated yet.

Comments. Unfortunately, neither the ♀ allotype deposited at the ZMTU, nor the ♀ paratype deposited at the HNHM possesses its epigyne, although in both cases there are separate micro-vials that should have contained them. Thus, our notion about the epigynal and vulval structures of *E. prima* is based on the original illustrations by Žabka (1985: figs 167–169).

Distribution. Southern Viet-Nam (Žabka 1985).

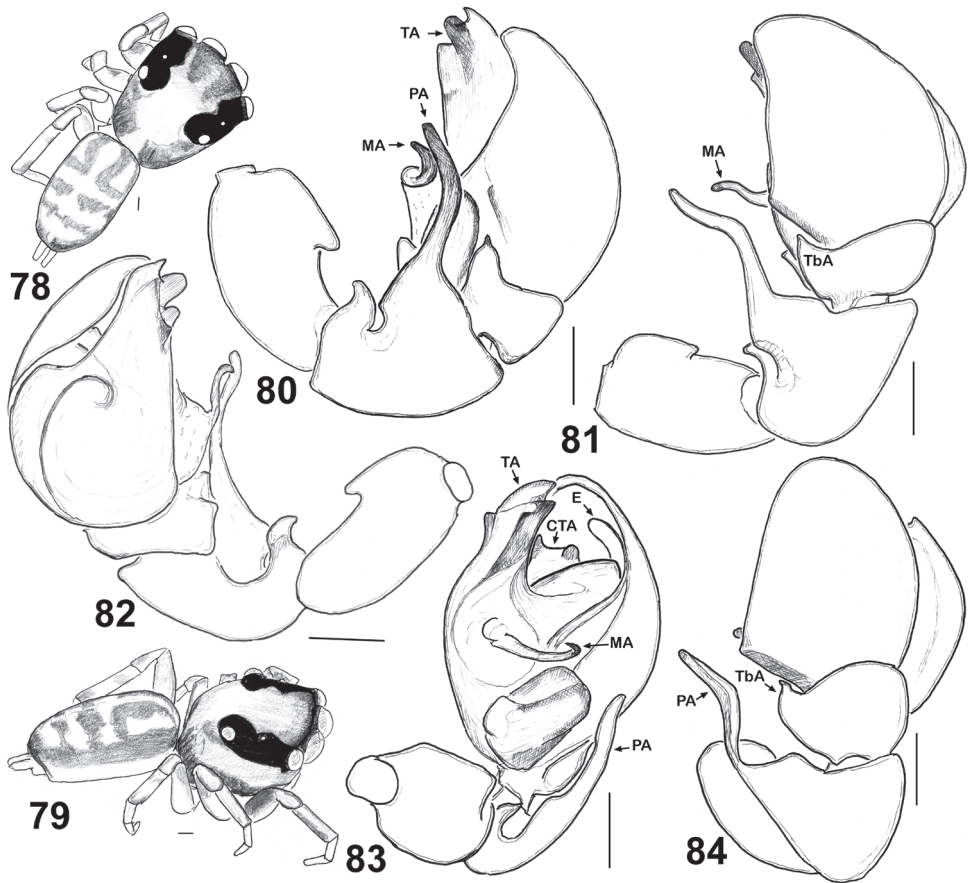
Description. MALE (the holotype). *Measurements.* Carapace 1.00 long, 0.89 wide and 0.55 high at PLE. Ocular area 0.64 long, 0.89 wide anteriorly and 0.81 wide posteriorly. Diameter of AME 0.29. Clypeus height 0.06, chelicera length 0.24. Abdomen 0.95 long, 0.61 wide. Length of leg segments: I: 0.54 + 0.26 + 0.34 + 0.36 + 0.19; II: 0.47 + 0.21 + 0.30 + 0.32 + 0.19; III: 0.46 + 0.21 + 0.27 + 0.35 + 0.23; IV: 0.71 + 0.30 + 0.51 + 0.39 + 0.29. *Leg spination.* Leg I: Tb v 1-1-1; Mt v 2-2-2ap. Leg II: Mt v 1-1-1ap. Leg III: Tb pr and rt 0-1. Leg IV: Tb pr 0-1; Mt pr and rt 1ap, v 0-1-0. *Coloration* (Figs 72–73, 78–79). Carapace yellow-brown, with a large yellow spot occupying almost the entire eye field; blackened around eyes. Clypeus naked, yellow, with a dark brown marginal line. Sternum, maxillae and labium yellow, tinged with brown. Chelicerae yellow, each with an anterior longitudinal brown stripe. Abdomen: dorsum brown, with shining scutum and a poorly marked yellow spot; sides brown; venter yellow. Book-lung covers yellow. Spinnerets: anterior pair brownish, posterior pair yellow. All legs yellow, but pro- and retrolateral sides of all segments (except for tarsi) brownish. Palps yellow-brown. Palpal structure as in Figs 74, 80–84: femur modified, with a wide proximal-ventral protuberance (as a short apophysis); patella with two apophyses, short basal apophysis and long median one, reaching almost a third of the



Figures 72–77. General appearance and somatic characters of *Eupoa prima* (♂ holotype and ♀ allotype). **72** male body, ventral view **73** ditto, dorsal view **74** diagrammatic course of the embolar path **75** female sternum, ventral view **76** female body, dorsal view **77** female carapace, lateral view. Scale bars: 0.25 mm (**76**).

cymbial length; tibial apophysis bi-ramous: its ventral branch wide, massive and visibly sclerotized and its dorsal branch short and cone-shaped; cymbium with triangular lobe in retrobasal part; tegulum well-developed; tegular apophysis situated on the median side of tegulum and directly anteroirly; median apophysis thin and hook-shaped, directed laterad; compound terminal apophysis low and wide, situated at the embolic base; embolus whip-shaped, making one revolution, its tip is resting on the dorsal side of tegular apophysis (its course is shown in Fig. 74).

FEMALE (the paratype). *Measurements*. Carapace 1.21 long, 1.01 wide and 0.60 high at PLE. Ocular area 0.76 long, 1.07 wide anteriorly and 0.96 wide posteriorly. Diameter of AME 0.36. Clypeus height 0.06, chelicera length 0.29. Abdomen 1.23 long, 0.86 wide. Length of leg segments: I: 0.70 + 0.30 + 0.43 + 0.43 + 0.21; II: 0.57 + 0.28 + 0.33 + 0.37 + 0.23; III: 0.56 + 0.21 + 0.36 + 0.43 + 0.27; IV: 0.89 + 0.29 + 0.64 + 0.56 + 0.31. *Leg spination*. Leg I: Tb v 2-2-2ap; Mt v 2-2-2ap. Leg II: Tb pr 0-1, v 1-1; Mt v 2-2-2ap. Leg III: Tb pr and rt 0-1-0; Mt pr 1-2ap, rt



Figures 78–84. General appearance and copulatory organs of *Eupoa prima* (♂ paratype). **78** male body, dorsal view **79** ditto, lateral view **80** male palp, retrolateral view **81, 84** ditto, dorsal view **82** ditto, median view **83** ditto, ventral view. Abbreviations as explained in ‘Material and methods’. Scale bars: 0.1 mm.

2ap, v 1-0. Leg IV: Tb pr and rt 0-1-0, v 1-0; Mt pr 1-2ap, rt 1-1ap, v 1-0. *Coloration* much lighter than in the male (Figs 75, 77). Carapace yellow, with two wide brown stripes on sides. Blackened around eyes. Clypeus and ‘cheeks’ naked, yellow. Sternum, maxillae, labium and chelicerae yellow. Abdomen: dorsum yellow, with four transverse brown bands; sides yellow, each with a longitudinal brown stripe; venter yellow. Book-lung covers and spinnerets yellow. Legs I yellow, with pro- and retrolateral sides of femora, patellae and tibiae brownish. Legs II-IV yellow, with brownish patches at segment joints. Palps yellows, tinged with brown, but tarsi entirely yellow. Epigyne and vulva as in Žabka (1985: figs 167–169): epigynal plate flat, of the shape of inverted trapezium; paired copulatory openings spaced up; insemination ducts narrow and weakly sclerotized, directed to each other; receptacles sclerotized, bean-shaped.

***Eupoa pulchella* sp. n.**

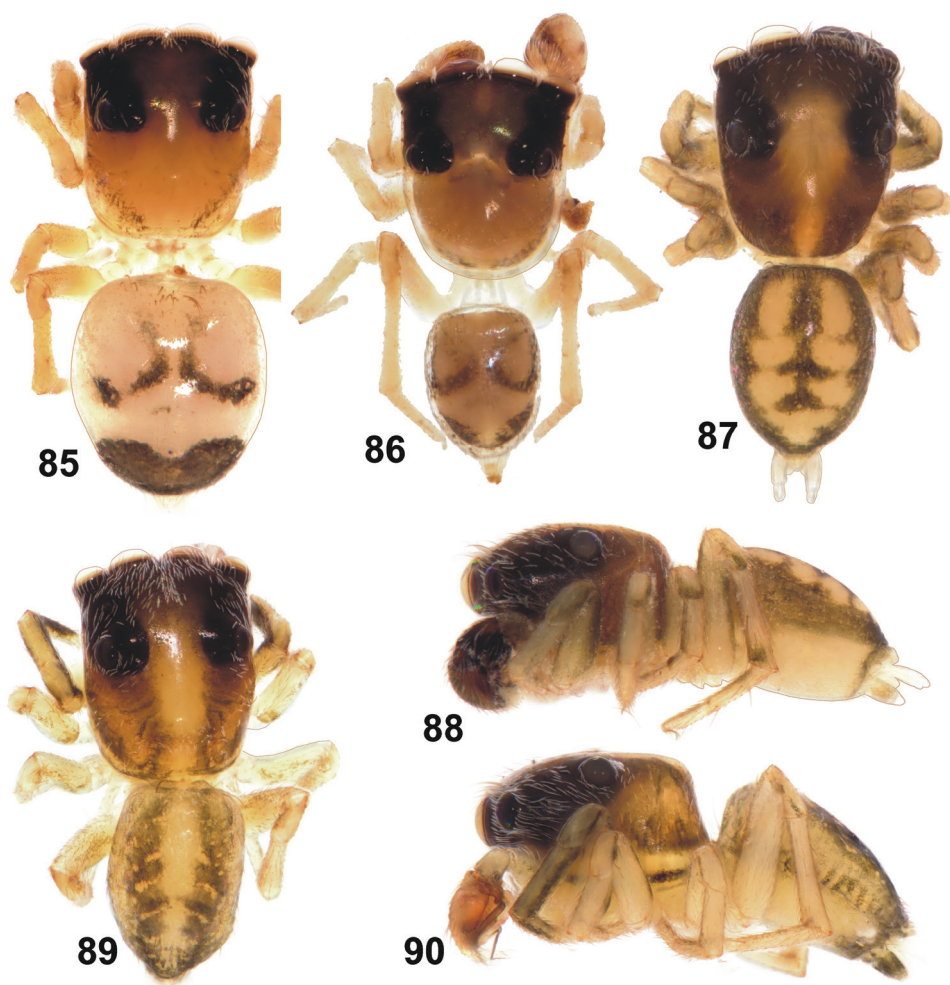
<http://zoobank.org/DB59AEEB-D36B-4440-AF08-79C284E997C1>

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

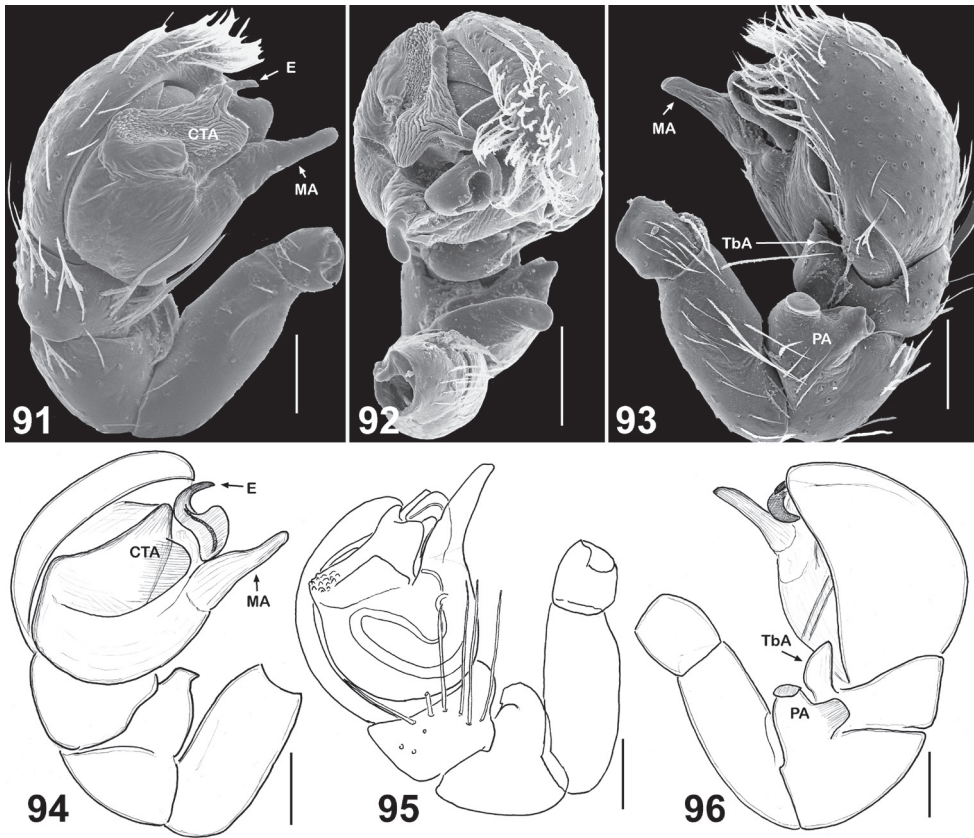
Figs 87–88, 91–96

Type. Holotype ♂ (MHNG, both palps separated) from Thailand, Prov. Chiang Mai, Chiang Dao Distr., Doi Chiang Dao Wildlife Sanctuary, 510 m a.s.l., pitfall traps, 23.12.1990–15.01.1991, P. J. Schwendinger.

Paratypes: THAILAND: 3♂ (MHNG; palps of all specimens are separated), together with the holotype; 1♂ (MHNG; with the single detached palp), same locality, 510 m a.s.l., pitfall traps, 25.10–23.11.1990, P. J. Schwendinger.



Figures 85–90. General appearance of *Eupoa pulchella* sp. n. (87–88, ♂ paratype), *E. schwendingeri* sp. n. (♂ holotype, 89–90) and *E. thailandica* sp. n. (♀ and ♂ paratypes, 85–86). 85 female body, dorsal view 86–87, 89 male body, dorsal view 88, 90 ditto, lateral view.



Figures 91–96. Copulatory organs of *Eupoa pulchella* sp. n. (91–93, the holotype; 94–96, ♂ paratype). 91, 94–95 male palp, median view 92 ditto, apical view 93, 96 ditto, retrolateral view. Abbreviations as explained in ‘Material and methods’. Scale bars: 0.1 mm.

Etymology. From the Latin word ‘*pulchellus*’ meaning ‘pretty’.

Diagnosis. This species differs from all *Eupoa* species known to us in having all the bulbal sclerites in apical position, as if grouped together at the top of tegulum (Figs 91–96), and the unique shape of patellar apophysis, which is short, thick and bi-ramous (Figs 93, 96). The female of *E. pulchella* sp. n. remains unknown.

Distribution. The type locality only.

Description. MALE (♂ paratype with the palp). *Measurements.* Carapace 0.94 long, 0.73 wide and 0.46 high at PLE. Ocular area 0.56 long, 0.75 wide anteriorly and 0.70 wide posteriorly. Diameter of AME 0.23. Clypeus height 0.06, chelicera length 0.20. Abdomen 0.76 long, 0.59 wide. Length of leg segments: I: $0.44 + 0.21 + 0.29 + 0.29 + 0.19$; II: $0.39 + 0.19 + 0.23 + 0.24 + 0.17$; III: $0.37 + 0.16 + 0.23 + 0.26 + 0.27$; IV: $0.59 + 0.23 + 0.41 + 0.33 + 0.21$. *Leg spination.* Leg I: Tb v 2-2-2ap; Mt v 2-2ap. Leg II without spines. Leg III: Tb pr and rt 0-1-0. Leg IV: Tb pr and rt 0-1-1; Mt pr 1-2ap, rt 1-1ap. *Coloration.* Carapace brown, with a wide median yellow stripe

started from the middle part of eye field and running to thorax; blackened around eyes. Clypeus naked and brown. Sternum, maxillae, labium and chelicerae pale yellow. Abdomen: dorsum brown, with two longitudinal rows of large yellow spots; sides brown; venter yellow. Book-lung covers yellowish brownish. Spinnerets: anterior pair brownish, posterior pair pale yellow. All legs yellow, with brown patches at segment joints, but femora, patellae and tibiae pro-ventrally and retrolaterally brown. Palps dark brown. Palpal structure as in Figs 91–96: patellar apophysis short, thick and bi-ramous; tibial apophysis short and cone-shaped; tegulum well-developed; regular apophysis not developed; median apophysis fingerlike, directed anteriorly; compound terminal apophysis wide, plate-shaped and rugose; embolus short, S-shaped.

FEMALE unknown.

***Eupoa schwendingeri* sp. n.**

<http://zoobank.org/58EF7EFD-7F8C-42FF-9719-3DA2BC5C001B>

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

Figs 89–90, 97–105

Type. Holotype 1♂ (MHNG) from northern Thailand, Chiang Mai Prov. and Distr., Doi Suthep-Pui National Park, Doi (=Mount) Suthep, 1180 m a.s.l., 1-30.03.1987, P. J. Schwendinger.

Paratypes: THAILAND: 2♀ (MHNG), together with the holotype; 1♂ (MHNG), northern Thailand, Chiang Mai Prov. and Distr., Doi Suthep-Pui National Park, near Pin Pak Pai Waterfall, 1155 m a.s.l., pitfall traps 10.01-11.02.1997, P. Dankittipakul.

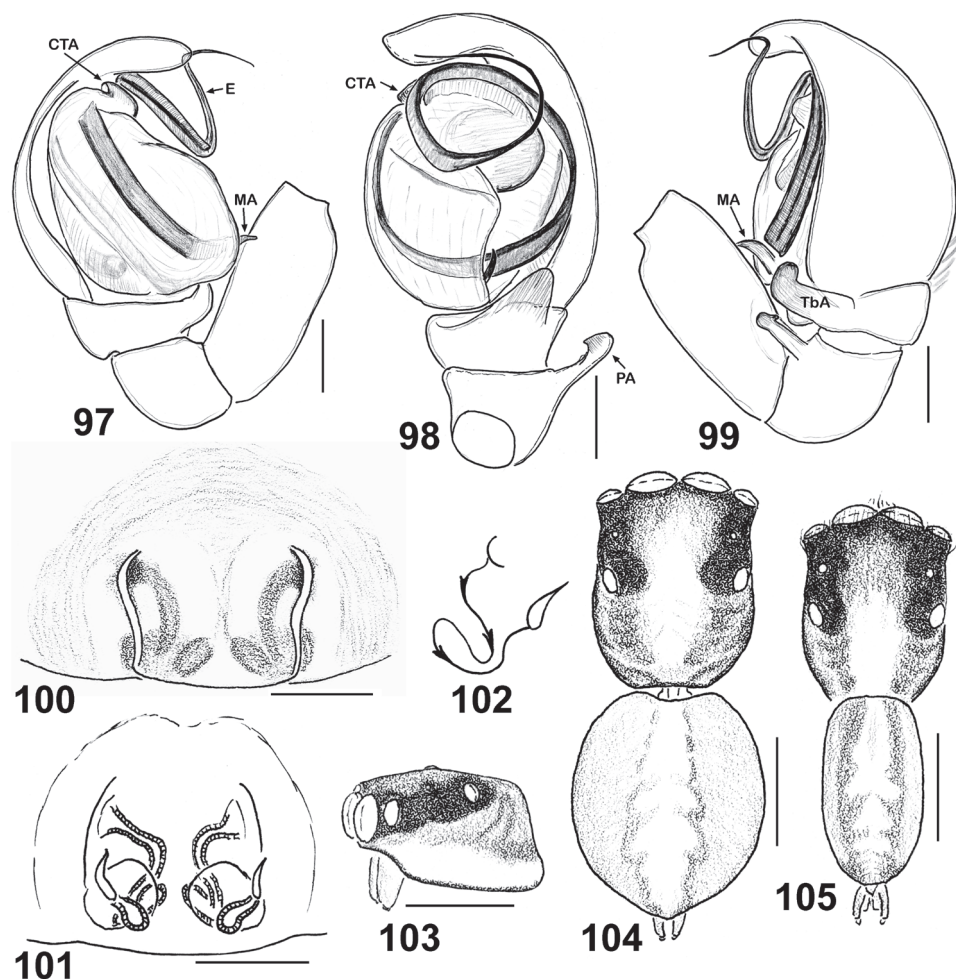
Etymology. The species is named in honour of our colleague, the well-known arachnologist, Dr Peter Schwendinger (Geneva, Switzerland), who collected the type series and who made the majority of the *Eupoa* specimens treated in the present work available to us.

Diagnosis. The male palp of *E. schwendingeri* sp. n. differs from those of all *Eupoa* species known to us in having the rather small and inconspicuous median and compound terminal apophyses (Figs 97–99). The female of *E. schwendingeri* sp. n. has the unique epigyne shaped as a square plate, with parallel sides (Fig. 100) and the entrances of insemination ducts directed to each other (Fig. 101). Besides, both sexes of this species have a very characteristic body colour pattern consisting of two longitudinal subparallel grey stripes on dorsum (Figs 89, 104–105).

Distribution. The only locality in Thailand: Doi Suthep-Pui National Park.

Comments. The ♂ paratype was lost after having been photographed, as the observation glass was incidentally dropped down to the floor. Thus, the ♂ paratype is represented by the male palp only (Figs 97–99) that is retained in the MHNG.

Description. MALE (the holotype). *Measurements.* Carapace 0.90 long, 0.60 wide and 0.45 high at PLE. Ocular area 0.57 long, 0.73 wide anteriorly and 0.64 wide posteriorly. Diameter of AME 0.23. Clypeus height 0.04, chelicera length 0.30. Abdomen 0.88 long, 0.53 wide. Length of leg segments: I: 0.50 + 0.23 + 0.33 + 0.29 + 0.21; II:



Figures 97–105. Copulatory organs and somatic characters of *Eupoa schwendingeri* sp. n. (♂ and ♀ paratypes). **97** male palp, median view **98** ditto, ventral view **99** ditto, retrolateral view **100** epigyne, ventral view **101** vulva, dorsal view **102** diagrammatic course of insemination ducts **103** female carapace, lateral view **104** female body, dorsal view **105** male body, dorsal view. Abbreviations as explained in 'Material and methods'. Scale bars: 0.1 mm (97–101), 0.25 mm (103–105).

0.40 + 0.16 + 0.23 + 0.26 + 0.20; III: 0.37 + 0.16 + 0.24 + 0.27 + 0.21; leg IV is missing. *Leg spination*. Legs I and II: no spines. Leg III: Mt pr 0-1-0. Leg IV is missing. *Coloration* (Figs 89–90, 104). Carapace yellow, with two wide longitudinal light brown bands. Eye field dark grey, blackened around eyes. Clypeus naked, yellowish brownish. Sternum, labium, maxillae and chelicerae light yellow. Abdomen yellow, with two longitudinal light grey stripes on dorsum. Book-lung covers light yellow. Spinnerets: anterior pair dark grey, posterior pair yellow. Leg I yellow, but femur (its distal part), patella, tibia and metatarsus with black pro-lateral longitudinal stripe, tibia and metatarsus also

with light grey retro-lateral longitudinal stripe. Leg II yellow, but tibia ventrally with light grey longitudinal stripe. Legs III and IV yellow. Palps yellow, with brownish cymbia. Palpal structure as in Figs 97–99: patellar apophysis short, fingerlike; tibial apophysis thick and obtuse, directed ventrad with its tip bend dorsad; tegulum developed on its prolateral side only; tegular apophysis poorly developed, looking like an anterior ridge of tegulum; median apophysis spine-shaped, situated at the proximal end of tegulum; compound terminal apophysis poorly developed, looking like a hook-shaped process at the basal part of embolus; embolus coiled, making two revolutions.

FEMALE. Measurements. Carapace 0.98 long, 0.76 wide and 0.55 high at PLE. Ocular area 0.63 long, 0.79 wide anteriorly and 0.71 wide posteriorly. Diameter of AME 0.24. Clypeus height 0.07, chelicera length 0.29. Abdomen 0.90 long, 0.68 wide. Length of leg segments: I: $0.54 + 0.20 + 0.35 + 0.34 + 0.21$; II: $0.50 + 0.20 + 0.26 + 0.29 + 0.21$; III: $0.44 + 0.16 + 0.29 + 0.33 + 0.20$; IV: $0.73 + 0.26 + 0.54 + 0.43 + 0.26$. **Leg spination.** Leg I: Tb v 2-2-2ap; Mt v 2-2-2ap. Leg II: Tb pr 0-1, v 1-1; Mt v 2-2-2ap. Leg III: Tb pr and rt 0-1-0; Mt pr and rt 1-0. Leg IV: Tb pr and rt 0-1-0; Mt pr and rt 1-1. **Coloration** as in the male (Fig. 105), but palps and both pairs of spinnerets entirely yellow. Epigyne and vulva as in Figs 100–102: epigyne as square-shaped plate, with parallel sides; insemination ducts at their entrances directed to each other and then run posteriorly; receptacles small and pear-shaped.

***Eupoa thailandica* sp. n.**

<http://zoobank.org/6E26B6C3-1CE6-43E4-8C17-58C4F7CCD61F>

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

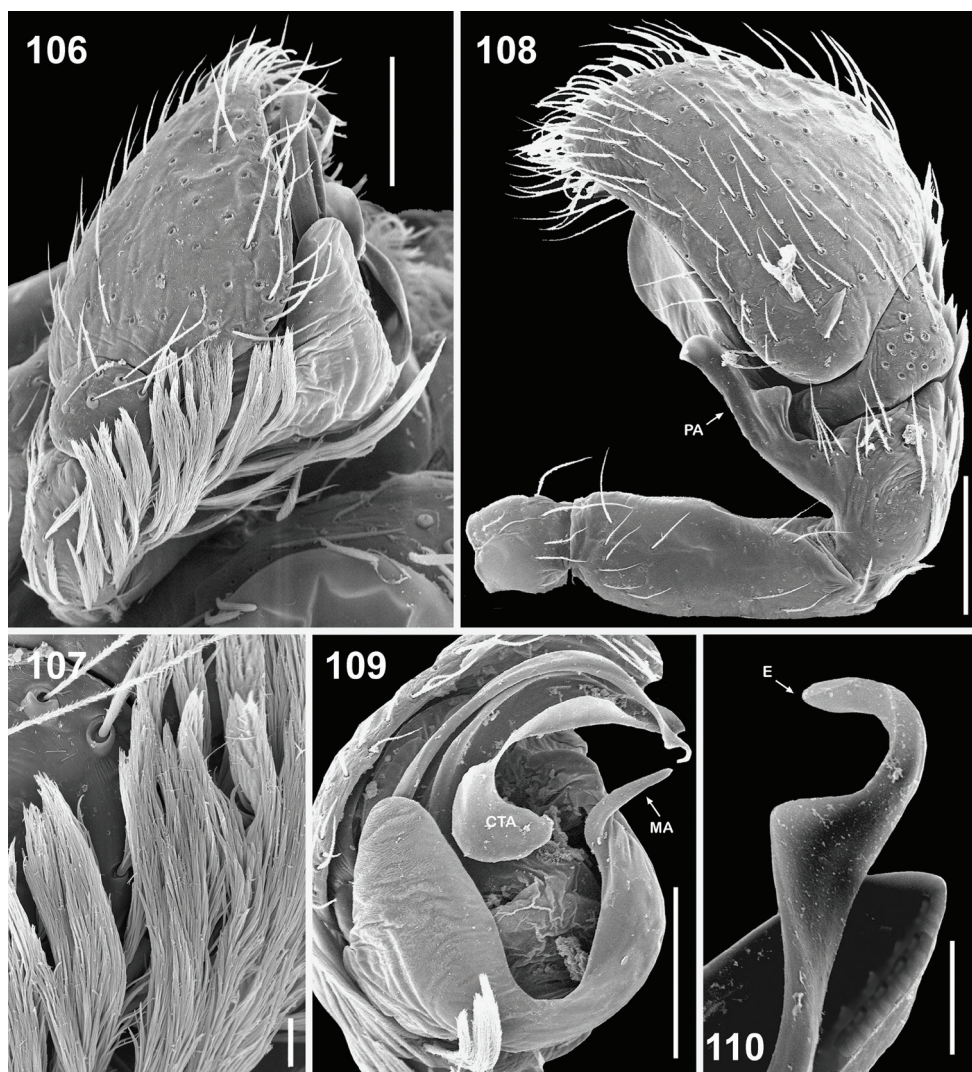
Figs 85–86, 106–118

Type. Holotype 1♂ (MHNG) from Thailand, Trat Prov., Ko Chang, west side ($12^{\circ}03'N$, $102^{\circ}18'E$), WINKLER-extraction in secondary forest with primary spots (AS-T-5), 50–200 m a.s.l., 3–23.12.1999, A. Schultz.

Paratypes: THAILAND: 2♂1♀ (MHNG, one male without abdomen and palp), together with the holotype.

Etymology. The species epithet originates from the country of origin of the type series.

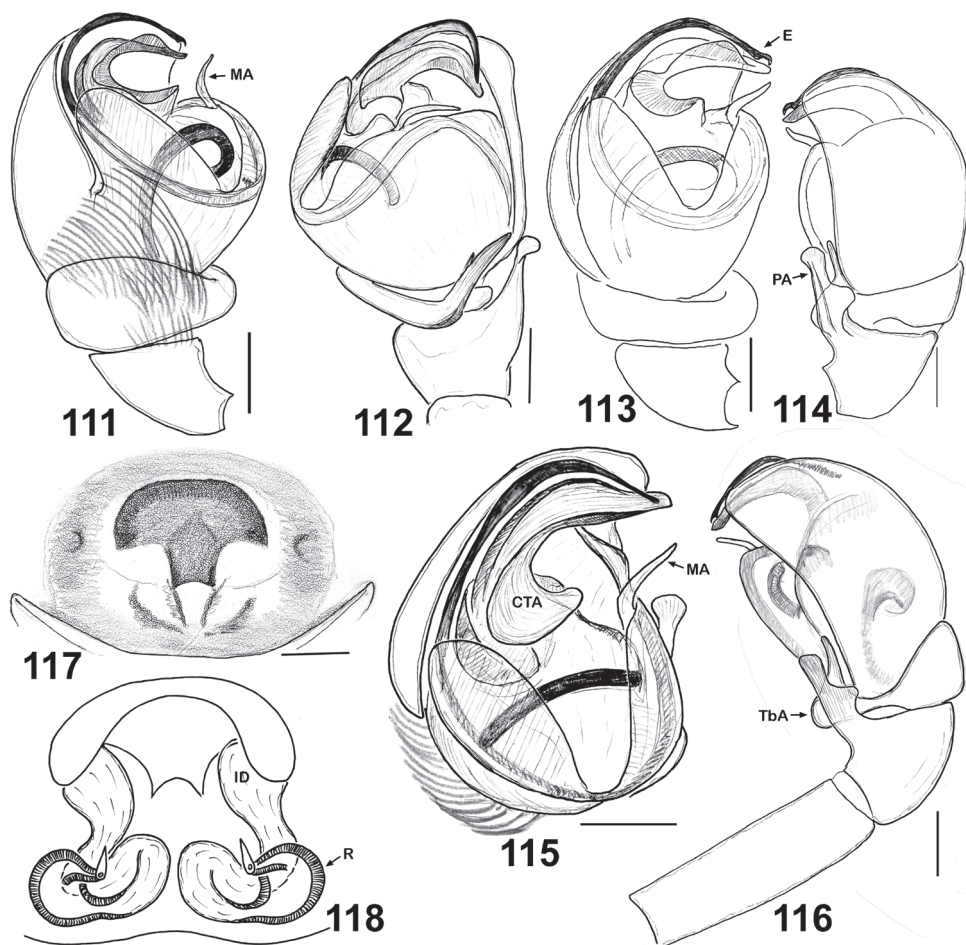
Diagnosis. By having the massive compound terminal apophysis with a deep longitudinal groove on its apical edge (Fig. 109, 115), the male of *E. thailandica* sp. n. is most similar to that of *E. pappi* sp. n. (Fig. 67–68), from which it differs in having the smaller and more closed apical cavity of tegulum and the shape of tegular and compound terminal apophyses. The hook-shaped embolic tip of *E. thailandica* sp. n. (Fig. 110) is unique among all the *Eupoa* species known to us. The female of *E. thailandica* sp. n. has a characteristic, mushroom-shaped central epigynal plate (Fig. 117) and the distinct spermathecae (Fig. 118). Besides, both sexes of *E. thailandica* sp. n. have a very characteristic colour pattern on the dorsum containing a large transverse brown spot at its rear end (Figs 85–86); of the *Eupoa* species known to us, only the female of *E. yunnanensis* has got a similar colour pattern (Fig. 121).



Figures 106–110. Copulatory organs of *Eupoa thailandica* sp. n. (♂ paratype). **106** male palp, median view **107** bunches of white hairs at the base of cymbium, median view **108** male palp, retrolateral view **109** ditto, ventral view **110** embolus tip, apical view. Abbreviations as explained in ‘Material and methods’. Scale bars: 10 µm (**107**, **110**), 0.1 mm (**106**, **108–109**).

Distribution. The type locality only.

Description. MALE (the holotype). *Measurements.* Carapace 0.87 long, 0.73 wide and 0.54 high at PLE. Ocular area 0.56 long, 0.77 wide anteriorly and 0.66 wide posteriorly. Diameter of AME 0.24. Clypeus height 0.13, chelicera length 0.24. Abdomen 0.67 long, 0.50 wide. Length of leg segments: I: $0.50 + 0.21 + 0.33 + 0.30 + 0.21$; II: $0.39 + 0.16 + 0.31 + 0.27 + 0.20$; III: $0.39 + 0.17 + 0.26 + 0.27 + 0.18$; IV: $0.67 + 0.26 + 0.47 + 0.36 + 0.23$. *Leg spination.* Leg I: Tb v 2-2-2ap; Mt v 2-2-2ap. Leg II: Tb v



Figures 111–118. Copulatory organs of *Eupoa thailandica* sp. n. (♂ and ♀ paratypes). **111, 113** male palp, median view **112** ditto, ventral view **114** male palp, dorsal view **115** ditto, ventral view **116** ditto, retrolateral view **117** epigyne, ventral view **118** vulva, dorsal view. Abbreviations as explained in 'Material and methods'. Scale bars: 0.1 mm.

1-0; Mt v 1-1. Leg III: Tb pr 0-1-0. Leg IV: Tb pr 0-1-0; Mt pr 1ap. *Coloration* (Fig. 86). Carapace yellow, with a brownish marginal stripe at rear end and with brownish eye filed. Blackened around eyes. Clypeus naked, yellow. Sternum, maxillae, labium and chelicerae pale yellow. Abdomen pale yellow, but dorsum with a colour pattern consisting of two brown semi-rings in its fore-half and a transverse brown spot at the rear end (just in front of the spinnerets). Book-lung covers and spinnerets pale yellow. All legs and palps yellow. Palpal structure as in Figs 106–116: femur rather long and thin, almost equal to the length of cymbium; patellar apophysis medium-sized, fingerlike, with a dorso-basal bulge, reaching almost a third of the cymbial length; tibia with set of long hairs prolaterally, tibial apophysis hook-shaped, directed ventrad

with its sharp tip bend upward and directed anteriorly; cymbium with a median, basal bunch of thick white hairs; tegulum well-developed; tegular apophysis not developed; median apophysis thin, directed ventrad and situated in the central part of tegulum; compound terminal apophysis massive, as a large, thick hook having a longitudinal groove on its dorsal edge; embolus coiled, making one and a half revolutions, its tip hook-shaped.

FEMALE. Measurements. Carapace 0.96 long, 0.77 wide and 0.54 high at PLE. Ocular area 0.59 long, 0.81 wide anteriorly and 0.69 wide posteriorly. Diameter of AME 0.24. Clypeus height 0.07, chelicera length 0.31. Abdomen 1.04 long, 0.91 wide. Length of leg segments: I: 0.54 + 0.21 + 0.36 + 0.34 + 0.20; II: 0.44 + 0.19 + 0.26 + 0.27 + 0.20; III: 0.41 + 0.17 + 0.30 + 0.31 + 0.21; IV: 0.73 + 0.22 + 0.59 + 0.43 + 0.25. *Leg spination.* Leg I: Tb v 2-2-2ap; Mt v 2-2-2ap. Leg II: Tb pr 0-1, v 1-2; Mt pr 1-1, rt 0-1-0, v 2-0-2ap. Leg III: Tb pr and rt 0-1-0; Mt pr and rt 0-1-0. Leg IV: Tb pr 0-1-0; Mt pr and rt 1-0-1ap. *Coloration* as the male, but the dark brown spot on dorsum is larger (Fig. 85). Epigyne and vulva as in Figs 117–118: central epigynal plate mushroom-shaped, sclerotized and contrastingly darker than the rest of epigyne; wide transparent insemination ducts; round receptacles that are spaced up.

***Eupoa yunnanensis* Peng & Kim, 1997**

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

Figs 119–128

Eupoa yunnanensis Peng & Kim, 1997: 196, figs 3A–C (D♂).

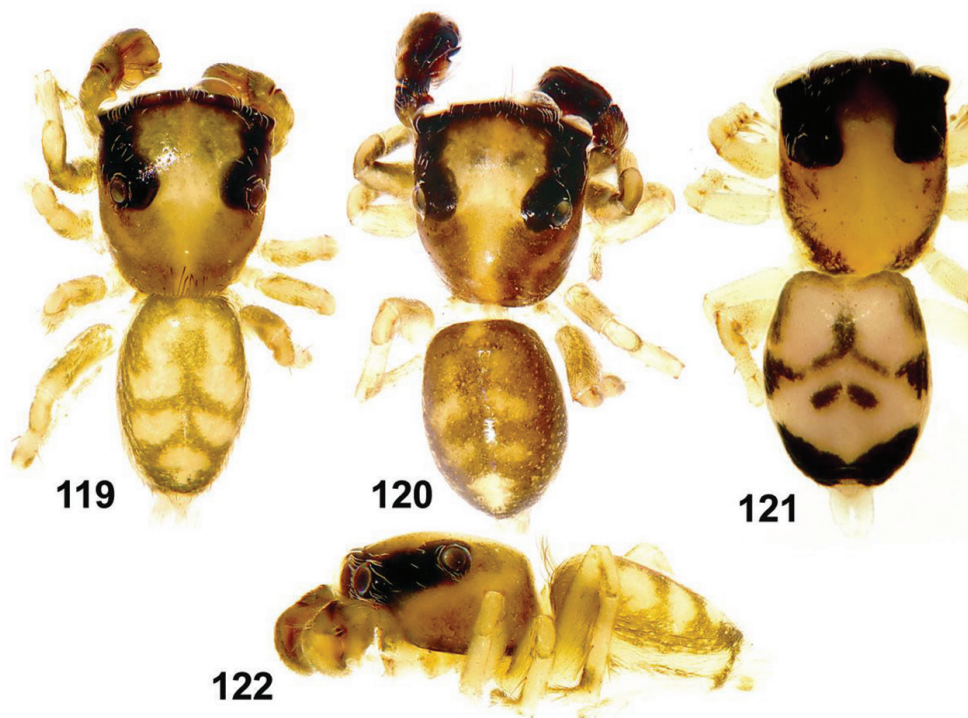
Eupoa yunnanensis: Song et al. 1999: 509, figs 292O, 325J (♂).

Material. LAOS: 2♂ (SMFM), Luang Prabang Prov., NE Luang Prabang, Nam Ou, Nong Khiao, Tham Pathok (20°33.082'N, 102°37.925'E), 373 m a.s.l., outside cave, sieving leaf litter, 17–18.03.2007, P. Jäger & F. Steinmetz; 2♀ (SMFM), Luang Prabang Prov., SE Luang Prabang, Xieng Nguen Distr., Nam Khan, Ban Keng Koung (19°40.963'N, 102°18.442'E), 372 m a.s.l., along stream, sieving leaf litter, 22.03.2007, P. Jäger; 1♀ (SMFM), same locality, disturbed forest, dry stream bed, sieving and WINKLER-extraction, 21–23.02.2008, P. Jäger.

Diagnosis. The male of *E. yunnanensis* has the unique, widest and strongest patellar apophysis (Figs 124, 126) among all the *Eupoa* species known to us. The female has the unique conformation of its epigyne: viz., the singular atrium formed by the posterior chitinous margin and the anterior transverse pocket (Fig. 127) and the S-shaped spermathecae (Fig. 128).

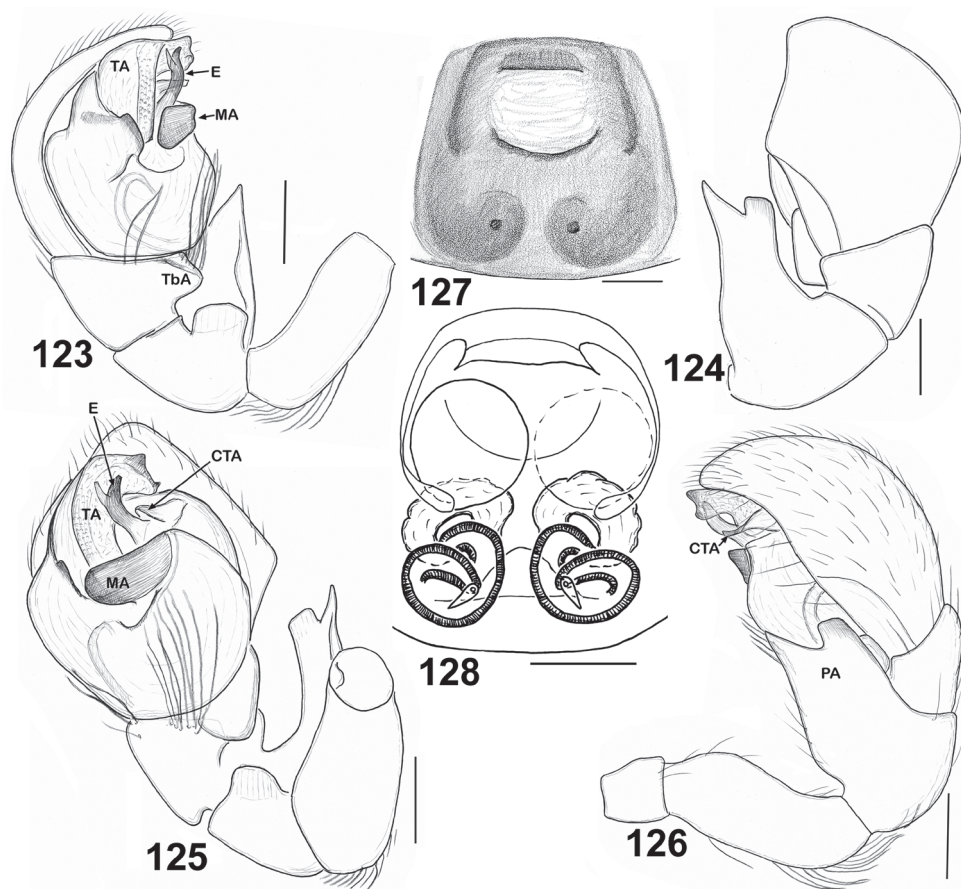
Distribution. China (Yunnan) (Peng and Kim 1997) and northern Laos (Luang Prabang province) (present data).

Description. MALE. *Measurements.* Carapace 0.96 long, 0.79 wide and 0.50 high at PLE. Ocular area 0.60 long, 0.83 wide anteriorly and 0.75 wide posteriorly. Diameter of AME 0.29. Clypeus height 0.06, chelicera length 0.21. Abdomen 0.83



Figures 119–122. General appearance of *Eupoa yunnanensis* from Laos. **119, 120** male body, dorsal view **121** female body, dorsal view **122** male body, lateral view.

long, 0.50 wide. Length of leg segments: I: $0.49 + 0.19 + 0.30 + 0.31 + 0.21$; II: $0.43 + 0.20 + 0.23 + 0.27 + 0.21$; III: $0.43 + 0.19 + 0.24 + 0.31 + 0.26$; IV: $0.64 + 0.24 + 0.47 + 0.39 + 0.29$. *Leg spination*. Leg I: Mt v 2-2-2ap. Leg II: no spines. Leg III: Tb pr and rt 0-1-0. Leg IV: Tb pr and rt 0-1-0; Mt d, pr and rt 1-1ap. *Coloration* (Figs 119–120, 122). Carapace brownish, with a wide longitudinal median yellow stripe, the area between PLEs also yellow; blackened around eyes. Clypeus naked, brownish yellow. Sternum, labium, maxillae and chelicerae yellow. Abdomen: dorsum and sides dark grey, with two longitudinal rows of yellow spots on dorsum; dorsum with shining scutum; venter yellow. Book-lung covers yellow. Spinnerets: anterior pair dark grey, posterior pair yellow. All legs yellow, but femora I and patellae I grey on their sides, tibiae I ventrally grey and patellae II-IV grey on their sides. Palps brownish. Palpal structure as in Figs 123–126: patellar apophysis thick, massive and split at its tip, reaching almost a half of the cymbial length; tibial apophysis short and wide, poorly-developed; tegulum well-developed; tegular apophysis wide and strong, looking like a median extension; median apophysis thick and visibly sclerotized, situated in the central part of tegulum; compound terminal apophysis short, situated at the basis of embolus; embolus fingerlike, with a short hook-shaped process on its tip.



Figures 123–128. Copulatory organs of *Eupoa yunnanensis* from Laos. **123** male palp, median view **124** ditto, dorsal view **125** ditto, ventral view **126** ditto, retrolateral view **127** epigyne, ventral view **128** ditto, dorsal view. Abbreviations as explained in ‘Material and Methods’. Scale bars: 0.1 mm.

FEMALE. Measurements. Carapace 1.13 long, 0.86 wide and 0.60 high at PLE. Ocular area 0.59 long, 0.89 wide anteriorly and 0.76 wide posteriorly. Diameter of AME 0.29. Clypeus height 0.06, chelicera length 0.20. Abdomen 1.10 long, 0.85 wide. Length of leg segments: I: $0.65 + 0.28 + 0.48 + 0.40 + 0.25$; II: $0.53 + 0.23 + 0.35 + 0.35 + 0.23$; III: $0.51 + 0.23 + 0.38 + 0.40 + 0.25$; IV: $0.90 + 0.33 + 0.73 + 0.50 + 0.30$. **Leg spination.** Leg I: Tb v 2-2-2ap; Mt v 2-2-2ap. Leg II: Tb pr and rt 0-1-0, v 1-2; Mt v 2-2-2ap. Leg III: Tb pr and rt 0-1-0; Mt pr and rt 1-0. Leg IV: Tb pr and rt 0-1-0; Mt pr 1-0-2ap, rt 1-0-1ap. **Coloration** (Fig. 121). Carapace yellow, with brownish margins and brownish eye field; blackened around eyes. Clypeus naked and yellow. Sternum, labium, maxillae and chelicerae yellow. Abdomen: dorsum yellow, with two dark brown pattern consisting of Λ -shaped figure and two round merging spots at its rear; venter yellow. Book-lung and spinnerets yellow. All legs and palps yellow. Epigyne and vulva as in Figs 127–128: central

atrium present, it is formed by the posterior chitinous margin and the anterior transverse pocket; relatively short, transparent insemination ducts make a C-shaped loop; there are also visible large transparent sacs that seem to be disconnected from the insemination ducts (in the studied vulva only one sac is left); sclerotized receptacles bean-shaped.

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The authors wish to express their warmest thanks to the following curators for giving access to their museum collections: P Schwendinger (of the MHNG), P Jäger and J Altmann (of the SMFM), S Koponen (of the ZMTU), and KG Mikhailov (of the ZMUM). GN Azarkina (Novosibirsk, Russia) is thanked for making some illustrations of *E. schwendingeri* sp. n. (Figs 100–105), and T Szuts for providing us with the SEM micrographs of *E. pappi* sp. n. Two anonymous referees are obliged for their critical comments on the earlier draft helping to improve it. This project was supported in part by the Russian Foundation for Fundamental Research (grant # 12–04–01548).

References

- Logunov DV (1998) The spider genus *Neon* Simon, 1876 (Araneae, Salticidae) in SE Aia, with notes on the genitalia and skin pore structures. *Bulletin of the British arachnological Society* 11(1): 15–22.
- Maddison WP, Zhang JX, Bodner MR (2007) A basal phylogenetic placement for the salticid spider *Eupoa*, with descriptions of two new species (Araneae: Salticidae). *Zootaxa* 1432: 23–33.
- Ono H (1988) A revisional study of the spider family Thomisidae (Arachnida, Araneae) of Japan. National Science Museum, Tokyo, 252 pp.
- Peng XJ, Li SQ (2006) Description of *Eupoa liaoi* sp. nov. from China (Araneae: Salticidae). *Zootaxa* 1285: 65–68.
- Peng XJ, Kim JP (1997) Three new species of the genus *Eupoa* from China (Araneae: Salticidae). *Korean Journal of Systematic Zoology* 13(2): 193–198.
- Platnick N (2014) The World Spider Catalog, Version 14.5. (accessed on January 21st 2014), American Museum of Natural History. <http://research.amnh.org/entomology/spiders/catalog/INTRO1.html> [Salticidae page last updated 13.12.2013]
- Wijesinghe DP (1992) A new genus of jumping spider from Borneo with notes on the spartacine palp (Araneae: Salticidae). *Raffles Bulletin of Zoology* 40(1): 9–19.
- Żabka M (1985) Systematic and zoogeographic study on the family Salticidae (Araneae) from Viet-Nam. *Annales Zoologici, Polska Academia Nauk* 39(11): 197–485.
- Zhou YY, Li SQ (2013a) Two new genera of jumping spiders from Hainan Island, China (Araneae, Salticidae). *Zootaxa* 3712(1): 1–84. doi: 10.11646/zootaxa.3712.1.1
- Zhou YY, Li SQ (2013b) *Sinoinsula*, a name to replace *Insula* (Araneae, Salticidae). *Acta arachnologica Sinica* 21: 95.

Birds of Antioquia: Georeferenced database of specimens from the Colección de Ciencias Naturales del Museo Universitario de la Universidad de Antioquia (MUA)

Andrea Morales Rozo¹, Fernando Valencia², Alexis Acosta², Juan Luis Parra¹

1 Instituto de Biología, Grupo de Ecología y Evolución de Vertebrados, Universidad de Antioquia, calle 67 No 53-108, Medellín, Colombia **2** Museo Universitario de la Universidad de Antioquia, calle 67 No 53-108, Medellín, Colombia

Corresponding author: Juan Luis Parra (juanluisparra@gmail.com)

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Resource citation: Museo Universitario Universidad de Antioquia (2014). Colección de Aves Museo Universitario de la Universidad de Antioquia. 663 Registros, contributed by Morales-Rozo A., Parra, J.L., Valencia, F. and Acosta, A. Online at http://ipt.sibcolombia.net/sib/resource.do?r=aves_udea, version 1.0 (last updated on 2014-03-31), GBIF key: <http://www.gbif.org/dataset/27465742-2f96-4cb5-83eb-c8bbb9f850ee>, Data Paper ID: doi: 10.3897/zookeys.410.7109

Abstract

The department of Antioquia, Colombia, lies in the northwestern corner of South America and provides a biogeographical link among divergent faunas, including Caribbean, Andean, Pacific and Amazonian. Information about the distribution of biodiversity in this area is of relevance for academic, practical and social purposes. This data paper describes the dataset containing all bird specimens deposited in the Colección de Ciencias Naturales del Museo Universitario de la Universidad de Antioquia (MUA). We curated all the information associated with the bird specimens, including the georeferences and taxonomy, and published the database through the Global Biodiversity Information Facility network. During this process we checked the species identification and existing georeferences and completed the information when possible. The collection holds 663 bird specimens collected between 1940 and 2011. Even though most specimens are from Antioquia (70%), the collection includes material from several other departments and one specimen from the United States. The collection holds specimens from three endemic and endangered species (*Coeligena orina*, *Diglossa gloriosissima*, and *Hypopirrhys pyrohipogaster*), and includes localities poorly represented in other collections. The information contained in the collection has been used for biodiversity modeling, conservation planning and management, and we expect to further facilitate these activities by making it publicly available.

Keywords

Antioquia, Aves, Birds, Colombia, Georeference, Museum, Specimens, Universidad de Antioquia

Introduction

The department of Antioquia lies in the northwestern corner of Colombia and is one of the most biodiverse regions in the country. Several factors contribute to the concentration of biodiversity within this area, including high environmental heterogeneity and the confluence of the Panamanian and Neotropic zoogeographical regions (Holt et al. 2013). Currently, Antioquia is under severe pressure from mining and hydroelectric projects (Finer and Jenkins 2012). Knowledge of the spatial distribution of biodiversity in the department is of critical importance for assessing the impacts of these activities and deciding where to grant exploitation licenses. Nonetheless, spatially explicit information about the occurrence of birds in this region is relatively unusual, apart from data from museum collections. However, most of this information is still not available in the public domain in databases such as ORNIS or global networks such as GBIF (Fig. 1). Thus, our primary motivation is to make the information present in the collection of the Universidad de Antioquia available for the general public. Despite its small size (663 specimens), the collection holds specimens that are rare in other collections, including three endemic and endangered birds, and localities that have been poorly sampled such as the eastern flank of the Central Andes (Fig. 1). By making this information available we expect it to be further used in academic endeavors such as ecological niche modeling (e.g., Velásquez-Tibatá et al. 2012) and for practical purposes related to conservation planning and management (e.g., Krabbe et al. 2005).

Project details

Project title: Geographic distribution of species richness in the Colombian Andes with a special emphasis on aquatic systems of the northwestern region.

Personnel: Andrea Morales Rozo (research assistant, data collector), Juan Luis Parra (principal investigator), Fernando Valencia (collection manager), Alexis Acosta (collection coordinator, data collector).

Funding: The Nature Conservancy (TNC).

Taxonomic coverage

General taxonomic coverage description: The collection holds specimens from 313 species, 54 families and 19 orders (Fig. 3). Nonetheless, this is still a poor representation of the total number of species in Colombia (~17%) and the department of Antioquia

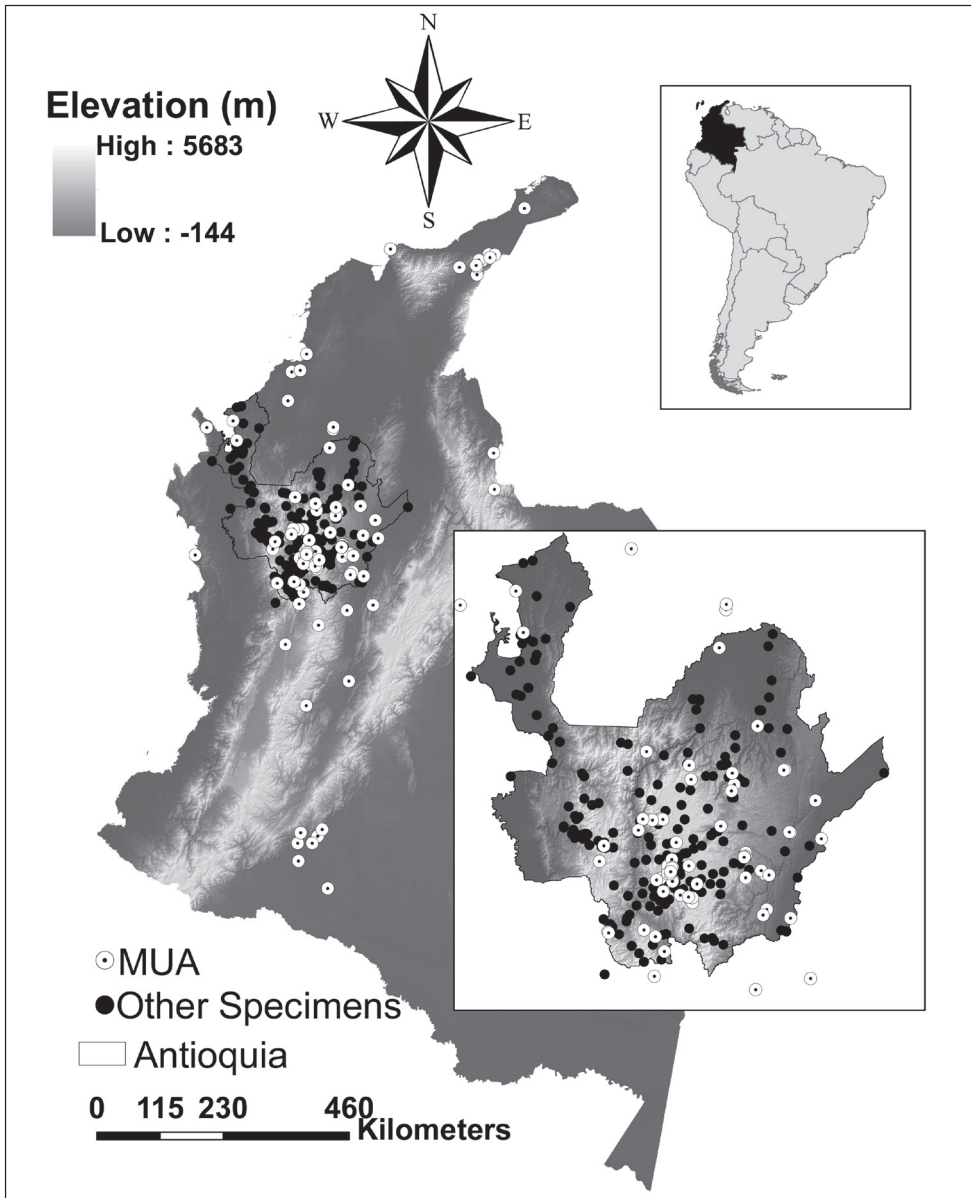


Figure 1. Map of Colombia showing the collection localities for all bird specimens held in the MUA (white dots) and all specimens from Antioquia held in other collections (black dots). The upper right inset highlights Colombia within South America and the lower right inset provides a closer look at the distribution of points in Antioquia.

(~37%). The three most represented families are Thraupidae (41 species, 96 specimens), Tyrannidae (35, 63) and Trochilidae (33, 69). Specimens of particular relevance in this collection are from *Terenura callinota* and *Spizastur melanoleucus*, representing the only

specimens of these species in Antioquia. In addition, the collection includes specimens from three endemic and endangered species: *Coeligena orina* (1 specimen, CR), *Diglossa gloriosissima* (1, EN) and *Hypopirrhus pyrohipogaster* (2, VU).

Taxonomic ranks

Kingdom: Animalia

Class: Aves

Order: Accipitriformes, Anseriformes, Apodiformes, Caprimulgiformes, Charadriiformes, Columbiformes, Coraciformes, Cuculiformes, Falconiformes, Galbuliformes, Galliformes, Gruiformes, Passeriformes, Pelecaniformes, Piciformes, Podicipediformes, Psittaciformes, Strigiformes, Suliformes.

Family: Accipitridae, Alcedinidae, Anatidae, Anhingidae, Aramididae, Ardeidae, Bucconidae, Capitonidae, Caprimulgidae, Cardinalidae, Charadriidae, Columbidae, Conopophagidae, Corvidae, Cotingidae, Cracidae, Cuculidae, Donacobiidae, Emberizidae, Falconidae, Formicariidae, Fringillidae, Furnariidae, Galbulidae, Grallaridae, Hirundinidae, Icteridae, Incertae sedis, Jacanidae, Mimidae, Momotidae, Odontophoridae, Parulidae, Phalacrocoracidae, Picidae, Pipridae, Podicipedidae, Psittacidae, Rallidae, Ramphastidae, Recurvirostridae, Rhinocryptidae, Steatornithidae, Strigidae, Thamnophilidae, Thraupidae, Threskiornithidae, Tityridae, Trochilidae, Trogglodytidae, Turdidae, Tyrannidae, Tytonidae, Vireonidae.

Common names: Birds.

Spatial coverage

General spatial coverage: The sampling localities range from 71°S to 78°S longitude and from 0°N to 12°N latitude. All specimens are from Colombia except one from the United States. The dataset represents an improvement over the area sampled within Antioquia, in particular the eastern part of the department where no specimens exist in other collections (Fig. 1). Clearly, there are gaps in collection effort throughout the department, but we highlight the Pacific lowlands, the Western Andes and the lowlands in the northern part of the Central and Western Andes as areas that should be the focus of biodiversity expeditions.

Coordinates: 0°0'0"N and 12°0'0"N Latitude; 71°0'0"W and 78°0'0"W Longitude.

Temporal coverage: Specimens in the collection date from 1940 to 2011 with two clear increments during the early 1970s and 2000s (Fig. 3). The most recent peak in collections traces to the establishment of a large project focused on cataloguing the department's biodiversity, and the early peak is related to a successful collaboration between the curators of the largest collections in the department of Antioquia (MUA and ITM).

Natural collections description

Parent collection identifier: Museo Universitario de la Universidad de Antioquia

Collection name: Colección de Aves

Collection identifier: Fernando Valencia

Specimen preservation method: Skin

Methods

Method step description: The database of bird specimens was developed with the aim of determining the current distribution of avian richness along major river banks. Birds are a particularly useful taxon for conservation assessments since they are easy to identify and are one of the best-known groups in terms of their distribution and abundance (Blair 1999). Many bird species concentrate along river banks and other water bodies and can be used as indicators of ecosystem health (Péron et al. 2013). To obtain a georeferenced database for all specimens in the collection, we followed the procedure represented in Figure 3. We initiated by organizing the information present in the original collection database according to the biodiversity information standards established in Darwin Core 2.0. Each specimen was identified by AMR and all localities specified in the specimen labels were georeferenced using gazeteers (Paynter 1997), maps from the National Institute of Geography (IGAC), Google Earth (URL: <http://www.google.com/earth/>) and Geonames (URL: <http://www.geonames.org/>). Finally, we published the database to the GBIF network through the Humboldt Institute, the Colombian GBIF node (Fig. 2). After we finished data collection and validation, we mapped the specimen localities and compared them to other museums (Fig. 1).

Study extent description: The department of Antioquia lies in the northwestern corner of Colombia close to the border with Panama. Most of the bird specimens in the collection (459) are from within the department, with the following exceptions: Córdoba (69 specimens), Caquetá (46), Amazonas (3), Caldas (6), Chocó (12), La Guajira (28), Magdalena (9), Meta (6), Norte de Santander (2), Sucre (2), Tolima (4), and Valle del Cauca (7). One specimen is from the United States and nine specimens only listed Colombia in the locality information (Fig. 1). The area encompassed by Antioquia is of high relevance to biodiversity conservation due to its biogeographic position (Haffer 1967), its high environmental heterogeneity, and its current threat due to mining and hydroelectric pressures (Holt et al. 2013). This area contains a high number of Colombian endemics and a concentration of range restricted and endangered birds (Velasquez-Tibatá et al. 2012). The department of Antioquia encompasses a wide range of environments, including dry forests in the Magdalena and Cauca river valleys, wet lowland forests in the Pacific and montane forests and páramo on the Central and Western Andes (Toro-Murillo and Cuervo-Maya 2002). Despite its great significance as a biodiversity hotspot in Colombia, Antioquia is also recognized for its high rates of deforestation (Orrego 2009).

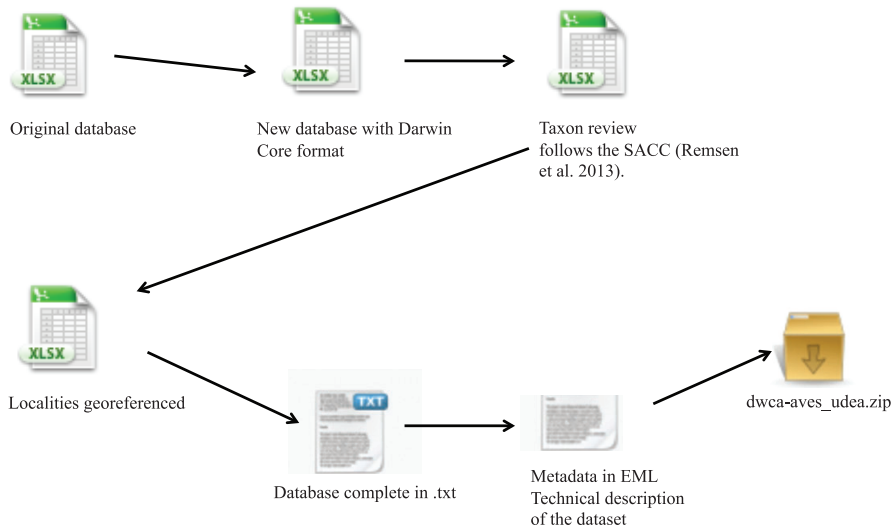


Figure 2. Schematic flowchart of the steps taken to format the collection database according to the Darwin Core and submitting it for public access through GBIF.

Sampling description: The specimens held in the collection come from a variety of sources including field expeditions from the curators, research projects focused on particular species and private donations. Thus, there is no single collection or specimen preparation protocol: Nonetheless, most specimens have been captured through the use of mist nets and the majority of specimens are complete skins.

Quality control description: An experienced ornithologist (AMR) identified all specimens with the aid of field guides (Del-Hoyo et al. 1999, Hilty and Brown 1986, McMullan et al. 2010). The taxonomy of each bird was updated to reflect the South American Classification Committee version 20 May 2013 (Remsen et al. 2013). Each georeference was considered in light of the species distribution given by Birdlife International (Ridgely et al. 2012) and elevation ranges according to Hilty and Brown (1986) and McMullan et al. (2010). We used this information in addition to the georeferencing protocols suggested by Chapman and Wieczorek (1999) to estimate the uncertainty of the georeference whenever possible. There were 46 specimens that could not be georeferenced given the information on the label.

Dataset description

Object name: Darwin Core Archive for the Database of Birds of MUA

Character encoding: UTF-8

Format name: Darwin Core Archive format

Format version: 1.0

Distribution: http://ipt.sibcolombia.net/sib/resource.do?r=aves_udea

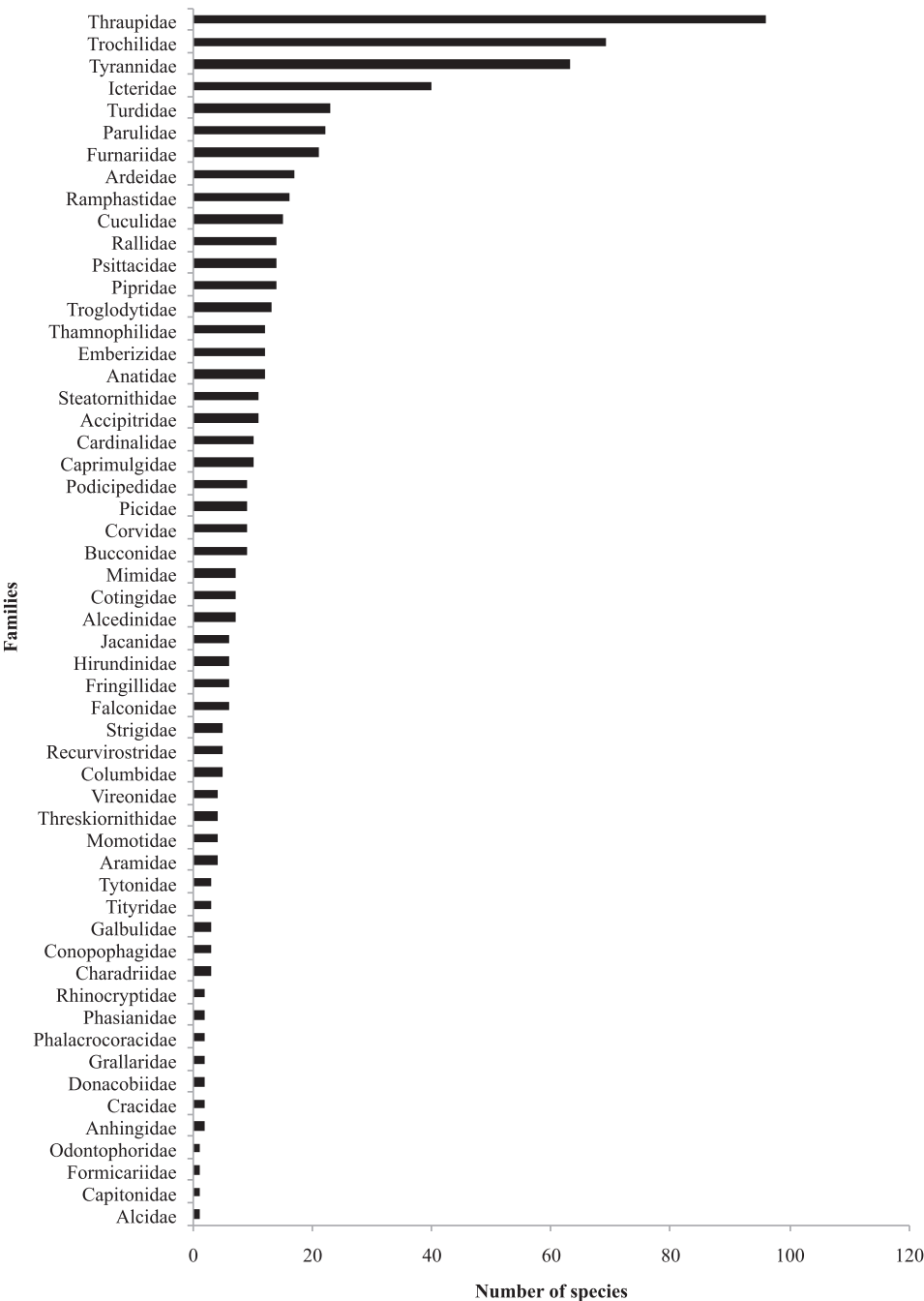


Figure 3. Distribution of specimens in the collection according to families.

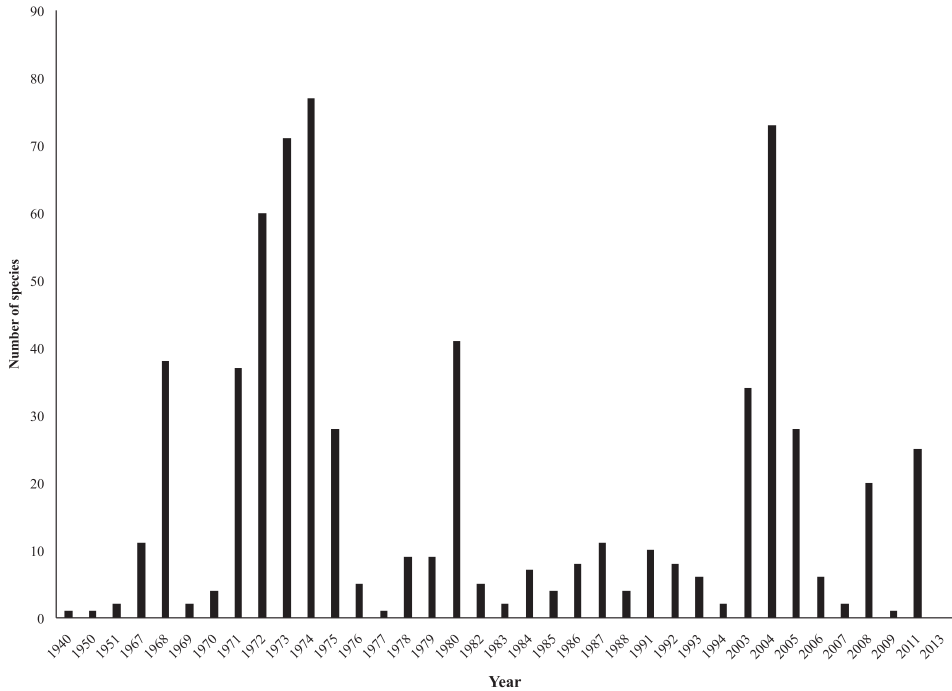


Figure 4. Distribution of specimens through time, showing two peaks in collection activity during the early 1970s and 2000s. Both time periods correspond to the timing of large-scale projects.

Publication date of data: March 31st 2014

Language: Spanish

Metadata language: Spanish

Date of metadata creation: March 31st 2014

Hierarchy level: Dataset

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References

1) References cited within the metadata

Blair RB (1999) Birds and Butterflies along an urban gradient: Surrogate taxa for assessing biodiversity? *Ecological Applications* 9:164–170. doi: 10.1890/1051-0761(1999)009[0164:BA-BAAU]2.0.CO;2

- Finer M, Jenkins C (2012) Proliferation of hydroelectric dams in the Andean Amazon and implications for Andes-Amazon connectivity. *PLoS ONE* 7: e35126. doi: 10.1371/journal.pone.0035126
- Haffer J (1967) Speciation in Colombian forest birds west of the Andes. *American Museum novitates* 2294: 1–57.
- Hilty SH, Brown WL (1986) *A guide to the birds of Colombia*. Princeton University Press, Princeton, NJ, USA.
- Holt BG, Lessard J-P, Borregaard MK, Fritz SA, Araujo MB, Dimitrov D, Fabre P-H, Graham CH, Graves GR, Jönsson KA, Nogués-Bravo D, Wang Z, Whittaker RJ, Fjeldså J, Rahbek C (2013) An Update of Wallace's Zoogeographic Regions of the World. *Science* 339: 74–78. doi: 10.1126/science.1228282
- Krabbe N, Flórez P, Suárez G, Castaño J, Arango JD, Pulgarín-R PC, Múnera WA, Stiles GF, Salaman P (2005) Rediscovery of the Dusky Starfrontlet *Coeligena orina*, with a description of the adult plumages and a reassessment of its taxonomic status. *Ornitología Colombiana*, 325–332.
- Péron G, Ferrand Y, Leray G, Gimenez O (2013) Waterbird demography as indicator of wetland health: The French-wintering common snipe population. *Biological Conservation*, 164: 123–128. doi: 10.1016/j.biocon.2013.04.015
- Orrego SA (2009) *Economic Modeling of Tropical Deforestation in Antioquia (Colombia), 1980-2000: An Analysis at a Semi-Fine Scale with Spatially Explicit Data*. PhD Dissertation. Oregon State University, 137 pp.
- Toro-Murillo JL, Cuervo-Maya AM (2002) *Aves en peligro de extinción en la jurisdicción de Corantioquia*. CORANTIOQUIA, Medellín, Colombia.
- Velásquez-Tibatá J, Salaman P, Graham CH (2012) Effects of climate change on species distribution, community structure, and conservation of birds in protected areas in Colombia. *Regional Environmental Change* 13: 235–248. doi: 10.1007/s10113-012-0329-y

2) References used in developing the database

- Chapman AD, Wicczorek J (Eds) (2006) *Guide to Best Practices for Georeferencing*. Global Biodiversity Information Facility, Copenhagen, 90 pp.
- Del-Hoyo J, Elliot A, Sargatal J (1999) *Handbook of the birds of the world, Vol. 5. Barnowls to Hummingbirds*. Lynx Editions, Barcelona, 759 pp.
- Hilty SH, Brown WL (1986) *A guide to the birds of Colombia*. Princeton University Press, Princeton, NJ, USA.
- McMullan M, Quevedo A, Donegan TM (2010) *Guía de Campo de las aves de Colombia*. Fundación Proaves, Colombia, 226 pp.
- Paynter RA (1997) *Ornithological gazetteer of Colombia*. Second Edition. Harvard University, Cambridge, USA. doi: 10.5962/bhl.title.14638
- Remsen JV Jr, Cadena CD, Jaramillo A, Nores M, Pacheco JF, Pérez-Emán J, Robbins MB, Stiles FG, Storz DF, Zimmer KJ (2013) *A classification of the bird species of South America*. American Ornithologists' Union. <http://www.museum.lsu.edu/~Remsen> [version Version 29 Nov 2013]
- Ridgely RS et al. and BirdLife International (2012) *Digital Distribution Maps of the Birds of the Western Hemisphere, version 5.0*. In: BirdLife International and NatureServe (2012) *Bird species distribution maps of the world*.

A new species of *Alopoglossus* lizard (Squamata, Gymnophthalmidae) from the tropical Andes, with a molecular phylogeny of the genus

Omar Torres-Carvajal^{1,†}, Simón E. Lobos^{1,‡}

¹ Escuela de Biología, Pontificia Universidad Católica del Ecuador, Avenida 12 de Octubre y Roca, Apartado 17-01-2184, Quito, Ecuador

[†] <http://zoobank.org/EE1B0BD5-4C91-4AB4-98C3-8A7602BF0338>

[‡] <http://zoobank.org/7E8CE333-B7F6-419F-881E-999C39013EA3>

Corresponding author: Omar Torres-Carvajal (omartorcar@gmail.com)

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Abstract

We describe a new species of *Alopoglossus* from the Pacific slopes of the Andes in northern Ecuador based on morphological and molecular evidence. The new species differs most significantly from all other congeners in having a double longitudinal row of widened gular scales, lanceolate dorsal scales in transverse rows, 29–32 dorsal scales in a transverse row at midbody, and 4 longitudinal rows of ventrals at midbody. It is most similar in morphology to *A. festae*, the only species of *Alopoglossus* currently recognized in western Ecuador. We analyze the phylogenetic relationships among species of *Alopoglossus* based on the mitochondrial gene ND4. Cis-Andean [east of the Andes] and Trans-Andean [west of the Andes] species are nested in two separate clades, suggesting that the uplift of these mountains had an important effect in the diversification of *Alopoglossus*. In addition, we present an updated key to the species of *Alopoglossus*.

Resumen

Describimos una especie nueva de *Alopoglossus* de las estribaciones occidentales de los Andes al norte de Ecuador, en base a evidencia morfológica y molecular. La nueva especie se distingue de otros congénéricos por poseer una hilera longitudinal doble de escamas gulares ensanchadas, escamas dorsales lanceoladas en hileras transversales, 29–32 escamas dorsales sobre una línea transversal al medio cuerpo, y 4 hileras longitudinales de escamas ventrales al medio cuerpo. La nueva especie es semejante en morfología a *A. festae*, la

única especie actualmente registrada para el occidente de Ecuador. Analizamos las relaciones filogenéticas entre las especies de *Alopoglossus* en base al gen mitocondrial ND4. Las especies Cis-andinas [este de los Andes] y Trans-andinas [oeste de los Andes] están agrupadas en dos clados distintos, lo cual sugiere que el levantamiento de los Andes tuvo un efecto importante en la diversificación de *Alopoglossus*. Presentamos una clave actualizada para las especies de *Alopoglossus*.

Keywords

Alopoglossus, Andes, Ecuador, Gymnophthalmidae, lizards, systematics

Introduction

The New World lizard clade Gymnophthalmidae Merrem 1820 includes 241 extant species assigned to 46 taxa traditionally ranked as genera (Uetz 2014). One of them is *Alopoglossus*, which differs from other gymnophthalmid genera except *Ptychoglossus* in having the dorsal surface of the tongue completely covered with anteromedially converging plicae rather than scale-like papillae (Harris 1994; Hoogmoed and Avila-Pires 1992). *Alopoglossus* differs from *Ptychoglossus* (character states for *Ptychoglossus* in parentheses) in having keeled scales on forelimbs (smooth forelimb scales), and rhomboid, laterally imbricating dorsal scales (parallel-sided dorsal scales; Harris 1994).

The close relationship between *Alopoglossus* and *Ptychoglossus* suggested by Harris (1994) based on morphological similarities has been corroborated by phylogenetic analyses of DNA sequence data; these genera are sister taxa and form the clade Alopoglossinae (Castoe et al. 2004). Moreover, this clade seems to be sister to all other gymnophthalmids (Pellegrino et al. 2001; Castoe et al. 2004; Trefaut et al. 2007) as first suggested by Harris (1994). Therefore, studying the phylogenetic systematics of Alopoglossinae is crucial to understand the evolution of gymnophthalmid lizards.

Alopoglossus includes six currently recognized species (*A. angulatus*, *A. atriventris*, *A. buckleyi*, *A. copii*, *A. festae*, and *A. lehmanni*) widely distributed across tropical South America (Köhler et al. 2012). Of these, only *A. lehmanni* (endemic to Colombia) does not occur in Ecuador; *A. festae* occurs west of the Andes, whereas the remaining species occur east of the Andes (Köhler et al. 2012; Torres-Carvajal et al. 2014; Torres-Carvajal 2001). In this paper we describe a new species of *Alopoglossus* from northwestern Ecuador and infer its phylogenetic affinities to other species in the genus as currently understood.

Materials and methods

Morphological data

All type specimens of the new species described in this paper are listed in the type series below, and were deposited at the Museo de Zoología, Pontificia Universidad Católica del Ecuador, Quito (QCAZ). Specimens of other species of *Alopoglossus* examined in

this study are listed in the Appendix. All measurements were made with digital calipers and recorded to the nearest 0.01 mm: head length (HL), head width (HW), shank length (ShL), axilla-groin distance (AGD), lateral neck scale size (ANS), snout-vent length (SVL), and tail length (TL). Each measurement was taken twice and averaged. Sex was determined by noting the presence of everted hemipenes or by dissection. We follow the terminology of Avila-Pires (1995) and Köhler et al. (2012) for measurements and squamation.

DNA sequence Data

Total genomic DNA was digested and extracted from liver or muscle tissue using a guanidinium isothiocyanate extraction protocol. Tissue samples were first mixed with Proteinase K and lysis buffer and digested overnight prior to extraction. DNA samples were quantified using a Nanodrop® ND-1000 (NanoDrop Technologies, Inc), re-suspended and diluted to 25 ng/ul in ddH₂O prior to amplification.

We amplified 596 nucleotides (nt) of the mitochondrial gene NADH dehydrogenase subunit 4 (ND4) from one individual each of *Alopoglossus angulatus*, *A. atriventrtris*, *A. buckleyi*, *A. copii*, *A. festae*, and the new species described herein. ND4 was amplified using the primers ND4F and ND4R (Pellegrino et al. 2001). Additionally, we used sequences of *A. angulatus* (erroneously identified as *A. copii* in Pellegrino et al. 2001), *Bachia flavescens*, *Ecpleopus gaudichaudii*, *Heterodactylus imbricatus*, *Ptychoglossus brevifrontalis*, *Rhachisaurus brachylepis* and *Riama unicolor* from GenBank. Gene regions of taxa included in phylogenetic analyses along with their GenBank accession numbers and locality data are shown in Table 1. Amplification of genomic DNA consisted of an initial cycle at 96 °C for 3 min, followed by 40 cycles of a denaturation at 95 °C for 30 s, annealing at 52 °C for 1 min, and extension at 72 °C for 1 min, as well as a final extension at 72 °C for 10 min.

Phylogenetic analyses

Editing, assembly, and alignment of sequences were performed with Geneious Pro™ 5.5 (Drummond et al. 2010). Phylogenetic relationships were assessed under a Bayesian approach in MrBayes 3.2.0 (Ronquist and Huelsenbeck 2003). The data matrix was partitioned by codon. The model of character evolution for each partition was obtained in JModeltest (Posada 2008) under the Bayesian information criterion. Four independent analyses were performed to reduce the chance of converging on a local optimum. Each analysis consisted of ten million generations and four Markov chains with default heating values. Trees were sampled every 1,000 generations resulting in 10,000 saved trees per analysis. Stationarity was confirmed by plotting the log-likelihood scores per generation in the program Tracer 1.2 (Rambaut et al. 2013). Additionally, the standard deviation of the partition frequencies and the potential scale reduction factor (Gelman and Rubin 1992)

Table 1. Vouchers, locality data, and GenBank accession numbers of taxa included in this study. Asterisks indicate new sequences obtained for this study.

Taxon	Voucher	Locality	Genbank number (ND4)	GenSeq nomenclature
<i>Alopoglossus angulatus</i> ¹	LSUMZ H12692	Ecuador: Sucumbíos: Cuyabeno	AF420865	genseq-4
<i>A. angulatus</i> 2	QCAZ 8915	Ecuador: Pastaza: Cononaco Lodge	KJ705317	genseq-4
<i>A. atriventris</i>	QCAZ 5622	Ecuador: Sucumbíos: Cuyabeno	KJ705319	genseq-4
<i>A. buckleyi</i>	QCAZ 9961	Ecuador: Pastaza: Ingaru Community, Ankaku Reserve	KJ705320	genseq-4
<i>A. copii</i>	QCAZ 8314	Ecuador: Pastaza: Tarangaro Community, Villano Camp Bloque 10-Agip Oil	KJ705318	genseq-4
<i>A. festae</i>	QCAZ 9158	Ecuador: Guayas: Bosque Protector Cerro Blanco	KJ705315	genseq-4
<i>A. viridiceps</i> sp. n.	QCAZ 10670 (holotype)	Ecuador: Pichincha: Nanegal, Santa Lucía Cloud Forest Reserve	KJ705316	genseq-1
<i>Ptychoglossus brevifrontalis</i>	MHNSM ²	—	AY507895	—
<i>Heterodactylus imbricatus</i>	LG 1504	Brazil: São Paulo: Serra da Cantareira	AF420885	genseq-4
<i>Ecleopus gaudichaudii</i>	LG 1356	Brazil: São Paulo: Boissucanga	AF420901	genseq-4
<i>Riama unicolor</i>	KU 217211	Ecuador: Imbabura: road to Laguna de Mojanda from Tabacundo	AY507893	genseq-4
<i>Bachia flavescens</i>	LSUMZ H12977	Brazil: Pará: Agropecuária Treviso, Santarém	AF420869	genseq-4
<i>Rhachisaurus brachylepis</i>	MRT 887336	Brazil: Minas Gerais: Serra do Cipó	AF420877	genseq-4

¹Erroneously identified as *Alopoglossus copii* in Pellegrino et al. (2001).

²Voucher number not provided in original publication (Castoe et al. 2004).

were used as convergence diagnostics for the posterior probabilities of bipartitions and branch lengths, respectively. Adequacy of mixing was assessed by examining the acceptance rates for the parameters in MrBayes and the effective sample sizes (ESS) in Tracer. After analyzing convergence and mixing, 1,000 trees were discarded as “burn-in” from each run. We then confirmed that the four analyses reached stationarity at a similar likelihood score and that the topologies were similar, and used the resultant 36,000 trees to calculate posterior probabilities (PP) for each bipartition on a 50% majority rule consensus tree. Interspecific sequence divergence was assessed with uncorrected distances, which were obtained in PAUP* (Swofford 2003).

Results

The taxonomic conclusions of this study are based on the observation of morphological features and color patterns, as well as inferred phylogenetic relationships. We consider this information as species delimitation criteria following the general species concept (de Queiroz 1998, 2007).

***Alopoglossus viridiceps* sp. n.**

<http://zoobank.org/1BF11DC5-BD0D-4CF1-ABF4-B5E2884B5812>

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

Proposed standard English name: Green-headed shade lizards

Proposed standard Spanish name: Lagartijas de sombra de cabeza verde

Holotype. QCAZ 10670 (Figs 1,2), an adult male from Nanegal, Santa Lucia Cloud Forest Reserve, 0.113528°N; -78.6135°W (Decimal Degrees, WGS84), 1742 m, Provincia Pichincha, Ecuador, collected on 27 June 2010 by V. Aguirre-Peñafiel and J. Zanka.

Paratypes (11). ECUADOR: Provincia Pichincha: QCAZ 9738, Mindo, Hacienda San Vicente, -0.050720°N, -78.772350°W (DD), 1246 m, collected on 7 August 2009 by S. Poe, E. Schaad, I. Latella, N. Blea, T. Kennedy and F. Ayala-Varela; QCAZ 10821, 10826, Nanegal, Santa Lucía Cloud Forest Reserve, 0.117780°N, -78.607555°W (DD), 1580 m, collected on 9 March 2010 by B. Tolhurst, P. Mafla-Endara, S. Ryan and X. Cueva; QCAZ 11854–55, Nanegal, Santa Lucía Cloud Forest Reserve, trail to waterfalls, 0.109450°N, -78.609380°W (DD), 1645 m, collected on 12 September 2013 by D. Ortiz and O. Torres-Carvajal; QCAZ 11927–29, Nanegal, Santa Lucía Cloud Forest Reserve, 0.113330°N, -78.613280°W (DD), 1736 m, collected on 6 November 2013 by F. Ayala-Varela, E. Carrillo, V. Macias and T. Ostos; QCAZ 10666, 10753, same collection data as holotype, but collected on 14 July 2010 by V. Aguirre-Peñafiel and 26 July 2010 by S. Maddock and V. Aguirre-Peñafiel, respectively. QCAZ 10671, Nanegal, Santa Lucía Cloud Forest Reserve, 0.119280°N, -78.596470°W (DD), 1911 m, collected on 29 June 2010 by M.A. Chinchero.

Diagnosis. *Alopoglossus viridiceps* can be distinguished from all other known congeners except *A. festae* by having a double longitudinal row of widened gular scales and lanceolate dorsal scales in transverse rows. From *A. festae* (character states in parentheses, taken from Köhler et al. 2012), the new species differs in having 29–32 dorsal scales in a transverse row at midbody (16–24, mean = 19.14 ± 2.25), four ventral scales in a transverse row at midbody (six), and a distinct longitudinal light stripe from mouth commissure to shoulder (Fig. 3). Scale counts and measurements of *A. festae* and *A. viridiceps* are presented in Table 2.

Description of holotype. Male (Figs 1,2); SVL = 57.89; TL/SVL = 1.99; HL/SVL = 0.24; HW/SVL = 0.16; ShL/SVL = 0.16; AGD/SVL = 0.43; ANS/HL = 3.58.

Rostral hexagonal, 2.08 times as wide as high, visible from above, in broad contact with frontonasal. Frontonasal irregularly pentagonal, wider than long, laterally in contact with nasal. Prefrontals irregularly pentagonal, nearly as wide as long, with medial suture; laterally in contact with nasal, loreal, and first and second supraocular. Frontal irregularly hexagonal, nearly twice as long as wide, slightly wider anteriorly; at each side in contact with supraoculars II–III. Frontoparietals irregularly pentagonal, longer than wide, with a wide medial suture; each in contact with supraoculars III–IV. Interparietal pentagonal, lateral borders parallel to each other. A pair of irregularly hexagonal parietals, approximately as wide and as long as interparietal. Interparietal and parietals forming slightly



Figure 1. Holotype of *Alopoglossus viridiceps* sp. n. in dorsal (top) and ventral (bottom) views. Male, SVL = 57.89 mm, QCAZ10670. Photographs by OTC.

undulating posterior head margin. Occipitals absent. Four supraoculars, first one smallest and second one largest. Four elongate superciliaries, first one widest, followed by a post-superciliary scale, which is also in contact with supraocular IV and anterior supratemporal. Nasal divided, irregularly pentagonal, longer than wide, in contact with rostral anteriorly, first and second supralabials ventrally, frontonasal and prefrontals dorsally, loreal posterodorsally, and frenocular posteroventrally. Nostril in lower part of nasal, directed lateroposteriorly. Loreal small, quadrangular. Frenocular in contact with nasal, separating loreal from supralabials. Three suboculars, the one below eye very elongated (nearly three times the size of adjacent suboculars). Posterior subocular continuous with three postoculars. Semitransparent disc in lower eyelid with vertical sections delimiting six large scales on right side and five scales on left side. Five supralabials, third one longest

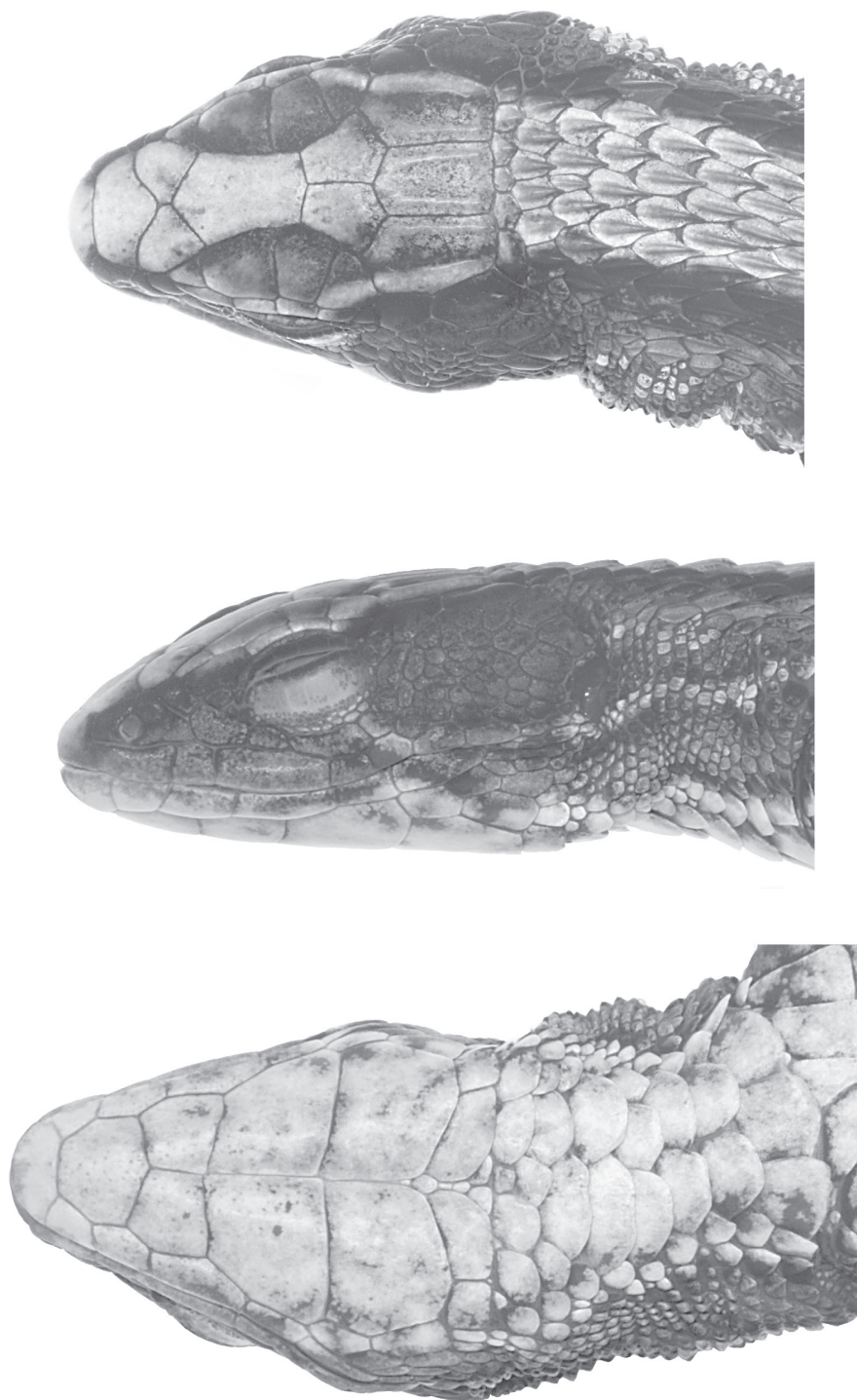


Figure 2. Head of holotype of *Alopoglossus viridiceps* sp. n. (QCAZ10670) in dorsal (top), lateral (middle) and ventral (bottom) views. Photographs by OTC.

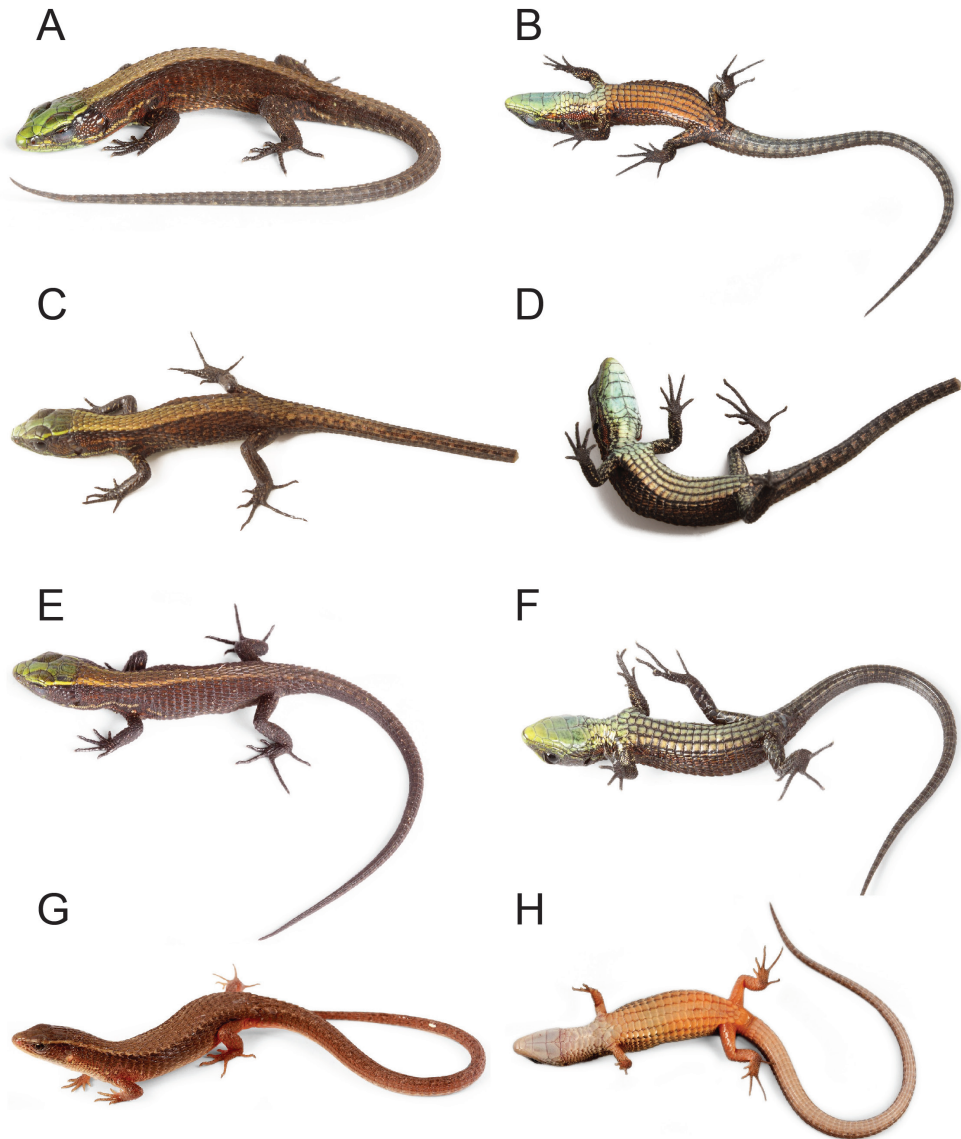


Figure 3. Species of *Alopoglossus* from western Ecuador. **A, B** *A. viridiceps* sp. n., paratype QCAZ11854, juvenile male, SVL = 38.67 mm **C, D** *A. viridiceps* sp. n., paratype QCAZ10671, juvenile female, SVL = 33.80 mm **E, F** *A. viridiceps* sp. n., paratype QCAZ11855, juvenile, SVL = 31.59 mm **G, H** *A. festae*, QCAZ 9161, female, SVL = 46.89 mm.

and below center of eye. Two postsupralabials. Temporals small, irregularly polygonal, juxtaposed, keeled. Two large supratemporal scales, posterior one keeled. Ear opening vertically oval, without denticulate margins. Tympanum recessed into a short auditory meatus. All dorsal and lateral head scales juxtaposed. Interparietal and parietals with lateral ridges, other dorsal head scales smooth. Mental trapezoidal, anterior margin nearly

Table 2. Scale counts and measurements of *Alopoglossus festae* and *A. viridiceps*. Range (first line) and mean \pm SD (second line) are presented when appropriate. Data for *A. festae* was taken from Köhler et al. (2012). Sample size for *A. viridiceps* is presented in parentheses if different from that in heading.

Character	<i>A. festae</i> Köhler et al. (2012)	<i>A. viridiceps</i> sp. n. N = 12
Maximum SVL (snout—vent length) males	60.0 mm	64.13 mm
Maximum SVL females	64.5 mm	57.22 mm
Longitudinal dorsal count	29–31 30.14 \pm 0.64	30–33 31.33 \pm 0.26
Transversal dorsal count	16–24 19.14 \pm 2.25	29–32 30.33 \pm 0.26
Longitudinal ventral count	16–19 17.29 \pm 1.03	17–18 (10) 17.2 \pm 0.12
Transversal ventral count	6 6.00 \pm 0.00	4 4.00 \pm 0.00
Gulars rows	6–8 7.25 \pm 0.68	7–8 7.08 \pm 0.08
Frontonasals	1 1.00 \pm 0.00	1 1.00 \pm 0.00
Supraoculars	3–4 3.97 \pm 0.18	4 4.00 \pm 0.00
Anterior supralabials	3 3.00 \pm 0.00	3 3.00 \pm 0.00
Posterior supralabials	3–4 3.95 \pm 0.21	2 2.00 \pm 0.00
Infralabials	4–5 4.82 \pm 0.38	4 4.00 \pm 0.00
Scales between third chin shields	1–2 1.08 \pm 0.26	1 1.00 \pm 0.00
Transparent eye disk fragments	4–6 4.90 \pm 0.64	6–8 6.6 \pm 0.19
Lamellae fourth toe	17–24 18.77 \pm 1.52	15–17 16.17 \pm 0.21
Femoral pores	3–8 5.67 \pm 1.15	1 (10) 1.00 \pm 0.00
Tail length / SVL (%)	134.1–222.5 183.66 \pm 22.54	164.56–199.92 (5) 177.83 \pm 5.56
Head length / SVL (%)	20.4–25.5 22.73 \pm 1.36	22.78–27.78 25.55 \pm 0.41
Head width / SVL (%)	13.5–19.3 15.90 \pm 1.34	15.85–19.99 18.11 \pm 0.34
Shank length / SVL (%)	13.0–18.1 15.66 \pm 1.22	15.81–19.02 17.88 \pm 0.31
Axilla-groin distance / SVL (%)	37.5–50.0 44.23 \pm 2.90	40.68–49.25 45.30 \pm 0.83
Lateral neck scale size / head length (%)	1.3–5.5 3.08 \pm 0.95	2.41–4.68 3.25 \pm 0.16

forming a semicircle. Postmental irregularly heptagonal, wider than long. Four infralabials, third one longest and below center of eye. One postinfralabial. Three pairs of chin shields, first two in contact medially and with infralabials; third one in contact medially but separated from infralabials. Third pair of chin shields separated from gulars by two

transverse rows of scales. Anterior row composed laterally by two scales (one on each side) similar in size to the scales on the posterior row, and medially by two enlarged scales (not in contact medially) similar in size to the enlarged gulars. Gulars imbricate, smooth, in four longitudinal rows, the medial double row formed by five pairs of distinctly widened scales. Posterior row (collar) with five scales, the medial three distinctly widened (Fig. 2).

Scales on nape similar to dorsals, except that anterior ones are shorter. Scales on sides of neck small, keeled and mostly granular. Dorsals and scales on flanks lanceolate, strongly keeled and mucronate, imbricate, in transverse rows; number of scales along a middorsal line from nape to base of tail 30; transversal dorsal count 31. Ventrals smooth, imbricate, with round posterior margin; 18 in a longitudinal count; four in a transverse count. Scales on flanks similar to dorsals. One femoral pore on each side, in preanal position, separated from each other by four ventral scales. Scales on tail keeled, slightly mucronate, imbricate; in transverse and longitudinal rows; dorsal keels sharp, forming four distinct longitudinal ridges. Scales on limbs mostly rhomboidal, imbricate, sharply keeled, and mucronate; smooth on ventral aspect of hind limbs, small and keeled or tuberculate on ventral aspect of upper arms and posterior aspect of thighs. Subdigital lamellae of fingers and toes single, transversely enlarged and smooth; 20 under fourth toe.

Color in life of holotype (Fig. 1). Dorsal background uniformly dark brown with a wide light brown vertebral stripe extending from occiput onto tail; vertebral stripe wider anteriorly; dorsal surface of head bright metallic green medially (rostral, frontonasal, prefrontals, frontal and frontoparietals) and dark brown laterally (supraoculars and supratemporals), with a lateral bright green stripe on each side extending posteriorly from the border between the loreal and the first supraocular, over the superciliaries, to the lateral border of the parietal; lateral aspect of neck with a longitudinal yellowish-green stripe extending posteriorly from mouth commissure, over ventral margin of tympanum, to shoulder; most scales between lateral neck stripe and gular region reddish brown forming a short irregular stripe between last infralabial and shoulder; ventral surface of head light green, brighter laterally; gular and pectoral regions same tone as chin shields but lighter; ventral aspect of body orange with scattered light green or light blue small marks; ventral aspect of tail with dark brown marks that form transverse bars on the posterior half.

Variation. Intraspecific variation in scale counts and measurements in *Alopoglossus viridiceps* sp. n. is presented in Table 2. Color in preservative of holotype is similar to its color in life, except that the bright green tones of the head and orange tones of the venter have faded away.

Color in life of juvenile paratypes QCAZ10671, QCAZ11854–55 is similar to that of the holotype except that these juveniles have a reddish-brown longitudinal stripe extending from the dorsal border of the tympanum to the shoulder and fading away on the flanks (Fig. 3). The orange ventral coloration of male juvenile QCAZ11854 does not extend onto tail as in the holotype; female juvenile QCAZ10671 and juvenile QCAZ11855 (undetermined sex) have a light yellowish green background color on the venter, similar to that on gular region and chin (Fig. 3).

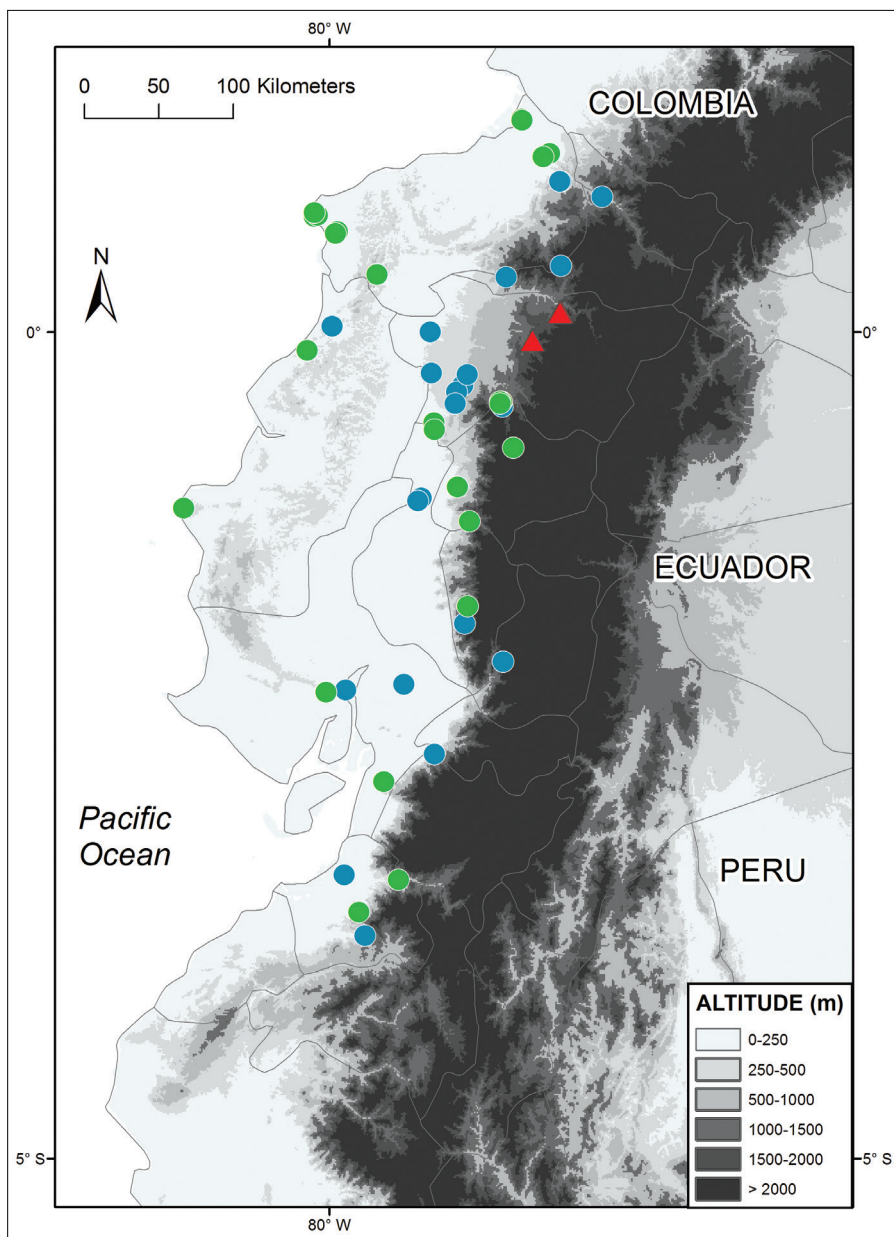


Figure 4. Distribution of *Alopoglossus viridiceps* sp. n. (triangles) and its sister species *A. festae* (circles) in Ecuador. Locality data for *A. festae* was taken both from the literature (blue circles; Almendáriz and Carr 2012; Köhler et al. 2012) and museum specimens (green circles; see Appendix).

Distribution and ecology. *Alopoglossus viridiceps* sp. n. inhabits cloud forests on the Pacific slopes of the Andes in northwestern Ecuador (Fig. 4). It occurs at elevations of 1246–1911 m in the province of Pichincha. Most type specimens were collected at

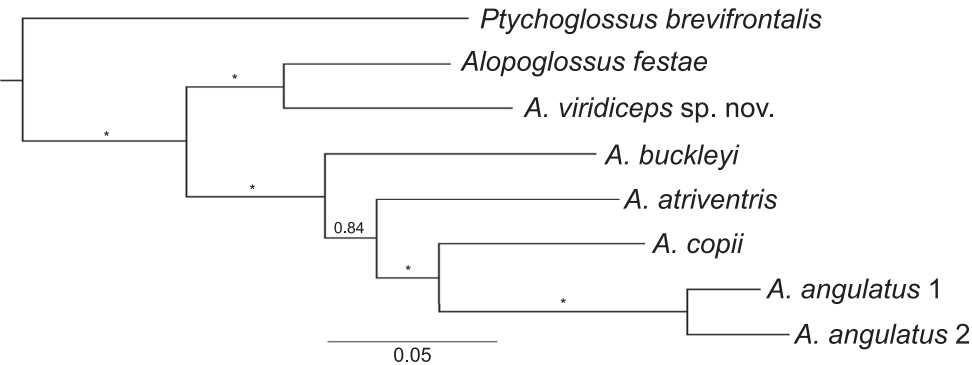


Figure 5. Phylogeny of Alopoglossinae. Majority rule (50%) consensus tree of 36,000 trees obtained from a Bayesian analysis of the mitochondrial gene ND4 and 8 specimens. Asterisks correspond to posterior probability values ≥ 0.97 . Voucher information is presented in Table 1.

Table 3. Pairwise ND4 genetic distances (uncorrected) among samples of alopoglossines included in this study.

Taxon	<i>Alopoglossus angulatus</i> 1	<i>A. angulatus</i> 2	<i>A. atriventris</i>	<i>A. buckleyi</i>	<i>A. copii</i>	<i>A. festae</i>	<i>A. viridiceps</i>
<i>Alopoglossus angulatus</i> 1							
<i>A. angulatus</i> 2	0.060						
<i>A. atriventris</i>	0.159	0.158					
<i>A. buckleyi</i>	0.171	0.166	0.161				
<i>A. copii</i>	0.149	0.156	0.148	0.158			
<i>A. festae</i>	0.163	0.169	0.158	0.171	0.178		
<i>A. viridiceps</i>	0.185	0.185	0.178	0.168	0.180	0.124	
<i>Ptychoglossus brevifrontalis</i>	0.208	0.213	0.205	0.219	0.225	0.197	0.205

Santa Lucía Cloud Forest Reserve, which extends between 1400–2560 m and has an area of 756 ha; annual precipitation ranges from 1500 to 2800 mm, and average annual temperature is recorded at 16 °C (Rivas-Martínez and Navarro 1995). Specimens of *A. viridiceps* sp. n. were found active between 9h30–11h30 on leaf litter in primary forest, or on the border of sugar cane plantations. Other species of small ground lizards collected in the same area include the sphaerodactylid gecko *Lepidoblepharis conolepis*, the gymnophthalmids *Cercosaura vertebralis* and *Echinosaura brachycephala*, as well as an undescribed species of the gymnophthalmid genus *Riama*.

Etymology. The specific epithet *viridiceps* is an adjective derived from the Latin words “viridis” and “ceps”, which mean “green” and “head”, respectively. It refers to the distinctive bright green coloration of the dorsal and ventral aspects of the head of *Alopoglossus viridiceps* sp. n.

Phylogenetic relationships. Of the 596 nucleotide characters included in our analysis 290 were constant, 70 parsimony uninformative, and 236 were parsimony informative.

Selected models of evolution were 012013+I+G+F, TPM2uf+I+G, and 010220+I+G+F for ND4 partitions codon 1, 2, and 3, respectively. The resulting 50% majority rule consensus tree (Fig. 5) supports strongly (PP=1) the monophyly of Alopoglossinae (i.e., *Ptychoglossus* and *Alopoglossus*) and *Alopoglossus*. Within *Alopoglossus* there is a basal split into two strongly supported (PP=1) clades, one containing trans-Andean taxa (*A. festae* and *A. viridiceps* sp. n.), and the other including cis-Andean taxa (*A. angulatus*, *A. atriventris*, *A. buckleyi*, and *A. copii*). Within the cis-Andean clade, *A. angulatus* and *A. copii* are recovered as sister species with maximum support (PP=1), forming a clade sister to *A. atriventris* (PP=0.84); *A. buckleyi* is sister to all other cis-Andean species (Fig. 5).

Uncorrected genetic distances for ND4 are presented in Table 3. Distance values between *Ptychoglossus brevifrontalis* and species of *Alopoglossus* ranged between 0.197–0.225. The genetic distance between *A. viridiceps* sp. n. and its sister species *A. festae* (0.124) is slightly lower than all other interspecific distance values within *Alopoglossus* (0.148–0.185). *A. angulatus*, the only species for which we had two samples, had an intraspecific distance value of 0.06.

Discussion

The phylogenetic tree presented in this paper (Fig. 5) supports strongly the monophyly of *Alopoglossus* and its sister taxon relationship with *Ptychoglossus*, as suggested by previous authors based on morphological evidence (Harris 1994). The basal split between cis-Andean and trans-Andean species of *Alopoglossus* suggests that the uplift of the Andes represented an important event that allowed allopatric speciation in *Alopoglossus*, whether resulting from dispersal or vicariance.

Alopoglossus viridiceps sp. n. can be distinguished readily from its sister species *A. festae* based on morphological and color characters (see Diagnosis). *A. festae* occurs as close as 30 km W from the known distribution of *A. viridiceps* sp. n. below 1000 m (Fig. 4), suggesting that these species originated by allopatric or parapatric speciation. Although we did not attempt to examine variation within *A. festae*, we found differences among some populations of this species that suggest it might represent a species complex as currently circumscribed. A more detailed systematic study of *A. festae*, as well as all species of *Alopoglossus* east of the Andes in Ecuador with extensive geographic sampling is underway.

Alopoglossus viridiceps sp. n. is one of two new species of lizards that have been discovered recently in the same area. The other one is an undescribed species of the gymnophthalmid genus *Riama*. These discoveries indicate that the herpetofauna of the cloud forests in this region is more diverse in species numbers than previously thought. We recommend increasing field surveys in this region as it includes several protected areas (e.g., Santa Lucía Cloud Forest Reserve, Mindo-Nambillo Protected forest, Maquipucuna Reserve, El Cedral Ecological Reserve) that provide an opportunity to find species of lizards that might not occur elsewhere.

Key to the species of *Alopoglossus* (modified from Köhler et al. 2012)

- 1 A double longitudinal row of widened gular scales; dorsal scales lanceolate in transverse rows only.....**2**
- No double longitudinal row of widened gular scales; dorsal scales hexagonal in transverse rows only or rhomboidal in oblique and transverse rows.....**3**
- 2 Fewer than 25 dorsal scales in a transverse row at midbody; no distinct light stripe from mouth commissure to shoulder.....*Alopoglossus festae*
- More than 29 dorsal scales in a transverse row at midbody; distinct light stripe from mouth commissure to shoulder.....*A. viridiceps*
- 3 Dorsal scales hexagonal with parallel lateral edges, in transverse rows only; transverse ventral count 10*A. lehmanni*
- Dorsal scales rhomboidal or lanceolate, in oblique and transverse rows; transverse ventral count 4–8**4**
- 4 Keels on posterior part of dorsum form longitudinal ridges; scales on side of neck large and conical with apparent bare skin between conical scales; longitudinal dorsal count 23–24.....*A. copii*
- Keels on posterior part of dorsum do not form longitudinal ridges; scales on side of neck small and granular or keeled and somewhat imbricate without apparent bare skin between scales; longitudinal dorsal count 24–34**5**
- 5 Scales on side of neck leaf-like (similar in shape to dorsal scales, nongranular) and somewhat imbricate; longitudinal dorsal count 24–28*A. angulatus*
- Scales on side of neck small and granular; longitudinal dorsal count 29–34 **6**
- 6 Ventral scales smooth*A. buckleyi*
- Ventral scales distinctly keeled *A. atriventris*

Acknowledgments

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References

- Almendáriz A, Carr JL (2012) Lista actualizada de los anfibios y reptiles registrados en los remanentes de bosque de la Cordillera de la Costa y áreas adyacentes del suroeste del Ecuador. *Revista Politécnica* 30(3): 184–194.
- Avila-Pires TCS (1995) Lizards of Brazilian Amazonia (Reptilia: Squamata). *Nationaal Natuurhistorisch Museum Zoologische Verhandelingen* 299: 1–706
- Castoe TA, Doan TM, Parkinson CL (2004) Data partitions and complex models in Bayesian analysis: The phylogeny of gymnophthalmid lizards. *Syst Biol* 53(3): 448–469.
- de Queiroz K (1998) The general lineage concept of species, species criteria, and the process of speciation. In: Howard DJ, Berlocher SH (Eds) *Endless Forms: Species and Speciation*. Oxford University Press, Oxford, 57–75.
- de Queiroz K (2007) Species Concepts and Species Delimitation. *Syst Biol* 56(6): 879–886. doi: 10.1080/10635150701701083
- Drummond AJ, Ashton B, Buxton S, Cheung M, Cooper A, Heled J, Kearse M, Moir R, Stones-Havas S, Sturrock S, Thierer T, Wilson A (2010) Geneious v5.5. Biomatters. <http://www.geneious.com>
- Gelman A, Rubin DB (1992) Inference from iterative simulation using multiple sequences. *Stat Sci* 7: 457–511.
- Harris DM (1994) Review of the teiid lizard genus *Ptychoglossus*. *Herpetol Monogr* 8: 226–275.
- Hoogmoed MS, Avila-Pires TCS (1992) Studies on the species of the South American lizard genus *Arthrosaura* Boulenger (Reptilia: Sauria: Teiidae), with the resurrection of two species. *Zoologische Mededelingen Leiden* 66(35): 453–484.
- Köhler G, Diethert H-H, Vesely M (2012) A contribution to the knowledge of the lizard genus *Alopoglossus* (Squamata: Gymnophthalmidae). *Herpetol Monogr* 26(1): 173–188. doi: 10.1655/herpmonographs-d-10-00011.1
- Pellegrino KCM, Rodrigues MT, Yonenaga-Yassuda Y, Sites JW (2001) A molecular perspective on the evolution of microteiid lizards (Squamata, Gymnophthalmidae), and a new classification for the family. *Biol J Linn Soc* 74(3): 315–338. doi: 10.1111/j.1095-8312.2001.tb01395.x
- Posada D (2008) jModelTest: Phylogenetic Model Averaging. *Mol Biol Evol* 25: 1253–1256.
- Rambaut A, Suchard MA, Xie D, Drummond AJ (2013) Tracer v1.6. <http://beast.bio.ed.ac.uk/software/tracer/>
- Rivas-Martínez S, Navarro G (1995) Bioclimatic Map of South America: Bioclimates. Scale 1: 22,000,000. Cartographic Service, University of Leon, Spain.
- Ronquist F, Huelsenbeck JP (2003) MrBayes 3: Bayesian phylogenetic inference under mixed models. *Bioinformatics* 19 (12): 1572–1574.
- Swofford DL (2003) PAUP* Phylogenetic Analysis Using Parsimony (*and Other Methods), v. 4. Sinauer Associates, Sunderland.
- Torres-Carvajal O (2001) Lizards of Ecuador: checklist, distribution, and systematic references. *Smithsonian Herpetological Information Service* 131: 1–35.
- Torres-Carvajal O, Salazar-Valenzuela D, Merino-Viteri A (2014) ReptiliaWebEcuador. Versión 2014.0. Museo de Zoología QCAZ, Pontificia Universidad Católica del Ecuador. <http://zoologia.puce.edu.ec/Vertebrados/reptiles/reptilesEcuador>

- Trefaut RM, Pellegrino KCM, Dixo M, Verdade VK, Pavan D, Argolo AJS, Sites Jr. JW (2007) A new genus of microteiid lizard from the Atlantic forests of state of Bahia, Brazil, with a new generic name for *Colobosaura mentalis*, and a discussion of relationships among the Heterodactylini (Squamata, Gymnophthalmidae). *Am Mus Novit* 3565: 1–27.
- Uetz P (2014) The Reptile Database. <http://www.reptile-database.org>. [accessed at 20 February 2014]

Appendix

Specimens examined

Alopoglossus festae – ECUADOR: *Azuay*: QCAZ 5002, Recinto La López, campamento minero Produmin S.A., -3.08732°N, -79.71493°W, 425 m; QCAZ 7249, Sarayunga 41 km desde Santa Isabel por la vía hacia Pasaje, -3.31423°N, -79.58145°W; *Bolívar*: QCAZ 7952–53, Recinto San Francisco, -1.65977°N, -79.16384°W, 1379 m; *Cotacachi*: QCAZ 7250, between Corazón and Moraspungo, -1.14643°N, -79.15170°W, 873 m; QCAZ 2764, 2783, La Maná, -0.93839°N, -79.22536°W, 250 m; QCAZ 10386, Naranjito, Bosque Integral Otonga (BIO), Finca Familia Tapia, -0.42322°N, -78.95702°W, 1425 m; QCAZ 7835, San Francisco de Las Pampas, -0.43326°N, -78.966733°W; QCAZ 5308, Sigchos, -0.42371°N, -78.96765°W, 1500 m; QCAZ 3527, Sigchos, Asache, -0.70124°N, -78.88795°W; *El Oro*: QCAZ 8987, 8991, Bella María, near Valle Hermoso, -3.51168°N, -79.82026837°W; *Esmeraldas*: QCAZ 6400, 7km W Durango, 1.07961°N, -78.66817°W, 220m; QCAZ 5740, 5742, surroundings of Caimito, río Tongora headwaters, 0.70425°N, -80.07254°W, 14 m; QCAZ 5261, Caimito, 0.69755°N, -80.09014°W, 121 m; QCAZ 8442–43, Caimito, 0.72096°N, -80.09117°W, 518 m; QCAZ 6990, El Barro, 0.59500°N, -79.96300°W; QCAZ 6190, La Tortuga, 0.60792°N, -79.95050°W, 91 m; QCAZ 7554, 5 km from Playón de San Francisco on way to Urbina, 1.05983°N, -78.70742°W, 136 m; QCAZ 6874, Bilsa Ecological Reserve, 0.34705°N, -79.71140°W; QCAZ 1404, San Lorenzo, 1.28130°N, -78.83476°W; *Guayas*: QCAZ 9114, 9121, 9131, 9147, 9158, 9161, Bosque Protector Cerro Blanco, -2.17833°N, -80.02139°W, 281 m; QCAZ 3325–26, Naranjal, 15 min on road to Pasaje, Nueva Unión Campesina cooperative, -2.72159°N, -79.67007°W, 45 m; *Los Ríos*: QCAZ 2180, 2222, Centro Científico Río Palenque (CCRP), 48 km on road Santo Domingo-Quevedo, -0.592133°N, -79.36395°W; *Manabí*: QCAZ 11428, Jama Coaque, 3.12 km W Camarones, -0.1187°N, -80.1231°W, 349 m; QCAZ 11508, 11514, Pacoche Lodge, -1.06675°N, -80.88100°W, 335 m; QCAZ 4643, 5885, Jama Coaque Reserve, -0.09098°N, -80.14719°W; *Pichincha*: QCAZ 5080, río Chirapi headwaters, 0.116°N, -78.91 °W; QCAZ 1425, ENDESA, forest reserve near Puerto Quito, 0.098°N, -79.117°W; QCAZ 6735, Mindo, -0.05067°N, -78.77188°W.

Four new Mouse Spider species (Araneae, Mygalomorphae, Actinopodidae, *Missulena*) from Western Australia

Laura Tavares Miglio^{1,†}, Danilo Harms^{2,3,4,‡},
Volker Wilhelm Framenau^{4,3,2,§}, Mark Stephen Harvey^{3,2,5,6,7,||}

1 Laboratório de Aracnologia, Museu Paraense Emílio Goeldi, Caixa Postal 399, 66017-970 Belém, PA, Brazil **2** School of Animal Biology, The University of Western Australia, 35 Stirling Highway, Crawley, Western Australia 6009, Australia **3** Department of Terrestrial Zoology, Western Australian Museum, Locked Bag 49, Welshpool DC, Western Australia 6986, Australia **4** Phoenix Environmental Sciences Pty Ltd, 1/511 Wanneroo Road, Balcatta, Western Australia 6021, Australia **5** School of Natural Sciences, Edith Cowan University, Joondalup, Western Australia 6027, Australia **6** Division of Invertebrate Zoology, American Museum of Natural History, 79th Street @ Central Park West, New York, New York 10024–5192, USA **7** Department of Entomology, California Academy of Sciences, Golden Gate Park, San Francisco, California 94103–3009 USA

† <http://zoobank.org/3D46F4E6-6525-47E5-AD08-E90D9CA6F6AC>

‡ <http://zoobank.org/7BABB8FF-8CFF-4E2C-ACDE-3E5614685C55>

§ <http://zoobank.org/9D67C6B0-37C2-4009-BD30-D02C4136F562>

|| <http://zoobank.org/FF5EBAF3-86E8-4B99-BE2E-A61E44AAEC2C>

Corresponding author: Laura Tavares Miglio (lauramiglio@gmail.com)

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Abstract

Four new species of the Mouse Spider genus *Missulena* Walckenaer, 1805 (family Actinopodidae) are described from Western Australia based on morphological features of adult males. *Missulena leniae* **sp. n.** (from the Carnarvon and Yalgoo biogeographic regions), *Missulena mainae* **sp. n.** (Carnarvon), *Missulena melissae* **sp. n.** (Pilbara) and *Missulena pinguipes* **sp. n.** (Mallee) represent a broad spectrum of morphological diversity found in this genus and differ from other congeners by details of the male copulatory bulb, colour patterns, eye sizes, leg morphology and leg spination. Two of the species, *M. pinguipes* **sp. n.** and *M. mainae* **sp. n.**, are characterised by swollen metatarsi of the fourth legs in males, a feature not previously recorded in the family. A key to males of all named *Missulena* species from Australia is presented and allows their identification based on external morphology.

Keywords

Biodiversity, Gondwanan fauna, systematics, taxonomy, trapdoor spiders

Introduction

The mygalomorph spider family Actinopodidae Simon, 1892 has a southern Gondwanan distribution with species found in the Neotropical and Australasian regions, specifically the tropical and temperate zones of Australia, South and Central America. The family includes 42 described species in three genera: the Neotropical *Actinopus* Perty, 1833 (27 described species), *Missulena* Walckenaer, 1805 from Australia and Chile (13 species), and the exclusively Chilean genus *Plesiolenia* Goloboff & Platnick, 1987 (2 species) (Platnick 2014).

Species belonging to *Missulena*, commonly referred to as Mouse Spiders, are amongst the most recognisable Australian arachnids, with males of *M. insignis* (O. Pickard-Cambridge, 1877), *M. langlandsi* Harms & Framenau, 2013, *M. occatoria* Walckenaer, 1805 and *M. reflexa* Rainbow & Pulleine, 1918 displaying conspicuous red fangs and cephalic areas. Adult males wander during the day, adding to their prominent status amongst naturalists and resulting in their frequent illustration in field guides (e.g. Brunet 1994; Brunet 2000; Mascord 1970). Not all species are colourful and the red markings can be reduced, e.g. in *M. hoggi* Womersley, 1943, or entirely absent as in *M. dipsaca* Faulder, 1955, *M. granulosa* (O. Pickard-Cambridge, 1869), *M. faulderi* Harms & Framenau, 2013, *M. rutraspina* Faulder, 1995 and *M. torbayensis* Main, 1996. Mouse spiders have also received attention due to the toxicity of their venom that appears to be similar in composition to that of Australian funnel-web spiders (family Hexathelidae); however, severe cases of envenomation are rare and not all species appear equally harmful (Herzig et al. 2008; Isbister 2004; Rash et al. 2000).

Several species, namely the type species *M. occatoria*, but also *M. granulosa* and *M. insignis*, were amongst the first spiders to be collected and described from Australia, resulting in a confusing taxonomic history because early type localities were not recorded (e.g. “New Holland” for the nominate species *M. occatoria*), old taxonomic descriptions were poor by modern standards, and some type specimens appear to be lost (Main 1985).

The first attempt towards a more integrated taxonomy (Womersley 1943) recognised six species, only four of which are known from both male and female specimens. Little taxonomic work was undertaken subsequently, with the description of *M. pruinosa* from the Northern Territory by Levitt-Gregg (1966). Main (1985) catalogued all species, summarised the taxonomic literature and provided preliminary distribution data. Her contribution stimulated several subsequent taxonomic papers, all adding additional species from Western Australia: *M. dipsaca*, *M. rutraspina* (both Faulder 1995b), *M. torbayensis* (Main 1996), and more recently *M. faulderi* and *M. langlandsi* (both Harms

and Framenau 2013). It was also after the publication of Main's (1985) catalogue that that the first Chilean representative, *M. tussulena* Goloboff, 1994, was described.

In addition to taxonomic advances, the major phylogenetic treatises of Raven (1985) and Goloboff and Platnick (1987) developed a diagnosis of *Missulena* against other mygalomorph spiders: the anterior row of eyes is almost straight, the posterior median eyes are closer to the anterior lateral eyes than the posterior lateral eyes, the male pedipalps are shorter than the first leg, the patella of the first leg has robust spines, the sternum is rebordered, and the male pedipalp embolus is almost straight and thinner than that of other Actinopodidae.

Missulena currently has the highest species diversity in Western Australia where ten of the 12 Australian species occur, six of which are endemic to the state (Table 1). Recent large-scale environmental surveys conducted in Western Australia (e.g. Durrant et al. 2010; Main et al. 2000) have discovered additional morphospecies and confirm the previous notion that the diversity of this genus is underrepresented by the current taxonomy (Harms and Framenau 2013; Main 1985). It is clear, that the species of Australian *Missulena* known to date represent merely a fraction of the actual species diversity in this region.

The aim of this paper is twofold. Firstly, we add four new species of *Missulena* to the currently described Australian fauna, resulting in a total of 16 species (Table 1). These new species have very distinctive male morphologies and differ clearly from all other named species although the taxonomic status of some of these remains poorly resolved. Secondly, we provide a key that aids in the identification of males of all de-

Table 1. Distribution of *Missulena* species in Australia.

Species	Distribution	Remarks/selected source ¹
<i>M. bradleyi</i> Rainbow, 1914	Qld, NSW, Vic	Faulder (1995b), Raven and Seeman (2008), Walker et al. (2003)
<i>M. dipsaca</i> Faulder, 1995	NSW, Vic, SA, WA, Qld	Faulder (1995b)
<i>M. faulderi</i> Harms & Framenau, 2013	WA	Harms and Framenau (2013)
<i>M. granulosa</i> (O. Pickard-Cambridge, 1869)	WA	Faulder (1995a)
<i>M. hoggi</i> Womersley, 1943	WA	Womersley (1943)
<i>M. insignis</i> (O. Pickard-Cambridge, 1877)	WA	Faulder (1995a)
<i>M. langlandsi</i> Harms & Framenau, 2013	WA	Harms and Framenau (2013)
<i>M. leniae</i> sp. n.	WA	This study
<i>M. mainae</i> sp. n.	WA	This study
<i>M. melissae</i> sp. n.	WA	This study
<i>M. occatoria</i> Walckenaer, 1805	NSW, Qld, Vic, ACT, SA, NT, WA	Type locality unknown; Faulder (1995a)
<i>M. pinguipes</i> sp. n.	WA	This study
<i>M. pruinosa</i> Levitt-Gregg, 1966	Qld, WA, NT	Raven and Seeman (2008), Faulder (1995a)
<i>M. reflexa</i> Rainbow & Pullleine, 1918	SA	Womersley (1943)
<i>M. rutraspina</i> Faulder, 1995	WA, SA, Vic	Faulder (1995b)
<i>M. torbayensis</i> Main, 1996	WA	Main (1996)

¹ published literature and university theses only

scribed species. A comprehensive key has not been published since Womersley (1943), although most species were described since then.

A comprehensive revision of *Missulena*, which includes a considerable undocumented fauna is beyond the scope of this study as it would require substantial funding and full-time commitment.

Material and methods

Morphology

Specimens used for morphological examination were preserved in 75% ethanol. Material was examined using a Leica MZ16A stereomicroscope. Digital images were taken using a Leica DFC 500 digital camera attached to a Leica MZ16A stereomicroscope controlled by the Leica Application Suite Version 3.7. This program allows the alignment of images taken at different focal planes (here ca. 20–40 images) and combines them into a single image. The images were edited and formatted in Adobe Photoshop, version CS5.

The specimens examined for this study are lodged in the Western Australian Museum, Perth, Australia (WAM). We also examined type material of all Australian *Missulena* that was available to us (Table 2).

The distribution data for species is described within the context of the Interim Biogeographic Regionalisation for Australia (IBRA) (Department of the Environment 2013).

All measurements are expressed in millimetres. The format of the descriptions and measurements follows Griswold and Ledford (2001), except for the spination pattern of the legs that is described according to Harms and Framenau (2013). Spine counts were taken from the right legs. The number of teeth on the claws is given as the formula “leg number: number of teeth of lateral claws/number of teeth of median claw”. The leg formula is given as the order of the leg lengths from longest to shortest. The leg “index” is given here as the leg length divided by carapace length and indicates the ratio of leg lengths versus carapace. The term “rasps” refers to the presence of short but strong conical spines on the patellae of all legs. The presence of such rasps on patella I is a potential synapomorphy for *Missulena* species (Goloboff and Platnick 1987).

The following abbreviations were used:

Morphology: (EL) embolar lamella, (DET) distal embolar tooth, (BEI) basal embolar intumescence, (d) dorsal, (v) ventral, (p) prolateral, (r) retrolateral, (PME) posterior median eyes, (PLE) posterior lateral eyes, (ALE) anterior lateral eyes, (AME) anterior median eyes, (MOQ) median ocular quadrangle, (OAL) ocular area length, (OAW) ocular area width, and (HF) height from the fovea.

Distribution: (NSW) New South Wales, (Qld) Queensland, (Vic) Victoria, (SA) South Australia, (WA) Western Australia, (ACT) Australian Capital Territory, (NT) Northern Territory.

Table 2. Type material of Australian *Missulena* examined for this study.

Species	Type	Location and repository
<i>M. bradleyi</i> Rainbow, 1914	holotype male allotype female	North Sydney (NSW) (AM KS6402), Willoughby (NSW) (AM KS6401)
<i>M. dipsaca</i> Faulder, 1995	holotype male	Junee (NSW) (AM KS9308)
<i>M. faulderi</i> Harms & Framenau, 2013	holotype male paratype male	Jinayri (WA) (WAM T97017), Jinayri (WA) (WAM T96132)
<i>M. langlandsi</i> Harms & Framenau, 2013	holotype male paratype male	Newman (WA) (WAM T115948), Newman (WA) (WAM T112076)
<i>M. pruinosa</i> Levitt-Gregg, 1966	holotype male	Groote Eylandt Island (NT) (AM KS6403)
<i>M. reflexa</i> Rainbow & Pulleine, 1918	holotype male	Keith (SA) (AM KS6404)
<i>M. torbayensis</i> Main, 1996	holotype male	Torbay (WA) (WAM 95/2)

Museums: (WAM) Western Australian Museum, (AM) Australian Museum.

The taxonomic key is based on a complete inventory of the available literature and examination of type material of many species. We have restricted this key to males because nine of the now 16 Australian described species are known from the male gender only; females remain unknown and are morphologically less distinct. We note that this key is preliminary because many additional unnamed species are present in collections, at least from Western Australia.

Systematics

Family Actinopodidae Simon, 1892

Missulena Walckenaer, 1805

Missulena Walckenaer, 1805: 8. Type species: *Missulena occatoria* Walckenaer, 1805, by monotypy.

Eriodon Latreille, 1806: 85. Type species: *Eriodon occatorius* Latreille, 1806, by monotypy.

Missulena melissae sp. n.

<http://zoobank.org/ABC49948-F3B9-4F6C-9C86-67B18B20605A>

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

Figs 1A, 2A–J, 3A–J

Type material. AUSTRALIA: Western Australia: holotype male, Millstream-Chichester National Park, 6 km N. of Millstream Homestead, site PW11, 21°32'24.8"S, 117°03'25.2"E, 15 July 2003–11 October 2004, wet pitfall trap, Department of CALM staff (WAM T97323). Paratypes: 2 males, same data as holotype, except Corunna Downs, 52.5 km N. of Nullagine, Pilbara Biological Survey site NW11,

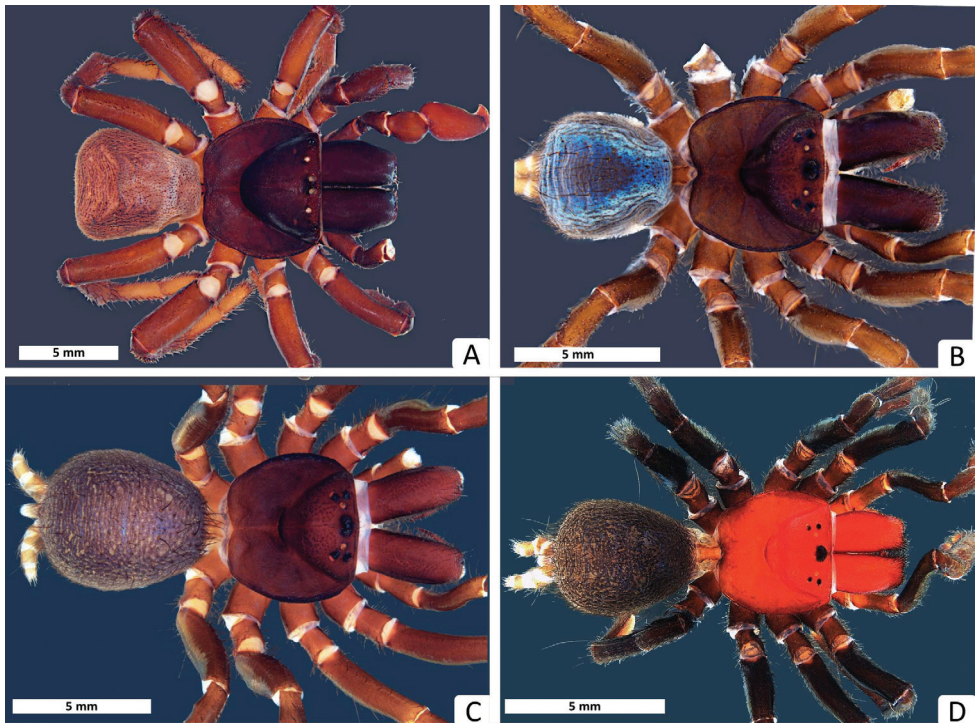


Figure 1. Dorsal habitus of species described in this paper: **A** *Missulena melissae* sp. n., holotype male from Millstream-Chichester National Park (WAM T97323) **B** *Missulena pinguipes* sp. n., holotype male from Digger Rocks (WAM T92331) **C** *Missulena leniae* sp. n., holotype male from Nanga Station, Shark Bay (WAM T96784) **D** *Missulena mainae* sp. n., holotype male from Quobba Station, Cape Cuvier (WAM T96782).

21°24'27.7"S, 120°04'16.7"E, 3 August 2003–20 October 2004, Department of CALM staff (WAM T120931).

Etymology. The specific epithet is a patronym in honour of Melissa Thomas, the third author's partner, for her continuing support of late-night arachnological endeavours.

Diagnosis. Males of *M. melissae* sp. n. differ from the two other species with a brown body colour, strongly-sclerotised rastellum with thick spines, smooth and glabrous chelicerae with prominent horizontal ridges and short claws (i.e. *M. faulderi* and *M. rutraspina*) by details of the bulb and somatic morphology: embolus short and with a distal tooth (exceeding length of the bulb and without distal tooth in *M. faulderi*), carapace length ca. 4 cm (3.5 cm in *M. rutraspina*), patella I–III with rasps (patella III only in *M. faulderi*), rastellum on a low mound (mound distinct in *M. faulderi*), inner row of cheliceral teeth divided (first six teeth fused in *M. faulderi*), and pedipalp patella and tibia swollen (much more slender in *M. faulderi*). Males of *M. rutraspina* differ in having a simple embolus tip without processes, a straight embolus, rasps on patella III only, rastellum on a distinct mound, inner row of cheliceral teeth with six spaced teeth, and pedipalp tibia and patella more slender. The female of *M. melissae* sp. n. is unknown.

Description. Adult male, based on holotype (WAM T97323). Medium-sized mygalomorph spider (total length 8.00).

Colour: carapace (Fig. 1A) dark reddish-brown, margins dark brown; eye region (Fig. 2B) dark brown, anterior median eyes on black tubercle; chelicerae (Fig. 3I) dark reddish-brown, fangs reddish-brown; abdomen (Fig. 1A) pale brown with a grey metallic spot in dorsal region; sternum (Fig. 3H) yellowish-brown, margins contoured dark yellowish-brown, sigillae yellowish-brown; labium (Fig. 3G) and maxillae (Fig. 3C) dark reddish-brown; legs (Figs 1A, 3A–B) yellowish brown, tarsi and metatarsi ventrally yellow; spinnerets (Fig. 3J) pale gray, spigots white.

Carapace: 3.81 long, 4.0 wide; clypeus 0.13; fovea 2.18; caput and eye region (Fig. 2A–C) laterally elevated, strongly arched; fovea (Fig. 2A, C) very deep, wide and strongly procurved, medially extending as triangular depression, pars cephalica smooth around the eyes and between the eyes and fovea, pars thoracica rugose with bands of fine, random fissures centered around fovea (Fig. 2C).

Eyes: OQ 3.61 times wider than long, occupying 1.12 of cephalic width; OAW 3.54; OAL 2.68; IPF 0.40; width of anterior eye group 2.95, with of posterior group 2.36, OQ length 0.81; PME 0.19; PLE 0.22; ALE 0.26; AME 0.22, AME on tubercle, 0.27 long, 0.62 wide; AME inter-distance 0.65; AME to ALE 1; AME to PME 0.40; PLE to ALE 0.55; PLE to PME 0.41; PME inter-distance 1.41; PME to ALE 0.55; eye region (Fig. 2B) with reduced setation although some setae present anterior to AME and between posterior eyes and fovea.

Chelicerae: 2.95 long, 1.54 wide; distally broad, diagonal, slightly conical; edges smoothly rounded; with weak transverse ridges which distally extend over entire length (Fig. 3I), without setae in area of transverse ridges but with ca. 60 short setae along inner margin of chelicera; rastellum developed, slightly pronounced, consisting of a sclerotised process with 3 strong conical spines and 12–14 disordered setae (Fig. 3I), 12–13 long setae extend forward from anterior margin of each chelicera and cover base of fang, setae largest on latero-ventral side; inner margin of cheliceral furrow with 3 rows of teeth (Fig. 3E); prolateral (inner) row with ca. 12 teeth, 3 proximal teeth fused together and the rest spaced; intermediate row with 9 proximal, spaced teeth; retrolateral (outer) row with 3 proximal, spaced teeth.

Maxillae: 1.86 long; 1.31 wide, longer than wide (Fig. 3C, D), with ca. 57 pointed cusps along entire anterior margin, distally pointed and extended into a prominent heel.

Labium: 1.04 long, 0.77 wide; conical, ca. 20 pointed cusps anteriorly (Fig. 3G); labiosternal suture developed as a shallow groove; a pair of sigilla near labiosternal suture (Fig. 3H), developed as irregular, poorly-defined patches.

Sternum: 2.27 long, 2.09 wide; oval and rebordered (Fig. 3H), with prominent setae, arranged irregularly but denser lateral to labium; 4 pairs of sigillae, anterior and second pair (anterior-posterior) smallest and poorly defined, third pair bigger than 2 anterior pairs and poorly defined, and posterior pair bigger than all others, roughly oval and well defined, 3 posterior sigillae slightly depressed.

Abdomen: 4 long, 3.54 wide; roughly oval (Fig. 3F); 4 spinnerets (Fig. 3J), PLS 0.72 long, 0.45 wide, apical segment domed; PMS 0.40 long, 0.13 wide.

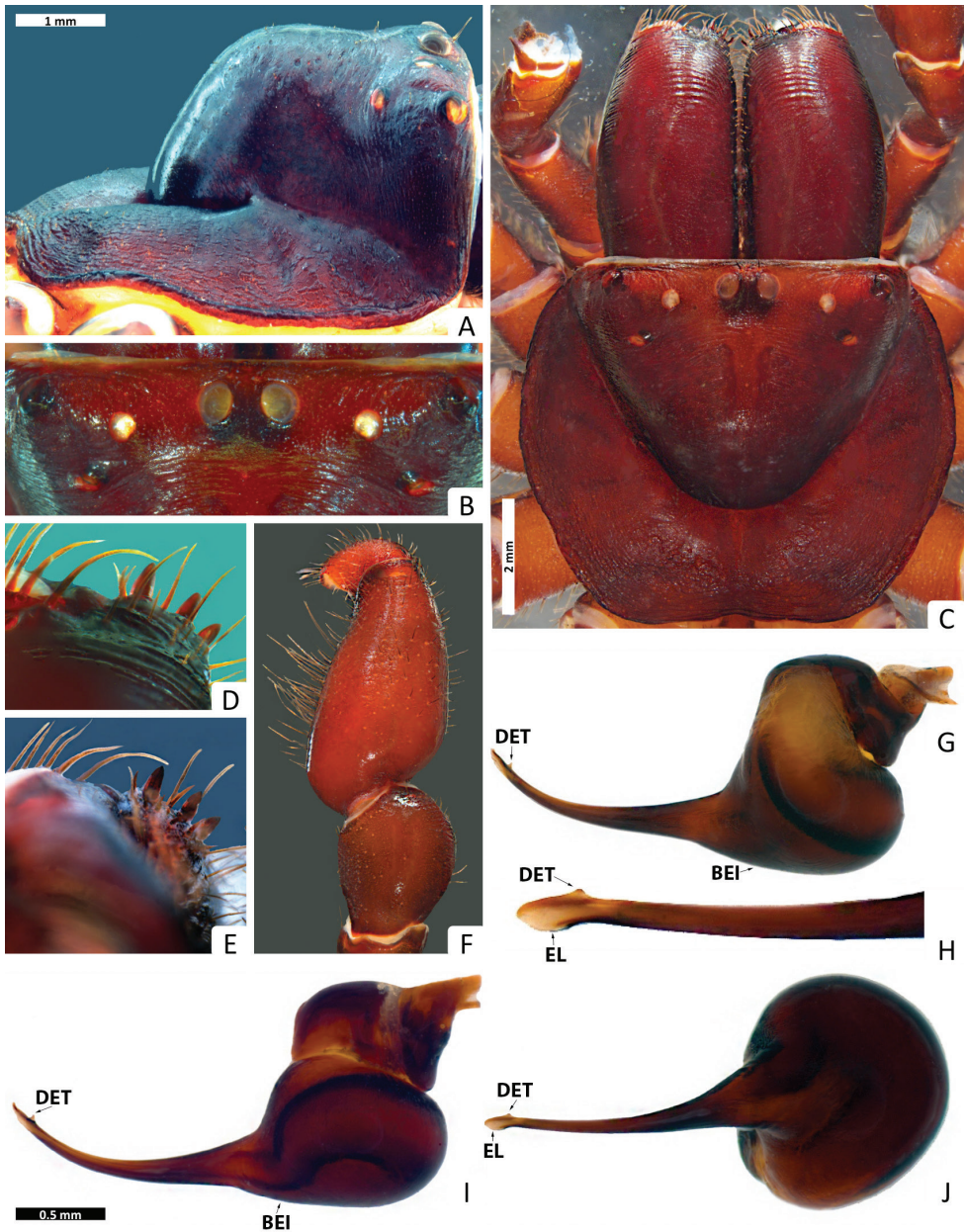


Figure 2. *Missulena melissae* sp. n., holotype male (WAM T97323): **A** carapace, lateral view **B** eye group, dorsal view **C** carapace, dorsal view **D** rastellum, dorsal view **E** same, ventral view **F** pedipalp, proventral view **G** bulb and embolus, retrolateral view **H** embolus, ventral view **I** bulb and embolus, prolateral view **J** same, ventral view. Arrows: (EL) embolar lamella, (DET) distal embolar tooth, and (BEI) basal embolar intumescence.

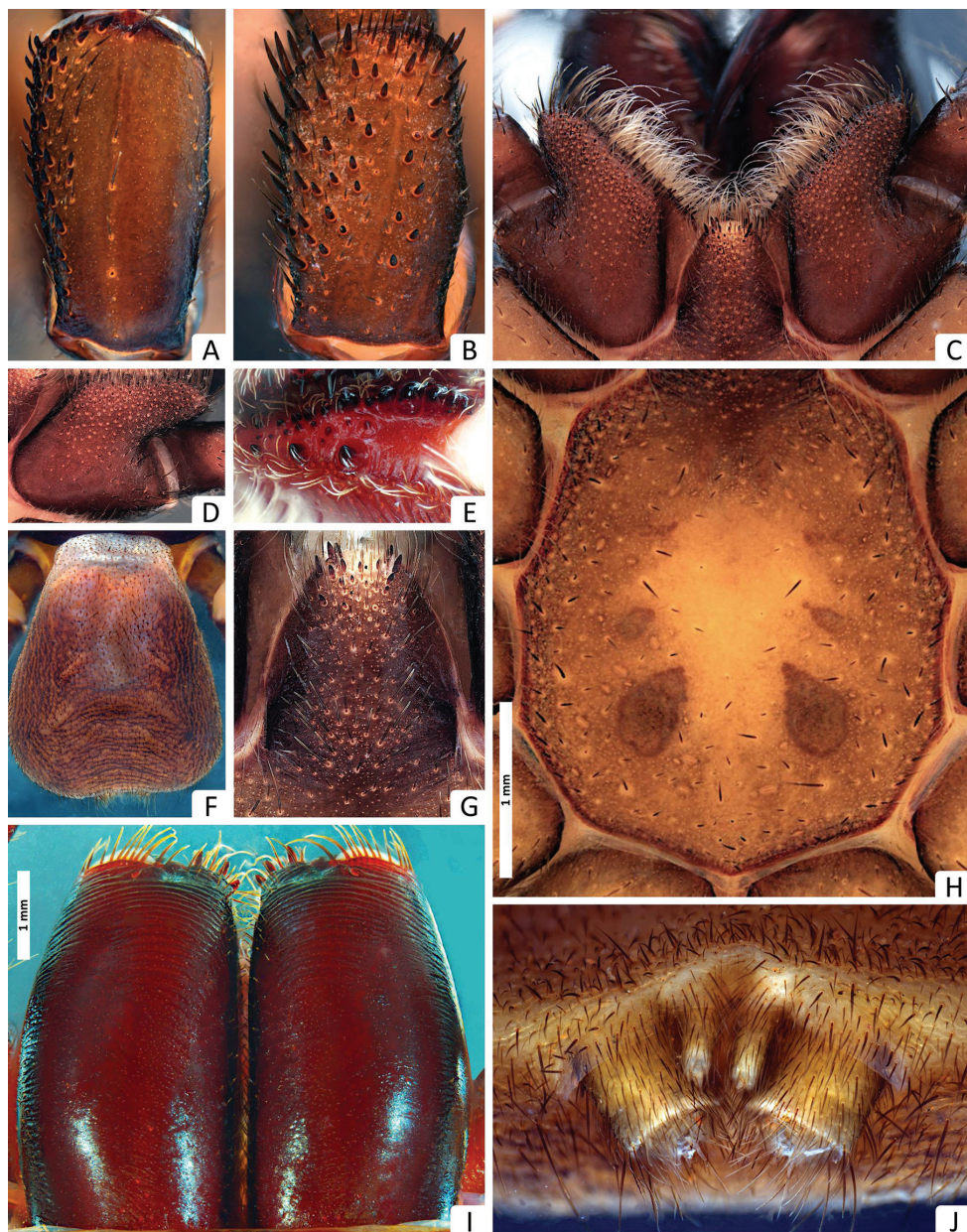


Figure 3. *Missulena melissae* sp. n., holotype male (WAM T97323): **A** patella II, dorsal view **B** patella III, dorsal view **C** coxae and labium of pedipalp, ventral view **D** coxae of pedipalp, ventral view **E** cheliceral groove, retroventral view **F** abdomen, dorsal view **G** labium, ventral view **H** sternum and sigillae, ventral view **I** chelicerae, dorsal view **J** spinnerets, ventral view.

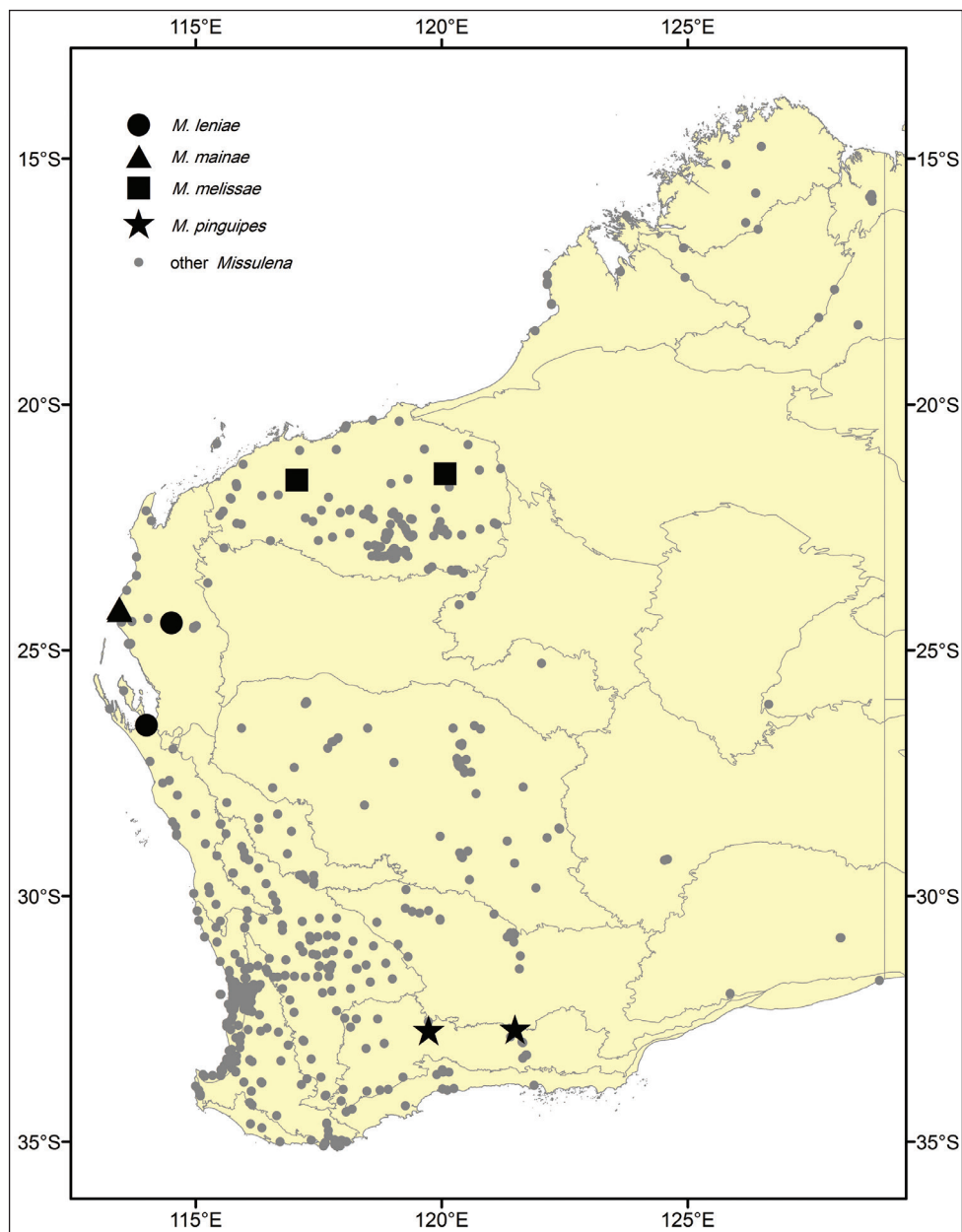


Figure 4. Distribution records of *Missulena* spp. in Western Australia.

Pedipalp: length of trochanter 0.85, femur 2.11, patella 0.33, tibia 0.66, tarsus 0.18; entire palp is aspinose, femur more than 3 times longer than tibia, tarsus terminally blunt (Fig. 2F); bulb pyriform and rather stout than globular (Fig. 2G, I–J), 2 strongly sclerotised sections connected by a velar median structure (“haematodocha”, Fig. 2G, I); bulb strongly twisted proventrally (Fig. 2I); embolus short, with an

intumescence in proximal region (BEI), a strong curvature in the duct in prolateral view, tapering and slightly twisted medially (Fig. 2I, J); embolus tip triangular, with a lamella (EL) well-developed and a prominent tooth (DET) in all views (Fig. 2G–J).

Legs: with few brown setae, ventral setae of tibiae and metatarsi generally much longer and thicker than dorsal setae and bent towards the exterior; dorsal, lateral and ventral setae of tibiae and metatarsi longer than the diameter of respective segment; preening comb distal in tarsi, very small and plain; metatarsi and tarsi I and II ascopulate, metatarsi and tarsi III and IV densely scopulate but in metatarsi, the length of scopula reaches only 80% of the segment length. Metatarsi I and II with ca. 23, 33 fine ventral setae distally, respectively. *Leg measurements*: Leg I: femur 2.37, patella 2.00, tibia 2.00, metatarsus 2.00, tarsus 1.00, total 9.37. Leg II: 2.25, 1.87, 1.62, 2.12, 1.00, 8.87. Leg III: 2.5, 1.62, 1.5, 2.37, 1.00, 9.00. Leg IV: 3.25, 1.62, 2.00, 2.25, 1.37, 10.5. Formula 4123.

Trichobothria: arranged in discontinuous rows; tibiae I–II with 2 rows of 2 in retrodorsal and prodorsal position, respectively; tibiae III with 2 rows of 2 in retrolatero-dorsal and proximo-prodorsal position, respectively; tibiae IV with 2 rows, the first row with 2 in retrolatero-dorsal and the second row with 3 in proximolateral position; metatarsi with 5 in proximo-dorsal position, tarsi I+II with 4 and 6 medio-dorsally, respectively, III+IV with 5 and 6 medio-dorsally, respectively, all trichobothria in medio-dorsal position.

Leg spination: pedipalp aspinose; leg I: tibia rv0–0–0, v3–3–7, pv1–2–0, d0–0–0; metatarsus rv2–1–1, v2–3–5, pv0–0–0, d0–0–0; tarsus rv1–4–3, v2–7–3, pv2–2–2, d0–0–0; leg II: tibia rv0–0–0, v0–0–0, pv0–1–0, d0–0–0; metatarsus rv0–0–0, v0–0–0, pv0–0–0, d0–0–0; tarsus rv3–5–4, v1–2–2, pv1–3–2, d0–0–0; leg III: tibia rv0–0–0, v0–3–2, pv2–2–2, d2–1–3; metatarsus rv2–2–3, v0–0–0, pv3–3–4, d8–4–2; tarsus rv3–5–4, v0–0–1, pv1–3–4, d0–2–2; leg IV: tibia rv0–2–0, v2–4–4, pv1–1–2, d3–0–0; metatarsus rv1–3–2, v0–0–0, pv1–3–4, d0–0–1; tarsus rv4–9–13, v0–0–1, pv1–4–6, d0–0–2; patellae I and II with ca. 53 and 35 rasps, in 8 and 6 oblique rows prolatero-dorsally, respectively; patella III with ca. 59 rasps widespread in dorsal view (Fig. 4B); patella IV with 19 rasps, in 8 and 6 oblique rows prolatero-dorsally, median rows shorter than lateral rows and with less spines, distal spines forming an interrupted crown of spines in the border of the article (Fig. 4B).

Tarsal claws: leg I: 5–4/1; leg II: 6–6/1; leg III: 5–4/1; leg IV: 3–3/1; claws slightly shorter than spines of tarsi.

Variation in paratypes ($N=2$): total length 6.72–7.36; carapace 3.45 long, 3.90–4.36 wide; number of labial cuspules 14–16, maxillary cuspules 48–67; rastellum with 1–4 thick and conical spines.

Distribution. This species is known from the type locality Millstream-Chichester National Park and Corunna Downs in the Pilbara biogeographic region of Western Australia (Fig. 4).

Habitat. All specimens were collected in pitfall traps. The collecting sites were dominated by *Acacia* spp., with one site having a eucalypt over-storey (McKenzie et al. 2009).

***Missulena pinguipes* sp. n.**

<http://zoobank.org/4F164298-F7D9-43BC-900F-8B04985F0999>

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

Figs 1B, 5A–J, 6A–K

Type material. AUSTRALIA: Western Australia: holotype male, Digger Rocks, 89.1 km SE. of Hyden (site DR10), 32°43'58"S, 119°44'03"E, 30 November 2006, dry pitfall trap, D. Kamien (WAM T92331). Paratypes: 4 males, same data as holotype (WAM T92332, T92333, T92334, T92336); 1 male, Exclamation Lake (site SG09B), 32°42'26"S, 121°29'31"E, 23–29 April 2002, dry pitfall trap, R. Teale, G. Harold, A. Sanders and P. Higgs (WAM T45910).

Etymology. The specific epithet is a Latin adjective referring to the swollen metatarsi IV of males (*pinguis*, fat; *pes*, foot).

Diagnosis. Males of *M. pinguipes* sp. n. differ from all other named species of the genus, except *M. mainae* sp. n. by the swollen metatarsus IV (Fig. 6K). They differ from *M. mainae* sp. n. by the brown carapace and chelicerae, which are red in the latter. Females of *M. pinguipes* sp. n. are unknown.

Description. Adult male, based on holotype (WAM T92331). Medium-sized mygalomorph spider (total length 5.00).

Colour: carapace (Fig. 5A, C) dark reddish-brown, margins dark brown; eye region (Fig. 5B) dark brown, anterior median eyes on black tubercle; chelicerae (Fig. 6I) dark reddish-brown, fangs reddish-brown; abdomen (Fig. 1B, 6F) iridescent blue with light blue longitudinal streaks; sternum (Fig. 6H) yellowish-brown, margins contoured dark yellowish-brown, sigillae yellowish-brown; labium and maxillae dark yellowish-brown (Fig. 6C, G); legs (Fig. 1B) yellowish-brown, tarsi and metatarsi ventrally yellow; spinnerets (Fig. 6J) pale gray, spigots white.

Carapace: 2.25 long, 2.37 wide; clypeus 0.17; fovea 0.71; caput and eye region (Fig. 5A) laterally elevated, strongly arched; fovea (Fig. 5C) very deep and strongly procurved, medially extending as triangular depression (Fig. 5C), pars cephalica with few granulations around the eyes and between the eyes and fovea, pars thoracica rugose with bands of fine, random fissures centered around fovea (Fig. 5C).

Eyes: OQ 3.5 times wider than long, occupying 0.83 of cephalic width; OAW 1.97; OAL 1.42; IPF 0.74; width of anterior eye group 1.35, with of posterior group 1.17, OQ length 0.38; PME 0.1; PLE 0.1; ALE 0.08; AME 0.1, AME on tubercle, 0.31 long, 0.41 wide; AME inter-distance 0.1; AME to ALE 0.47; AME to PME 0.11; PLE to ALE 0.22; PLE to PME 0.2; PME inter-distance 0.65; PME to ALE 0.27; eye region (Fig. 5B) with reduced setation although some setae present anterior to AME, between lateral eyes and between posterior eyes and fovea.

Chelicerae: 1.57 long, 0.82 wide; distally broad, diagonal, slightly conical; edges smoothly rounded; with weak transverse ridges which distally extend over entire length (Fig. 6I), without setae in area of transverse ridges but with ca. 30 setae along inner margin of chelicera; rastellum developed, pronounced, consisting of a sclerotised process with 9 strong conical spines and 18–22 disordered setae (Fig. 5D), 9 long setae

extend forward from anterior margin of each chelicera and cover base of fang, setae largest on latero-ventral side; inner margin of cheliceral furrow with 3 rows of teeth (Fig. 6E); prolateral (inner) row with ca. 6 teeth, all teeth spaced; intermediate row with 3 proximal, spaced teeth; retrolateral (outer) row with 3 proximal, spaced teeth; with 1 distal tooth.

Maxillae: 0.91 long; 0.71 wide, almost square (Fig. 6C, D), ca. 64 pointed cuspules along entire anterior margin, distally pointed and extended into a prominent heel.

Labium: 0.51 long, 0.45 wide; conical, ca. 17 pointed cuspules anteriorly (Fig. 6G); labiosternal suture developed as a shallow groove; a pair of sigilla near labiosternal suture (Fig. 6H), developed as irregular, poorly-defined patches.

Sternum: 1.37 long, 1.48 wide; oval and rebordered (Fig. 6H), with prominent setae, arranged irregularly but denser lateral to labium; 4 pairs of sigillae, anterior and second pair (anterior-posterior) smallest but well defined, third pair bigger than 2 anterior pairs and well defined, and posterior pair bigger than all others, roughly oval but not well defined, all sigillae slightly depressed.

Abdomen: 2.28 long, 2.00 wide; roughly oval (Fig. 6F); 4 spinnerets (Fig. 6J), PLS 0.85 long, 0.37 wide, apical segment domed; PMS 0.31 long, 0.14 wide.

Pedipalp: length of trochanter 0.74, femur 1.62, patella 0.92, tibia 1.51, tarsus 0.55; entire palp is aspinose, femur longer than tibia, tarsus terminally blunt (Fig. 5F); bulb pyriform and rather stout than globular (Fig. 5G–J), 2 strongly sclerotised sections connected by a velar median structure (“haematodocha”); bulb strongly twisted proventrally (Fig. 5G, I); embolus short, tapering and slightly twisted medially (Fig. 5H, J); embolus tip triangular, with a lamella well-developed (EL) and a very small tooth (DET) in ventral view (Fig. 5H, J).

Legs: with few brown setae, ventral setae of tibiae and metatarsi generally much longer and thicker than dorsal setae and bent towards the exterior; dorsal, lateral and ventral setae of tibiae and metatarsi longer than the diameter of respective segment; preening comb distal in tarsi, very small and plain; metatarsi I, II and III ascopulate; metatarsus IV swollen with dense scopula ventrally across entire length (Fig. 6K); tarsi I, II, III and IV ascopulate but with ca. 33, 24, 21, 17 fine ventral setae distally, respectively. *Leg measurements*: Leg I: femur 2.11, patella 1.03, tibia 1.51, metatarsus 1.44, tarsus 0.85, total 6.96. Leg II: 1.81, 0.96, 1.07, 1.33, 0.85, 6.03. Leg III: 1.74, 0.92, 1.14, 1.22, 0.77, 5.81. Leg IV: 1.85, 1.00, 1.25, 1.29, 0.74, 6.14. Formula 4123.

Trichobothria: arranged in discontinuous rows; tibiae I–II with 1 row of 3 in retrolateral and dorsal position, respectively; tibiae III–IV with 2 rows of 4–5 in dorsal position, first row situated prodorsally and second row situated retrodorsally; metatarsi with 2 in medio-dorsal position, tarsi I+II with 2, III+IV with 3, all trichobothria in medio-dorsal position.

Leg spination: pedipalp aspinose; leg I: tibia rv0–0–0, v3–3–7, pv0–0–0, d0–0–0; metatarsus rv2–1–1, v2–3–5, pv0–0–0, d0–0–0; tarsus rv1–1–1, v1–3–2, pv0–0–0, d0–0–0; leg II: tibia rv0–0–0, v3–3–4, pv0–0–0, d0–0–0; metatarsus rv0–1–0, v3–2–3, pv0–1–0, d0–0–0; tarsus rv0–2–0, v0–3–0, pv0–2–0, d0–0–0; leg III: tibia rv1–1–1, v2–2–5, pv0–0–1, d0–0–4; metatarsus rv0–2–0, v2–5–4, pv0–1–0, d0–0–3;

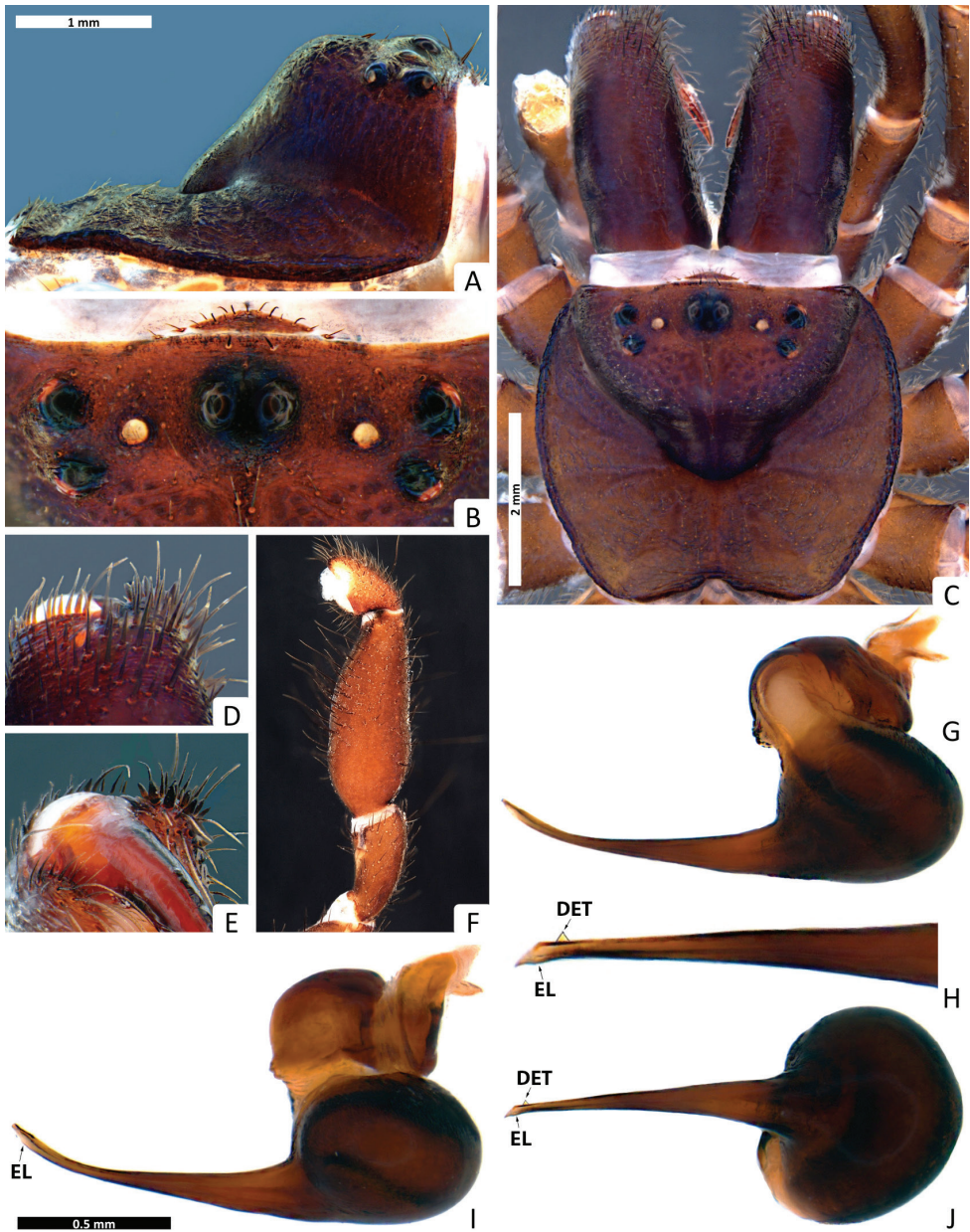


Figure 5. *Missulena pinguipes* sp. n., holotype male (WAM T92331): **A** carapace, lateral view **B** eye group, dorsal view **C** carapace, dorsal view **D** rastellum, dorsal view **E** same, ventral view **F** pedipalp, proventral view **G** bulb and embolus, retrolateral view **H** embolus with apical process depicted, ventral view **I** bulb and embolus, prolateral view **J** same, ventral view. Arrows: (EL) embolar lamella, and (DET) distal embolar tooth.

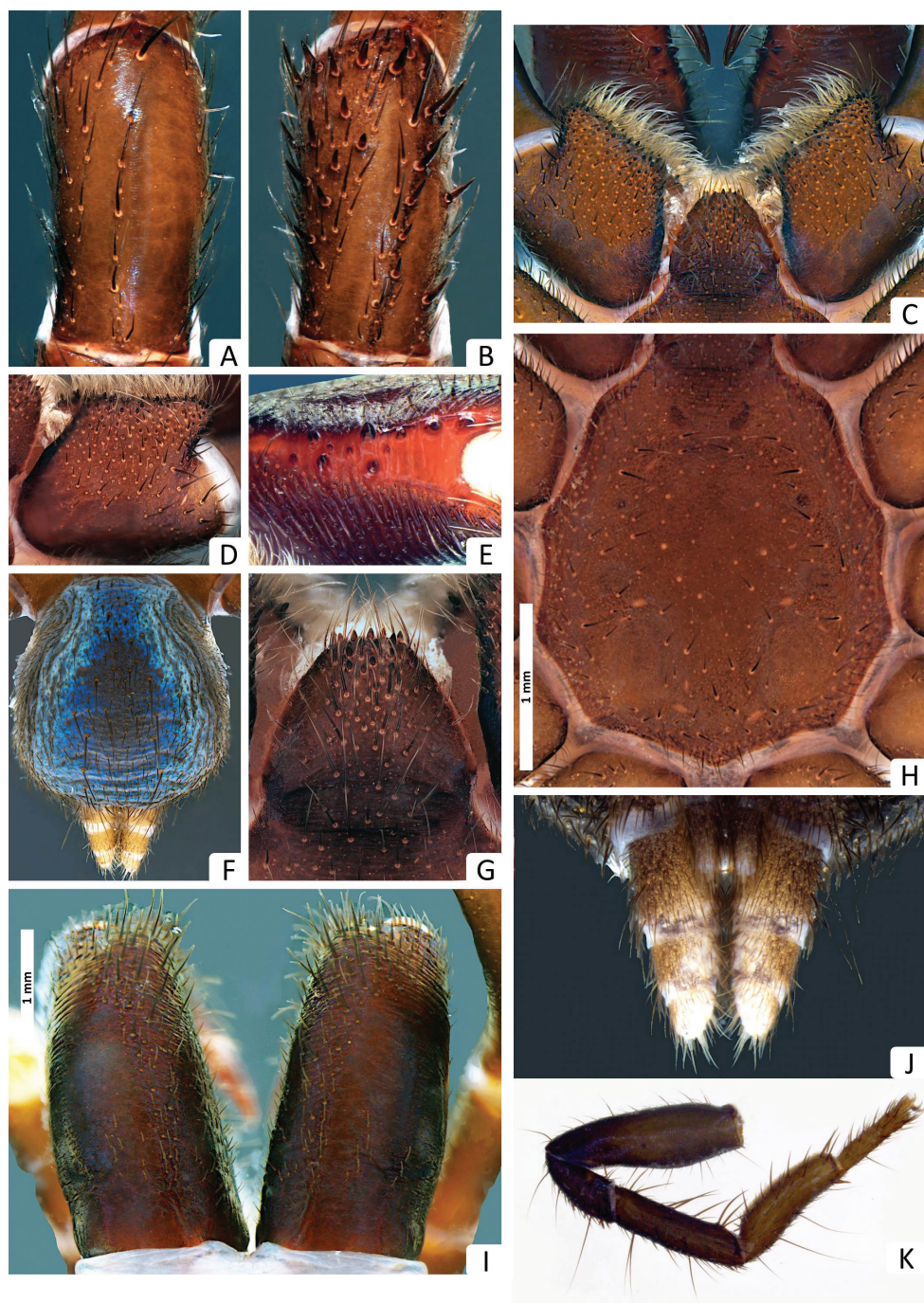


Figure 6. *Missulena pinguipes* sp. n., holotype male (WAM T92331): **A** patella II, dorsal view **B** patella III, dorsal view **C** coxae and labium of pedipalp, ventral view **D** coxae of pedipalp, ventral view **E** cheliceral groove, retroventral view **F** abdomen, dorsal view **G** labium, ventral view **H** sternum and sigillae, ventral view **I** chelicerae, dorsal view **J** spinnerets, ventral view **K** right leg IV, prolateral view.

tarsus rv0–2–1, v1–3–3, pv0–0–1, d0–0–2; leg IV: tibia rv0–0–0, v3–5–4, pv0, d1–0–2; metatarsus rv2–3–1, v0–0–0, pv3–4–3, d0–1–2; tarsus rv1–2–1, v1–5–3, pv0, d0–0–2; patellae I, II without rasps and spines (Fig. 6A), patella III with ca. 26 rasps in 8 oblique rows dorsally, median rows shorter than lateral rows and with less spines, distal spines forming a interrupted crown of spines in the border of the article (Fig. 6B); patella IV with 6 rasps retrolaterally and 12 thick and short spines dorsally.

Tarsal claws: leg I: 3–2/2; leg II: 3–4/2; leg III: 4–3/2; leg IV: 1–2/ 0–1; claws slightly shorter than spines of tarsi.

Variation in paratypes ($N=5$): total length 4.00–5.00; carapace 1.77–2.37 long, 2.37–2.6 wide; number of labial cuspules 15–30, maxillary cuspules 40–66; rastellum with 6–11 thick and conical spines.

Distribution. This species is known only from the Mallee biogeographic region of southern Western Australia (Fig. 4).

Phenology and habitat preferences. The specimens were collected in pitfall traps in woodland habitats in either April or November.

***Missulena leniae* sp. n.**

<http://zoobank.org/BB6C03F8-C9BF-4F1E-A92C-2A7699408800>

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

Figs 1C, 7A–J, 8A–J

Missulena sp. 4: Main et al. 2000: 285.

Type material. AUSTRALIA: Western Australia: holotype male, Nanga Station, site NA3, 26°31'20.9"S, 114°00'08.3"E, 12 May–3 August 1995, pitfall trap, N. Hall (WAM T96784). Paratype: 1 male, Mardathuna Station, site MR2, 24°26'35.7"S, 114°30'41.5"E, 25 May–26 August 1995, pitfall trap, N. Hall (WAM T96785).

Etymology. The specific epithet is a patronym in honour of the second author's daughter, Leni Elise Harms.

Diagnosis. Males of *Missulena leniae* sp. n. differ from other small species (carapace < 4 mm) without red colouration on chelicerae and carapace by the weak rastellum without conical spines (elevated and with conical spines in *M. faulderi*, *M. melissae* and *M. rutraspina*), the presence of granulations on carapace and chelicerae (except *M. pinguipes* and *M. torbayensis*), the presence of long setae on the chelicerae (absent in *M. faulderi*, *M. melissae* and *M. rutraspina*), patella III with rasps (all patellae in *M. torbayensis*), pars cephalica dark brown (black in *M. dipsaca*) and abdomen with metallic blue lines (lacking in *M. dipsaca*). Females of *M. leniae* sp. n. are unknown.

Description. Adult male, based on holotype (WAM T96784). Medium-sized mygalomorph spider (total length 6.81).

Colour: carapace (Figs 1C, 7A, C) dark reddish-brown, margins dark brown; eye region (Fig. 7B) dark reddish-brown, anterior median eyes on black tubercle; chelicerae (Fig. 8I) dark reddish-brown, fangs reddish-brown; abdomen (Fig. 8F) pale grey

with few light blue longitudinal streaks; sternum (Fig. 8H) yellowish-brown, margins contoured dark yellowish-brown, sigillae yellowish-brown; labium and maxillae dark red-yellowish-brown (Fig. 8C, G); legs (Fig. 1C) yellowish-brown, tarsi and metatarsi ventrally pale yellowish-brown; spinnerets (Fig. 8J) pale gray, spigots white.

Carapace: 2.63 long, 3.18 wide; clypeus 0.15; fovea 1.06; caput and eye region (Fig. 7B) laterally elevated, strongly arched; fovea (Fig. 7C) very deep and strongly procurved, medially extending as a very deep triangular depression; carapace with numerous large granulations, widespread over carapace and dorsally on chelicerae; weaker on pars thoracica, with bands of fine, random fissures centered around fovea (Fig. 7C).

Eyes: OQ 2.89 times wider than long, occupying 1.34 of cephalic width; OAW 2.4; OAL 1.62; IPF 0.91; width of anterior eye group 1.57, with of posterior group 1.45, OQ length 0.54; PME 0.14; PLE 0.14; ALE 0.20; AME 0.16, AME on tubercle, 0.31 long, 0.59 wide; AME inter-distance 0.11; AME to ALE 0.40; AME to PME 0.14; PLE to ALE 0.20; PLE to PME 0.25; PME inter-distance 0.77; PME to ALE 0.22; eye region (Fig. 7B) with reduced setation although some setae present anterior to AME, anterior ALE and between posterior eyes and fovea.

Chelicerae: 2.04 long, 0.95 wide; distally broad, diagonal, slightly conical; edges smoothly rounded; with transverse ridges which distally extend over entire length and many strong granulations widespread in dorsal view (Fig. 8I), with ca. 22 long setae widespread in inner area of transverse ridges and with more than 70 short setae along inner margin of chelicera; rastellum (Fig. 7D) poorly developed, weakly pronounced, consisting of a sclerotised process with 2 strong conical spines and 9–10 disordered setae, 9 long setae extend forward from anterior margin of each chelicera and cover base of fang, setae largest on latero-ventral side; inner margin of cheliceral furrow with 3 rows of teeth (Fig. 8E); prolateral (inner) row with ca. 9 teeth, all teeth spaced; intermediate row with 4 proximal, spaced teeth; retrolateral (outer) row with 3 proximal, spaced teeth.

Maxillae: 1.25 long; 0.93 wide, longer than wide (Fig. 8C, D), ca. 86 pointed cusps along entire anterior margin, distally pointed and extended into a prominent heel.

Labium: 0.63 long, 0.61 wide; conical, ca. 12 pointed cusps anteriorly (Fig. 8G); labiosternal suture developed as a shallow groove; a pair of sigilla near labiosternal suture (Fig. 8H), developed as irregular, very small and poorly-defined patches.

Sternum: 1.95 long, 1.72 wide; oval and rebordered (Fig. 8H), with prominent setae, arranged irregularly but denser lateral to labium; 4 pairs of sigillae, anterior pair very small, irregular and undefined; second pair (anterior-posterior) smallest but well defined; third pair bigger than 2 anterior pairs and well defined; and posterior pair bigger than all others, roughly oval but not well defined; 3 posterior sigillae slightly depressed.

Abdomen: 3.31 long, 3.04 wide; roughly oval (Fig. 8F); 4 spinnerets (Fig. 8J), PLS 1.22 long, 0.40 wide, apical segment domed; PMS 0.29 long, 0.15 wide.

Pedipalp: length of trochanter 0.75, femur 2.54, patella 1.09, tibia 1.90, tarsus 0.81; entire palp is aspinose, femur longer than tibia, tarsus terminally blunt (Fig. 7F); bulb pyriform and rather stout than globular (Fig. 7G, I–J), 2 strongly sclerotised sections connected by a velar median structure (“haematodocha”); bulb strongly twisted proventrally (Fig. 7G, I); embolus short, strong, tapering and slightly twisted medially

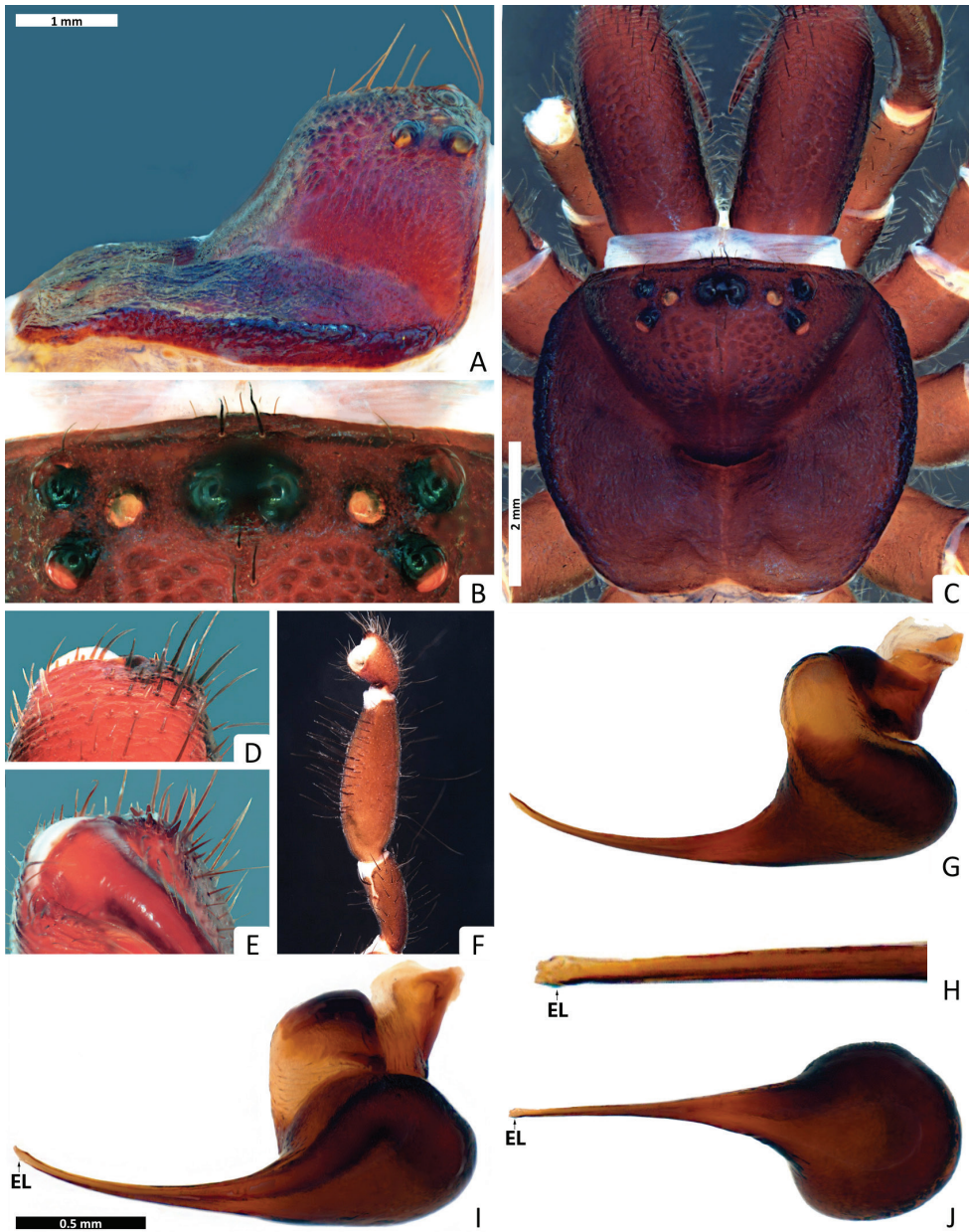


Figure 7. *Missulena leniae* sp. n., holotype male (WAM T96784): **A** carapace, lateral view **B** eye group, dorsal view **C** carapace, dorsal view **D** rastellum, dorsal view **E** same, ventral view **F** pedipalp, proventral view **G** bulb and embolus, retrolateral view **H** embolus, ventral view **I** bulb and embolus, prolateral view **J** same, ventral view. Arrows: (EL) embolar lamella.



Figure 8. *Missulena leniae* sp. n., holotype male (WAM T96784): **A** patella II, dorsal view **B** patella III, dorsal view **C** coxae and labium of pedipalp, ventral view **D** coxae of pedipalp, ventral view **E** cheliceral groove, retroventral view **F** abdomen, dorsal view **G** labium, ventral view **H** sternum and sigillae, ventral view **I** chelicerae, dorsal view **J** spinnerets, dorsal view.

(Fig. 7H, J); embolus tip triangular in prolateral/retrolateral views and subquadrate in ventral view, with a small lamella (EL) and without tooth in ventral view, duct straight in proximal embolus (Fig. 7H, I).

Legs: with few brown setae, ventral setae of tibiae and metatarsi generally much longer and thicker than dorsal setae and bent towards the exterior; dorsal, lateral and ventral setae of tibiae and metatarsi longer than the diameter of respective segment; preening comb distal in tarsi, very small and plain; metatarsi I and II ascopulate; metatarsi III and IV with a weak scopula occupying 75% of segment length; tarsi I and II ascopulate, tarsi III and IV with a weak scopula along entire length; metatarsi I and II with ca. 57 and 47 fine ventral setae distally, respectively. *Leg measurements*: Leg I: femur 3.14, patella 1.33, tibia 1.81, metatarsus 2, tarsus 1.22, total 9.51. Leg II: 2.66, 1.33, 1.77, 1.88, 1.22, 8.88. Leg III: 2.85, 1.40, 1.74, 1.96, 1.29, 9.25. Leg IV: 3.14, 1.33, 2.03, 2.03, 1.37, 9.92. Formula 4123.

Trichobothria: arranged in discontinuous rows; tibiae I–III with 2 rows of 2 in prodorsal position and 3 in retrodorsal position, respectively; tibiae IV with 7 widespread in dorsal position; metatarsi with 3 in proximo-dorsal position; tarsi I–IV with 3, all trichobothria in a row in medio-dorsal position.

Leg spination: pedipalp aspinose; leg I: tibia rv0–0–2, v2–3–3, pv0–0–0, d0–0–0; metatarsus rv0–2–1, v2–2–3, pv0–0–0, d0–0–0; tarsus rv0–1–1, v2–4–3, pv0–0–0, d0–0–0; leg II: tibia rv0–0–2, v2–3–3, pv0–0–0, d0–0–0; metatarsus rv0–1–2, v0–4–3, pv0–0–0, d0–0–0; tarsus rv0–2–0, v3–2–4, pv0–0–0, d0–0–0; leg III: tibia rv0–0–3, v0–2–7, pv0–0–2, d2–0–10; metatarsus rv1–1–2, v0–0–0, pv1–1–1, d1–1–3; tarsus rv1–3–2, v0–1–2, pv0–0–0, d0–1–2; leg IV: tibia rv0–0–0, v3–3–4, pv0–0–1, d1–1–2; metatarsus rv1–1–2, v0–0–0, pv1–2–3, d0–0–0; tarsus rv2–6–6, v1–3–2, pv0–0–0, d0–0–2; patellae I with ca. 7 rasps in 3 proximal oblique rows dorsally, patellae II with 1 rasp (Fig. 8A), patella III with ca. 16 rasps and 4 spines in 8 oblique rows dorsally, median rows shorter than lateral rows and with less rasps/spines, distal rasps/spines forming a interrupted crown of rasps/spines in the border of the article (Fig. 8B); patella IV with 4 rasps retrolaterally and 8 thick and short spines prodorsally.

Tarsal claws: leg I: 6–5/3; leg II: 4–5/3; leg III: 3–2/1; leg IV: 2–2/1; claws slightly shorter than spines of tarsi.

Variation in paratype (N=1): total length 4.90; carapace 2.63 long, 2.54 wide; number of labial cuspules 58–70, maxillary cuspules 14; rastellum with 4–4 thick and conical spines.

Distribution. This species is currently known from two sites located in the Carnarvon and Yalgoo biogeographic regions of Western Australia (Fig. 4).

Phenology and habitat preferences. The two specimens were collected in pitfall traps between May and August. They were listed as *Missulena* sp. 4 in a survey of mygalomorph spiders of the southern Carnarvon Basin by Main et al. (2000). The two sites are dominated by *Banksia* and eucalypt mallee woodland (site NA3), or *Acacia aneura* (site MR2) over stable but sandy substrates (Burbidge et al. 2000, Appendix A; Wyrwoll et al. 2000).

***Missulena mainae* sp. n.**

<http://zoobank.org/FA26CB3C-43A2-4DA7-AFD9-AC84E3366B1D>

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

Figs 1D, 9A–J, 10A–K

Missulena sp. 2: Main et al. 2000: 285.

Type material. AUSTRALIA: Western Australia: holotype male, Cape Cuvier, Quobba Station, site CU6, 24°08'20.4"S, 113°26'43.9"E, 31 May–25 August 1995, pitfall trap (WAM T96782). Paratypes: 2 males, Cape Cuvier, Quobba Station, site CU5, 24°11'34.0"S, 113°27'17.4"E, 27 September–2 October 1994, dry pitfall trap, P. West et al. (WAM T96781); 3 males, same data, 29 May–25 August 1995, N. Hall (WAM T96783).

Etymology. This species is named in honour of Barbara York Main in recognition of her substantial contributions to arachnology. She also was the first to recognize this taxon as a distinctive new species (Main et al. 2000).

Diagnosis. Males of *Missulena mainae* sp. n. differ from all other species by the uniformly red dorsal coloration of the carapace (pars cephalica and thoracica red; Figs 2D, 10C). Males share with *M. pinguipes* sp. n. the presence of a swollen metatarsus IV, but the character is less pronounced in *M. mainae* (Fig. 10K).

Description. Adult male, based on holotype (WAM T96782). Medium-sized mygalomorph spider (total length 7.90).

Colour. carapace (Fig. 9C) pale red, margins pale red; eye region (Fig. 9B) pale red, anterior median eyes on black tubercle; chelicerae (Fig. 10I) pale red, fangs dark red; abdomen (Fig. 10F) pale grey with little spots of blue and light gray longitudinal streaks; sternum (Fig. 10H) pale red, margins contoured pale brown, sigillae pale red and spots pale brown; labium (Fig. 10G) and maxillae pale red; legs (Fig. 1D) brown, coxae and trochanter pale brown; spinnerets (Fig. 10J) pale gray, spigots white.

Carapace: 2.59 long, 2.77 wide; clypeus 0.09; fovea 0.75; caput and eye region (Fig. 9A) laterally elevated, strongly arched in a rectangular form; fovea (Fig. 9C) very deep and strongly procurved, medially extending as triangular depression, pars cephalica with few granulations around the eyes, behind the eyes and between the eyes and fovea, pars thoracica with bands of fine, random fissures centered around fovea (Fig. 9C).

Eyes: OQ 3.06 times wider than long, occupying 1.26 of cephalic width; OAW 2.20; OAL 1.65; IPF 0.80; width of anterior eye group 1.40, with of posterior group 1.25, OQ length 0.45; PME 0.10; PLE 0.13; ALE 0.11; AME 0.16, AME on tubercle, 0.24 long, 0.42 wide; AME inter-distance 0.07; AME to ALE 0.44; AME to PME 0.22; PLE to ALE 0.17; PLE to PME 0.13; PME inter-distance 0.79; PME to ALE 0.16; eye region (Fig. 9B) with reduced setation although some setae present anterior to AME, between lateral eyes and between posterior eyes and fovea.

Chelicerae: 1.42 long, 0.88 wide; distally broad, diagonal, slightly conical; edges smoothly rounded; without transverse ridges (Fig. 10I), with 2 lines of dorsal setae,

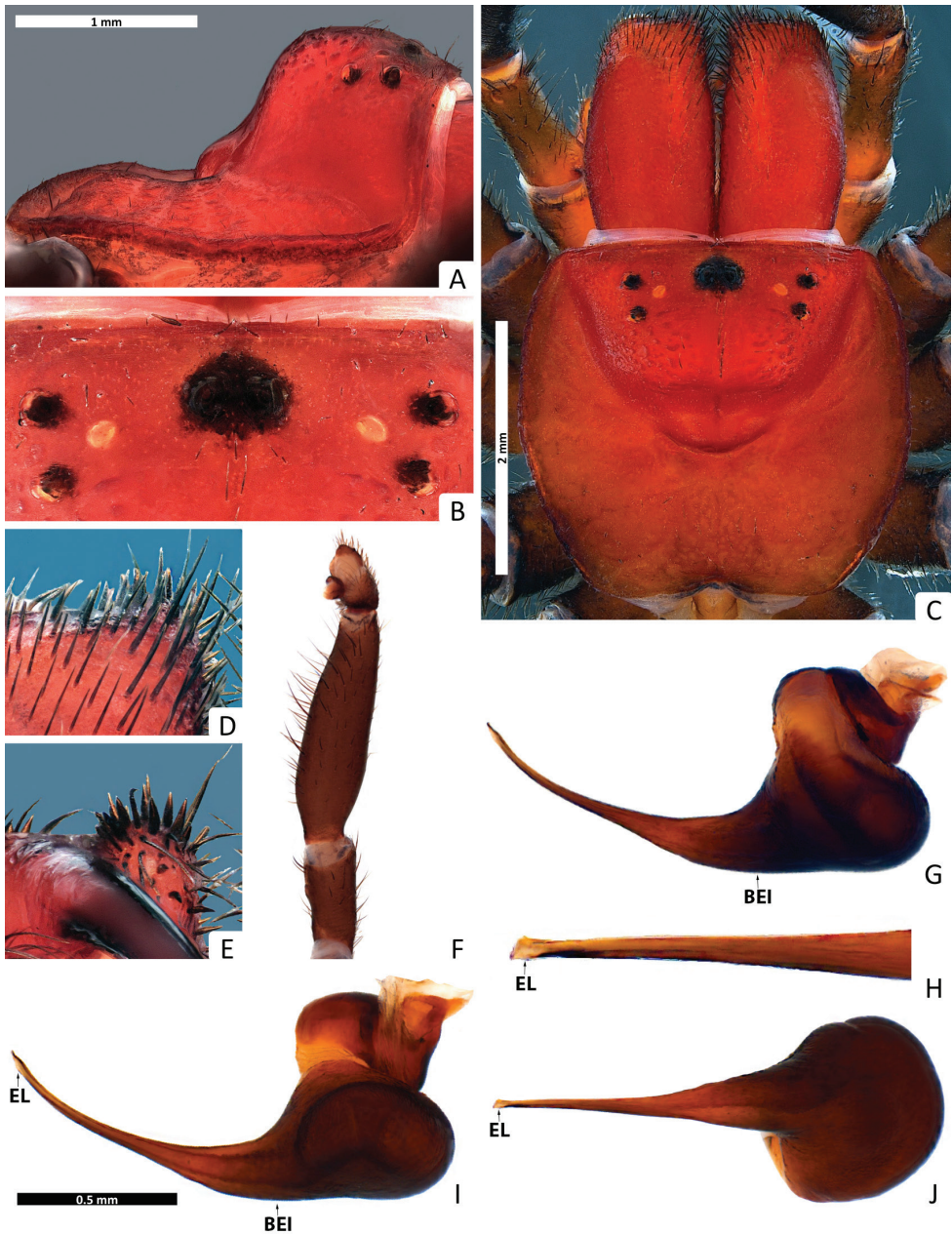


Figure 9. *Missulena mainae* sp. n., holotype male (WAM T96782): **A** carapace, lateral view **B** eye group, dorsal view **C** carapace, dorsal view **D** rastellum, dorsal view **E** same, ventral view **F** pedipalp, proventral view **G** bulb and embolus, retrolateral view **H** embolus, ventral view **I** bulb and embolus, prolateral view **J** same, ventral view. Arrows: (EL) embolar lamella, and (BEI) basal embolar intumescence.

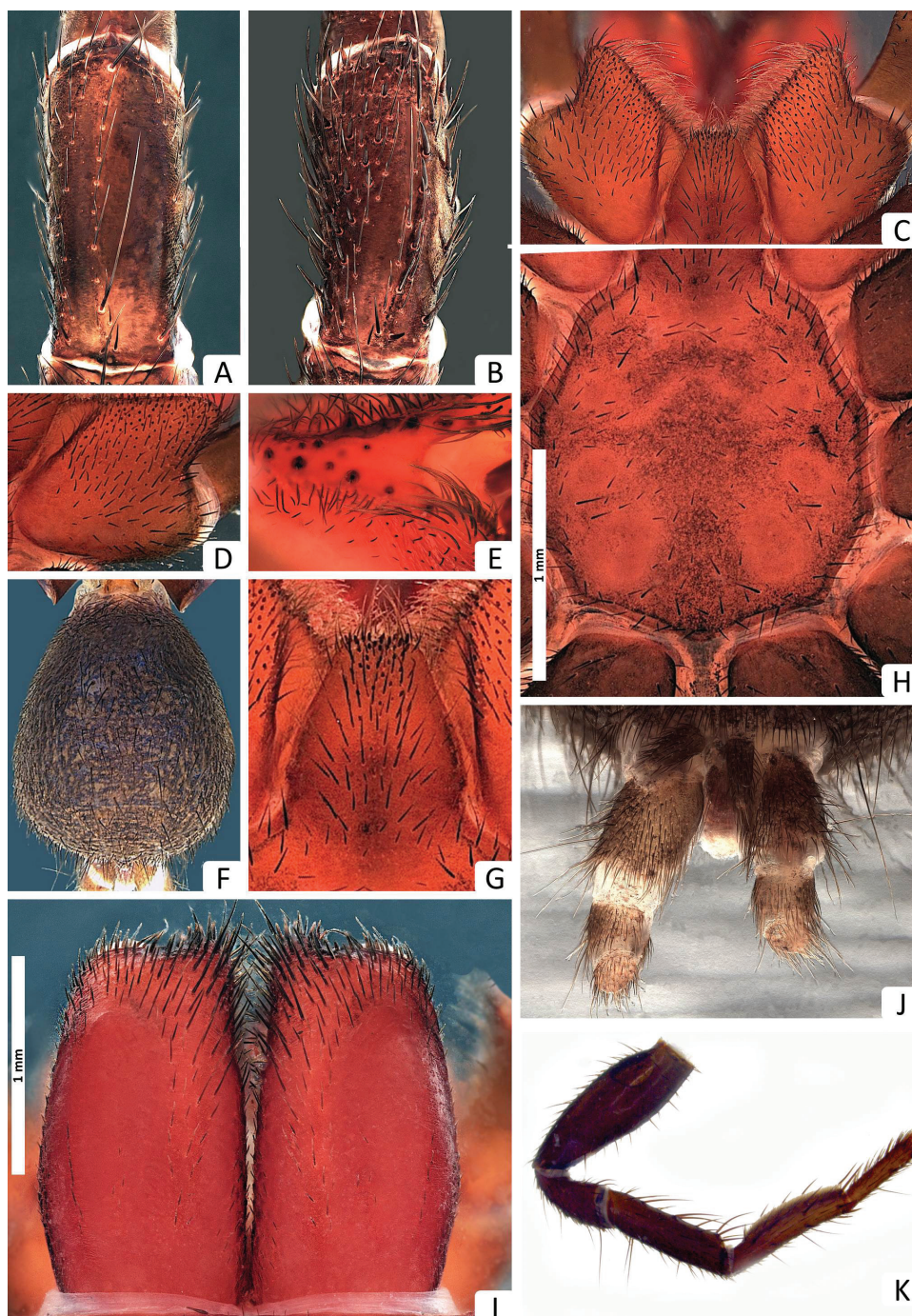


Figure 10. *Missulena mainae* sp. n., holotype male (WAM T96782): **A** patella II, dorsal view **B** patella III, dorsal view **C** coxae and labium of pedipalp, ventral view **D** coxae of pedipalp, ventral view **E** cheliceral groove, retroventral view **F** abdomen, dorsal view **G** labium, ventral view **H** sternum and sigillae, ventral view **I** chelicerae, dorsal view **J** spinnerets, ventral view **K** right leg IV, prolateral view.

prolateral with ca. 28 and retrolateral with ca. 15; with ca. 30 setae along inner margin of chelicera; rastellum (Fig. 9D, E) developed, pronounced, consisting of a sclerotised process with 11 strong conical spines and 16 disordered setae, 13 long setae extend forward from anterior margin of each chelicera and cover base of fang, setae largest on latero-ventral side; inner margin of cheliceral furrow with 3 rows of teeth (Fig. 10E); prolateral (inner) row with ca. 6 teeth, all teeth spaced; intermediate row with 5 proximal, spaced teeth; retrolateral (outer) row with 4 proximal, spaced teeth; with 2 distal teeth.

Maxillae: 1.31 long; 1.0 wide, longer than wide, almost square (Fig. 10C, D), ca. 96 pointed cuspules along entire anterior margin, distally pointed and extended into a prominent heel.

Labium: 0.80 long, 0.62 wide; conical, ca. 31 pointed cuspules anteriorly (Fig. 10G); labiosternal suture developed as a shallow groove; a pair of sigilla near labiosternal suture (Fig. 10H), developed as irregular, poorly-defined patches.

Sternum: 1.82 long, 1.71 wide; oval and rebordered (Fig. 10H), with prominent setae, arranged irregularly but denser lateral to labium; 4 pairs of sigillae, anterior pair smallest than others and undefined, second pair (anterior-posterior) smallest but well defined, third pair bigger than 2 anterior pairs and well defined, and posterior pair bigger than all others, roughly oval but not well defined, all sigillae slightly depressed.

Abdomen: 3.31 long, 2.54 wide; roughly oval (Fig. 10F); 4 spinnerets (Fig. 10J), PLS 1.00 long, 0.40 wide, apical segment domed; PMS 0.34 long, 0.15 wide.

Pedipalp: length of trochanter 1.0, femur 2.27, patella 1.0, tibia 2.09, tarsus 0.63; entire palp is aspinose, femur longer than tibia, tarsus terminally blunt (Fig. 9F); bulb pyriform and rather stout than globular (Fig. 9G–J), 2 strongly sclerotised sections connected by a velar median structure (“haematodocha”); bulb strongly twisted proventrally (Fig. 9G, I); embolus short, with a proximal intumescence (BEI) in prolateral view, tapering and slightly twisted medially (Fig. 9G–J); embolus tip triangular in prolateral/retrolateral view and rectangular in ventral view, with a small lamella (EL) and without tooth (Fig. 9H).

Legs: with few brown setae, ventral setae of tibiae and metatarsi generally much longer and thicker than dorsal setae and bent towards the exterior; dorsal, lateral and ventral setae of tibiae and metatarsi longer than the diameter of respective segment; preening comb distal in tarsi, very small and plain; metatarsi I, II and III ascopulate, tarsi I, II, III and IV ascopulate but with ca. 20, 24, 17, 13 fine ventral setae distally, respectively; metatarsus IV with dense scopula ventrally across entire length. *Leg measurements*: Leg I: femur 1.55, patella 1.22, tibia 1.40, metatarsus 1.48, tarsus 0.88, total 6.55. Leg II: 2.22, 1.18, 1.44, 1.48, 1, 7.33. Leg III: 2.18, 1.18, 1.48, 1.48, 1.03, 7.37. Leg IV: 2.22, 1.29, 1.55, 1.55, 1.03, 7.66. Formula 4123.

Trichobothria: arranged in discontinuous rows; tibiae I–II with 2 proximal rows of 3 in retrodorsal and prodorsal position, respectively; tibiae III–IV with 2 rows of 2–3 in prodorsal/retrolateral position; metatarsi with 4 in mediodorsal position, tarsi I+II with 2, III+IV with 3, all trichobothria in mediodorsal position.

Leg spination: pedipalp aspinose; leg I: tibia rv1-0-1, v2-3-5, pv0-0-0, d0-0-0; metatarsus rv0-0-1, v2-6-5, pv1-1-2, d0-0-0; tarsus rv0-0-0, v3-6-7, pv0-0-0, d0-0-0; leg II: tibia rv1-0-0, v3-4-4, pv0-0-0, d0-0-0; metatarsus rv1-2-1, v2-5-4, pv1-1-2, d0-0-0; tarsus rv0-1-1, v3-4-8, pv0-1-0, d0-0-0; leg III: tibia rv0-0-0, v1-2-3, pv0-0-1, d0-1-7; metatarsus rv1-2-2, v4-6-8, pv1-0-1, d3-3-3; tarsus rv0-0-0, v1-4-4, pv0-0-1, d0-0-3; leg IV: tibia rv0-0-0, v1-2-2, pv0-0-1, d1-0-4; metatarsus rv1-2-2, v0-0-0, pv1-4-3, d2-1-3; tarsus rv1-1-3, v3-4-6, pv0-0-0, d0-0-2; patellae I, II without rasps and spines (Fig. 10A), patella III with ca. 28 rasps in 8 oblique rows dorsally, median rows shorter than lateral rows and with less spines, distal spines forming a interrupted crown of spines in the border of the article (Fig. 10B); patella IV with 12 rasps retrolaterally and 6 thick and short spines dorsally.

Tarsal claws: leg I: 3-2/2; leg II: 6-6/2; leg III: 6-5/3; leg IV: 5-5/3; claws slightly shorter than spines of tarsi.

Variation in paratypes ($N=5$): total length 5.27-6.09; carapace 2.36-2.63 long, 2.54-3.27 wide; number of labial cuspules 19-26, maxillary cuspules 86-108; rastellum with 10-13 thick and conical spines.

Distribution. This species is known only from Quobba Station in the Carnarvon biogeographic region of Western Australia (Fig. 4).

Phenology and habitat preferences. All specimens were collected in pitfall traps in a period between May and October. They were listed as *Missulena* sp. 2 in a survey of mygalomorph spiders of the southern Carnarvon Basin (Main et al. 2000). The two sites are dominated by *Acacia* over dune substrates (Burbidge et al. 2000, Appendix A; Wyrwoll et al. 2000).

Key to the described males of *Missulena* from Australia

(Distribution indicative as in Table 1; some species may have a wider occurrence.)

- | | | |
|---|--|------------------------------------|
| 1 | Chelicerae, and sometimes parts of the carapace with red markings | 2 |
| - | Chelicerae and carapace brown or black..... | 6 |
| 2 | Pars cephalica and thoracica uniformly red [WA: Carnarvon].... | <i>M. mainae</i> sp. n. |
| - | Pars cephalica red but pars thoracica black or brown | 3 |
| 3 | Pars cephalica uniformly red..... | 4 |
| - | Pars cephalica almost black but with traces of dark-red [WA: Southwest] | <i>M. hoggi</i>¹ |
| 4 | Small species (carapace length < 3.0 mm); rastellum with fewer than 6 spines [WA: Pilbara] | <i>M. langlandsi</i> |
| - | Large species (carapace length > 4.0 cm); rastellum with more than 6 spines... | 5 |

¹ Faulder (1995a), in an unpublished thesis, considers *M. hoggi* and *M. granulosa*, mainly differentiated by the colour pattern of carapace and chelicerae, conspecific.

- 5 Abdomen dark yellow but with a lighter patch anteriorly [SA].....***M. reflexa***
 – Abdomen dark brown and without yellow patch
 ..***M. occatoria*** [NSW, Qld, Vic, ACT, SA, NT, WA] and ***M. insignis*** [WA]²
- 6 Abdomen dorsally with pale colouration7
 – Abdomen dorsally lacks pale colouration, mainly brownish-grey or metallic blue8
- 7 Abdomen dorsally greyish-white; rastellum with 10 spines [WA: Kimberleys; NT; Qld]***M. pruinosa***
 – Abdomen dorsally with a bluish-grey patch in anterior position but otherwise dark brown; rastellum with 5–6 spines [Qld, NSW, Vic]***M. bradleyi***
- 8 Outer surface of chelicerae with longitudinal ridges9
 – Outer surface of chelicerae smooth11
- 9 Patella II prolaterally with rasps; tip of embolus with process [WA: Pilbara]...
***M. melissae* sp. n.**
 – Patella II without rasps; tip of embolus without processes10
- 10 Proventral teeth of cheliceral furrow fused; embolus significantly longer than bulb and medially curved; patella III with fewer than 40 rasps [WA: Pilbara]***M. faulderi***
 – Proventral teeth of cheliceral furrow not fused; embolus not significantly longer than bulb and straight; patella III with greater than 50 rasps [WA, SA, Vic]***M. rutraspina***
- 11 Length of carapace > 3.0 mm12
 – Length of carapace < 3.0 mm14
- 12 Rasps present on patella I13
 – Rasps absent on patella I; tarsus I ascopulate; thin scopula on tarsus III; sternum without pair of sigilla in labial groove [NSW, Vic, SA, WA, Qld]
***M. dipsaca***
- 13 Length of carapace < 4.0 mm, rasps on all patellae [WA: Southwest]
***M. torbayensis***
 – Length of carapace > 5.0 mm, rasps on patellae I and III only [WA: Southwest]***M. granulosa***
- 14 Abdomen entirely metallic blue, patella III with more than 25 rasps [WA: Mallee]***M. pinguipes* sp. n.**
 – Abdomen with some metallic blue markings but otherwise reddish brown; patella III with fewer than 25 rasps [WA: Carnarvon and Yalgoo]***M. leniae* sp. n.**

2 There is confusion about the identity of *M. insignis* and *M. occatoria*. Both species cannot be diagnosed based on the original description. The holotype of *M. insignis* is from Swan River, Western Australia and that of *M. occatoria* from an unidentified locality in “New Holland” (= Australia). Main (1985) suggested referring Western Australian specimens to *M. insignis* (the ‘western’ species) and eastern Australian specimens to *M. occatoria* (the ‘eastern’ species).

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References

- Brunet B (1994) The silken web: a natural history of Australian spiders. Reed, Chatswood, N.S.W., 208 pp.
- Brunet B (2000) Spider watch: a guide to Australian spiders. New Holland, Chatswood, N.S.W., 177 pp.
- Burbidge AH, Harvey MS, McKenzie NL (Eds) (2000) Biodiversity of the southern Carnarvon Basin. Records of the Western Australian Museum, Supplement 61: 595 pp.
- Department of the Environment (2013) Australia's bioregions (IBRA). <http://www.environment.gov.au/topics/land/national-reserve-system/science-maps-and-data/australias-bioregions-ibra> [accessed 28 October 2013]
- Durrant BJ, Harvey MS, Framenau VW, Ott R, Waldock JM (2010) Patterns in the composition of ground-dwelling spider communities in the Pilbara bioregion, Western Australia. Records of the Western Australian Museum, Supplement 78: 185–204.
- Faulder RJ (1995a) Systematics and Biogeography of the Spider Genus *Missulena* Walckenaer. Master of Science thesis, University of Sydney, Sydney.
- Faulder RJ (1995b) Two new species of the Australian spider genus *Missulena* Walckenaer (Araneeae: Actinopodidae). Records of the Western Australian Museum Supplement 52: 73–78.
- Goloboff PA, Platnick NI (1987) A review of the Chilean spiders of the superfamily Migoidea (Araneae, Mygalomorphae). American Museum Novitates 2888: 1–15.
- Griswold CE, Ledford J (2001) A monograph of the migid trap door spiders of Madagascar and review of the world genera (Araneae, Mygalomorphae, Migidae). Occasional Papers of the California Academy of Sciences 151: 1–120.
- Harms D, Framenau VW (2013) New species of mouse spiders (Araneae: Mygalomorphae: Actinopodidae: *Missulena*) from the Pilbara region, Western Australia. Zootaxa 3637: 521–540.

- Herzig V, Khalife AA, Youmie C, Isbister GK, Currie BJ, Churchill TB, Horner S, Escoubas P, Nicholson GM, Hodgson WC (2008) Intersexual variations in Northern (*Missulena pruinosa*) and Eastern (*M. bradleyi*) mouse spider venom. *Toxicon* 51: 1167–1177. doi: 10.1016/j.toxicon.2008.02.001
- Isbister GK (2004) Mouse spider bites (*Missulena* spp.) and their medical importance. *Medical Journal of Australia* 180: 225–227
- Main BY (1985) Mygalomorphae. In: Walton DW (Ed) *Zoological Catalogue of Australia* 3 Arachnida, Mygalomorphae, Araneomorphae in Part, Pseudoscorpionida, Amblypygida, Palpigradi. Australian Government Publishing Service, Canberra, 1–48.
- Main BY (1996) Biosystematics of Australian mygalomorph spiders: description of a new species of *Missulena* from southwestern Australia (Araneae: Mygalomorphae: Actinopodidae). *Records of the Western Australian Museum Supplement* 17: 355–359
- Main BY, Sampey A, West PLJ (2000) Mygalomorph spiders of the southern Carnarvon Basin, Western Australia. *Records of the Western Australian Museum, Supplement* 61: 281–293.
- Mascord RE (1970) *Australian spiders in colour*. Reed, Sydney.
- McKenzie NL, van Leeuwen S, Pinder AM (2009) Introduction to the Pilbara Biodiversity Survey, 2002–2007. *Records of the Western Australian Museum, Supplement* 78: 3–89.
- Platnick NI (2014) The World Spider Catalog, Version 14.5. <http://research.amnh.org/iz/spiders/catalog/INTRO1.html> [accessed 8 April 2014]
- Rash D, Birinyi-Strachan LC, Nicholson GM, Hodgson WC (2000) Neurotoxic activity of venom from the Australian eastern mouse spider (*Missulena bradleyi*) involves modulation of sodium channel gating. *British Journal of Pharmacology* 130: 1817–1824. doi: 10.1038/sj.bjp.0703494
- Raven RJ (1985) The spider infraorder Mygalomorphae (Araneae): cladistics and systematics. *Bulletin of the American Museum of Natural History* 182: 1–180.
- Raven RJ, Seeman O (2008) *Spiders of the Greater Brisbane region*. Queensland Museum, Brisbane, 68 pp.
- Walckenaer CA (1805) *Tableau des Aranéides ou caractères essentiels des tribus, genres, familles et races que renferme le genre Aranea de Linné, avec la désignation des espèces comprises dans chacune de ces divisions*. Dentu, Paris, 88 pp.
- Walker KL, Yen AL, Milledge GA (2003) *Spiders and scorpions commonly found in Victoria*. Royal Society of Victoria, Melbourne, Vic, 144 pp.
- Womersley H (1943) A revision of the spiders of the genus *Missulena* Walckenaer, 1805. *Records of the South Australian Museum* 7: 249–269.
- Wyrwoll K-H, Stoneman T, Elliott G, Sandercock P (2000) The geoecological setting of the study area: geology, geomorphology and soils. *Records of the Western Australian Museum, Supplement* 61: 29–75.