

Ecotone shifts in southern Madagascar: first barcoding data and six new species of the endemic millipede genus *Riotintobolus* (Spirobolida, Pachybolidae)

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Abstract

Six new species of the Spirobolida millipede genus *Riotintobolus* Wesener, 2009, are described from the spiny forest in southern Madagascar utilising genetic barcoding, drawings and scanning electron microscopy: *Riotintobolus tsimelahy* **sp. nov.**, *R. mangatsiaka* **sp. nov.**, *R. lavanono* **sp. nov.**, *R. bovinus* **sp. nov.**, *R. antafoky* **sp. nov.** and *R. makayi* **sp. nov.** One other *Riotintobolus* population from the spiny forest might represent an additional species based on genetic data, but it cannot be described as no male specimens were collected. At present, the genus *Riotintobolus* Wesener, 2009 has eight species from the spiny forest and two species from the littoral rainforest. A determination key to all ten species of the genus is provided. Molecular data reveal that the two critically endangered species from the humid littoral rainforest are not closely related to one another, but have their closest relative in the dry spiny forest ecosystem. *Riotintobolus mandenensis* Wesener, 2009, only known from the southern littoral rainforest of Mandena is related to *R. tsimelahy* **sp. nov.** from the nearby spiny forest at Tsimelahy with a *p*-distance of 11%, while *R. minutus* Wesener, 2009 from the littoral forest of Sainte Luce is more distant to all other *Riotintobolus* species, but more closely related to *R. bovinus* **sp. nov.** from the southwestern forest of the Makay.

Keywords

biodiversity, Diplopoda, DNA barcoding, littoral rainforest, soil arthropod, spiny forest

Introduction

Madagascar is one of the ten hottest biodiversity hotspots (Myers et al 2000). The long isolation of Madagascar from other land masses (Krause 2003; Ali and Aitchison 2008) makes the island a great model to study the speciation mechanisms in numerous of its endemic animal groups (Vences et al. 2009). The evolutionary mechanisms among the rise of such a stunning diversity of a high number of animal groups on Madagascar are still little understood, as most studies focus on the vertebrate fauna of the island (e.g. Pearson and Raxworthy 2009). Invertebrates might be better suited for studying biogeographical patterns, as they can survive in smaller habitat fragments during climatically unsuitable times (Brühl 1997; Uys et al. 2009; Yeates et al. 2009).

Among the endemic mega-invertebrate fauna on Madagascar are the so-called fire millipedes of the order Spirobolida with their striking red/black coloration (Wesener et al. 2009a, b, 2011a), and the large giant pill-millipedes of the order Sphaerotheriida with stridulation organs in both sexes (Wesener and VandenSpiegel 2009; Wesener et al. 2011b), reaching the size of a small orange when rolled-up (Enghoff 2003). For both groups, numerous species and genera could recently be described from Madagascar (Wesener et al. 2008, 2011a, 2014; Wesener 2009a, b, 2011; Wesener and Enghoff 2009). Especially diverse are the Spirobolida millipedes on Madagascar; previously only known from two genera, 14 new genera could be described since 2008, with numerous species being microendemic and even listed on the IUCN Red List as critically endangered (e.g. Rudolf and Wesener 2017a, b). One of these genera is *Riotintobolus* Wesener, 2009, aptly named after the mining company Rio Tinto, which is currently active in the only known southern littoral rainforests (Vincelette et al. 2007) where two of the critically endangered species of the genus live (Rudolf and Wesener 2017c, d). The other two species of the genus are known from the desert-like spiny forest ecosystem (Du Puy and Moat 1996; Moat and Smith 2007) in southern Madagascar and seem to have a more widespread distribution. *Riotintobolus* is therefore one of the few genera of Malagasy Spirobolida whose species, distributed in littoral rainforests and dry spiny forests, underwent one or several so-called ecotone shifts (Wirta et al. 2008; Wesener et al. 2011a).

An expedition to Madagascar conducted by TW in 2007, as well as sorting through different museum collections, led to the discovery of six additional *Riotintobolus* species, all from the spiny and gallery forests in the desert-like south of Madagascar.

Material and methods

Abbreviations

CAS	California Academy of Sciences, San Francisco, U.S.A;
CASENT	Entomology collection, California Academia of Sciences;
FMNH	Field Museum, Chicago, U.S.A;
FMMC	Insect and Myriapoda collection voucher numbers;
MZUF	Museum “La Specola”, Florence, Italy;

SEM	scanning electron microscopy;
ZFMK	Zoological Research Museum A. Koenig, Leibniz Institute for Animal Biodiversity, Bonn, Germany;
ZFMK-MYR	collection number of the Myriapoda collection at the ZFMK.

Illustrations

Dissecting and camera lucida drawings were done under an Olympus SZX12 stereo-microscope. For scanning electron microscopy, the samples were dehydrated via an ethanol chain, mounted on stubs and dried overnight. The stub was sputter-coated with 100 nm of gold in a Hummer VI (Anatech, USA) sputtering system. Images were obtained using a Hitachi S-2460 SEM. Multi-layer photographs were taken with a Leica Z6 Imaging-System based at the ZFMK. Stacked images were put together using the software Auto-Montage (Syncroscopy). All images were later modified using Adobe Photoshop version CS2 and assembled into plates using Adobe Illustrator version CS2.

DNA extraction and sequencing

DNA was extracted from 14 specimens (see Table 1) of *Riotintobolus*: ten of them preserved in 95% ethanol, the remaining in 75% ethanol. The HCO/LCO primer pair (Folmer et al. 1994) was used to sequence a 652 bp fragment of the mitochondrial cytochrome *c* oxidase subunit I (COI) gene. DNA extraction, PCR, purification, and sequencing protocols were identical to those used in a previous study (Wesener et al. 2010). While the COI gene, being a mitochondrial gene as well as containing little resolution at deeper evolutionary splits, is limited in the resolution of a reconstructed phylogeny of

Table 1. Specimens sequenced for the Barcoding analysis. GenBank numbers, voucher numbers, and species identification with a shortened location information.

GenBank #	Voucher #	Species
HQ891241.1		<i>Madabolus maximus</i> Wesener, 2008
HQ891229.1		<i>Aphistogoniulus infernalis</i> Wesener, 2009
HQ891238.1		<i>Aphistogoniulus vampyrus</i> Wesener, 2009
HQ891233.1		<i>Aphistogoniulus sanguineus</i> Wesener, 2009
HQ891244.1		<i>Spiromimus triaureus</i> Wesener & Enghoff, 2009
MT603148	FMNH-INS	<i>Riotintobolus mandenensis</i> A, Mandena
MT603149	FMNH-INS	<i>Riotintobolus mandenensis</i> B, Mandena
MT603150	ZFMK MYR 9906	<i>Riotintobolus minutus</i> A, Sainte Luce S9
MT603151	ZFMY MYR 9907	<i>Riotintobolus minutus</i> B, Sainte Luce S9
MT603152	CASENT 9032805	<i>Riotintobolus aridus</i> , MGF059
MT603153	ZFMK MYR 9940	<i>Riotintobolus tsimelaby</i> A sp. nov., Tsimelaby
MT603154	ZFMK MYR 941	<i>Riotintobolus tsimelaby</i> B sp. nov., Tsimelaby
MT603155	CASENT9032808	<i>Riotintobolus tsimelaby</i> C sp. nov., Mahavelo
MT603156	ZFMK MYR 9801	<i>Riotintobolus mangatsiaka</i> A sp. nov. Mangatsiaka
MT603157	ZFMK MYR 938	<i>Riotintobolus mangatsiaka</i> B sp. nov. Mangatsiaka
MT603158	ZFMK MYR 942	<i>Riotintobolus lavanono</i> sp. nov., Lavanono
MT603159	ZFMK MYR 939	<i>Riotintobolus makayi</i> sp. nov., Makay
MT603160	ZFMK MYR 940	<i>Riotintobolus bovinus</i> sp. nov., Makay
MT603161	ZFMK MYR 2438	<i>Riotintobolus</i> sp. 01, Faux Cap iv

the *Riotintobolus* species, we aimed at finding a unique identifier allowing us to study and illustrate the genetic distances between the different species of the genus. All sequences obtained were checked via Blast searches (Altschul et al. 1997), no contaminations were discovered. The sequences were aligned by hand in BioEdit (Hall 1999) together with those obtained during the only other molecular study on Malagasy Spirobolida (Wesener et al. 2011a), using as outgroup taxa specimens of the genera *Spiromimus* DeSaussure & Zehntner, 1901 and *Aphistogoniulus* Silvestri, 1897 as the near outgroup, and a sequence of the species *Madabolus maximus* Wesener & Enghoff, 2008 of the tribe Pachybolini as the far outgroup. All newly sequenced *Riotintobolus* sequences were uploaded to GenBank (Accession #: MT603148–MT603161, see Table 1).

DNA analysis

To find the best substitution model, modeltest implemented in MEGA 6 (Tamura et al. 2013) was utilised. Codon positions included were 1st+2nd+3rd. All positions containing gaps and missing data were eliminated. There was a total of 652 positions in the final dataset. The lowest Bayesian Information Criterion score of 10760 was obtained by the Tamura-Nei model plus gamma distribution to be best fitting (FreqA = 0.2848, FreqC = 0.1882, FreqT = 0.3572, FreqG = 0.17, gamma shape = 0.4526). Maximum Likelihood analyses were conducted in MEGA6 (Tamura et al. 2013). The bootstrap consensus tree (Fig. 1) from 1000 replicates (Felsenstein 1985) is taken to represent the evolutionary history of the analysed taxa. The tree with the highest log likelihood (-5174.8354) is shown. Initial tree(s) for the heuristic search were obtained automatically by applying Neighbour-Joining and BioNJ algorithms to a matrix of pairwise distances estimated using the Maximum Composite Likelihood (MCL) approach, and then selecting the topology with superior log likelihood value. A discrete Gamma distribution was used to model evolutionary rate differences among sites (5 categories (+G, parameter = 0.4535)). The tree is drawn to scale, with branch lengths measured in the number of substitutions per site. The analysis involved 19 nucleotide sequences. Codon positions included were 1st+2nd+3rd. All positions with less than 5% site coverage were eliminated. That is, fewer than 95% alignment gaps, missing data, and ambiguous bases were allowed at any position. There was a total of 652 positions in the final dataset. Evolutionary analyses were conducted in MEGA 6 (Tamura et al. 2013). Genetic distances were also analysed in MEGA 6. The analysis involved 19 nucleotide sequences. Codon positions included were 1st+2nd+3rd. All ambiguous positions were removed for each sequence pair. Results are shown in the supplemental material (Suppl. material 1).

Results

Genetic distance analyses

Interspecific distances vary inside *Riotintobolus* between 11–16.4%, while intraspecific distances are between 1.5–4.1% (Suppl. material 1). The maximum likelihood analysis

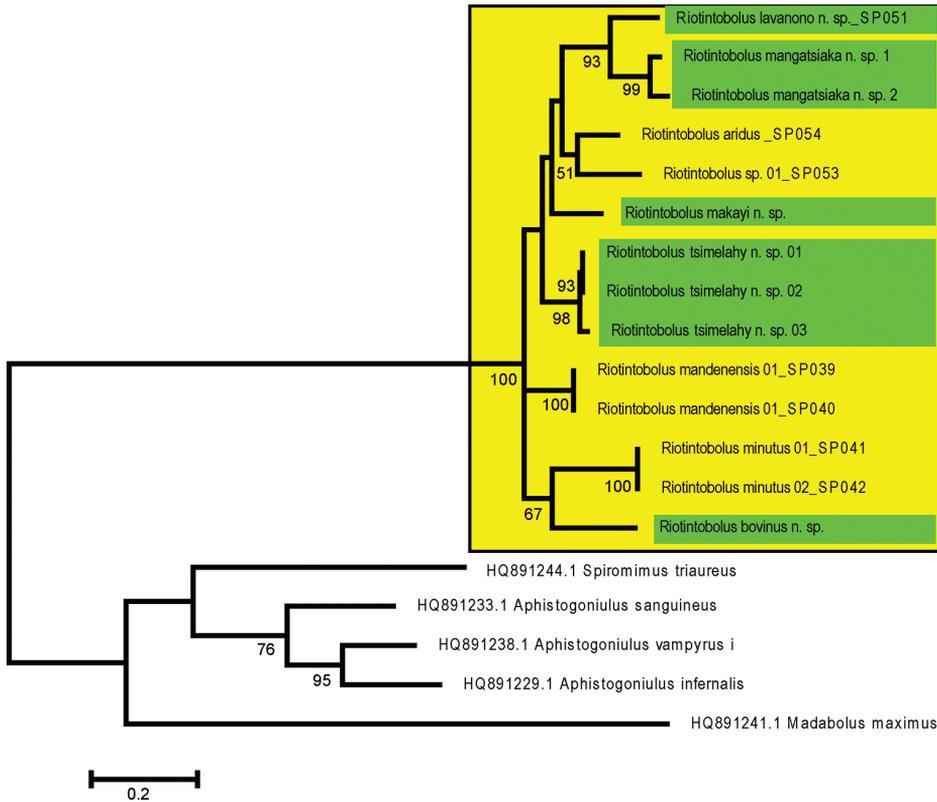


Figure 1. Relationships of *Riotintobolus* species. The evolutionary history of *Riotintobolus* was inferred by using the Maximum Likelihood method based on the Tamura-Nei model. The tree with the highest log likelihood (-5174.8354) is shown. The tree is drawn to scale, with branch lengths measured in the number of substitutions per site. Yellow box marks the genus *Riotintobolus*, green colour bars mark the new species described here. For specimen information, see Table 1. Numbers refer to bootstrap values, values < 50% not shown.

of the COI barcoding gene strongly supports the monophyly of *Riotintobolus* (Fig. 1, 100% bootstrap support). Inside *Riotintobolus*, groups of the eight species and the one candidate species are not well-supported, with the exception of *R. mangatsiaka* sp. nov. being related to *R. lavanono* sp. nov. (Fig. 1, 93% bootstrap support). The species, however, are all recovered as monophyletic receiving a bootstrap support of > 90%.

Taxonomy

Order Spirobolida, family Pachybolidae sensu Hoffman 1980

Genus *Riotintobolus* Wesener, 2009

Type species. *Riotintobolus mandenenensis* Wesener, 2009, by original designation.

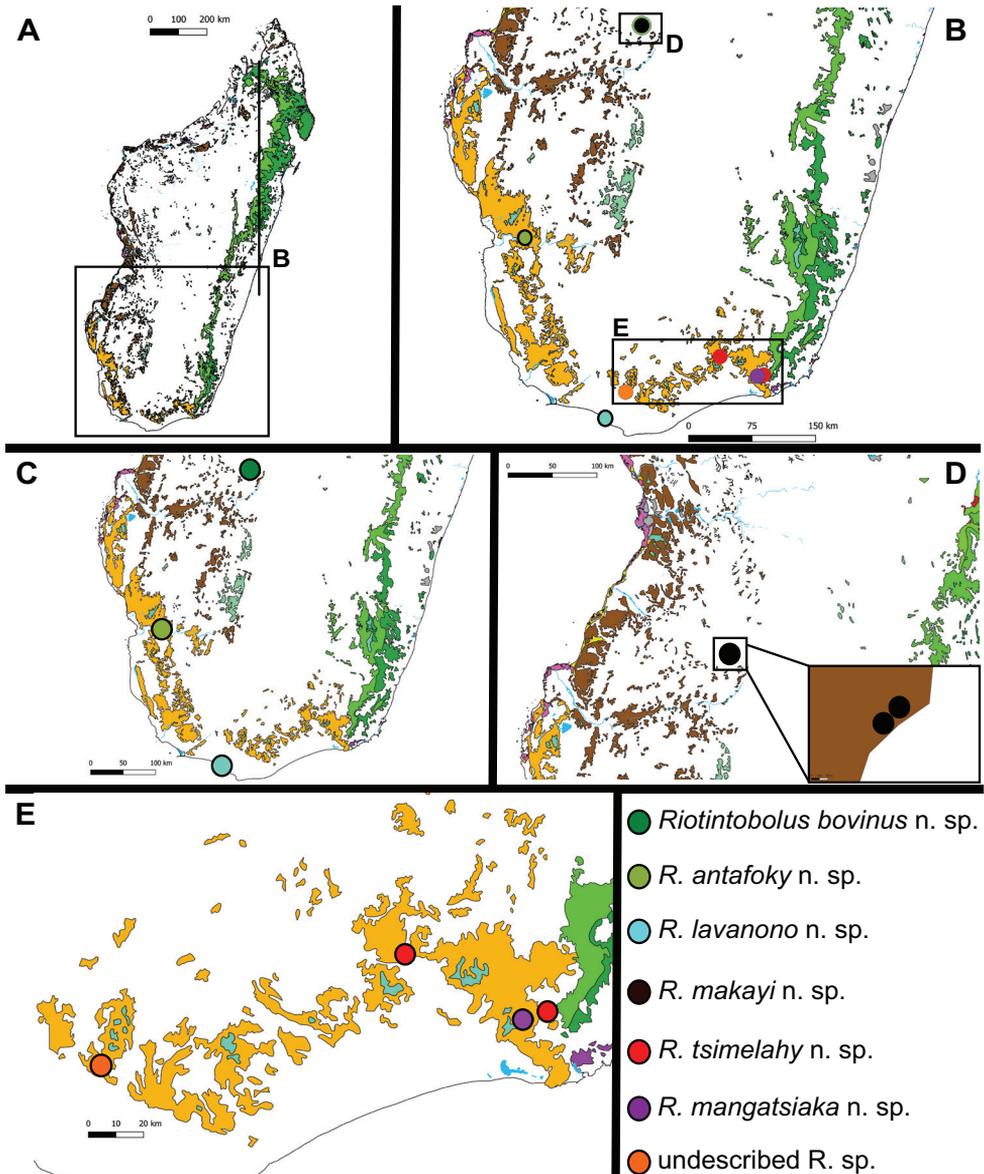


Figure 2. Distribution of the newly described *Riointobolus* species, as well as of the still undescribed species. Vegetation marks modified from Moat and Smith 2007.

Other species included.

Riointobolus minutus Wesener, 2009
Riointobolus aridus Wesener, 2009
Riointobolus anomalus Wesener, 2009
Riointobolus tsimelahy sp. nov.

Riotintobolus mangatsiaka sp. nov.

Riotintobolus lavanono sp. nov.

Riotintobolus bovinus sp. nov.

Riotintobolus antafoky sp. nov.

Riotintobolus makayi sp. nov.

Distribution. Southern spiny forests and gallery forests, southeastern littoral rain-forests (Fig. 2).

Determination key to the species of *Riotintobolus*

- 1 Epiproct of telson projecting into a short process 2
- Epiproct of telson not projecting 5
- 2 Male legs without tarsal pads. Eyes consisting of 20 or less ommatidia. Anal valves with a deep groove between anterior half and sharp-edged lips 3
- Male legs 3–7 with tarsal pads. Eyes with more than 25 ommatidia. Anal valves with neither a groove, nor sharp-edged lips 4
- 3 Specimens 35–43 mm long. Colour laterally black, dorsally with a thick, light brown stripe. Telopodite of posterior gonopod laterally with one large and second small finger-shaped process ***R. mandenensis* Wesener, 2009**
- Specimens shorter than 25 mm. Colour laterally black, dorsally with a thick, red stripe. Telopodite of posterior gonopod laterally with two large finger-shaped processes of equal size ***R. minutus* Wesener, 2009**
- 4 Apical membrane on posterior gonopod weakly developed. Telopodite at mesal margin with a conspicuous horn. Process ‘x’ on lateral margin without recurved tip ***R. aridus* Wesener, 2009**
- Apical membrane on posterior gonopod present as a sail (Fig. 10G: ‘z’). Mesal margin without a horn. Process ‘x’ on lateral margin with a recurved tip bending mesally (Fig. 10G). Efferent duct ending free ***R. makayi* sp. nov.**
- 5 Posterior telopod, telopodite with two or more slender, sharp projections (Fig. 3E) 6
- Posterior gonopod, telopodite, projecting in a simple ‘flag’ (Fig. 9C) 9
- 6 Males > 40 mm, > 45 segments plus telson. Posterior gonopod separated into three parts (Fig. 3E) 7
- Male ca. 25 mm long, 41 segments plus telson. Posterior gonopod only separated into coxite and telopodite (Fig. 8F) ***R. bovinus* sp. nov.**
- 7 Antennae and legs red (Fig. 3A). Posterior gonopod, lateral process slender. Membranous mesal area spanning whole mesal side of tip (Fig. 3E: ‘z’) 8
- Antennae and legs dark grey (Fig. 7A). Posterior gonopod, lateral process wide, straight, well-rounded (Fig. 7E). Membranous mesal area globular (Fig. 7E: ‘z’) ***R. lavanono* sp. nov.**
- 8 Posterior gonopod with two lateral processes (Fig. 3E) ***R. tsimelahy* sp. nov.**
- Posterior gonopod with single lateral process (Fig. 4I) ***R. mangatsiaka* sp. nov.**

- 9 Males > 45 mm long, dorsally with a red stripe. Antenna short, protruding back to segment 3. Male legs 3 to at least midbody legs with tarsal pad. Anterior gonopod, coxal process inconspicuous, not reverted. Posterior gonopod, apical part with membranous flag ***R. anomalus* Wesener, 2009**
- Males only 33 mm long, dorsally without any stripe. Antenna long, protruding back to segment 5. Male legs without a tarsal pad. Anterior gonopod, coxite process, apical margin reverted (Fig. 9A). Posterior gonopod, apical part of telopodite, flag with a sclerotised projection (Fig. 9C)..... ***R. antafoky* sp. nov.**

***Riotintobolus tsimelahy* sp. nov.**

<http://zoobank.org/672376C7-CC91-4259-B896-B45229104743>

Figure 3

Material examined. 1 ♂ *holotype*, ZFMK MYR9940, Madagascar, PN Andohahe-la, Tsimelahy, 24°57.296'S, 046°37.214'E, 135 m, spiny forest, coll. Wesener and Schütte, 24.v.2007.

Paratypes: 9 ♂, 12 ♀, ZFMK MYR941, same data as holotype; 1 ♂, ZFMK MYR9950, same data as holotype; 1 ♂ with damaged gonopods; ZFMK MYR9949, same data as holotype.

Other material examined. 3 ♂ and ♀, BLF 5239 (CASENT9032808), Madagascar, Toliara, Forêt de Mahavelo, Isantoria River, 24°45'30"S, 46°9'26"E, 110 m, 28.i-1.ii.2002, spiny forest/thicket, EH18 pitfall trap, coll. B. L. Fisher et al.; 1 ♂, 1 imm., MZUF Fi-10, Madagascar; Andohahela, 6–12.xii.1991, leg B. Randriamampionona.

Etymology. Tsimelahy, after the type locality (Fig. 2), spiny forests next to the Tsimelahy River, Andohahela National Parc. Noun in apposition.

Diagnosis. *Riotintobolus tsimelahy* sp. nov. shares the absence of a projecting epiproct on the telson only with *R. anomalus*, *R. antafoky* sp. nov., *R. bovinus* sp. nov., *R. mangatsiaka* sp. nov. and *R. lavanono* sp. nov. The posterior telopod featuring two slender, sharp projections is only shared with *R. bovinus* sp. nov., *R. mangatsiaka* sp. nov. and *R. lavanono* sp. nov. A posterior gonopod separated into three parts is only shared with *R. mangatsiaka* sp. nov. and *R. lavanono* sp. nov., whose habitus and gonopods look very similar to those of *R. tsimelahy* sp. nov. Both species differ in details of the tip of the posterior gonopod and in the colour of their antennae and legs, which are red in *R. tsimelahy* sp. nov. and dark grey in *R. lavanono* sp. nov. *R. tsimelahy* sp. nov. differs from *R. mangatsiaka* sp. nov. in the presence of two lateral processes on the posterior gonopod. All three species differ by >11% uncorrected p-distance in the COI barcoding gene.

Description. Measurements: Telson not included in counts of segments. Male holotype with 50+0 segments, ca. 44 mm long, 4.3 mm wide. Largest females of type series with 49 or 50+0 segments, up to 50 mm long, 5.3 mm wide.

Colour (in living specimens): Body rings grey, appendages red. Head, paraprocts and posterior margins of body segments darker grey to black. Ozopore openings highlighted by black spot (Fig. 3A, C).

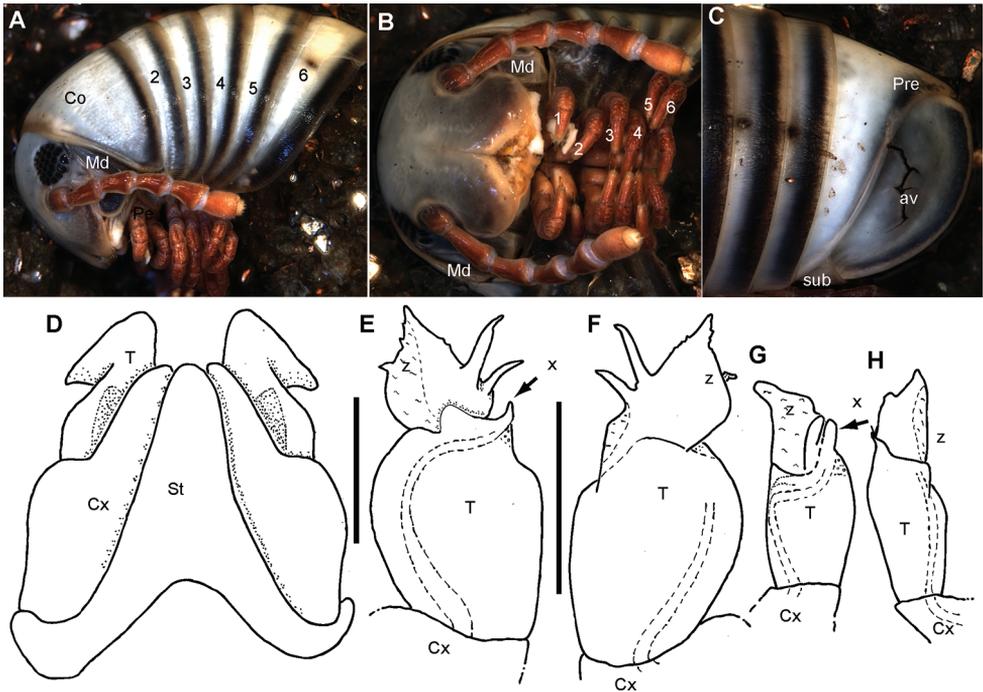


Figure 3. *Riotintobolus tsimelahy* sp. nov., holotype (ZFMK MYR99940) (A–F) and male paratype (ZFMK MYR99949) (G, H) A multi-layer photograph, male anterior body, lateral view B multi-layer photograph, male leg pairs 1–7, ventral view C multi-layer photograph, male posterior body end with telson D anterior gonopod, anterior view E left posterior gonopod, posterior view F right posterior gonopod, anterior view G damaged? left posterior gonopod, posterior view H damaged? right posterior gonopod, anterior view. **Abbreviations:** av = paraprotects; Co = collum (ring 1); Cx = coxite; Md = basal joints of mandible; Pre = epiproct; St = sternite; sub = hypoproct; T = telopodite; x = lateral swollen process; z = apical membranous ‘flag’; numbers refer to leg pair number. Scale bars: 1 mm.

Head: each eye with 30–35 ommatidia in six rows. Incisura lateralis open (Fig. 3A). Labrum with standard three irregular teeth and a single row of 10–12 stout marginal setae. Clypeus with two setiferous foveolae on each side (Fig. 3B). Antennae long, protruding back to segment 5. Length of antennomeres: $1 < 2 > 3 = 4 = 5 = 6$. Second antennomere slenderer but twice as long as first. Terminal antennomere with four large sensory cones located together inside a membranous area.

Gnathochilarium: lamellae linguales each with two standard setae located behind one another. Stipites each with three apical setae. Palpi of similar size. Endochilarium not dissected.

Mandible not dissected.

Collum: smooth, laterally not protruding as far as ring 2 (Fig. 3A).

Body rings: ozopores starting at segment 6, marked by a black spot. Located on suture between meso- and metazonite. Rings with smooth, but irregular coriaceous surface, ventrally on metazona with transverse ridges.

Telson: paraprocts elongated, with weak lips, abundant micropunctuation especially towards edges (Fig. 3C). Epiproct well-rounded, covering, but not reaching above paraproct (Fig. 3C). Hypoproct inconspicuous (Fig. 3C).

Legs: leg 1 with a large cylindrical coxa, twice as long as other podomeres. Tarsus with three pairs of ventral spines and an apical spine beyond claw. Leg 2 with an elongated coxa. Tarsus with three pairs of ventral spines and a short apical spine. Midbody legs with a rectangular coxa, as long as other podomeres. Each podomere ventrally with a single or a pair of apical setae, tarsus with a single apical and three pairs of ventral spines. Length of midbody legs ca. 1.2 times body diameter in males.

Female sexual characters. No tarsal pads, antennae shorter than male, only protruding back to ring 2. Vulvae not dissected.

Male sexual characters: tarsal pads present from leg 3 to midbody, small, inconspicuous (Fig. 3B). Coxae 3–7 without coxal processes, but coxae 3–5 swollen (Fig. 3B).

Anterior gonopod sternite massive (Fig. 3D), elongated into a wide, well-rounded triangular lobe (Fig. 3D). Sternite in anterior view well-visible, without discernible apodemes, protruding almost higher than coxal processes. Coxite with a large, well-rounded mesal process (Fig. 3D). Telopodite with process arising mesally (Fig. 3D), process apically curved with a large triangular projection (Fig. 3D), tip well-rounded, slightly protruding above lateral margin of telopodite (Fig. 3D). Whole telopodite process resembling an even-sided triangle.

Posterior gonopods consisting of three parts, separated by sutures or articulations: a basal coxite with a slender coxite projection and a slightly shorter telopodite, efferent duct discharging laterally (Fig. 3E, F). Process of coxite and telopodite standing in same axis (Fig. 3E, F). Pair of posterior gonopods located parallel to each other, connected by a small, sclerotised and visible sternite. Basal part of coxite wide, mesally with a large triangular sclerite located on lower level than remaining part. Coxite elongated. Efferent duct running at mesal margin of coxite (Fig. 3E) before curving to the lateral margin at beginning of telopodite (Fig. 3E). Telopodite as wide as but much shorter than coxite, standing in same axis (Fig. 3F), apically membranous, with one triangular apical process and two slender lateral processes (Fig. 3E, F). Lateral processes straight, running almost parallel to one another, slender and sclerotised, efferent duct seems to be ending at base of lateral process (Fig. 3E). Base of lateral process with a short, membranous-white projection (Fig. 3E).

Intraspecific variation. The number of segments varies, even within one population, between 47 and 51. The population from the Forêt de Mahavelo (Fig. 1) differs by 1.5% uncorrected p-distance of the COI gene to those from the type locality, Tsimelahy (Suppl. material 1). One small male from the type series (ZFMK MYR9949) has incompletely developed posterior gonopods, either a sign of healed damage (there are black spots on it), or maybe not fully developed (Fig. 3G, H).

Live observations. *R. tsimelahy* sp. nov. could be found in great numbers in the early morning (7–9 a.m.) on the forest floor of the spiny bush. The otherwise dry spiny bush was still quite wet because of dew. No juveniles were observed. Contrary to other *Riotintobolus* species, such as *R. mandenensis* and *R. minutus*, *R. tsimelahy* sp. nov. did

not remain stiff like a stick when disturbed, but rolled-up into a spiral, a common defence behaviour for juliform millipedes.

***Riotintobolus mangatsiaka* sp. nov.**

<http://zoobank.org/9B563AE0-D187-481A-893B-88DF1CE920A3>

Figures 4–6

Material examined. 1 ♂ *holotype*, ZFMK MYR9801, Madagascar, PN Andohahe-la, Mangatsiaka, 24°58.051'S, 046°33.206'E, 90 m, spiny forest, leg. Wesener and Schütte, 23.v.2007.

Paratypes: 7 ♂, 14 ♀, ZFMK MYR938, same data as holotype.

Other material examined. 1 ♂, 1 ♀, FMMC 5413, Province Toliara; RNI d'Andohahela, parcel 2; 120 m; 24°49.0'S, 46°36.6'E; pitfalls, camp 6; leg. S. Goodman 7–15.xii.1995; 1 ♂, FMMC 5379, Province Toliara; RNI d'Andohahela, parcel 2; 120 m; 24°49.0'S, 46°36.6'E; pitfalls, camp 6; leg. S. Goodman 7–15.xii.1995;

Etymology. Mangatsiaka, after the type locality (Fig. 2), spiny forests next to a site called Mangatsiaka, Andohahela National Parc. Noun in apposition.

Diagnosis. *Riotintobolus mangatsiaka* sp. nov. shares the absence of a projecting epiproct on the telson only with *R. anomalus*, *R. antafoky* sp. nov., *R. bovinus* sp. nov., *R. tsimelahy* sp. nov. and *R. lavanono* sp. nov. The posterior telopod featuring two slender, sharp projections is only shared with *R. bovinus* sp. nov., *R. tsimelahy* sp. nov. and *R. lavanono* sp. nov. A posterior gonopod separated into three parts is only shared with *R. tsimelahy* sp. nov. and *R. lavanono* sp. nov., whose habitus and gonopods look very similar to those of *R. mangatsiaka* sp. nov. Both species differ in details of the tip of the posterior gonopod and in the colour of their antennae and legs, which are red in *R. mangatsiaka* sp. nov. and dark grey in *R. lavanono* sp. nov. *R. mangatsiaka* sp. nov. differs from *R. tsimelahy* sp. nov. in the presence of just one lateral processes on the posterior gonopod. All three species differ by >11% uncorrected p-distance in the COI barcoding gene.

Description. Measurements: male holotype with 49+0 segments, ca. 42 mm long, 4.1 mm wide. Largest females of type series with 48 to 51+0 segments, up to 52 mm long, 5.4 mm wide.

Colour (in living specimens): Body rings grey, appendages red. Head, paraprocts and posterior margins of body segments darker grey to black (Fig. 4A). Ozopore openings highlighted by black spot (Fig. 4A, B).

Head: each eye with 30–35 ommatidia in six rows. Incisura lateralis open (Fig. 4C). Labrum with standard three irregular teeth and a single row of 10–12 stout marginal setae. Clypeus with two setiferous foveolae on each side (Fig. 4D). Antennae long, protruding back to segment 5. Length of antennomeres: 1<2>3=4=5=6. Second antennomere slenderer but twice as long as first. Terminal antennomere with four large sensory cones located together inside a membranous area (Fig. 5A). Antennomere 5 with 3 rows, antennomere 6 latero-apically with a single row of sensilla basiconica

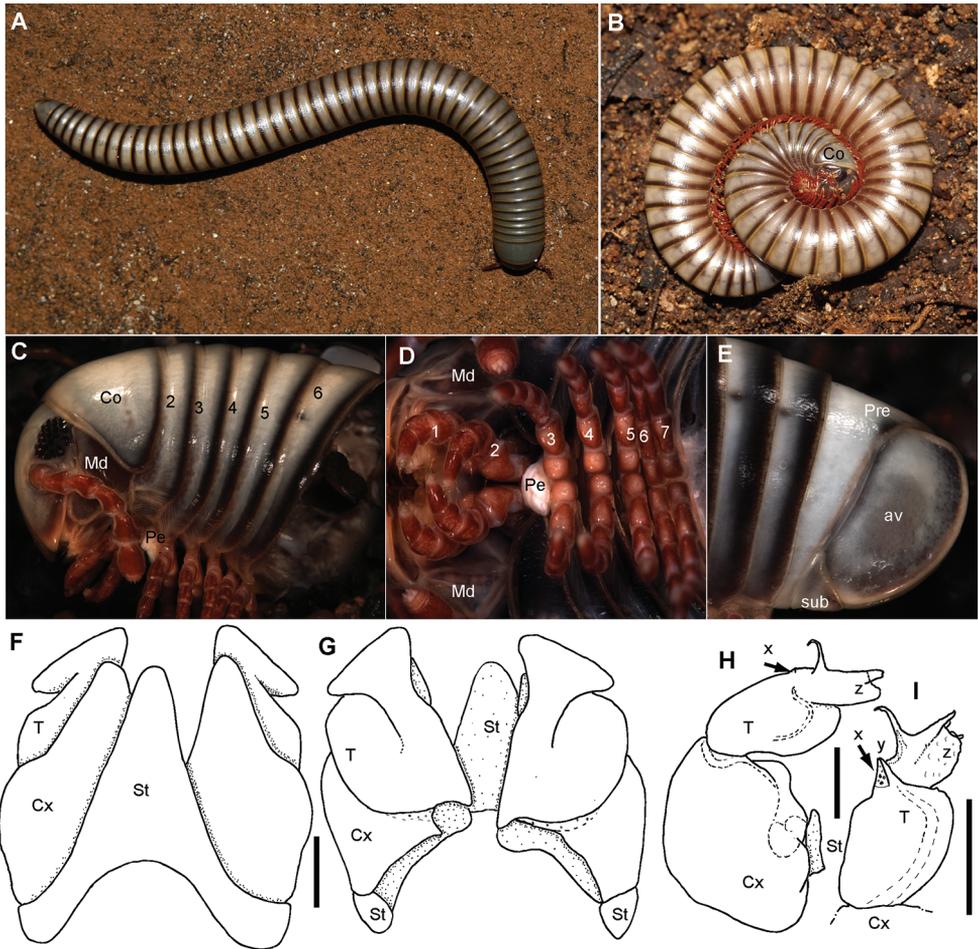


Figure 4. *Riotintobolus mangatsiaka* sp. nov., paratypes (ZFMK MYR938) **A** living female **B** living male in defensive position **C** multi-layer photograph, male anterior body, lateral view **D** multi-layer photograph, male leg pairs 1–7, ventral view **E** multi-layer photograph, male posterior body end with telson **F** anterior gonopod, anterior view **G** anterior gonopod, posterior view **H** right posterior gonopod, posterior view **I** right posterior gonopod, anterior view. **Abbreviations:** av = paraprocts; Co = collum (ring 1); Cx = coxite; Md = basal joints of mandible; Pe = penis; Pre = epiproct; St = sternite; sub = hypoproct; T = telopodite; x = lateral swollen process; y = opening of efferent duct; z = apical membranous ‘flag’; numbers refer to leg pair number. Scale bars: 1 mm.

(Fig. 5B–E). Antennomere 6 with an unknown type of at least three sensilla or duct openings located close to disc (Fig. 5D, E).

Gnathochilarium: lamellae linguales each with two standard setae located behind one another. Stipites each with three apical setae. Palpi of similar size (Fig. 5F). Central pads with standard two sets of sensory cones, apical area with ten cones, higher area with ~ 30 (Fig. 5G).

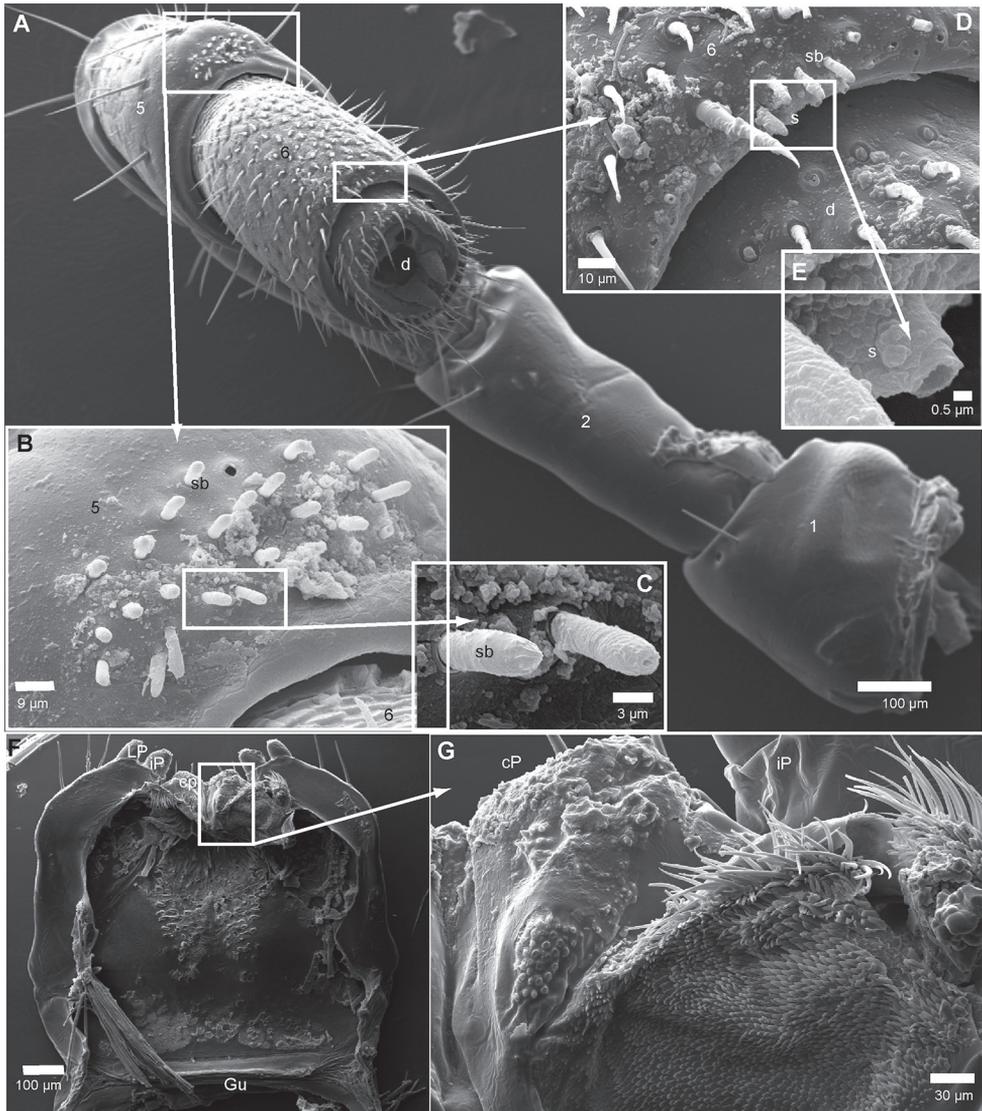


Figure 5. *Riotintobolus mangatsiaka* sp. nov., male (FMMC 5413), SEM **A** left antennae **B** antennomere 5 **C** details of sensilla basiconica **D** antennomere 6 **E** detail of unknown sensilla/pore opening **F** gnathochilarium underside **G** gnathochilarium, detail of right central pad. **Abbreviations:** cP = central pads; d = disc; iP = inner palpus; LP = lateral palpus; s = unknown sensillum; sb = sensilla basiconica; numbers refer to antennomere number. Scale bars as indicated.

Mandible: Stipes without projection, well rounded (Fig. 4C). Gnathal lobe, external tooth simple, rounded; mesal tooth with three cusps (Fig. 6A). Eight pectinate lamellae. Mesal margin of pectinate area (intermediate area) with ca. four rows of small, slender spines. Molar plate with few, five, transverse furrows (Fig. 6A).

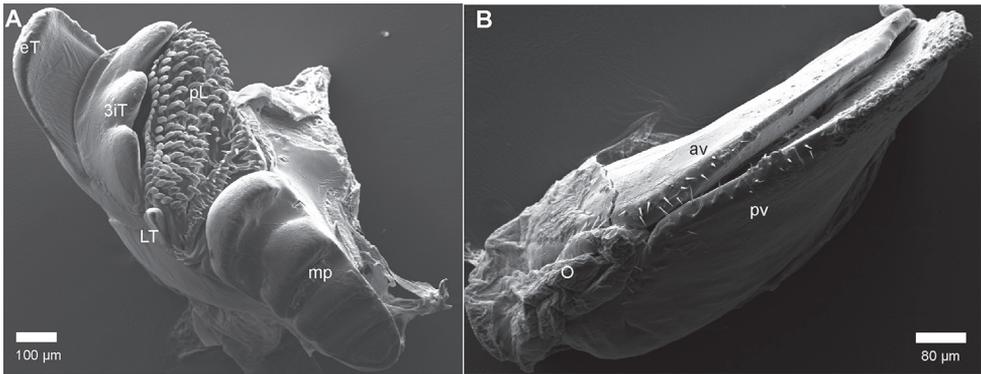


Figure 6. *Riotintobolus mangatsiaka* sp. nov., male and female (FMMC 5413), SEM **A** left gnathal lobe of mandible, mesal view **B** left female vulva, lateral view. **Abbreviations:** av = anterior orientated plate; 3iT = 3-combed inner tooth; eT ? external tooth; LT = lateral tooth; mp = molar plate; O = operculum; pL = pectinate lamellae; pv = posterior orientated plate. Scale bars as indicated.

Collum: smooth, laterally not protruding as far as ring 2 (Fig. 4C).

Body rings: ozopores starting at segment 6, marked by a black spot. Located on suture between meso- and metazonite. Rings with smooth, but irregular coriaceous surface, ventrally on metazona with transverse ridges.

Telson: paraprocts elongated, with weak lips, abundant micropunctuation especially towards edges (Fig. 4E). Epiproct well-rounded, covering, but not reaching above paraproct (Fig. 4E). Hypoproct inconspicuous (Fig. 4E).

Legs: leg 1 with a large cylindrical coxa, twice as long as other podomeres. Tarsus with three pairs of ventral spines and an apical spine beyond claw. Leg 2 with an elongated coxa. Tarsus with three pairs of ventral spines and a short apical spine. Midbody legs with a rectangular coxa, as long as other podomeres. Each podomere ventrally with a single or a pair of apical setae, tarsus with a single apical spine and three pairs of ventral spines. Length of midbody legs ca. 1.2 times body diameter in males.

Female sexual characters. No tarsal pads, antennae shorter than male, only protruding back to ring 2. Female vulva simple, bivalve-like (Fig. 6B). Anterior plate smaller than posterior plate, opening with one row of setae on each plate, close to operculum.

Male sexual characters: tarsal pads present from leg 3 to midbody, small, inconspicuous (Fig. 4D). Coxae 3–7 without coxal processes, but coxae 3–5 swollen (Fig. 3D).

Anterior gonopod sternite massive (Fig. 4F), elongated into a wide, well-rounded triangular lobe (Fig. 4F). Sternite in anterior view well-visible, without discernible apodemes, protruding almost as high as coxal processes. Coxite with a large, well-rounded mesal process (Fig. 4F, G). Telopodite with process arising mesally (Fig. 4G), process apically curved with a large triangular projection (Fig. 4G), tip well-rounded, slightly protruding above lateral margin of telopodite (Fig. 4F). Whole telopodite process resembling an even-sided triangle.

Posterior gonopods consisting of three parts, separated by sutures or articulations (Fig. 4H): a basal coxite with a slender coxite projection and a slightly shorter telopo-

dite, efferent duct discharging laterally (Fig. 4H, I). Process of coxite and telopodite standing in same axis (Fig. 4H). Pair of posterior gonopods located parallel to each other, connected by a small, sclerotised and visible sternite (Fig. 4H). Basal part of coxite wide, mesally with a large triangular sclerite located on lower level than remaining part (Fig. 4H). Coxite elongated. Efferent duct running at mesal margin of coxite (Fig. 4H, I) before curving to the lateral margin at beginning of telopodite (Fig. 4I). Telopodite as wide as but much shorter than coxite, standing in same axis (Fig. 4H, I), apically membranous, with two slender apical processes both diverging (Fig. 4H, I). Mesal process membranous and wider, lateral process longer, slenderer and sclerotised, efferent duct seems to be ending at base of lateral process (Fig. 4H, I). Base of lateral process with a short, membranous-white projection (Fig. 4I).

Intraspecific variation. The number of segments varies between 47 and 51.

Live observations. *R. mangatsiaka* sp. nov. could be found in great numbers in the early morning (7–9 a.m.) on the forest floor of the spiny bush. The otherwise dry spiny bush was still quite wet because of dew. No juveniles were observed. Contrary to other *Riotintobolus* species, such as *R. mandenensis* and *R. minutus*, *R. mangatsiaka* sp. nov. did not remain stiff like a stick when disturbed, but rolled-up into a spiral (Fig. 4B), a common defence behaviour for juliform millipedes.

***Riotintobolus lavanono* sp. nov.**

<http://zoobank.org/4BBC68AE-EAB0-4311-88EA-DDCFD5C1882F>

Figure 7

Material examined. 1 ♂ *holotype*, ZFMK MYR9941, Madagascar, South, Lavanono Beach, 25°25.404'S, 044°56.414'E, 27 m, spiny bush at the coast, after rain, leg. Wesener and Schütte, 18.vi.2007.

Paratypes: 16 ♂, 18 ♀, ZFMK MYR942, same data as holotype;

Etymology. Lavanono, after the type locality, spiny forests directly next to the Lavanono Beach (Fig. 2). Noun in apposition.

Diagnosis. *Riotintobolus lavanono* sp. nov. shares the absence of a projecting epiproct on the telson with *R. anomalus*, *R. antafoky* sp. nov., *R. bovinus* sp. nov., *R. tsimelahy* sp. nov. and *R. mangatsiaka* sp. nov., The posterior telopod featuring two slender, sharp projections is only shared with *R. bovinus* sp. nov., *R. mangatsiaka* sp. nov. and *R. tsimelahy* sp. nov. A posterior gonopod separated into three parts is only shared with *R. mangatsiaka* sp. nov. and *R. tsimelahy* sp. nov., whose habitus and gonopods look very similar to those of *R. lavanono* sp. nov. Both species differ in details of the tip of the posterior gonopod and in the colour of their antennae and legs, which are dark grey in *R. lavanono* sp. nov. and red in both *R. mangatsiaka* sp. nov. and *R. tsimelahy* sp. nov. All three species differ by >11% uncorrected p-distance in the COI barcoding gene.

Description. Measurements: male holotype with 47+0 segments, ca. 42 mm long, 4.2 mm wide. Largest females of type series with 46–48+0 segments, up to 58 mm long, 6.4 mm wide.

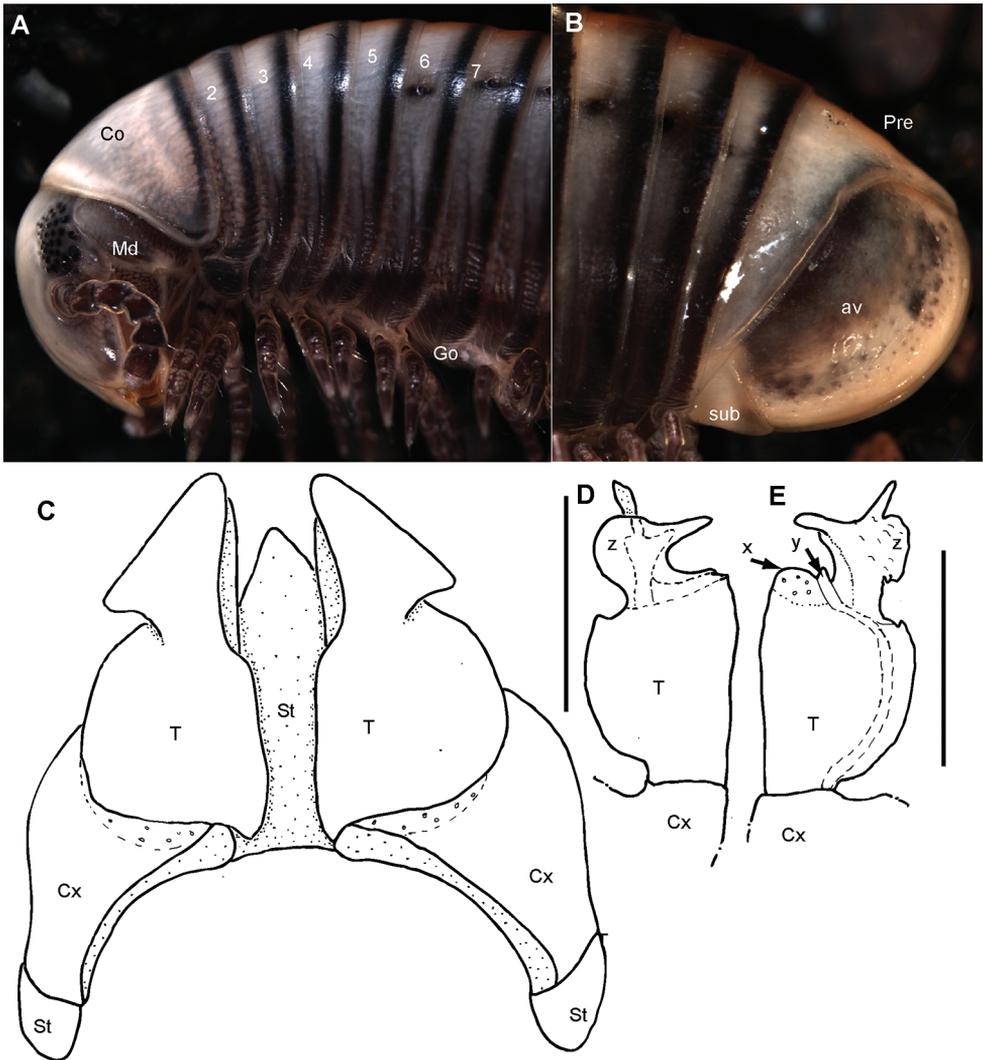


Figure 7. *Riotintobolus lavanono* sp. nov., paratype male (ZFMK MYR942) **C** anterior gonopod, anterior view; posterior view **D** telopodite of left posterior gonopod, posterior view **E** left posterior gonopod, anterior view. **Abbreviations:** av = paraprocts; Co = collum (ring 1); Cx = coxite; Go = gonopods; Md = basal joints of mandible; Pre = epiproct; St = sternite; sub = hypoproct; T = telopodite; x = lateral swollen process; y = opening of efferent duct; z = apical membranous ‘flag’; numbers refer to leg pair or segment number. Scale bars: 1 mm.

Colour (in living specimens): Body rings and head grey, appendages black (Fig. 7A). Paraprocts and posterior margins of body segments darker grey to black (Fig. 7B). Ozopore openings highlighted by black spot.

Head: each eye with 28–32 ommatidia in six rows. Incisura lateralis open (Fig. 7A). Labrum with standard three irregular teeth and a single row of 10–12 stout marginal

setae. Clypeus with two setiferous foveolae on each side. Antennae long, protruding back to segment 5. Length of antennomeres: 1<2>3>4=5=6. Terminal antennomere with four large sensory cones located together inside a membranous area. Antennomere 5 and 6 latero-apically with sensilla basiconica.

Gnathochilarium: lamellae linguales each with two standard setae located behind one another. Stipites each with three apical setae. Endochilarium not dissected.

Mandible: Stipes without projection, well rounded (Fig. 7A). Gnathal lobe not investigated.

Collum: smooth, laterally not protruding as far as ring 2 (Fig. 7A).

Body rings: ozopores starting at segment 6, marked by a black spot. Located on suture between meso- and metazonite. Rings with smooth, but irregular coriaceous surface, ventrally on metazona with transverse ridges.

Telson: paraprocts elongated, with weak lips, abundant micropunctuation especially towards edges (Fig. 7B). Epiproct well-rounded, covering, but not reaching above paraproct (Fig. 7B). Hypoproct inconspicuous (Fig. 7B).

Legs: leg 1 with a large cylindrical coxa, twice as long as other podomeres. Tarsus with three pairs of ventral spines and an apical spine beyond claw. Leg 2 with an elongated coxa. Tarsus with three pairs of ventral spines and a short apical spine. Midbody legs with a rectangular coxa, as long as other podomeres. Each podomere ventrally with a single or a pair of apical setae, tarsus with a single apical and four pairs of ventral spines. Length of midbody legs ca. 1.2 times body diameter in males.

Female sexual characters. No tarsal pads, antennae shorter than male, only protruding back to ring 2. Female vulva simple, bivalve-like.

Male sexual characters: tarsal pads present from leg 3 to midbody, small, inconspicuous. Coxae 3–7 without coxal processes, but coxae 3–5 swollen.

Anterior gonopod sternite massive, elongated into a wide, well-rounded triangular lobe (Fig. 7C). Sternite in anterior view well-visible, without discernible apodemes, protruding almost as high as coxal processes. Coxite with a large, well-rounded mesal process. Telopodite with slender process arising mesally (Fig. 7C), process apically curved with a large triangular projection, tip well-rounded, slightly protruding above lateral margin of telopodite.

Posterior gonopods consisting of three parts, separated by sutures or articulations (Fig. 7D): a basal coxite with a slender coxite projection and a shorter telopodite, efferent duct discharging laterally (Fig. 7E). Process of coxite and telopodite standing in same axis. Pair of posterior gonopods located parallel to each other, connected by a small, sclerotised and visible sternite. Basal part of coxite wide, mesally with a large triangular sclerite located on lower level than remaining part. Coxite elongated. Efferent duct running at mesal margin of coxite before curving to the lateral margin at beginning of telopodite (Fig. 7E). Telopodite half as wide and much shorter than coxite, standing in same axis, apically membranous, with two slender apical processes both diverging (Fig. 7D, E). Mesal process membranous and wider, lateral process bent 90 degrees laterally, longer, slenderer and sclerotised, efferent duct seems to be ending at base of lateral process (Fig. 7E). Base of lateral process with a short, membranous-white projection (Fig. 7E).

Intraspecific variation. Specimens of the same population differing between 45–47 in segment number. Females appear to be more brownish than the more greyish males.

Live observations. *R. lavanono* sp. nov. could be found in great numbers after a rainy day in the late afternoon (3–5 p.m.) in a small remnant of spiny bush and under dead *Opuntia* remains. The specimens were only encountered in an area of a few square meters in view of the coast. Contrary to other *Riotintobolus* species, such as *R. mandenensis* and *R. minutus*, *R. lavanono* sp. nov. did not remain stiff like a stick when disturbed, but rolled-up into a spiral.

***Riotintobolus bovinus* sp. nov.**

<http://zoobank.org/5292954C-AE5F-486B-BEDE-941ADA580C1C>

Figure 8

Material examined. 1 ♂ *holotype*, ZFMK MYR940, Madagascar, Province de To-liara, Makay Mts., forêt de galerie, 21°13'27.5"S, 045°19'35.4"E, 531 m, coll. Jean Noel, 30.xi.2010.

Etymology: bovinus, after the gonopods which resemble the horns of a cow. Noun in apposition.

Diagnosis. *Riotintobolus bovinus* sp. nov. shares the absence of a projecting epiproct on the telson only with *R. anomalus*, *R. antafoky* sp. nov., *R. tsimelahy* sp. nov., *R. mangatsiaka* sp. nov. and *R. lavanono* sp. nov. The posterior telopod featuring two slender, sharp projections is only shared with *R. tsimelahy* sp. nov., *R. mangatsiaka* sp. nov. and *R. lavanono* sp. nov. *R. bovinus* sp. nov. differs from *R. tsimelahy* sp. nov., *R. mangatsiaka* sp. nov. and *R. lavanono* sp. nov. in a much smaller segment number and size, and strong differences in the posterior telopod, whose telopodite is uniquely shaped with two sharp processes running parallel to one another resembling a bull's horn. *R. bovinus* sp. nov. differs by more than 14% uncorrected p-distance in the COI barcoding gene from all other *Riotintobolus* species.

Description. Measurements: 41+0 segments. Ca. 25 mm long (broken), 2.4 mm wide.

Colour (after 10 years in ethanol): Head and body rings grey, appendages red. Ventral site reddish. Posterior margins of body segments and whole margin of collum black. Anal valves black.

Head: each eye with 24–27 ommatidia in six rows. Incisura lateralis open (Fig. 8A). Labrum with standard three irregular teeth and a single row of 10–12 stout marginal setae. Clypeus with two setiferous foveolae on each side (Fig. 8B). Antennae short, protruding back to segment 3. Length of antennomeres: 1<2>3>4=5=6, second only slightly longer than 3rd. Terminal antennomere with four large sensory cones located together inside a membranous area (Fig. 8B). Antennomere 5 and 6 latero-apically with sensilla basiconica.

Gnathochilarium: lamellae linguales each with two standard setae located behind one another. Stipites each with three apical setae. Endochilarium not dissected.

Mandible: Stipes without projection, well rounded (Fig. 8A, B). Gnathal lobe not dissected.

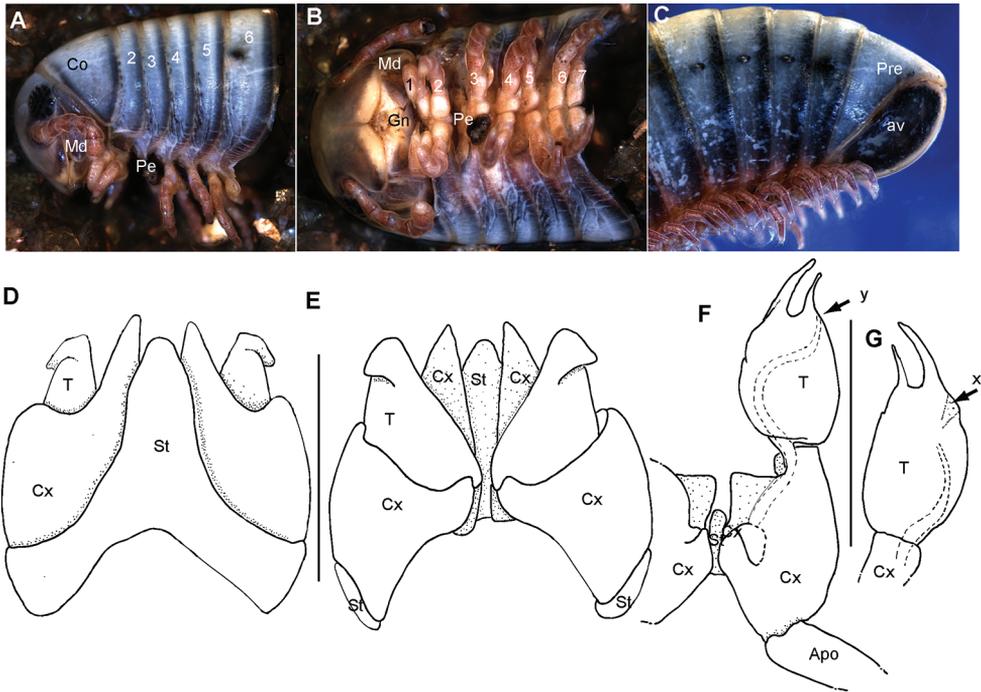


Figure 8. *Riotintobolus bovinus* sp. nov., male holotype (ZFMK MYR940) **A** multi-layer photograph, anterior body, lateral view **B** multi-layer photograph, leg pairs 1–7, ventral view **C** multi-layer photograph, posterior body end with telson **D** anterior gonopod, anterior view **E** anterior gonopod, posterior view **F** left posterior gonopod, posterior view **G** left posterior gonopod, anterior view. **Abbreviations:** Apo = apodeme; av = paraproct; Co = collum (ring 1); Cx = coxite; Gn = gnathochilarium; Md = basal joints of mandible; Pe = penis; Pre = epiproct; St = sternite; T = telopodite; x = lateral swollen process; y = opening of efferent duct; numbers refer to leg pair or segment number. Scale bars: 1 mm.

Collum: smooth, laterally not protruding as far as ring 2 (Fig. 8A).

Body rings: ozopores starting at segment 6, marked by a black spot. Located slightly before, but touching suture between meso- and metazonite. Rings with smooth, but irregular coriaceous surface, ventrally on metazona with transverse ridges.

Telson: paraproct without lips, abundant micropunctation especially towards edges (Fig. 8C). Epiproct well-rounded, covering, but not reaching above paraproct (Fig. 8C). Hypoproct inconspicuous (Fig. 8C).

Legs: leg 1 with a large cylindrical coxa, twice as long as other podomeres. Tarsus with three pairs of ventral spines and an apical spine beyond claw. Leg 2 with an elongated coxa and a strongly swollen prefemur. Tarsus with two pairs of ventral spines and a short apical spine. Midbody legs with a rectangular coxa, as long as other podomeres. Each podomere ventrally with a single or a pair of apical setae, tarsus with a tarsal pad, a single apical and two pairs of ventral spines. Length of midbody legs ca. 1.2 times body diameter in males.

Female: unknown.

Male sexual characters: tarsal pads absent (Fig. 8B). Coxae 3–7 without coxal processes (Fig. 8B).

Anterior gonopod sternite massive (Fig. 8D), elongated into a wide, well-rounded triangular lobe (Fig. 8D). Sternite in anterior view well-visible, without discernible apodemes, protruding almost as high as coxal processes. Coxite with sharp triangular mesal process (Fig. 8D, E). Telopodite with slender process arising mesally (Fig. 8E), process apically curved with a short triangular projection (Fig. 8D), tip well-rounded tip, slightly protruding above lateral margin of telopodite (Fig. 8E).

Posterior gonopods consisting of two parts, separated by an articulation (Fig. 8F): a long coxite and a slightly shorter telopodite, efferent duct discharging apically (Fig. 8F, G). Process of coxite and telopodite standing in same axis (Fig. 8F). Pair of posterior gonopods located parallel to each other, connected by a small, sclerotised and visible sternite (Fig. 8F). Basal part of coxite wide, mesally with a large triangular sclerite located on lower level than remaining part (Fig. 8F). Coxite elongated. Efferent duct running at mesal margin of coxite (Fig. 8F, G). Telopodite as wide as but slightly shorter than coxite, standing in same axis (Fig. 8F, G), apically membranous, with two slender apical processes resembling a bull's horns (Fig. 8F, G). Mesal process wider and longer than lateral process. Efferent duct seems to be ending at base of mesal process (Fig. 8F, G).

Remarks. *Riotintobolus bovinus* sp. nov. lives in direct sympatry with another species of the genus, *Riotintobolus makayi* sp. nov. (Fig. 2).

***Riotintobolus antafoky* sp. nov.**

<http://zoobank.org/9F3E2163-ACA9-4A1F-B6D0-D24CD3A692D8>

Figure 9

Material examined. *Holotype*: ♂, **CASENT 9032794**, MGF007, Madagascar, Province Toliara, Antafoky, 80 m, spiny thicket, 23°29'16"S, 44°4'39"E, coll. Frontier project, millipede dig (3 m x 3 m), 14.xi.2001.

Paratypes: 1 ♂, 1 ♀, **CASENT 9032794**, same data as holotype

Etymology. Antafoky, after the type locality, spiny forest of Antafoky (Fig. 2). Noun in apposition.

Diagnosis. *R. antafoky* sp. nov. shares the flag-like membranous tip of the posterior gonopod with *R. mandenensis*, *R. minutus*, *R. aridus*, *R. anomalus* and *R. makayi* sp. nov. *R. antafoky* sp. nov. shares the absence of tarsal pads only with *R. bovinus* sp. nov., and the relatively simple tip of the posterior gonopod only with *R. anomalus*. *R. antafoky* sp. nov. differs from the sympatric *R. anomalus* in details of the posterior gonopod, the absence of a dorsal red stripe, the much longer antenna (protruding back to body ring 5), and the much smaller size (*R. anomalus* males 45 mm long, 4.3 mm wide, *R. antafoky* sp. nov. ca. 33 mm long, 3.2 mm wide).

Description. Measurements (holotype): 51+0 segments, ca. 33 mm long (fragmented) and 3.2 mm wide.

Coloration: segments grey, with a dark grey posterior margin, ozopore highlighted by a black spot. Head, antennae and legs dark grey.

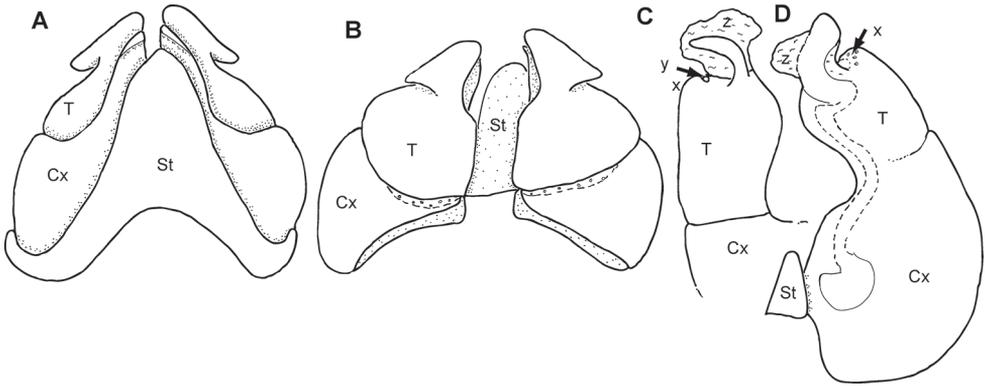


Figure 9. *Riotintobolus antafoky* sp. nov., holotype (CASENT9032794) **A** anterior gonopod, anterior view **B** anterior gonopod, posterior view **C** telopodite of left posterior gonopod, anterior view **D** left posterior gonopod, posterior view. **Abbreviations:** Cx = coxite; St = sternite; T = telopodite; x = lateral swollen process; y = opening of efferent duct; z = apical membranous ‘flag’. Not to scale.

Head: each eye with 34 ommatidia in six rows. Incisura lateralis open. Labrum with standard three irregular teeth and a single row of 10–12 stout marginal setae. Clypeus with two setiferous foveolae on each side. Antennae long, protruding back to segment 5. Terminal antennomere with four large sensory cones located together inside a membranous area. Antennomere 5 and 6 latero-apically with sensilla basiconica.

Gnathochilarium: lamellae linguales each with two standard setae located behind one another. Stipites each with three apical setae. Endochilarium not dissected.

Mandible: Stipes without projection, well rounded. Gnathal lobe not dissected.

Collum: smooth, laterally not protruding as far as ring 2.

Body rings: ozopores starting at segment 6, marked by a black spot. Located slightly before, but touching suture between meso- and metazonite. Rings with smooth, but irregular coriaceous surface, ventrally on metazona with transverse ridges.

Telson: paraprocts without lips, abundant micropunctuation especially towards edges. Epiproct well-rounded, covering, but not reaching above paraproct. Hypoproct inconspicuous.

Legs: leg 1 with a large cylindrical coxa, twice as long as other podomeres. Tarsus with three pairs of ventral spines and an apical spine beyond claw. Leg 2 with an elongated coxa and a strongly swollen prefemur. Tarsus with two pairs of ventral spines and a short apical spine. Midbody legs with a rectangular coxa, as long as other podomeres. Each podomere ventrally with a single or a pair of apical setae, tarsus without a tarsal pad, a single apical and two pairs of ventral spines. Length of midbody legs ca. 0.9 times body diameter in males.

Female: not investigated.

Male sexual characters: tarsal pads absent. Coxae 3–7 without coxal processes, but coxae 6 and 7 flattened, rectangular.

Anterior gonopod sternite massive (Fig. 9A), elongated into a wide, well-rounded triangular lobe (Fig. 9A). Sternite in anterior view well-visible, without discernible

apodemes, protruding almost as high as coxal processes. Coxite with sharp triangular mesal process (Fig. 9A, B), upper rim bending forward in anterior view (Fig. 9A). Telopodite with strong process arising mesally (Fig. 9B), process apically curved with a short triangular projection (Fig. 9A), tip well-rounded, protruding above lateral margin of telopodite (Fig. 9B).

Posterior gonopods consisting of two parts, separated by an articulation: a long coxite and a slightly shorter telopodite, efferent duct discharging apically (Fig. 9C, D). Process of coxite and telopodite standing in same axis (Fig. 9D). Pair of posterior gonopods located parallel to each other, connected by a small, sclerotised and visible sternite (Fig. 9D). Basal part of coxite wide, mesally with a triangular sclerite located on lower level than remaining part (Fig. 9C). Coxite elongated. Efferent duct running at mesal margin of coxite (Fig. 9C, D). Telopodite as wide as but slightly shorter than coxite, standing in same axis (Fig. 9D), apically with a membranous ‘flag’ (Fig. 9C, D). Laterally with sclerotised projection bending laterally and completely surrounded by membranous flag. (Fig. 9C, D). Efferent duct ending at base of process (Fig. 9C, D). Apex laterally with weakly developed finger-shaped process.

Remarks. this species lives in direct sympatry with the much larger *R. anomalus*.

***Riotintobolus makayi* sp. nov.**

<http://zoobank.org/233B0416-1281-4AB0-8D12-72688CFEE696>

Figure 10

Material examined. 1 ♂ **holotype**, ZFMK MYR7173, Madagascar, Province de Toliara, Makay Mts., forêt de galerie, 21°13'25.1"S, 045°19'36.0"E, 512 m, coll. Jean Noel, 29.xi.2010. Paratypes: 1 ♂, 1 ♀, ZFMK MYR939, Madagascar, Province de Toliara, Makay Mts., forêt de galerie, 21°13'27.5"S, 045°19'35.4"E, 531 m, coll. Jean Noel, 01.xii.2010.

Etymology. Makayi, after the type locality, the area of Makay (Fig. 2). Noun in apposition.

Diagnosis. *R. makayi* sp. nov. shares the flag-like membranous tip of the posterior gonopod with *R. mandenensis*, *R. minutus*, *R. aridus*, *R. anomalus* and *R. antafoky* sp. nov. *Riotintobolus makayi* sp. nov. shares the wide dorsal stripe, presence of tarsal pads on at least male legs 3–7, and a projecting epiproct only with *R. mandenensis*, *R. minutus*, and *R. aridus*. *R. makayi* sp. nov. differs from *R. mandenensis* and *R. minutus* in the configuration of the flag of the posterior telopod, which consists only of a single fold, while it has two folds in the latter two species. The curved lateral process and the freely ending efferent duct are unique characters for *R. makayi* sp. nov.

Description (based on male holotype): **Measurements:** Male holotype: 38+0 segments. Ca. 22 mm long (broken), 2.4 mm wide. Female paratype: 38+0 segments. Ca. 33 mm long (broken), 3.5 mm wide.

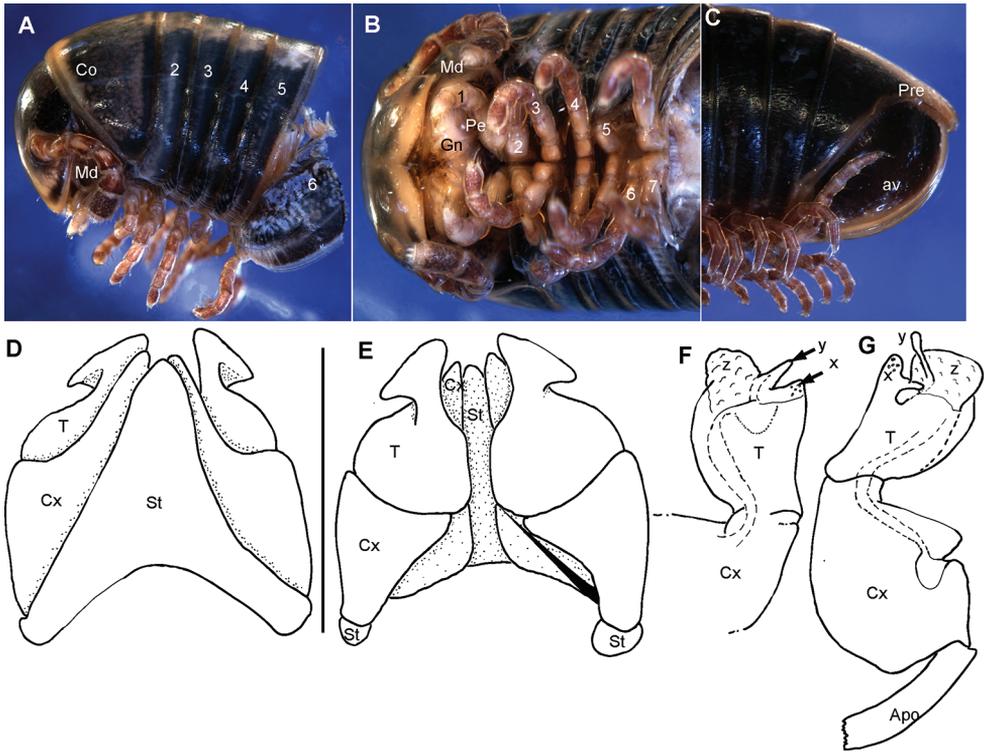


Figure 10. *Riotintobolus makayi* sp. nov., male holotype (ZFMK MYR939) **A** multi-layer photograph, anterior body, lateral view **B** multi-layer photograph, leg pairs 1–7, ventral view **C** multi-layer photograph, posterior body end with telson **D** anterior gonopod, anterior view **E** anterior gonopod, posterior view **F** right posterior gonopod, anterior view **G** right posterior gonopod, posterior view. **Abbreviations:** Apo = apodeme; av = paraproct; Co = collum (ring 1); Cx = coxite; Gn = gnathochilarium; Md = basal joints of mandible; Pre = epiproct; St = sternite; T = telopodite; x = lateral swollen process; y = opening of efferent duct; z = apical membranous ‘flag’; numbers refer to leg pair or segment number. Scale bars: 1 mm.

Colour (after ten years in ethanol): Head except for light clypeus black, body rings black, appendages red (Fig. 10A, B). Anterior margin of collum light brown. Dorsally with two wide light brown-reddish stripes, divided by a black stripe, all stripes even crossing the epiproct. Anal valves black, margin light brown, hypoproct light brown (Fig. 10C).

Head: each eye with 26–28 ommatidia in six rows. Incisura lateralis open (Fig. 10A). Labrum with standard three irregular teeth and a single row of 10–12 stout marginal setae. Clypeus with two setiferous foveolae on each side (Fig. 10B). Antennae short, protruding back to segment 3. Length of antennomeres: 1 < 2 = 3 = 4 = 5 = 6. Terminal antennomere with four large sensory cones located together inside a membranous area (Fig. 10B). Antennomere 5 and 6 latero-apically with sensilla basiconica.

Gnathochilarium: lamellae linguales each with two standard setae located behind one another. Stipites each with three apical setae. Endochilarium not dissected.

Mandible: Stipes without projection, well rounded (Fig. 10A, B). Gnathal lobe not dissected.

Collum: smooth, laterally not protruding as far as ring 2 (Fig. 10A).

Body rings: ozopores starting at segment 6, located slightly before, but touching suture between meso- and metazonite. Rings with smooth, but irregular coriaceous surface, ventrally on metazona with transverse ridges.

Telson: paraprocts with lips, abundant micropunctuation especially towards edges (Fig. 10C). Epiproct well-rounded, reaching slightly above paraproct with a massive process (Fig. 10C). Hypoproct inconspicuous (Fig. 10C).

Legs: leg 1 with a large cylindrical coxa, twice as long as other podomeres. Tarsus with three pairs of ventral spines and an apical spine beyond claw. Leg 2 with an elongated coxa. Tarsus with two pairs of ventral spines and a short apical spine. Midbody legs with a rectangular coxa, as long as other podomeres. Each podomere ventrally with a single or a pair of apical setae, tarsus of leg 3– midbody with a tarsal pad, a single apical and three or four pairs of ventral spines (Fig. 10B). Legs on posterior part of body without a tarsal pad and two or three pairs of ventral spines. Length of midbody legs ca. 1.2 times body diameter in male.

Female sexual characters. No tarsal pads, antennae even shorter than male, only protruding back to collum. Female vulva simple, bivalve-like.

Male sexual characters: tarsal pads present from leg 3 to midbody (Fig. 10B). Coxae 3–7 without coxal processes (Fig. 10B).

Anterior gonopod sternite massive, elongated into a wide, well-rounded, triangular lobe (Fig. 10D). Sternite in anterior view well-visible, without discernible apodemes, protruding almost as high as coxal processes. Coxite with sharp triangular mesal process (Fig. 10D, E). Telopodite with slender process arising mesally (Fig. 10E), process apically curved with a strong triangular projection (Fig. 10D), tip well-rounded tip, protruding above lateral margin of telopodite (Fig. 10C).

Posterior gonopods consisting of two parts, separated by an articulation: a long coxite and a slightly shorter telopodite, efferent duct discharging apically (Fig. 10G). Process of coxite and telopodite standing in same axis (Fig. 10F, G). Pair of posterior gonopods located parallel to each other, connected by a small, sclerotised and visible sternite (Fig. 10G). Basal part of coxite wide, mesally with a triangular sclerite located on lower level than remaining part (Fig. 10G). Coxite elongated. Efferent duct running at mesal margin of coxite (Fig. 10F, G). Telopodite as wide as but slightly shorter than coxite, standing in same axis, apically with a membranous ‘flag’ (Fig. 10F, G). Laterally with sclerotised projection with a slender mesad-orientated branch (Fig. 10F, G). Membranous ‘flag’ longer than lateral process. Efferent duct ending freely, projecting above ‘flag apically’ (Fig. 10F, G).

Comments. this species lives in direct sympatry with *Riotintobolus bovinus* sp. nov. The female carried eggs in the body.

Discussion

Genetic distances in the Barcoding gene of *Riotintobolus* species compared to other Diplopoda

The interspecific distance of 11–16.4% between *Riotintobolus* species is comparable to those found in the only other Malagasy Spirobolida genus for which molecular data are available, *Aphistogoniulus*. *Aphistogoniulus* species are much more widespread and showing even higher interspecific distances (Wesener et al. 2009b, 2011a), being found all over Madagascar, while *Riotintobolus* is currently known only from the South. For other millipedes from Madagascar, interspecific distances are known for two genera of giant pill-millipedes (Sphaerotheriida), *Sphaeromimus* DeSaussure & Zehntner, 1902 and *Zoosphaerium* Pocock, 1895. In *Sphaeromimus*, whose species show a distribution restricted to southern Madagascar comparable to those of *Riotintobolus*, interspecific distances vary mainly between 8.3–20.8% (Wesener et al. 2014; Moritz and Wesener 2017). In the widespread genus *Zoosphaerium*, only a handful of species were sequenced (Wesener et al. 2010; Sagorny and Wesener 2017; Wesener and Anilkumar 2020), with interspecific distances varying between 9.1–16.3%.

A hidden soil arthropod diversity in Madagascar's driest areas

Our discovery of six new species, especially of the occurrence of two unrelated species of *Riotintobolus* in direct sympatry and the presence of an additional candidate species, shows that *Riotintobolus* is an important component of the soil macrofauna in Madagascar's spiny forest ecosystem.

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Supplementary material I

P-Distances between *Riotintobolus* species

Author: Thomas Wesener

Data type: p-distances

Explanation note: The number of base differences per site from between sequences are shown. The analysis involved 19 nucleotide sequences. Codon positions included were 1st+2nd+3rd. All ambiguous positions were removed for each sequence pair.

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Link: <https://doi.org/10.3897/zookeys.953.53977.suppl1>

An unexpected new species of *Habrophlebia* from Algeria (Ephemeroptera, Leptophlebiidae)

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Abstract

We describe a new species of *Habrophlebia*, *H. djurdjurenensis* **sp. nov.**, based on nymphal, imaginal, and egg stages obtained by sampling from the Great Kabylia watershed, north-central Algeria. The new species was previously identified as *H. cf. fusca* by Lounaci et al. 2000. *Habrophlebia djurdjurenensis* is in fact more related to *H. vaillantorum* Thomas, 1996 but can be separated by characters on the nymphs and male imago. This is the fourth species of *Habrophlebia* reported from North Africa.

Keywords

Habrophlebia djurdjurenensis sp. nov., taxonomy, ecology, Djurdjura, Kabylia

Introduction

The genus *Habrophlebia* was established by Eaton (1881) and currently contains seven West Palaearctic species (Barber-James et al. 2013), which are known at all ontogenetic stages (egg, nymph, male, and female imagos), except for the nymph of *H. antoninoi* Alba-Tercedor, 2000, which remains to be described. In North Africa, until recently, three species were known: *H. vaillantorum* Thomas, 1986 (Morocco), *H. consiglioi* Biancheri, 1959 (Tunisia), and *H. cf. fusca* (Thomas 1998; Lounaci et al. 2000) (Algeria). The work by Benhadji et al. (2018), which looked at populations of *Habrophlebia*

in northwestern Algeria (Tafna watershed) studied by Gagneur and Thomas (1988), revealed a new species (*H. hassainae* Benhadji & Sartori, 2018). It was suspected that further investigations of previously studied populations would, upon re-examination, reveal additional new species. The main objective of the present study was to investigate the populations, in north-central Algeria (Great Kabylia watershed), studied by Lounaci et al. (2000), with the help of freshly collected material at all stages.

Material and methods

During a period of three years, sampling sites situated in Kabylia watershed have been investigated (Fig. 1). The Kabylia of Djurdjura, located in North-central Algeria, is a mountain range whose uniqueness is the result of its climatic conditions. This region may be further subdivided into two distinct subregions: the Djurdjura, which constitutes the largest limestone massif of the Tell Atlas with peaks often exceeding 2000 m of altitude (maximum 2308 m), and the Sebaou Valley, an elongate, wide depression that is drained by Oued Sebaou, the major river of Djurdjura Kabylia. The study sites were within a drainage basin of about 4000 km², which has rugged terrain with steep slopes and significant changes in altitude. The main feature of the streams is the irregularity of discharge, with episodes of floods alternating with low water periods. Water deficit in the summer induces a temporary flow regime for a large number of streams. The sampling sites belong to three different tributaries, Wadi Boubhir, Wadi Aissi, and Wadi Bougdoura (Fig. 1). They reflect the diversity of habitats and cover a wide range of ecological situations. The climate of the studied area varies from humid to sub-humid. It is characterized by a rainy season from November to May and a dry season which extends from June to October.

The average annual precipitation is around 1200 mm in the Djurdjura massif (altitude >1000 m), and around 800 mm in the Sebaou valley (Derridj 1990; Lounaci and Vinçon 2005). One of the major characteristics of the rivers studied is the significant warming of the waters in summer. In the middle and lower reaches, the maximum water temperature is high (25–30 °C), and the annual amplitudes oscillate around 20 °C. In the upper parts, the maximum temperature does not exceed 20 °C.

Nymphs were sampled either by kick sampling or by picking specimens directly from the substrate with entomological forceps. Specimens collected between 2016 and 2019 were preserved in 80% or 100% ethanol. Specimens were observed under a Leica MZ12 and M205C stereomicroscope. Mouthparts, legs, and the abdomen were mounted on microscopic slides and observed and photographed under an Olympus BX51 microscope. Photographs of the habitus were taken with a LK system (Dun Inc., Virginia). For SEM photomicrographs, eggs were dehydrated in pure ethanol, coated with 12 nm platinum; SEM work was performed at Lausanne University with a FEI Quanta FEG 250 at 10kV with a WD = 12 mm. Final figures were assembled in Adobe Photoshop CC 2018.

Material is deposited in the Museum of Zoology, Lausanne, Switzerland (MZL) and in the personal collection of the first author (KLHC).

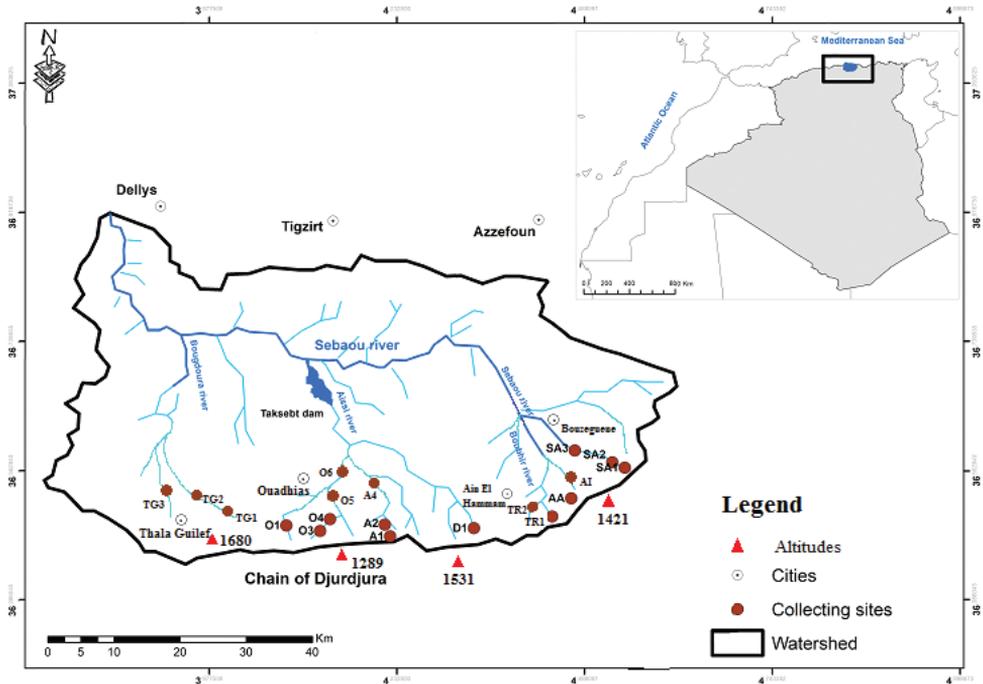


Figure 1. Map of Kabylia with the sampling sites.

Taxonomy

Family Leptophlebiidae Banks, 1900

Genus *Habrophlebia* Eaton, 1881

Habrophlebia djurdjurenensis Kechemir, Sartori & Lounaci, sp. nov.

<http://zoobank.org/96465B72-4E0C-4887-A067-5FEF4A56545A>

Habrophlebia cf. gr. *fusca* Thomas 1998: 14 (partim)

Habrophlebia cf. *fusca* Lounaci et al. 2000: 47

Material examined. Holotype: 1 female nymph in ethanol, (GBIFCH00672427), Algeria, Tizi-Ouzou Wilaya, Sebaou watershed, Wadi Aissi, Assif Aghalladh (O3), 36°29.28'N, 4°07.36'E, 1040 m, 09 July 2019, L.H. Kechemir coll. [MZL]. **Paratypes:** 1 male imago (GBIFCH00672426), 15 nymphs (GBIFCH00672428, GBIFCH00672425), same data as holotype in ethanol [MZL]; 7 nymphs (GBIFCH00606856–GBIFCH00606860 and GBIFCH00673198 - GBIFCH00673199), same data as holotype on slide (Euparal) L.H. Kechemir coll. [MZL].

Other material (non-type material). Algeria, Kabylia, Tizi-Ouzou Wilaya, Assif Aghalladh (O3), 36°29.28'N, 4°07.36'E, 1040 m, 24 May 2016; 26 nymphs in ethanol [KLHC] • same locality, 29 March 2017; 8 nymphs in ethanol [KLHC] • same locality,

19 April 2017; 17 nymphs in ethanol [KLHC] • same locality, 26 May 2018; 20 nymphs in ethanol [KLHC] • same locality, 07 July 2019; 7 nymphs in ethanol [KLHC].

Algeria, Kabylia, Tizi-Ouzou Wilaya, Assif Aghalladh (O4), 36°29.48'N, 4°07.49'E, 950 m, 26 May 2017, 59 nymphs in ethanol (GBIFCH00672429) [MZL]; 19 nymphs in ethanol [KLHC] • same locality, 18 March 2017; 11 nymphs in ethanol [KLHC] • same locality, 19 April 2017; 14 nymphs in ethanol [KLHC] • same locality, 27 May 2017; 28 nymphs in ethanol [KLHC] • same locality, 29 March 2018; 18 nymphs in ethanol [KLHC].

Algeria, Kabylia, Assif Aghalladh (O5), 36°30.72'N, 4°06.67'E, 500 m, 24 May 2016; 7 nymphs in ethanol [KLHC] • same locality, 18 March 2017; 5 nymphs in ethanol [KLHC] • same locality, 19 April 2017; 12 nymphs in ethanol [KLHC] • same locality, 26 May 2018; 11 nymphs in ethanol [KLHC].

Algeria, Kabylia, Assif Tamdha (O1), 36°29.98'N, 4°03.93'E, 800 m, 24 May 2016; 19 nymphs in ethanol [KLHC] • same locality, 27 May 2017; 15 nymphs in ethanol [KLHC] • same locality, 26 May 2018; 3 nymphs in ethanol [KLHC].

Algeria, Kabylia, Assif Ouadhias (O6), 36°31.88'N, 4°06.85'E, 290 m, 24 May 2016; 9 nymphs in ethanol [KLHC] • same locality, 19 April 2017; 8 nymphs in ethanol [KLHC] • same locality, 2 May 2018; 5 nymphs in ethanol [KLHC].

Algeria, Kabylia, Assif Tirourda, Com. de Tirourda (TR1), 36°29.43'N, 4°21.69'E, 1200 m, 24 April 2017; 1 nymph on slide (Euparal) (GBIFCH00673196) • same data; 4 nymphs in ethanol (GBIFCH00672430) [MZL]; 34 nymphs in ethanol [KLHC] • same locality, 26 March 2017; 10 nymphs in ethanol [KLHC] • same locality, 25 April 2017; 42 nymphs in ethanol [KLHC] • same locality, 28 May 2017; 30 nymphs in ethanol [KLHC] • same locality, 2 June 2017; 3 nymphs in ethanol [KLHC] • same locality, 30 March 2018; 8 nymphs in ethanol [KLHC].

Algeria, Kabylia, Assif Tirourda (TR2), 36°29.43'N, 4°21.53'E, 1150 m, 14 April 2016; 6 nymphs in ethanol [KLHC] • same locality, 26 March 2017; 5 nymphs in ethanol [KLHC] • same locality, 28 May 2017; 6 nymphs in ethanol [KLHC] • same locality, 30 March 2018; 12 nymphs in ethanol [KLHC] • same locality, 20 June 2018 ; 3 nymphs in ethanol [KLHC].

Algeria Kabylia, Assif Ath Atsou, Com. de Ath Atsou (AA), 36°29.71'N, 4°22.38'E, 1080 m, 14 April 2016; 3 nymphs in ethanol [KLHC] • same locality, 26 March 2017; 10 nymphs in ethanol [KLHC] • same locality, 25 April 2017; 10 nymphs in ethanol [KLHC] • same locality, 28 May 2017; 10 nymphs in ethanol [KLHC] • same locality, 30 March 2018; 15 nymphs in ethanol [KLHC] • same locality, 30 March 2018; 15 nymphs in ethanol [KLHC] • same locality, 20 June 2018; 7 nymphs in ethanol [KLHC].

Algeria, Kabylia, Assif Illithen, Com.de Illithen (AI), 36°30.41'N, 4°24.28'E, 1010 m, 24 April 2017; 2 nymphs on slide (Euparal) (GBIFCH00673194–GBIFCH00673195) ; same data 21 nymphs in ethanol (GBIFCH00672431)[MZL] • same locality, 14 April 2016; 2 nymphs in ethanol [KLHC] • same locality, 26 March 2017; 12 nymphs in ethanol [KLHC] • same locality, 28 May 2017; 27 nymphs in ethanol [KLHC] • same locality, 30 March 2018; 13 nymphs in ethanol [KLHC] • same locality, 20 June 2018; 10 nymphs in ethanol [KLHC].

Algeria, Kabylia, Assif Djemâa, Com. D'Akbil (D1), 36°30.38'N, 4°19.94'E, 900 m, 14 April 2016; 8 nymphs in ethanol [KLHC] • same locality, 28 May 2017; 23 nymphs in ethanol [KLHC] • same locality, 30 March 2018; 14 nymphs in ethanol [KLHC].

Algeria, Kabylia, Assif d'Ath Agad, Com. des Ouacifs (A1), 19 March 2017; 12 nymphs in ethanol [KLHC] • same locality, 24 May 2017; 25 nymphs in ethanol [KLHC] • same locality, 30 April 2018; 22 nymphs in ethanol [KLHC].

Algeria, Kabylia, Assif d'Ath Agad (A2), 36°30.26'N, 4°11.93'E, 510 m, 19 March 2017; 10 nymphs in ethanol [KLHC] • same locality, 24 May 2017; 3 nymphs in ethanol [KLHC] • same locality, 30 April 2018; 7 nymphs in ethanol [KLHC].

Algeria, Kabylia, Assif Larbâa (A4), 36°31.07'N, 4°12.07'E, 380 m, 19 March 2017; 4 nymphs in ethanol [KLHC] • same locality, 24 May 2017; 6 nymphs in ethanol [KLHC] • same locality, 30 April 2018; 5 nymphs in ethanol [KLHC].

Algeria, Kabylia, Assif Sahel, Com. de Ath zikki (SA1), 36°32.71'N, 4°29.58'E, 1200 m, 21 April 2017; 32 nymphs in ethanol [KLHC] • same locality, 30 May 2018; 15 nymphs in ethanol [KLHC].

Algeria, Kabylia, Assif Sahel (SA2), 36°32.78'N, 4°29.58'E, 1140 m, 21 April 2017; 11 nymphs in ethanol [KLHC] • same locality, 30 May 2018; 8 nymphs in ethanol [KLHC].

Algeria, Kabylia, Assif Sahel (SA3), 36°35.37'N, 4°27.57'E, 430 m, 21 April 2017; 5 nymphs in ethanol [KLHC] • same locality, 30 March 2018; 3 nymphs in ethanol [KLHC].

Algeria, Kabylia, Assif Chemlili, Com. Boghni (TG2), 36°28.27'N, 3°59.84'E, 1250 m, 25 May 2018; 8 nymphs in ethanol (GBIFCH00835059) ; 2 nymphs on slide, (GBIFCH00673194–GBIFCH00673195) [MZL] • same locality, 1 June 2016; 29 nymphs in ethanol [KLHC] • same locality, 15 March 2017; 10 nymphs in ethanol [KLHC] • same locality, 29 April 2017; 30 nymphs in ethanol [KLHC] • same locality, 2 June 2017; 18 nymphs in ethanol [KLHC] • same locality, 25 May 2018; 38 nymphs in ethanol [KLHC] • same locality, 12 June 2019; 7 nymphs in ethanol [KLHC].

Algeria, Kabylia, Assif Chemlili (TG1), 36°28.32'N, 4°00.16'E, 1450 m, 1 June 2016; 28 nymphs in ethanol [KLHC] • same locality, 15 March 2017; 10 nymphs in ethanol [KLHC]. All L.H. Kechemir coll.

Description. Male imago. Size: body length: 6.5 mm; forewing length: 7 mm; cerci and terminal filament length: 8.2 mm.

Head medium brown, dark brown between ocelli; basal portion of compound eyes greyish, upper portion orange brown (Fig. 2), scape medium brown, pedicel dark brown, flagellum light brown.

Thorax. Pronotum greyish brown, washed with dark brown; meso- and metanotum uniformly dark brown, pleurae, coxae, and trochanters greyish brown, washed with dark brown; fore femora greyish brown, fore tibiae medium brown, tarsi light brown; mid- and hind legs with femora greyish brown on upper surface, tibiae greyish brown in proximal part, light brown in distal part and tarsi medium brown (Fig. 2).

Femur/tibia/tarsi ratio in fore leg: 1/0.9/0.2/0.2/0.1/0.1; mid leg: 1/0.8/0.09/0.09/0.05/0.2; hind leg: 1/0.9/0.05/0.04/0.05/0.15. Fore claws similar,



Figure 2. *Habrophlebia djurdjurenensis* sp. nov., male imago in lateral view. Scale bar: 1 mm.

paddle-shaped, mid- and hind claws dissimilar, one paddle-like and one hooked. Fore wing (Fig. 3A) transparent, pterostigmatic area milky with ca 7 oblique and simple transversal veins, longitudinal veins light brown, transversal veins whitish. MA and MP forks asymmetrical, cubital field with two short and two long intercalary veins. Hind wing (Fig. 3B) with rounded costal process approximately in the middle of the wing; vein Sc short, not reaching the apex of the wing.

Abdomen. Terga and sterna colorations as in the nymph.

Stylicher plate medium brown, first segment of the gonopods greyish brown, segments 2 and 3 yellowish brown. Posterior margin of the stylicher plate strongly convex in the middle, median incision regularly rounded, U-shaped (Fig. 3C); segment 1 slightly shorter than segments 2 and 3 combined; ratio length segment 1 vs segment 2: app. 1.5 and segment 1 vs segment 3: app. 1.7; inner margin of segment 1 with a broad base, and a bulge on the outer margin. Penis lobes rounded and well separated from each other, ventral spine long, thin and curved, reaching the base of the stylicher plate (Fig. 3D)

Cerci and terminal filament light brown, darker at base.

Eggs (extracted from mature female nymphs). General shape ovoid, ca 170 μm \times 70 μm (Fig. 4A), chorion covered by long longitudinal ribs almost running from one pole to the other, less than 3 μm wide, entire, without punctuation; micropyle in equatorial area (Fig. 4B).

Nymph. Body length of final instar, excluding caudal filaments, 5.3–6.3 mm for male and 7.2–10 mm for female. Cerci longer than body length. General coloration dark brown with light brown markings mainly on abdominal terga (Fig. 5).

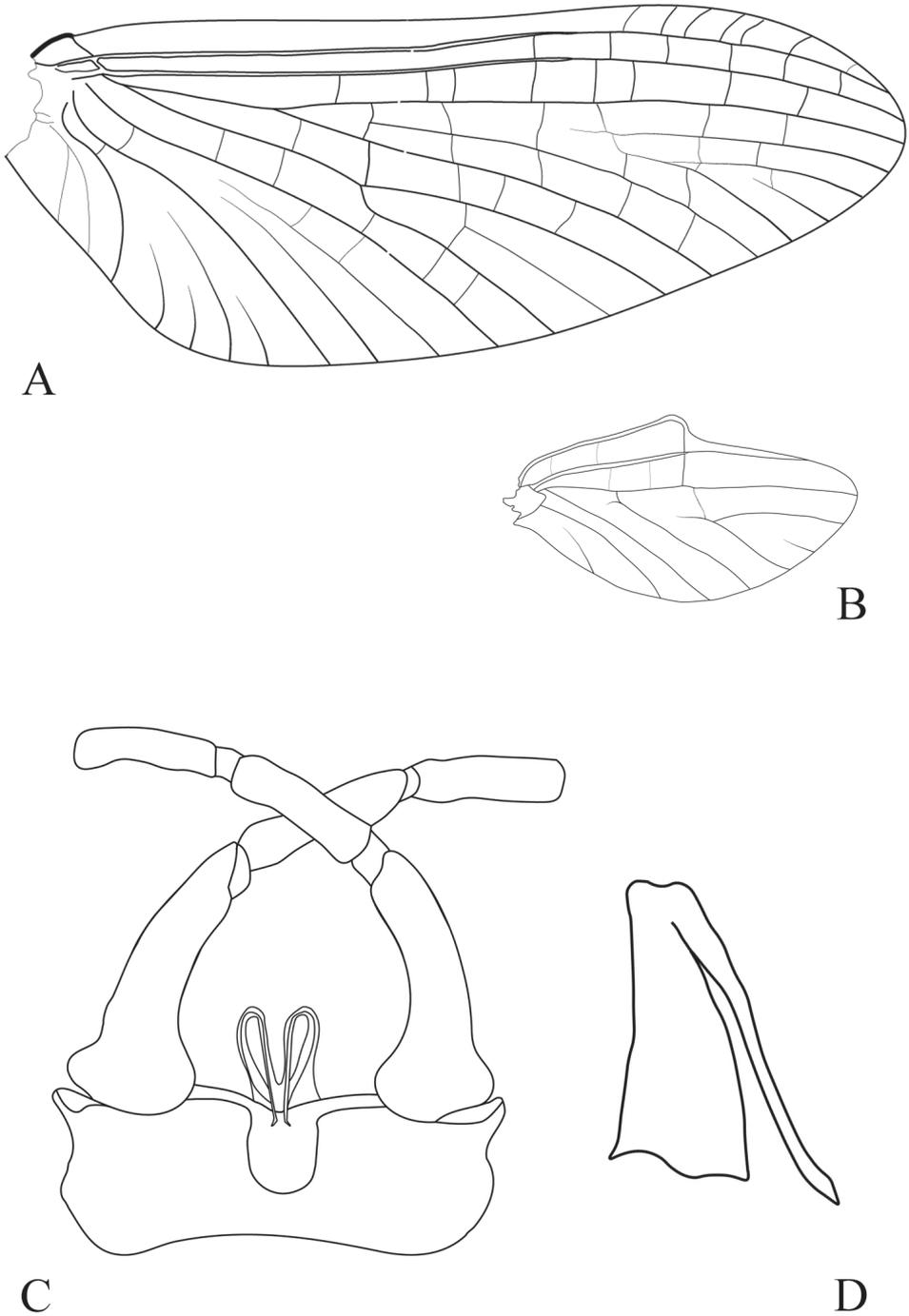


Figure 3. *Habrophlebia djurdjurenensis* sp. nov., male imago. **A** Fore wing **B** hind wing **C** genitalia in ventral view **D** penis in lateral view.

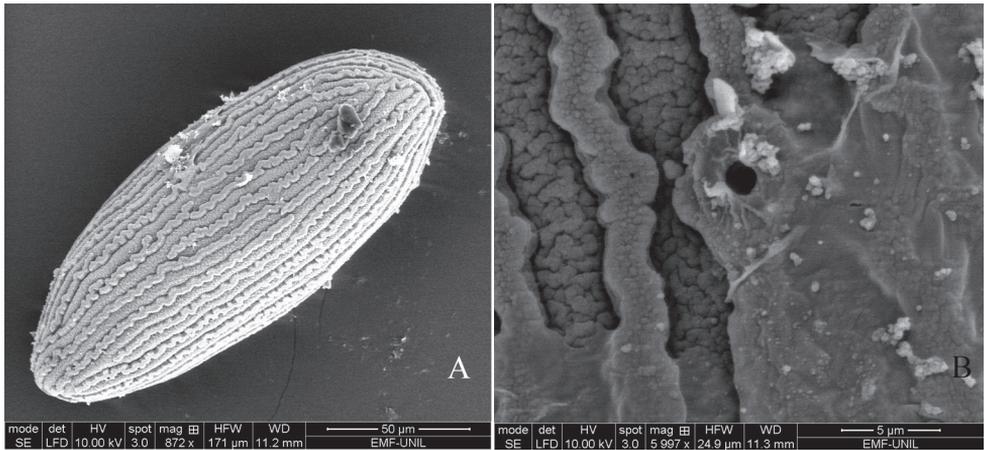


Figure 4. *Habrophlebia djurdjurensis* sp. nov., egg. **A** View of the general shape **B** details of the chorionic ridges and micropyle.



Figure 5. *Habrophlebia djurdjurensis* sp. nov., nymph in dorsal view. Scale bar: 1 mm.

Head. General coloration medium brown; paler area between compound eyes and lateral ocelli; between ocelli, a large dark-brown mark not reaching the clypeus distally, and extending laterally in front of the compound eyes; vertex sutures yellowish, well visible. Upper portion of male eyes orange-brown. Antenna with scape and pedicel greyish brown, filament whitish. Labrum (Fig. 6A) rectangular, wider than long; dorsal surface covered distally with scattered stout setae, proximally with long and thin setae; anterior margin with a row of stout and spatulate setae; anteromedian emargination narrow with four flat/rounded denticles; ventral surface with two bunches of stout setae medially. Maxilla (Fig. 6B) stocky, subapical row of 6 or 7 pectinate setae; maxillary palp 3-segmented, segment 1 as long as segment 2, and longer than seg-

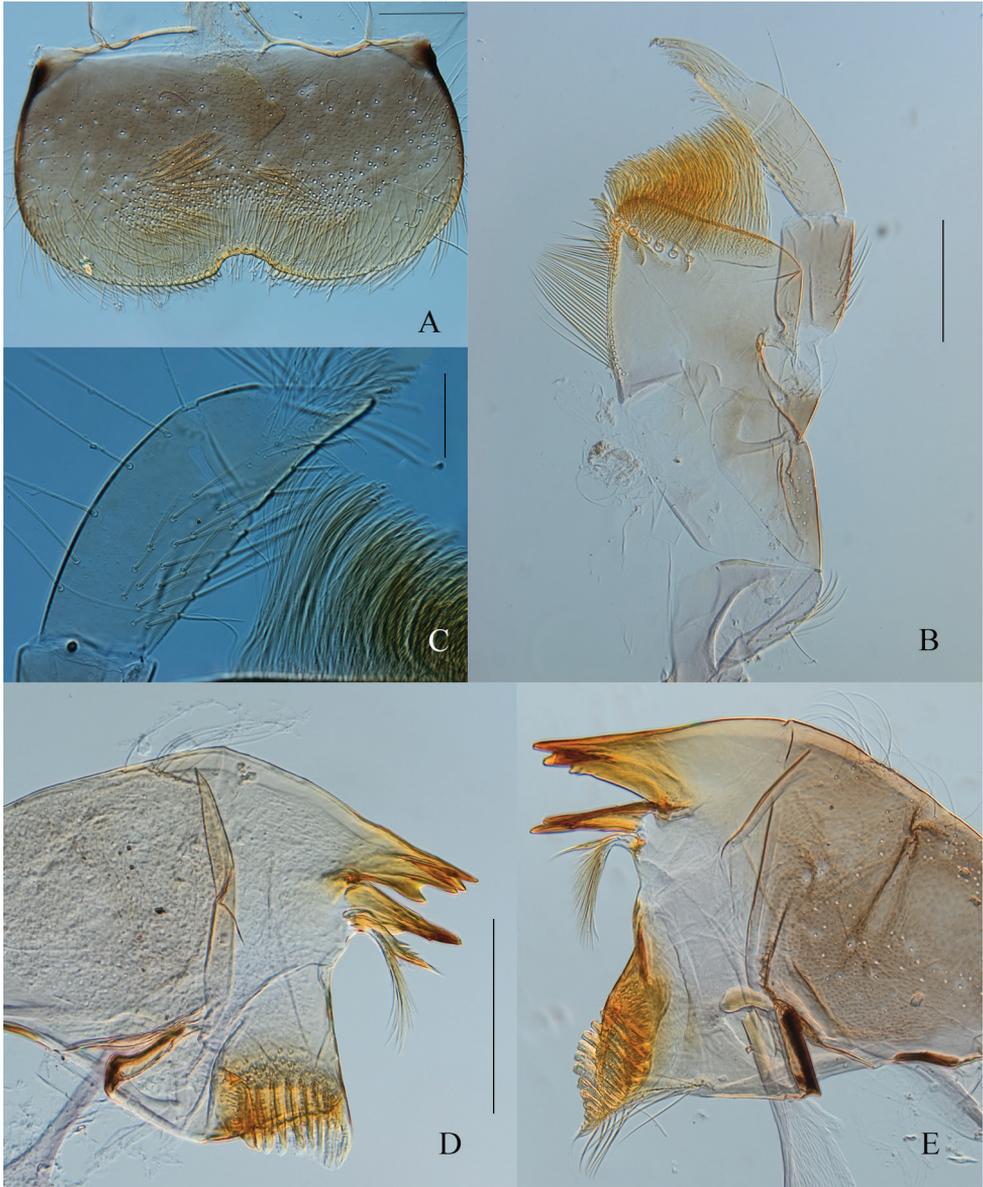


Figure 6. *Habrophlebia djurdjurenensis* sp. nov., nymphal mouthparts: **A** labrum in dorsal view **B** maxilla **C** apex of maxillary palp **D** right mandible in dorsal view **E** left mandible in dorsal view. Scale bars: 50 μm (**A**); 200 μm (**B–E**).

ment 3; segment 3 triangular app. 1.7 \times longer than wide at base; all stout setae on the palp entire, none feathery (Fig. 6C). Mandibles similar to other *Habrophlebia* species (Fig. 6D, E). Hypopharynx with developed superlinguae ending with a small membranous digitation (Fig. 7B). Labium (Fig. 7A) with glossae rhomboid, outer margin and

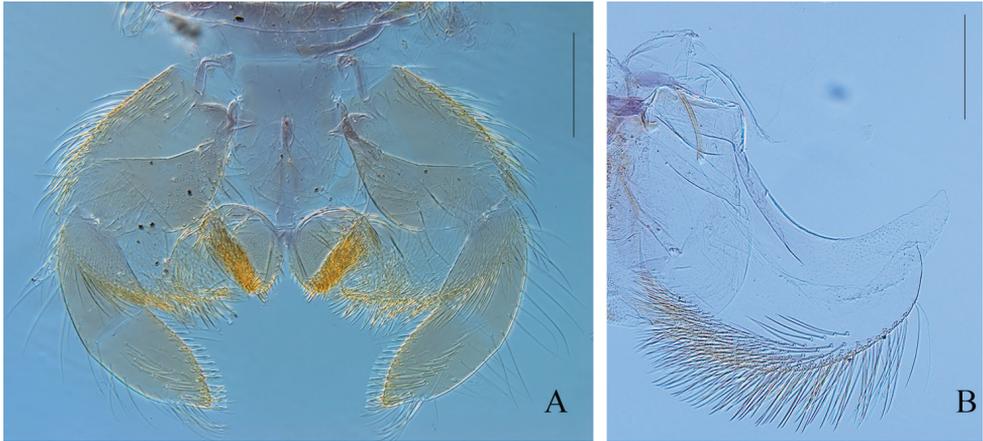


Figure 7. *Habrophlebia djurdjurenensis* sp. nov., nymphal mouthparts. **A** Labium in ventral view **B** hypopharynx (left half). Scale bars: 200 μ m.

apex covered with stout and short setae; paraglossae enlarged laterally, covered with thin and long setae on dorsal surface; with stout and long setae on outer margin; labial palp 3-segmented; inner margin of segment 1 greatly enlarged towards apex, ca 0.8 \times longer than maximum width, segments 2 and 3 subequal in length, ca 0.7 \times length of segment 1; segment 3 ca 1.2 \times longer than wide at base and slightly triangular.

Thorax. Pro- and mesonotum greyish brown, with black maculae, especially on lateral margins (Fig. 5). Legs yellowish brown to medium brown; dorsal surface of femora almost entirely washed with greyish brown macula; tarsi and tibiae generally lighter, except sometimes in mature nymphs. Anterolateral angles of each hemi-pronotum with a bunch of long setae, anterior margin with a single row of long setae not reaching the median suture. Fore femora (Fig. 8A) elongated, ca 2.3 longer than wide, upper surface covered with long, entire, and pointed setae; fore tibiae subequal in length to femora, outer margin with thin and long setae, inner margin with several rows of long stout and pointed setae not feathered; tarsi 0.8 \times length of tibiae, outer margin with long and thin setae, inner margin with two rows of long, stout, pointed setae. Middle legs (Fig. 8B) similar to fore legs, dorsal surface of femora with more numerous and slightly longer stout and pointed setae; tibiae 0.8 \times length of femora and tarsi 0.5 \times length of tibiae. Hind femora (Fig. 8C) 3 \times longer than wide, dorsal surface covered with stout, long, pointed and feathered setae (only visible at high magnification: 400 \times and more; Fig. 8F); ventral surface with few feathered setae; hind tibiae as long as hind femora, outer margin with scattered stout, pointed setae; inner margin with several rows of stout, pointed, entire setae; tarsi 0.4 \times length of tibiae, outer margin with long and thin setae, inner margin with two rows of long, stout, pointed setae. Claws (Fig. 8D) of all legs slightly hooked, with 15–18 long, thin, pointed denticles including three larger towards the middle of the claws.

Abdomen. Terga greyish brown to dark brown with characteristic light markings (Fig. 5). Terga I–II dark brown, terga II–IX with two sublateral elongated dark brown maculae, joining on the posterior margin, leaving two lateral light areas inconspicuous.

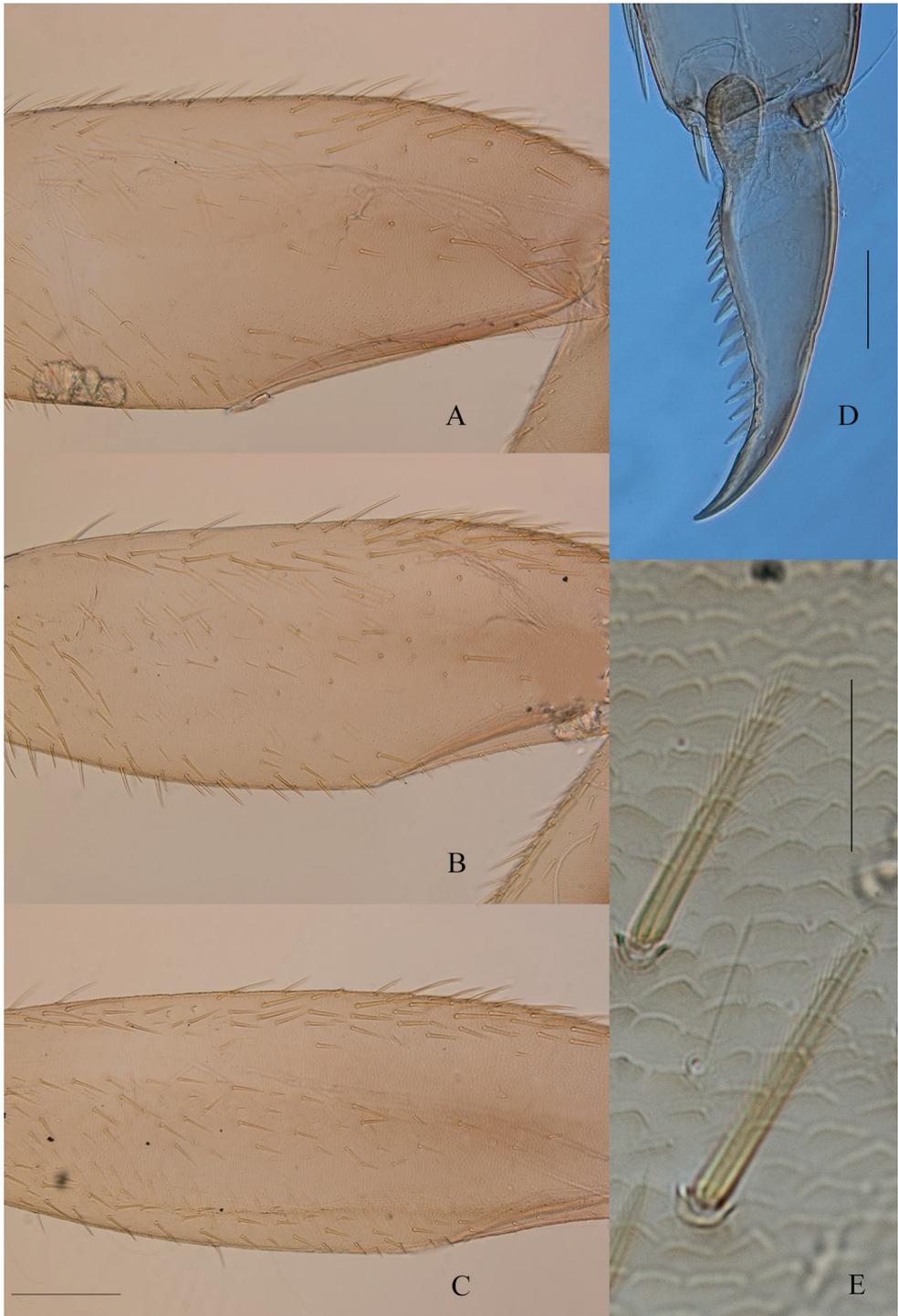


Figure 8. *Habrophlebia djurdjurenensis* sp. nov., nymphal legs. **A** Fore femur **B** middle femur **C** hind femur **D** tarsal claw **E** feathered setae on the dorsal face of hind femur. Scale bars: 200 μm (**A–C**); 50 μm (**D**); 30 μm (**E**).

ous on terga III–IV, more pronounced on terga V–IX; terga X light brown. Sternum I entirely greyish brown; sterna II–IX greyish brown with lateral and anterior bands light brown; nervous ganglia greyish brown. Posterolateral expansions only on segments VIII and IX. Ornamentation of the terga (Fig. 9): posterior margin of tergum X with well developed, narrow, pointed spines, ca 3× longer than wide; tergum IX with narrower and shorter spines, bordered with submarginal microdenticles; tergum VIII with minute spines, a little bit longer than the submarginal microdenticles; terga V–VII with tiny spines; terga I–IV with barely visible spines at high magnification (400×). Gills present on segments I–VII; all gills long and large; first gill (Fig. 10A) with ventral lamella bearing 3 or 4 filaments, upper lamella with 4 or 5 filaments, gills II–VI (Fig. 10B) with 4–7 and 8–11 filaments on the ventral and dorsal lamella respectively, gill VII (Fig. 10C) with about 6 filaments on ventral lamella and ca 9 filaments on upper lamella.

Cerci and terminal filament yellowish brown, medium brown in mature nymphs.

Etymology. The species is named after the Kabylia Massif of Djurdjura.

Affinities. The male imago of *Habrophlebia djurdjurenensis* sp. nov. can be easily separated from that of *H. antoninoi* by the shape of the hind wing, from *H. hassainae* by the length of vein Sc on the hind wing, from *H. antoninoi*, *H. consiglioi*, *H. eldae*, *H. fusca*, *H. lauta*, and *H. vaillantorum* by the shape of the notch of the stilyger which is more or less narrowed, from *H. consiglioi* by the shape of the bulge on the outer margin of the first segment of the gonopods, from *H. consiglioi* and *H. antoninoi* by the shape of the penial spine which is not stout, and from *H. vaillantorum*, *H. fusca*, and *H. lauta* by penis lobes in ventral view which are narrow and hold tight against each other with penial spine longer and curved at the apex. The new species is more similar to *H. lauta*, with whom it shares the shape of penial spine which is long, thin, and more pointed, and related with *H. hassainae*, with whom it shares the stilyger shape but differs by the length of the penial spine much shorter.

The nymph of *H. djurdjurenensis* differs from those of *H. consiglioi*, *H. eldae*, *H. fusca*, and *H. vaillantorum* by the pattern of coloration on the abdomen, from *H. eldae*, *H. fusca*, and *H. lauta* by the shape of the superlingua of the hypopharynx, and from all other species by the shape of the spines on the posterior margin of the terga. Pronotum ornamentation is similar to *H. hassainae*, somewhat intermediate between *H. consiglioi* and *H. eldae* (see Belfiore and Gaino 1985: figs 5, 6). The ventral surface of hind femora bears very few setae compared to *H. hassainae*. The nymph is most similar to that of *H. vaillantorum*, from which it can be separated by the abdomen color, the ornamentation of terga (especially tergum IX), the number and the length of filaments on gills which are longer in *H. djurdjurenensis* compared to *H. vaillantorum*.

Among all Palearctic species of *Habrophlebia*, *H. djurdjurenensis* is the second species after *H. hassainae* with the greatest number of denticles on claws (15–18 denticles vs 11–16 in others and 18–22 in *H. hassainae*). It possesses gills with the greatest number of filaments on each lamella still after *H. hassainae* (4–7 in ventral and 8–11 in dorsal, vs 1–6 and 3–9 in ventral and dorsal lamella, respectively in all other species, and 5–8 and 9–12 in ventral and dorsal lamella, respectively, in *H. hassainae*).

The eggs of *H. djurdjurenensis* have a length/width ratio of ca 2.4, intermediate between those of *H. lauta* (2.7), *H. hassainae* (2.1), and *H. vaillantorum* (1.7). These eggs

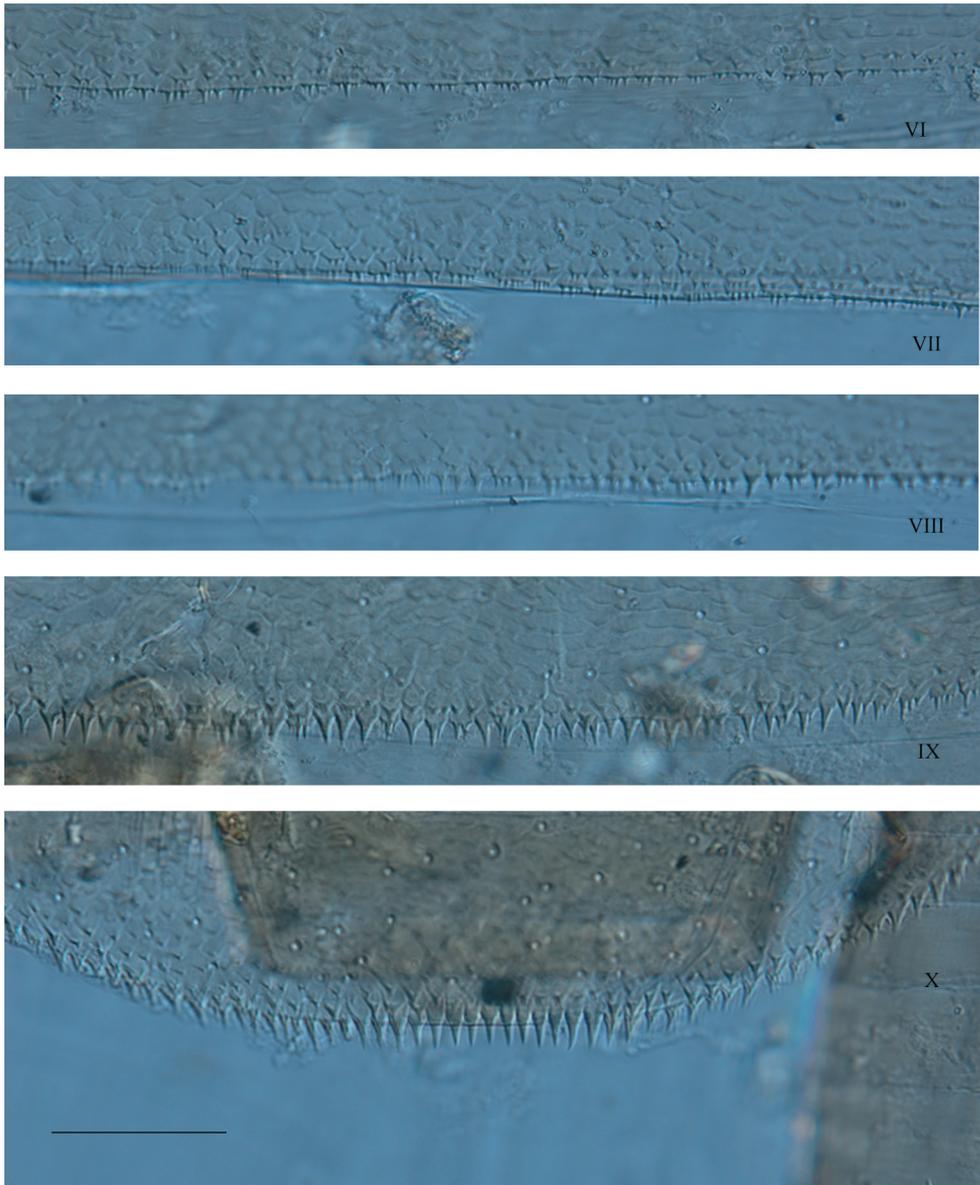


Figure 9. *Habrophlebia djurdjurenensis* sp. nov., posterior margin of abdominal terga VI–X. Scale bar: 50 μ m.

are also relatively smaller than the others; compared to *H. hassainae*, the longitudinal ribs are longer reaching almost from one pole to the other, whereas in the latter, two to three ribs are necessary to reach both poles.

Distribution and ecology. The genus *Habrophlebia* currently encompasses eight species in the Western Palearctic region. Two species, *H. lauta* McLachlan, 1884 and *H. fusca* (Curtis, 1834), are widely distributed in Europe. *Habrophlebia eldae* Jacob & Sartori, 1984 was considered a Mediterranean element, which recently expanded its

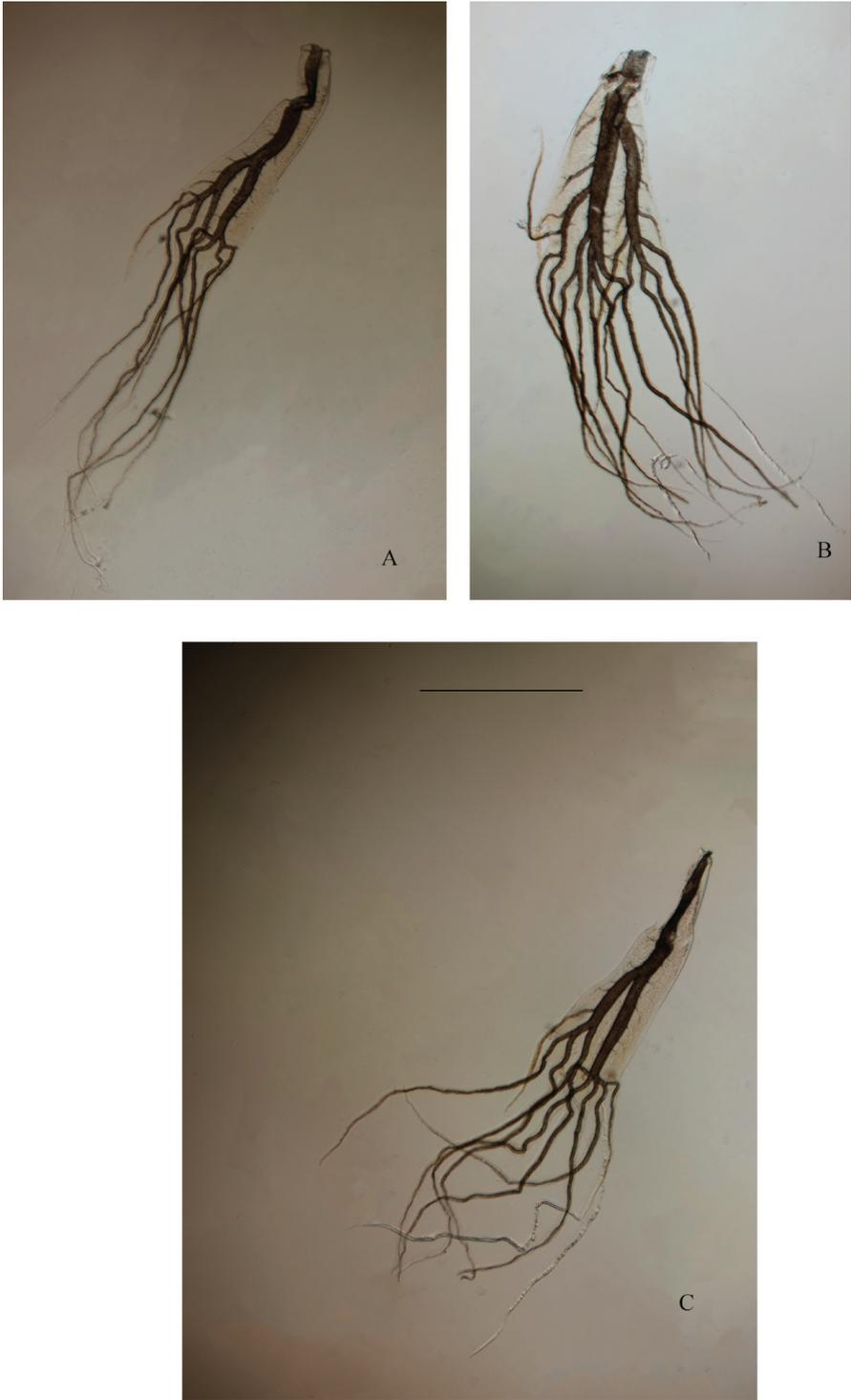


Figure 10. *Habroplebia djurdjurenensis* sp. nov., nymphal gills. **A** Gill I **B** gill IV **C** gill VII. Scale bar: 0.5 mm.

Table 1. Geographical and physical data of sampling sites of Great Kabylia basin Algeria (sampling sites with *H. djurdjurenensis*).

Sites	Latitude N/ Longitude E	Altitude (m)	Orientation	Distance from the source (km)	Width of riverbed (m)	Dominant Substrate	Turbidity	Maximum depth (cm)	Riparian vegetation
SA1	36°32.712'N, 004°29.575'E	1200	S-N	1.5	1.5	Sh, G	C	20	Ps
SA2	36°32.782'N, 004°29.557'E	1140	S-N	2	1.5	Sh, G,Vd	C	30	Ps
SA3	36°35.368'N, 004°27.572'E	430	S-N	6	2	Sh, G, S	T	30	Ps
TR1	36°29.4305'N, 004°21.693'E	1200	S-N	0.5	1.3	Sh, G, S	C	50	Ps
TR2	36°29.430'N, 004°21.534'E	1150	S-N	1.5	0.7	Sh, G, Si	C	20	Ps, Th
AA	36°29.710'N, 004°22.382'E	1080	S-N	0.5	1	Sh, G, S	C	20	Ps, Th
AI	36°30.412'N, 004°24.075'E	1010	S-N	1	1	Sh, G,	C	20	Ps, Th
D1	36°30.381'N, 004°19.937'E	900	S-N	0.5	1	Sh, G, S, Si, Vd	C	20	Ps
A1	36°29.683'N, 004°11.136'E	600	S-N	0.5	0.8	Sh, G,Vd	C	30	Ps
A2	36°30.260'N, 004°11.930'E	510	S-N	1	0.5	Sh, G,S,Vd	C	10	Ps
A4	36°31.066'N, 004°12.073'E	380	S-N	4.5	3	Sh, G, S	T	50	Hb, Th
O1	36°29.976'N, 004°03.931'E	800	S-N	2.5	2	Sh, G	C	30	Ps
O3	36°29.279'N, 004°07.362'E	1040	S-N	0.8	0.5	Sh, G	C	20	Ps, Th
O4	36°29.482'N, 004°07.489'E	950	S-N	1.5	1.8	Sh, G	C	30	Ps
O5	36°30.723'N, 004°06.666'E	500	S-N	13	3	Sh, S, Vd	C	30	Ps
O6	36°31.877'N, 004°06.848'E	290	S-N	20	3.5	Sh, G, S, Si	T	40	Ps, Th
TG1	36°28.320'N, 004°00.160'E	1450	S-N	1	0.7	Sh, G,Vd	C	10	Hb, Th
TG2	36°28.267'N, 003°59.84'E	1250	S-N	0.7	1	Sh, G,Vd	C	10	Ps
TG3	36°28.049'N, 003°58.308'E	900	S-N	0.5	0.8	Sh, G,Vd	C	15	Ps

Sh= shingle, G = gravels, S = sands, Si = silts, Vd= Vegetal debris, C = clear, T = turbid, Ps = pluristratified, Hb = herbaceous, Th= thorny.

geographic range to central Europe, probably due to global climate change (Wagner et al. 2007). *Habrophlebia consiglioi* was described from the island of Sardinia and later reported from Tunisia (Zrelli et al. 2011). The others have a much restricted distribution: *H. antoninoi* is only known from two locality near Andújar in southern Spain (Alba-Tercedor 2000), *H. vaillantorum* is probably endemic to the Moroccan High Atlas (Thomas et al. 1999), and *H. hassainae* has not been reported yet outside of the Tafna watershed (western Algeria). The presence of *H. djurdjurenensis* for now seems to be limited to the Kabylia massif of Djurdjura, and the species may be a microendemic

to this region of Algeria. Unpublished data from other parts of Algeria suggest this species is not found in those areas. *Habrophlebia djurdjurenensis* has a rithrophilic tendency and is widely distributed in the streams on the north slopes of the Djurdjura. It colonizes varied biotopes, from spring streams to foothill rivers. It was collected in 19 stations between 300 and 1450 m above sea level (Fig. 1). The habitats are characterized by a mixed substrate of pebbles, gravel, sand, and silts covered in some places by debris, moderate currents, and water temperatures not exceeding 20 °C (Table 1). This species appears unable to endure warmer waters at low altitudes and quickly disappears from stations below 380 m.

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A new species of *Oomyzus Rondani* (Hymenoptera, Eulophidae) reared from the pupae of *Coccinella septempunctata* (Coleoptera, Coccinellidae) in China

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Abstract

Oomyzus spiraculus Song, Fei & Cao **sp. nov.** (Hymenoptera, Eulophidae) is described and illustrated as a gregarious larval-pupal endoparasitoid of *Coccinella septempunctata* L. (Coleoptera, Coccinellidae). Differentiation between *O. spiraculus* and its similar species is discussed and a key to differentiate the female and male of these species is provided. DNA barcodes of *O. spiraculus* and *O. scaposus* are analyzed and compared.

Keywords

Chalcidoidea, lady beetle, new taxon, parasitoid wasps, taxonomy, Tetrastichinae

Introduction

The seven-spotted lady beetle, *Coccinella septempunctata* L. (Coleoptera, Coccinellidae), is widely recorded from the Palearctic and has a large distribution in China. It plays a significant role as an effective predator by suppressing populations of homopterian pests (e.g. aphids, whiteflies, and scales), which cause severe damage to agricultural crops (Pervez 2002). It is attacked by multiple parasitoids from Hymenoptera and Diptera (Honet et al. 2019).

Because of the ecological and economic significance of *C. septempunctata*, the interactions between *C. septempunctata* and its parasitoids have been traced and studied for many years (Li 1984; Semyanov 1986; Schaefer and Semyanov 1992; Triltsch 1996; Ceryngier et al. 2012). Among these parasitoids, *Oomyzus scaposus* (Thomson) is a common parasitoid wasp of coccinellids (Song et al. 2017). During a recent project related to interactions between coccinellids and their parasitoids, *O. scaposus* and another *Oomyzus* species were reared from the pupae of *C. septempunctata*. Here, this other *Oomyzus* species is described as new to science and compared to other known *Oomyzus* species.

Oomyzus is one of the smaller genera in Tetrastichinae (Hymenoptera, Eulophidae), with 26 described species prior to this study. Graham (1991) revised the European species of *Oomyzus* and included keys to the females of 12 species and males of 11 species. Although some species of *Oomyzus* (e.g. *O. gallerucae* (Fonscolombe) and *O. sokolowskii* (Kurdjumov)) have been recorded as cosmopolitan and some others have a large distribution across different continents owing to biocontrol introductions (e.g. *O. brevistigma* (Gahan)) (Noyes 2019), most species are rarely found or recorded from more than one zoogeographical region. This is possible because *Oomyzus* is difficult to characterize and shares some features with some other genera of Tetrastichinae, such as *Baryscapus* Förster, *Tetrastichus* Haliday, and *Quadrastichus* Girault. Species of *Oomyzus* are mainly larval or pupal parasitoids of Coleoptera, sometimes of Lepidoptera, Neuroptera, and Diptera, and sometimes as egg parasitoids of their hosts (Graham 1991). Some species, such as *O. incertus* (Ratzeburg), *O. brevistigma*, and *O. sokolowskii*, have been successfully used as biological control agents against some important agricultural pests of leaf beetles (LaSalle 1994).

Graham (1991) preliminarily discussed assignments of species groups for some European species of *Oomyzus* based on morphological studies. However, to confirm these species groups further evidence is required. Although DNA barcode fragments of *O. scaposus* and *O. spiraculus* were generated in this study, the assignment to species group is not included because of the absence of data for the other species. Therefore, only COI fragments of these two species were analyzed and compared, even though they do not seem very close using morphological data. Despite the lack of molecular data, the differences and similarities of this new species between some possibly close species are discussed based on morphology.

Materials and methods

Parasitoid wasp collection and rearing

The pupae of *C. septempunctata* were collected during field surveys in Nanjing, China, 2018. The host pupae were placed in plastic cups covered with mesh cloth and moved to the Laboratory of Biological Control in Nanjing Agricultural University and maintained in an insectary (25 ± 1 °C, $60 \pm 5\%$ RH, photoperiod L16: D 8 h) to rear adults of lady beetles or parasitoid wasps. Emerged wasps were then used to establish colonies using healthy larvae of *C. septempunctata*. Sample individuals from reared colonies were preserved in 95% ethanol after emergence for further use.

Taxonomy

Specimens used for morphological studies were critical-point dried with a Leica EM CPD300 automated critical point dryer. Then some specimens were mounted on cards and some others were dissected into head, mesosoma, metasoma, and gaster for scanning electron microscopy (SEM). Specimens were examined using a Nikon SMZ 1500 stereomicroscope fitted with a 10 mm ocular grid having 100 divisions. Habitus pictures were taken with a Nikon D7000 digital camera connected to the stereomicroscope. Dissected parts used for SEM were sputter-coated with gold using a Leica EM SCD050 super cool sputter coater. Micrographs were taken using an FEI Quanta 450 environmental scanning electron microscope. Photographs of appendages (fore wings, antennae, and legs) were taken with a Canon 550D digital camera connected to a Leica DM-2500 compound microscope. All color pictures were stacked using Helicon Focus software. The images were processed and combined into plates using Adobe Photoshop CC 2015.

The terminology follows Gibson (1997). Abbreviations are as follows: F1–F3, funiculars 1–3; MLM, midlobe of mesoscutum; Gtn, gastral tergite number; POL, the shortest distance between the posterior ocelli; OOL, the shortest distance between an eye and posterior ocellus. The type specimens were deposited in the Institute of Zoology, Chinese Academy of Sciences (IZCAS) and Nanjing Agricultural University (NAU).

Molecular analysis

A total of 16 specimens of *Oomyzus* (ten *O. spiraculus* and six *O. scaposus*) were used for extractions of whole genomic DNA by using the DNeasy Blood & Tissue Kit (Qiagen) following manufacturer's instructions. The primer pair LCO1490 (5'-GGTCA ACAA TCATA AAGAT ATTGG-3') and HCO2198 (5'-TAAAC TTCAG GGTGA CAAA AAATCA-3') (Folmer et al. 1994) were used to amplify the fragments of mitochondrial cytochrome c oxidase I (COI). All PCR procedures were performed using MyCycler Thermal Cycler (Bio-Rad, California, USA). The

PCR reactions were carried out with Ex-Taq polymerase (Takara, Japan) under the following conditions: initial denaturation for 3 min at 94 °C, 35 cycles at 94 °C for 30 s, 52 °C for 40 s, and 72 °C at 30 s, followed by extension at 72 °C for 10 min. Sequencing was performed in both directions. Sequences of both directions were assembled and edited in Sequencher version 4.5 (Gene Codes Corporation, Ann Arbor, MI, USA) and aligned in BioEdit version 7.0.9.0 (Hall 1999). The COI matrix was translated into the amino acids in MEGA7.0 (Kumar et al. 2016) to check for stop codons. The Neighbor-Joining (NJ) phylogenetic tree based on the Kimura 2-parameter (K2P) distances was constructed by using MEGA7.0 with 1000 bootstrap replicates to generate support value for nodes.

Voucher specimens are deposited in the Nanjing Agricultural University. The obtained DNA sequences in this study have been deposited in Genbank (accession numbers MT259797–MT259812).

Results

Two species of *Oomyzus* were reared from coccinellid pupae collected during field surveys in Jiangsu Province. One species was identified as *O. scaposus* and the other as a new species which is described and illustrated here.

A COI matrix containing 16 individuals of *Oomyzus* (ten *O. spiraculus* and six *O. scaposus*) with a length of 581 base pairs was generated after alignment and trimming, without insertion or deletion. Graphical representation of K2P distances between these 16 individuals based on COI is presented as an NJ tree in Figure 4. The minimum interspecific divergence (K2P distance) between *O. spiraculus* and *O. scaposus* is 7.6%. The maximum of intraspecific distance is 1.9% for *O. spiraculus* and 2.6% for *O. scaposus*.

Systematics

Genus *Oomyzus* Rondani, 1870

Oomyzus Rondani 1870: 141. Type species: *Pteromalus gallerucae* Fonscolombe, 1832, by monotypy.

Diagnosis. Body black with metallic tinge varying from very weak to quite strong, never with pale markings. Malar sulcus straight or nearly so. Submarginal vein with 1 dorsal seta. MLM with 2–5 adnotaular setae; median line often absent, sometimes present, indistinct (e.g. *O. propodealis* Graham) or distinct (some species of *gallerucae*-group). Antenna with F1 often shorter than pedicel; male scape with a variable ventral plaque, from short to very long, and flagellum with rather short basal whorl of setae, or without whorls.

Remarks. The genus *Oomyzus* is difficult to characterize and shares some features with some other genera of Tetrastichinae, such as *Baryscapus*, *Tetrastichus*, and *Quadrastichus*.

Oomyzus usually has 3 or 4 adnotaular setae on MLM, but *Quadrastichus* has only 2; *Oomyzus* often has the female antenna with quadrate funiculars, but *Quadrastichus* has funiculars at least 2× as long as broad; *Oomyzus* has the female gaster shorter and less acute apically. Some *Oomyzus* species (e.g. *O. brevistigma*, *O. scaposus*, and *O. sokolowskii*) were originally regarded as *Tetrastichus* species. However, the characteristic Y-shaped carina formed by the paraspiracular carina and an additional carina running posterior-medially from the paraspiracular carina differentiates *Tetrastichus* from *Oomyzus*. The genus *Baryscapus* is distinguished from *Oomyzus* by the submarginal vein having 2 dorsal setae and a distinctly curved malar sulcus, although some species of *Oomyzus* occasionally have 2 dorsal setae on the submarginal vein (e.g. *O. sokolowskii*) and sometimes have a more or less curved malar sulcus (e.g. *O. pegomyae* Graham), which can be differentiated from *Baryscapus* by the combination of other diagnostic characters listed above. See also discussions in Graham (1991) and LaSalle (1994).

Key to *Oomyzus* species similar to *O. spiraculus*

In this key both sexes are included and if ‘female’ or ‘male’ is not specified, then the features apply to both.

- 1 Propodeum with distinct paraspiracular carinae (e.g. Fig. 3b) **2**
- Propodeum without paraspiracular carinae **6**
- 2(1) MLM without submedian line (e.g. Fig. 3b) **3**
- MLM with submedian line **4**
- 3(2) Fore wing with speculum large, extending some distance below marginal vein and sometimes reaching stigmal vein, usually more or less open below; propodeum medially 1.5–2× as long as dorsellum; antennal scape and pedicel testaceous ***O. sempronius* (Erdős)**
- Fore wing with speculum small and hardly extending below marginal vein, closed below (Fig. 2h); propodeum medially relatively shorter, 1.1–1.2× as long as dorsellum (Fig. 3b); antennal scape and pedicel dark brown (Fig. 1b) ***O. spiraculus* Song, Fei & Cao**
- 4(2) Fore wing with speculum relatively large, extending below marginal vein, open below (Yefremova and Yegorenkova 2010: figs 7, 9); face smooth ***O. hemerobii* Yefremova**
- Fore wing with speculum small, not or only slightly extending to marginal vein, closed below; face weakly reticulate **5**
- 5(4) Propodeum relatively long, medially 3× as long as dorsellum; MLM with median line distinct (Yefremova and Yegorenkova 2010: fig. 16); male unknown ***O. rujumensis* Yefremova**
- Propodeum short, medially about as long as dorsellum; MLM with median line indistinct ***O. propodealis* Graham**
- 6(1) Anterior margin of clypeus with two distinct teeth or lobes; fore wing thickly or rather densely pilose, speculum very small; female antenna (Graham 1991:

- fig.192) short and stout, with pedicel distinctly longer than F1, F2 and F3 distinctly transverse; clava at most 2.6× as long as broad; male antenna having scape strongly swollen, at most 2× as long as broad, F2–F4 more than 1.5× as long as broad, each funicular with a compact subbasal whorl of long, dark setae (Graham 1991: fig. 210) *O. incertus* (Ratzeburg)
- Anterior margin of clypeus with two minute tubercles; fore wing rather less thickly pilose, speculum slightly larger; female antenna (Graham 1991: fig. 195) with pedicel not or hardly longer than F1; clava 2.7–3.1× as long as broad; male antenna (Graham 1991: fig. 207) having scape normally swollen, about 2.5× as long as broad, F2–F4 subquadrate or slightly transverse, each funicular without compact subbasal whorls of long setae
..... *O. scaposus* (Thomson)

Species treatment

Oomyzus spiraculus Song, Fei & Cao, sp. nov.

<http://zoobank.org/B57F37F6-51E7-4EC3-A9DA-9541DBC2DC2E>

Figures 1–3

Female. Body length 1.2–1.4 mm. Body black with more or less dark green tinge (Fig. 1a, b). Antenna brown with apical scape and pedicel more or less light brown ventrally. Legs with coxae brown, tips of femora broadly brown and tibiae pale yellow; fore tarsus fuscous, turning to brown towards tarsomere 4; mid and hind tarsi with tarsomeres 1+2 pale yellow and tarsomeres 3+4 brown (Fig. 2a–c). Wings hyaline, with brown veins (Fig. 2h).

Antenna (Figs 1b, 3f) with 3 funiculars and 3 clavomeres; scape nearly reaching median ocellus, scape with raised and longitudinal reticulation; pedicel slightly shorter

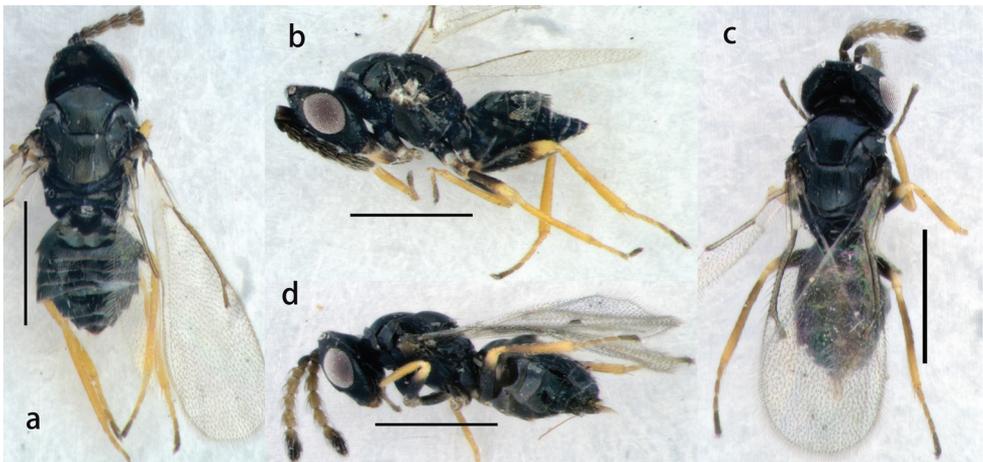


Figure 1. *Oomyzus spiraculus* Song, Fei & Cao. Female: **a** body in dorsal view **b** body in lateral view. Male: **c** body in dorsal view **d** body in lateral view. Scale bars: 0.5 mm.

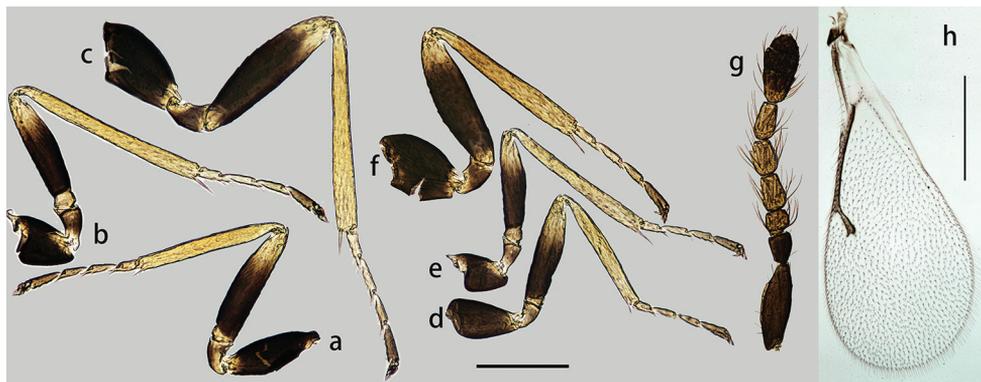


Figure 2. *Oomyzus spiraculus* Song, Fei & Cao. Female: **a** fore leg **b** mid leg **c** hind leg **h** fore wing Male: **d** fore leg **e** mid leg **f** hind leg **g** antenna. Scale bars: 0.2 mm.

than F1, with raised striations; F1–F2 subequal in length and each about 1.4× as long as broad, F3 longer and more slender than F1 and F2, about 1.6× as long as broad; clava 0.7–0.8× as long as funicle, clavomeres decreasing in length, clavomere 3 with a short and indistinct terminal spine. Each flagellomere with longitudinal sensilla and apically with a circle of scattered, mushroom-shaped capitate peg sensilla; each flagellomere except clavomere 3 truncate apically.

Head slightly broader than mesoscutum, and very easily collapsing when dried. OOL 1.58× POL (0.70: 0.44) (Fig. 3g). Ocelli arranged in an obtuse triangle (Fig. 3g), almost in a line if head is collapsed. Ocellar triangle slightly raised. Head in anterior view 1.23× as broad as high (2.7: 2.2), with vertex convex (Fig. 3h). Frons with a short and narrow V-shaped frontofacial suture connecting to ocellar area; upper face with a thin and raised carina between depressed scrobes; head easily collapsed along frontofacial sutures and outer margins of scrobes (Fig. 3h). Face with longitudinal reticulation, scrobes with indistinct reticulation. Toruli inserted slightly above lower margin of eyes. Eyes with short and sparse white hairs, diameter larger than malar space. Malar space 0.8–0.9× as long as mouth opening, and malar sulcus more or less straight. Anterior margin of clypeus weakly bilobed (Fig. 3h).

Pronotum strongly sloping and almost invisible in dorsal view; pronotum distinctly reticulate, neck and collar not delimited, without posterior carina (Fig. 3a, b). Mesoscutum with engraved and longitudinal reticulation, notaular grooves deep and curved; MLM with 3 adnotaular setae, without median line or with a trace of median line only posteriorly, with posterior margin straight (Fig. 3b). Axillae strongly shifted forward, with engraved reticulation in anterior 2/3 and with strongly raised striations, like carinae, in posterior 1/3 (Fig. 3b). Scutellum convex in profile, slightly broader than long (1.3: 1.2), with engraved, longitudinal reticulation; scutellum with distinct submedian lines that are slightly nearer to sublateral lines than to each other, enclosed space between submedian lines 2.1–2.2× as long as broad; with two pairs of setae on scutellum, subequal in length, anterior pair situated slightly before middle and posterior pair situated near posterior margin; scutellum with depressed frenum, delimited by groove and

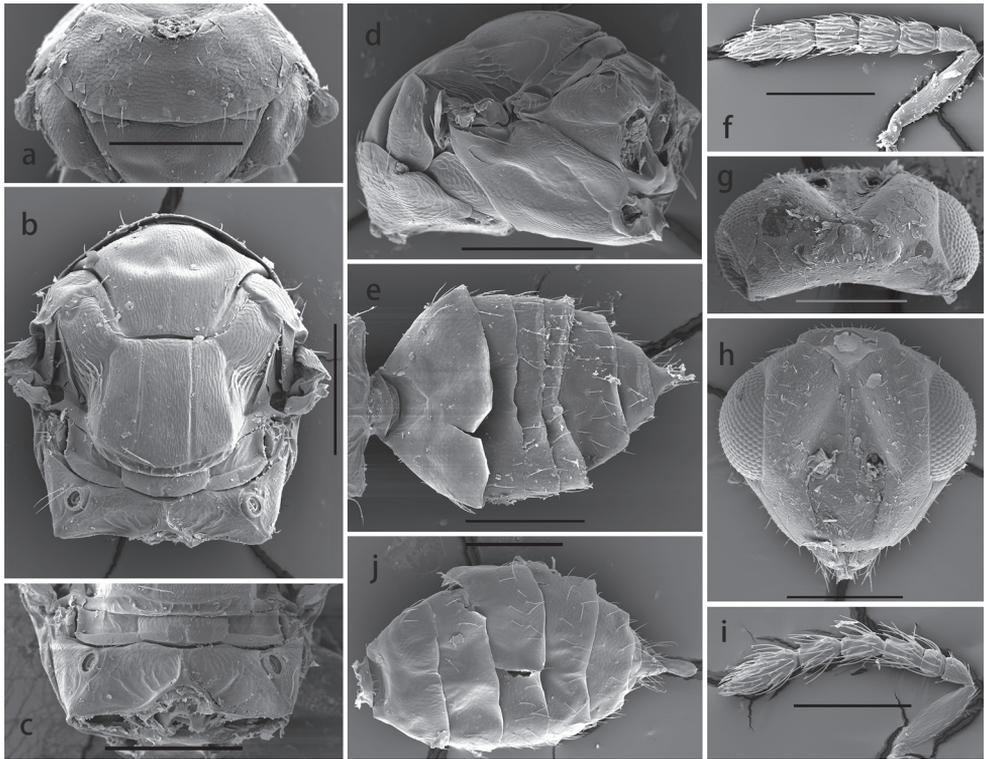


Figure 3. *Oomyzus spiraculus* Song, Fei & Cao. Female: **a** pronotum in dorso-anterior view **b** mesosoma in dorsal view **c** propodeum in dorsal view **d** mesosoma in lateral view **e** metasoma in dorsal view **f** antenna **g** head in dorsal view **h** head in frontal view. Male: **i** antenna **j** metasoma in dorsal view. Scale bars: 0.2 mm.

scattered, irregular carinae (Fig. 3b, d). Dorsellum about 2.6× as broad as long, with coarser engraved reticulation than scutellum; slightly incised in middle of posterior margin; lateral panel of metanotum smooth, with a carina medially (Fig. 3b, c). Propodeum incised medially along anterior and posterior margins, thus shortest medially, medially slightly longer than dorsellum; propodeum with median carina, broadening caudad and then extending laterally; propodeum with paraspiracular carinae, median area, delimited by paraspiracular carinae and median carina, with slightly raised reticulation and with irregular oblique carinae posteriorly (Fig. 3b, c); spiracles with entire rim exposed; callus reticulate, with 4 setae. Lateral panel of pronotum, prepectus, mesepimeron and mesepisternum reticulate, except a small area between mesepimeron and mesepisternum that is smooth; acropleuron smooth; metapleuron reticulate (Fig. 3d).

Petiole short and hidden (Figs 1a, 3e). Gaster (Fig. 3e) 1.2–1.6× as long as broad and easily collapsed, especially Gt_{2-4} easily shrink or expand after death, and thus the relative length of mesosoma and metasoma is variable; gastral tergites each with weak raised reticulation; Gt_7 with 4 cercal setae, the longest seta slightly longer than the other three setae that are subequal in length.

Legs (Fig. 2a–c) short and stout, with coxae, femora, and tibiae reticulate; tarsomere 1 of mid and hind legs almost as long as tarsomere 2. Fore wing (Fig. 2h) with

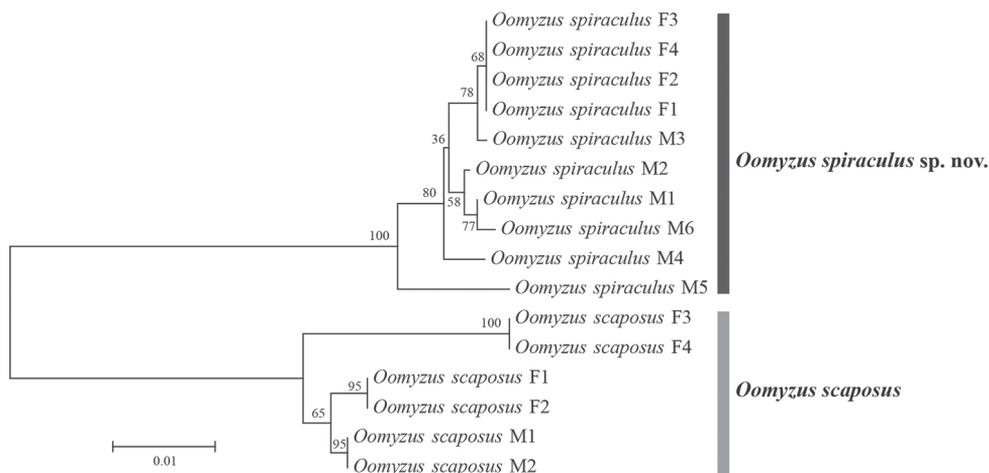


Figure 4. NJ tree of COI sequences from 16 *Oomyzus* specimens using K2P distances. Numbers above/below nodes represent bootstrap values.

postmarginal vein absent; submarginal vein with 1 seta on dorsal surface; speculum small, closed below, hardly extending below marginal vein.

Male. Body length about 1 mm (Fig. 1c, d). Differs from female as follows. Antenna (Figs 2g, 3i) with 4 funiculars and 3 clavomeres, scape and pedicel black, funicle and clavomere 1 brownish yellow, remainder of clava black; scape with ventral plaque 0.57× total length of scape; F1 1.25× as broad as long, distinctly shorter than pedicel and F2; F2–F4 slender, subequal in length, 1.85–2× as long as broad; clava slightly broader than funicle, about 2.6× as long as broad, shorter than combined length of F3 and F4; each funicular with a compact subbasal whorl of dark setae which reach beyond tip of flagellomere attached to. Fore tarsi less infuscate (Fig. 2d). Gaster distinctly pointed apically (Fig. 3j).

Etymology. From the Latin word *spiraculus* (spiracle), referring to the propodeum with paraspiracular carinae.

Type material. *Holotype* ♀, CHINA, Jiangsu, Nanjing, Baima Agricultural Field of Nanjing Agricultural University, 30.V.2019, coll. Minghui Fei, *ex.* pupa of *Coccinella septempunctata* L. (IZCAS, IOZ(E)225734). *Paratypes*: 5♀ 4♂, same data as holotype (IZCAS, IOZ(E)225735–IOZ(E)225742; NAU); 8♀ 3♂, CHINA, Jiangsu, Nanjing, V.2019, coll. Haowu Hu, *ex.* pupa of *Coccinella septempunctata* L., lab reared on the pupae of *Coccinella septempunctata* (IZCAS, IOZ(E)225743–IOZ(E)225753; NAU).

Additional material. 3♀ 3♂ on slides, CHINA, Jiangsu, Nanjing, V.2019, coll. Haowu Hu, *ex.* pupa of *Coccinella septempunctata* L., lab reared on the larva-pupa of *Coccinella septempunctata* (IZCAS).

Host and offspring information. This species was reared as a gregarious endoparasitoid from pupae of *C. septempunctata*. In the laboratory, each instar of the host larva could be parasitized and would pupate successfully when provided with adequate number of aphids. The parasitoid offspring emerged from the host pupa, after a development time of 14–18 days. The brood size ranged from 4–23 after a single bout of parasitization, and the male number ranged from 0–3, mostly 2 ($n=28$). Another two common ladybird species,

Harmonia axyridis Pallas and *Propylaea japonica* (Thunberg), were also included in the study and the result showed that the Japanese lady beetle, *P. japonica*, was a potential host.

Distribution. CHINA: Jiangsu.

Remarks. *Oomyzus spiraculus* is one of five species of *Oomyzus* known to have propodeum with distinct paraspiracular carinae; the other four are *O. hemerobii*, *O. rujumensis*, *O. propodealis*, and *O. sempronius*. However, *O. spiraculus* is currently not supported to form a species group with any above-mentioned species by any other evidence. Morphological similarities and differences among these species are summarized in Table 1.

In addition, the relatively short propodeum with paraspiracular carinae and the pale-yellow tibiae differentiate *O. spiraculus* from *O. scaposus* reared from the same host (Table 1). Male tibiae of *O. spiraculus* are mostly pale yellow as the female, sometimes slightly infuscate dorsally.

Table 1. Summary of morphological similarities and differences among *O. spiraculus* and some other *Oomyzus* species.

Species/ Characters	<i>O. spiraculus</i>	<i>O. hemerobii</i>	<i>O. rujumensis</i>	<i>O. propodealis</i>	<i>O. sempronius</i>	<i>O. scaposus</i>
Paraspiracular carinae on propodeum	present	present	present	present	present	absent
Median line on MLM	absent	present	present	present	indicated in posterior half or absent	absent
Female tibiae	pale yellow	pale yellow	dark yellow	pale yellow	pale yellow	brown to black
Medially relative length of propodeum/dorsellum	at most 1.20×	1.5–2.0×	about 3.0×	about 1.0×	1.5–2.0×	at most 1.5×
Male F1	transverse, shorter than pedicellus	subquadrate, shorter than pedicellus	unknown	longer than broad, as long as pedicellus	longer than broad, shorter than pedicellus	subquadrate, shorter than pedicellus
Cercal setae	one slightly longer than the other three	unavailable	unavailable	longest one nearly 2× length of next longest, kinked	unavailable	subequal
Face	sculptured	smooth	sculptured	sculptured	sculptured	sculptured
Speculum of fore wing	closed below, small, not extending below marginal vein	closed below, relatively large, extending along marginal vein	closed below, small, not extending below marginal vein	closed below, small, not extending below marginal vein	open below, large, extending some distance below marginal vein	closed below, small, not extending below marginal vein
Color of antennal scape in female	mainly brown, paler apically	yellow dorsally, brown dorsally	yellow	black	testaceous	fuscous to brown
Color of antennal pedicel in female	mainly brown, paler ventrally	yellow dorsally, brown dorsally	dark brown	black	testaceous	fuscous to brown

Discussion

Coccinella septempunctata is a dominant predator attacking aphids in agroecological ecosystems and has great potential as a biological control agent in the development of a green agricultural economy. Prior to this study, quite a few Chalcidoidea parasitoids of *C. septempunctata* have been reported, including species belonging to Encyrtidae, Eulophidae, and Pteromalidae. *Homalotylus* spp. (Hymenoptera: Encyrtidae) seem to be especially well associated with *C. septempunctata* (Noyes 2019). In China, *Oomyzus scaposus* and *Homalotylus flaminus* (Dalman) are the most common parasitoids of *C. septempunctata* (Jing and Huang 2002; Song et al. 2017). This study demonstrates that *O. spiraculus* is a new parasitoid species of *C. septempunctata*, and it provides an ideal model system together with *O. scaposus* for further studies of interactions with *C. septempunctata*, as well as competition among themselves. In addition, the description of this new species will facilitate the discussions of phylogenetic relationships between close species of *Oomyzus* and the divergence and speciation of parasitoids in the same niche.

Acknowledgements

We thank Natalie Dale-Skey (BMNH) for providing help to find the type specimens of *Oomyzus* deposited in BMNH; Dr Kui-Yan Zhang significantly helped Huan-Xi Cao with SEM photographs; and Dr Ran Li and Xiao-Han Shu for generating molecular data. We thank Dr Christer Hansson for his review and constructive comments, which improved the quality of this manuscript. We thank the Subject Editor, Dr Norman Johnson, for his reading and corrections. This study was supported by the National Natural Science Foundation of China (31625024, 31800355) and Natural Science Foundation of Jiangsu Province of China (BK20180547).

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The genus *Pterostichus* in China III: a brief review of subgenus *Chinapterus* Berlov (Coleoptera, Carabidae) with descriptions of two new species

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Abstract

The subgenus *Chinapterus* Berlov, 1998 of the genus *Pterostichus* is briefly reviewed and a new synonym is proposed: *Pterostichus singularis* Tschitschérine, 1889 = *Pterostichus balthasari* Jedlička, 1937 **syn. nov.** Two new species are described: *Pterostichus (Chinapterus) lianhuaensis* **sp. nov.** and *Pterostichus (Chinapterus) liupanensis* **sp. nov.** *Pterostichus przewalskyi* Tschitschérine, 1888 is moved from subgenus *Sinoreophilus* Sciaky, 1996 to *Chinapterus*, and lectotypes are designated for *P. balthasari* and *P. przewalskyi*. A key to four species of the subgenus *Chinapterus* is provided.

Keywords

China, *Pterostichus*, *Chinapterus*, new synonym, key

Introduction

The subgenus *Chinapterus* was erected by Berlov (1998) based on type species of *Pterostichus balthasari* Jedlička, 1937 from Gansu, China. This small subgenus is endemic to midwestern China. Recently, when sorting carabid specimens at the Institute of Zoology, Chinese Academy of Sciences, we found eight specimens from Lianhua Shan in Gansu, and three specimens from Liupan Shan in Ningxia belonging to this subgenus. After com-

parison with type specimens of *Chinapterus*, we believe they represent two new species. Furthermore, we also found that the type species, *P. balthasari* is a junior synonym of *Pterostichus singularis* Tschitschérine, 1889, and that another species, *Pterostichus przewalskyi* Tschitschérine, should be included in the subgenus *Chinapterus*. Therefore, we would like to make a brief review of species belonging to the subgenus *Chinapterus* in this paper.

Materials and methods

This paper is mainly based on the examination of specimens from China. The majority of specimens examined, including types of new species, are deposited in the collection of the Institute of Zoology, Chinese Academy of Sciences, Beijing, China (**IZAS**). The specimens examined or cited from other collections are indicated with abbreviations as follows.

MNHN Muséum National d’Histoire Naturelle, Paris, France.

MSNM Museo Civico di Storia Naturale, Milano, Italy.

NMPC Národní Muzeum Přírodovědecké Muzeum, Prague, Czech Republic.

ZIN Zoological Institute, Russian Academy of Sciences, St. Petersburg, Russia.

The body length (BL) was measured from the apical margin of the labrum to the elytral apex; the body width (BW) was measured along the elytral greatest width (EW). The metepisternum length (ML) was measured along the inner margin; width (MW) was measured along the basal margin. The pronotum width (PW) was measured along its greatest width; basal width (PBW) was measured along its basal margin; apical width (PAW) was measured along its apical margin, pronotum length (PL) was measured along its median line. Elytra length (EL) was measured along the suture from the base of the scutellar to the elytra apex. For the description of the endophallus, all lobes were named based on their homological inferences but not actual locations. The abbreviations used in the endophallus are as follows: gonopore (gp), gonopore lobe (gpl), gonopore piece (gpp), dorsal lobe (dl), left basal lobe (lbl), left apical lobe (lal), and right lobe (rl). Other terms used, dissection techniques, endophallus everting procedures, and photography are consistent with what we adopted in our previous work (Shi et al., 2013; Shi & Liang, 2015). Original labels are cited for types and non-types.

Taxonomy

Key to subgenera of the genus *Pterostichus* from China (part)

- 1 Mesofemur with four or more setae along posterior margin; spermatheca tubular, seminal canal and receptaculum not differentiated, spermathecal canal inserted between midpoint to the apical third of spermatheca..... **2**
- Mesofemur with two (occasionally three) setae along posterior margin; spermatheca usually with seminal canal and receptaculum differentiated, seminal

- canal more or less slenderer than receptaculum, OR spermatheca short, seminal canal and receptaculum not differentiated, spermathecal canal inserted near basal fourth of spermatheca..... ***Pterostichus* other subgenera**
- 2 Metepisternum long, length much greater than the width of anterior margin; hind wing well developed..... **3**
- Metepisternum short, length subequal to the width of anterior margin; hind wing reduced **4**
- 3 Pronotum strongly cordate; lateral region between lateral bead and basal fovea flat; apical setigerous pore on the third elytra interval near apical twelfth **sg. *Adelosia***
- Pronotum subquadrate or a little narrowed to the base; lateral region between lateral bead and basal fovea more or less ridged; apical setigerous pore on the third elytra interval near apical sixth **sg. *Platysma***
- 4 Elytral striae complete..... **5**
- Elytral striae tangled, interrupted, sinuate or replaced by rows of irregular coarse punctures **6**
- 5 Elytral microsculpture isodiametric, similar in both sexes; right paramere falciform, apex somewhat elongate **sg. *Chinapterus***
- Elytral microsculpture granular in females, isodiametric in males; right paramere rounded triangular, apex not elongate **sg. *Sinoreophilus***
- 6 Pronotum with two setae near posterior angle; legs bicolor with reddish brown femora **sg. *Plectes***
- Pronotum with one seta near posterior angle; legs unicolor, black or dark brown **sg. *Metallophilus***

Subgenus *Chinapterus* Berlov, 1998

Chinapterus Berlov, 1998: 14. Type species: *Pterostichus balthasari* Jedlička, 1937 [= *Pterostichus singularis* Tschitschérine, 1889], by original designation.

Diagnosis. Body slightly convex. Elytral striae regular, third interval with two or three setigerous pores. Metepisternum slightly wider than length. Mesofemur with four or more setae on ventral surface. Elytral plica absent or indistinct. Right paramere of male genitalia falciform, with somewhat elongated apex. Spermatheca with seminal canal and receptaculum not differentiated.

Subgeneric characters. Medium size, body length 9.0–15.0 mm. Black, elytra slightly shiny, without metallic luster. Submentum with two long setae on each side. Pronotum cordate or quadrate; basal foveae deep, inner and outer grooves indistinctly separated or outer groove absent; one baso-lateral seta inserted on basal angle. Elytra striae straight and continuous, neither interrupted nor sinuate; interval microsculpture isodiametric, similar in male and female, third interval usually with two or three setigerous pores, fifth interval without pore; ninth interval with umbilical series slightly sparser in the middle than basal and apical areas; elytral plica indistinct; scutellar stria

present; basal pore present or not. Metepisternum slightly wider than length. Terminal ventrite of males slightly depressed or without modification. Mesofemur with four or more setae on ventral surface, with a spine near apex; metacoxae with two setae; metatrochanters without seta. Fifth tarsomere with or without setae on ventral side. Apical orifice of aedeagus obviously twisted to left side; apical lamella narrow, short; right paramere falciform, apex more or less elongate and bent; endophallus bent to ventral-left or venter, gonopore opened to the base, with a large cap-like sclerotized gonopore piece (Figs 7–9). Gonocoxite II of ovipositor stout or slightly slender and bent, apex rounded, inner and outer margin each with one ensiform spine, apex with two very short nematiform setae in groove (Figs 60–65). Spermatheca tube-like, surface glabrous, receptaculum not differentiated from seminal canal, base of seminal canal sclerotized; spermathecal gland very fine, atrium and gland duct not differentiated, connected to the middle of spermatheca (Figs 58, 59).

Distribution. This subgenus is endemic to China. A total of four species are distributed in Qinghai, Sichuan, Gansu, and Ningxia.

Comparison. In its original description (Berlov, 1998), the subgenus *Chinapterus* was erected based on type species *Pterostichus balthasari* Jedlička, which was formerly a member of the subgenus *Euryperis* Motschulsky (Jedlička, 1962) and was subsequently synonymized with *Petrophilus* Chaudoir (Kryzhanovskij et al., 1995). *Chinapterus* is similar to *Euryperis* in having metepisternum slightly wider than length, metatrochanters without seta, and pronotum posterior angles widely rounded (only for *P. singularis*). But, *Chinapterus* is quite different from *Euryperis* in the following aspects: (1) mesofemur with four or more setae on the ventral side (with two setae in *Euryperis*); (2) elytral plica absent or indistinct (distinct in *Euryperis*); (3) spermatheca with seminal canal and receptaculum not differentiated (well differentiated in *Euryperis*).

Among the Chinese subgenera of *Pterostichus*, *Chinapterus* is most similar to the subgenera *Sinoreophilus* and *Metallophilus* in external appearance, and having the mesofemur with four or more setae near the hind margin, the metepisternum width subequal to its length, but differs in: (1) right paramere falciform, with the apex more or less elongate and bent; (2) elytral microsculpture isodiametric, similar in both sexes (in the other two subgenera, right paramere rounded triangular, apex not elongate, nor slightly bent; elytral microsculpture granular in females, isodiametric in males). Comparisons with other similar subgenera present in the key to subgenera.

Notes on systematics. Among all subgenera of *Pterostichus* from China, *Chinapterus* is doubtless closely related to other five subgenera (*Platysma*, *Adelosia*, *Metallophilus*, *Sinoreophilus*, *Plectes*) and shares the following important characters: (1) mesofemur with four or more setae along posterior margin; (2) elytral plica absent or indistinct; (3) metatrochanters without seta; (4) spermatheca tube-like, seminal canal and receptaculum not differentiated. These six subgenera form a monophyletic group (the *Platysma* group as defined here) supported by synapomorphic characters 1, 2, and 3 (character polarities discussed in this section follow Bousquet, 1999: 32–36). Except for the Chinese fauna, *Myosodus*, a subgenus centered in the Caucasus, also belongs to this group.

Among the above four characters, character 1 is exclusive for the *Platysma* group in *Pterostichus* and character 4 is plesiomorphic. The undifferentiated spermatheca is unusual in *Pterostichus* and may suggest a relatively basal position of the *Platysma* group in the genus. So far as we know, all species of the *Platysma* group have a distinctive form of the female reproductive tract: spermatheca tube-like, seminal canal and receptaculum not differentiated, spermathecal canal inserted between the midpoint to the apical third of the spermatheca. In contrast, for most subgenera of *Pterostichus*, the spermatheca is usually very long with the seminal canal and receptaculum differentiated. If not so distinctly differentiated, the seminal canal is at least a little slenderer than the receptaculum, as in the subgenus *Orientalostichus*. Except the *Platysma* group, only the subgenus *Argutor* and its relatives (five subgenera from China) have the undifferentiated spermatheca, but their spermathecae are always very short with the spermathecal canal inserted near the basal fourth of spermatheca.

The relationships among subgenera of the *Platysma* group are quite unclear, and even the monophyly of several subgenera is questioned. The subgenera *Platysma* and *Sinoreophilus* can be differentiated by plesiomorphic characters only, while other subgenera are merely defined by one or two apomorphic characters. Except for *Adelosia* (monotypic) and *Plectes* (includes two very closely related species), the monophyly of the other four subgenera are difficult to demonstrate.

We here redefine the subgenus *Chinapterus* and assign *P. przewalskyi* together with two new species very closely related to it into the subgenus for the following similarities: metepisternum length subequal to its basal width and right paramere falciform, apex rather elongated and bent. These two apomorphic characters may support the subgenus *Chinapterus* and can clearly differentiate it from all other related Chinese subgenera. However, the monophyly of *Chinapterus* is still questioned, because the elongate right paramere is also present in other subgenera of the *Platysma* group, including part of *Platysma* and all members of *Myosodus*. Moreover, *P. singularis* and *P. przewalskyi* do not look similar in their general appearances, and simply from the shape of right paramere, the former species is more similar to some species of *Platysma* while the latter is more like *Myosodus*. Nevertheless, the present definition of the subgenus *Chinapterus* is good for convenient taxa recognition at present. Under this, all Chinese *Pterostichus* species with multisetose mesofemora can be assigned to each subgenus. We expected an in-depth phylogenetic study will propose a better and more objective assignment of subgenera in the future.

When the present study on *Chinapterus* was conducted, we examined all *Pterostichus* species belonging to the *Platysma* group from China. We found that, *P. lanista* (Tschitschérine), *P. militaris* (Tschitschérine), and *P. peilingi* Jedlička should be moved into the subgenus *Sinoreophilus* for the following characters: mesofemur with four or more setae along posterior margin; elytra striae regular; metepisternum short, length subequal to the width of anterior margin; right paramere short and straight.

Key to species of the subgenus *Chinapterus* Berlov

- 1 Smaller size (9.0–11.0 mm); pronotum nearly quadrate, lateral margins slightly rounded before middle; elytra basal pore usually absent; males without modification on terminal ventrite; right paramere slightly elongate; Qilian mountain range..... *P. singularis* Tschitschérine
- Larger size (12.0–14.0 mm); pronotum more or less cordate, lateral margins strongly rounded before middle; elytra basal pore always present; male terminal ventrite shallowly depressed and rugose; right paramere strongly elongate..... **2**
- 2 Pronotal basal fovea depressed between inner and outer grooves, forming deep and wide basal fovea; femora reddish brown; elytra third interval usually with two setigerous pores, occasionally with three pores but all adjacent to second stria..... *P. przewalskyi* Tschitschérine
- Pronotal basal fovea convex between inner and outer grooves, outer groove rudimentary, forming narrow basal fovea; femora black; elytra third interval with three or more setigerous pores, the basal one adjacent to third stria..... **3**
- 3 Pronotum lateral margins strongly sinuate before basal angles; fifth tarsomere with one or two pairs of setae ventrally; apex of right paramere slightly angulate at dorsal-apical end. Gansu, Lianhua Shan *P. lianhuaensis* sp. nov.
- Pronotum lateral margins near straight before basal angles; fifth tarsomere glabrous ventrally; apex of right paramere completely rounded. Ningxia, Liupan Shan *P. liupanensis* sp. nov.

Pterostichus (Chinapterus) singularis Tschitschérine, 1889

Figs 1–23, 58, 64, 65

Pterostichus singularis Tschitschérine, 1889: 188 (holotype in ZIN; type locality: Amdo); Tschitschérine, 1898: 179 (*Feroperis*); Jedlička, 1962: 304 (sg. uncertain).

Pterostichus balthasari Jedlička, 1937: 47 (lectotype in NMPC; type locality: Gansu: Liangchow; sg. *Euryperis*); Jedlička, 1962: 256 (sg. *Euryperis*); Berlov, 1998: 14 (sg. *Chinapterus*). syn. nov.

Type locality. *Pterostichus singularis* Tschitschérine, Amdo, pres du fleuve Tay-tong-che (= Qinghai, Datong River). *Pterostichus balthasari* Jedlička, Gansu: Liangchow (= Gansu, Wuwei City).

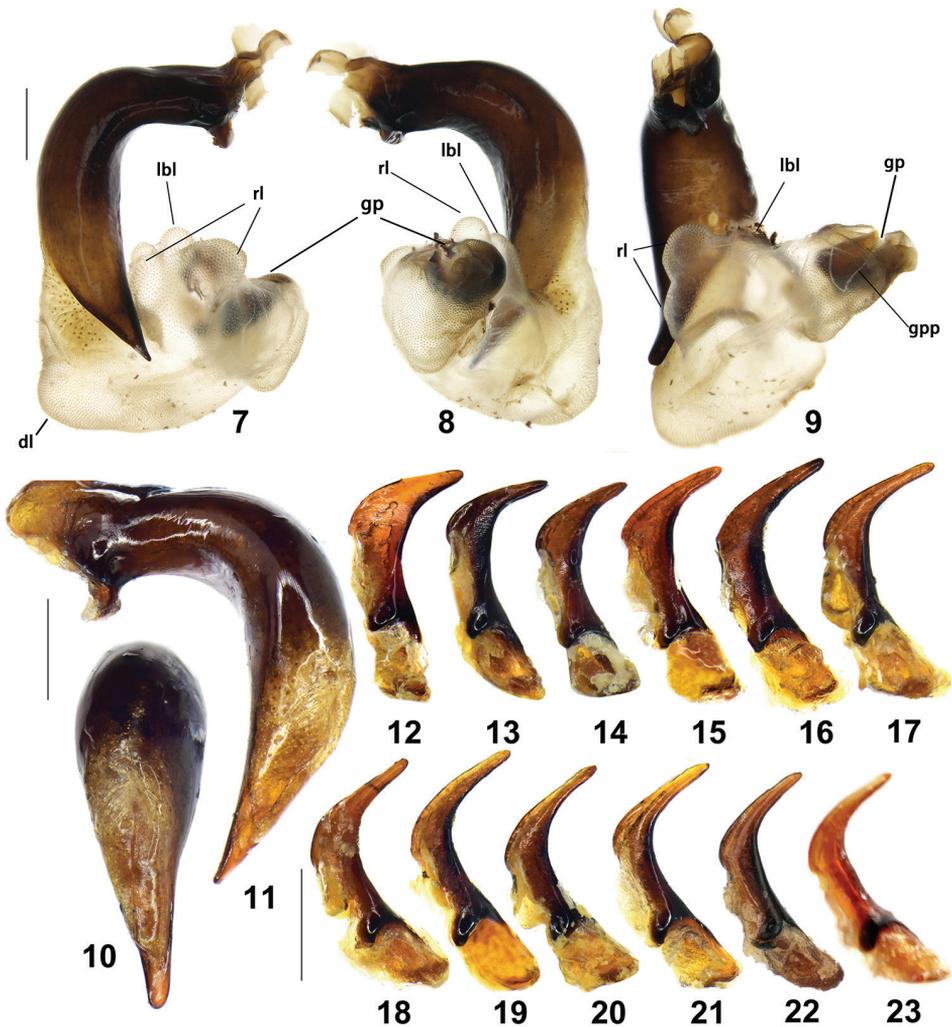
Type examined. *Holotype* of *Pterostichus singularis* Tschitschérine, male (ZIN) [Figs 1, 22], Amdo, 1886, G. Patani / *F. singularis* Typ. m. Tschitscherin det; **Lectotype** of *Pterostichus balthasari* Jedlička (designated herein), male (NMPC) [Figs 3, 23], Liangchow, W. Kansu / Type [red label] / Mus. Nat. Praga, Inv. 24641 [orange label] / *balthasari*, type, sp. n., Det. Ing. Jedlička [pink label]. **Paralectotypes** of *Pterostichus balthasari* Jedlička, 2 females (NMPC), Liangchow, W. Kansu / Cotype [red label] / Mus. Nat. Praga, Inv. 24642/24643 [orange label] / *balthasari*, sp. n., det. Ing. Jedlička.



Figures 1–6. Habitus of *Pterostichus* (*Chinapterus*) *singularis* Tschitschérine. **1** Holotype of *P. singularis* Tschitschérine, male (ZIN) **2** specimen determined by Tschitschérine, female, LT: alpes de Sinin (MNHN) **3** Lectotype of *P. balthasari* Jedlička, male (NMPC) **4** male, LT: Lajishan (IZAS) **5** male, LT: Lenglongling (IZAS) **6** male, LT: Dadongshu pass (IZAS).

Non-type materials. 1 female (MNHN) [Fig. 2], Thibet., alpes de Sinin [handwritten] / *F. singularis*, typ. m., Tschitscherin det [handwritten] / Museum Paris, coll. R. Oberthur. 1 male (MSNM), N slope of Xining mountains near Liandzha-sian, before 19–VI–1890, Gr.-Grzhimajlo leg. [in Russian] / *F. singularis*, typ. m. Tschitscher-

in det. / *Paralectotypus*, *Pterostichus*, *Singularis* Tschitsch. *Vejeschagina* 1983 [red label]. 1 female (NMPC), N slope Xining, Liandzha-sian vill., before 19–VI–1890, Grum leg. [in Russian] / *F. singularis*, *typ.*, *m.*, Tschitscherin det / Type [red label] / *singularis*, *typ.* Tsch., Det. Tschitscherin [pink label]. 5 males and 2 females (IZAS) [Figs 10, 11, 21], Gansu, Tianshu county, G312 Wushaoling pass; alpine shrub, 37.2057N, 102.8799E, 3307 m, under rock; 2017.VII.12, Shi HL, Lu ZB & Zhu PZ lgt. 1 male and 1 female (IZAS) [Figs 5, 20], Gansu Prov. Lenglong Ling, 80 km NNW Honggu, 3392–3900 m, 37°03'50.3"N, 102°39'57.2"E, alpine pasture with *Rhododendron*, under stones, 2011.VI.30–31, D.W. Wrase. 1 male and 1 female (IZAS) [Figs 4, 13], China, Qinghai Prov. Laji Shan pass, 34 km SSE Huangyuan, 36°23'01"–50"N, 101°19'31"–20'06"E, 3850–3880 m, wet plateau with depression, under stones/ clods, 8.VII.2011, D.W. Wrase. 1 female (IZAS), 2006.7.1–10, Qinghai Prov., Laji Shan. 2 males and 2 females (IZAS) [Figs 7–9, 14, 58, 64, 65], Qinghai, Qilian Shan, 3800m, pass Xi-ning-Guide, 9–11.08.10. M. Murzin. 7 males and 8 females (IZAS) [Figs 12, 16], Qinghai, Guide county, Lajishan pass, alpine meadow, N36.3573 E101.4463, 3829 m, under rock, 2017.VII.20, Shi HL, Lu ZB & Zhu PZ lgt. 2 males and 7 females (IZAS), Qinghai, Guide county, N. Slope of Guoshize Mt.; screes; 4007 m; 36.2914, 101.6005, 2017.VII.21, under stone, SHI HL & LU ZB leg. 1 male and 1 female (IZAS), Qinghai, Guide county, 3 km W of Lajishan pass, alpine meadow, 36.3622N, 101.4117E, 3686 m, pitfall trap; 2017.VII.21; Shi HL, Lu ZB & Zhu PZ lgt. 2 males and 1 female (IZAS) [Fig. 15], Qinghai, Guide county, Guoshizeshan pass, *Salix* shrubs, N36.3082 E101.5973, 3487 m, pitfall trap, 2017.VII.21; Shi HL, Lu ZB & Zhu PZ lgt. 1 male and 2 females (IZAS), Qinghai, Qilian, Datong Shan, 38.020364N, 100.134777E / 3770 m, 2012.V.31, Huang Xinlei leg. 6 males and 1 female (IZAS) [Figs 6, 18, 19], Qinghai, Qilian county, 8 km N of Dadongshu pass, alpine meadow, 38.0531N, 100.2273E, 3541 m, pitfall trap; 2017.VII.18, Shi HL, Lu ZB & Zhu PZ lgt. 1 male (IZAS) [Fig. 17], Qinghai, E. Qilian Shan, 4200 m, 1.8.1992, J.Kalab leg. / Compared with type, SHI HL 2011 / *Pterostichus balthasari* Jedlička, 1937 / ex coll. Sciaky 2011. 1 male and 1 females (IZAS), Qinghai, Menyuan county, Xianmi, Ningchan pass, alpine meadow, 37.5374N, 101.8704E, 3900 m, under rock, 2017.VII.14, Shi HL, Lu ZB & Zhu PZ lgt. 1 female (IZAS), Qinghai, Menyuan county, Xianmi xiang, Taola, *Picea* forest, 37.2309N, 102.0134E, 2636 m, under rock; 2017.VII.15, Shi HL, Lu ZB & Zhu PZ lgt. 1 female (IZAS), Qinghai, Menyuan county, Xianmi xiang, Bangusi, *Picea* forest, 37.2908N, 101.9438E, 2707 m, pitfall trap; 2017.VII.15, Shi HL, Lu ZB & Zhu PZ lgt. 1 male and 4 females (IZAS), Qinghai, Qilian county, Zhamashi, Zhamashixigou; alpine meadow; 3014 m, 38.1590N, 99.9921E, under rock; 2019.VIII.19; YAN Weifeng lgt. 4 males and 2 females (IZAS), Qinghai, Qilian county, Babao town, Lujiaogou; alpine meadow; 3461 m, 38.0991N, 100.4838E, under rock; 2019.VIII.17; YAN Weifeng lgt. 3 females (IZAS), Qinghai, Menyuan county, Xianmi, Qihankaigou; mixed forest; 2683 m, 37.1568N, 102.0278E, under rock; 2019.VIII.12; YAN Weifeng lgt. 2 males (IZAS), Qinghai, Qilian county, Epu town, Jingyangling pass; alpine meadow; 3716 m 37.8387N, 101.1117E, under rock; 2019.VIII.15; YAN Weifeng lgt. 2 females (IZAS), Qinghai, Qilian county, Babao town-



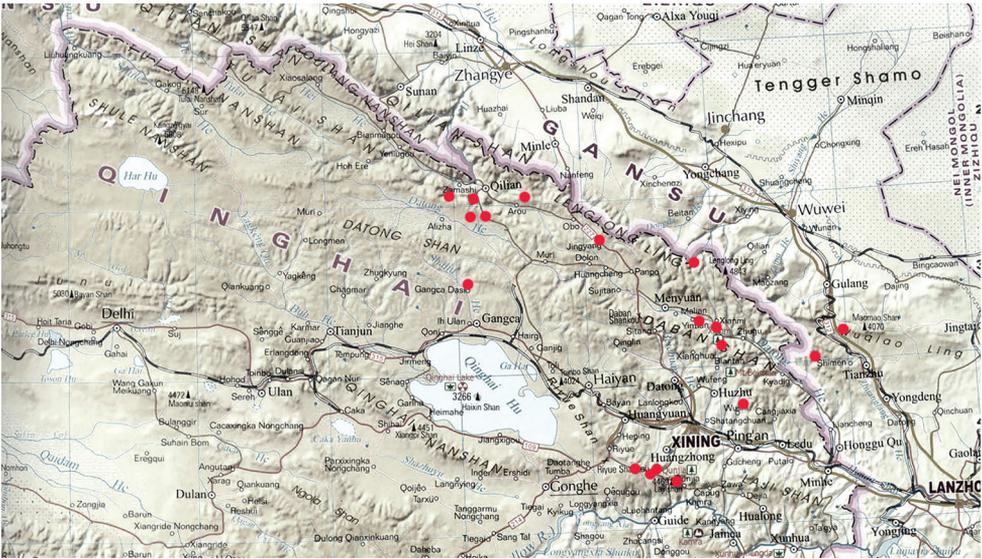
Figures 7–23. male genitalia of *Pterostichus (Chinapterus) singularis* Tschitschérine. **7–9** Endophallus, LT: Pass Xining-Guide (IZAS) **7** right lateral view **8** left lateral view **9** ventral view, abbreviations as stated in text **10–11** median lobe of aedeagus, LT: Wushaoling (IZAS) **10** dorsal view **11** left lateral view **12–23** right paramere, inner face **12** LT: Lajishan (IZAS) **13** LT: Lajishan (IZAS) **14** LT: Pass Xining-Guide (IZAS) **15** LT: Guoshizeshan (IZAS) **16** LT: Lajishan (IZAS) **17** LT: E Qilianshan (IZAS) **18** LT: Dadongshu pass (IZAS) **19** LT: Dadongshu pass (IZAS) **20** LT: Lenglongling (IZAS) **21** LT: Wushaoling (IZAS) **22** Holotype of *P. singularis* (ZIN) **23** Lectotype of *P. balthasari* (NMPC). Scale bars: 0.5 mm.

ship, Binggou; alpine meadow; 3826 m 38.1171N, 100.1716E, under rock; 2019. VIII.18; YAN Weifeng lgt. 1 male (NMPC), China: Qinghai province, Gangca Dasi [lamasery]., 37°32.4'–33.0'N, 100°05.3'–06.0'E, 3505–3840 m, 11–12.VII.2005, J. Hajek, D.Kral & J.Ruzicka leg; individually under stones, in excrements and on vegetation; spring; alpine meadows and pastures around the lamasery and in the nearby

valley. 1 female (NMPC), China: Qinghai province, Yuning Si [lamasery], 2890 m, 36°45.6'N, 102°10.6'E, 16.VII.2005, J. Hajek, D. Kral & J. Ruzicka leg, individually under stones and logs, in excrements, and on vegetation in coniferous forest, on the pastures, and along the path to a village; pool.

Diagnosis. Femora black. Pronotum quadrate; lateral margins slightly rounded before middle, nearly straight before basal angles; basal angles rounded, or slightly rectangular with an indistinct denticle; basal fovea depressed between outer and inner grooves; elytral basal pore usually absent, third interval usually with two setigerous pores; fifth tarsomere with one or two pairs of fine setae ventrally; right paramere falciform, apex acicular or triangular.

Description. BL 9.2–10.8 mm, BW 3.9–4.4 mm. Robust, black, elytra shiny. **Head** large; frons smooth or very sparsely punctate; genae short, less than one-third length of eyes; eyes small, slightly prominent. **Pronotum** quadrate; widest before middle, PW/HW = 1.26–1.43, PW/PL = 1.37–1.50; lateral margins slightly rounded from apical angles to the middle, nearly straight before basal angles, mid-lateral seta present at apical third; basal margin slightly wider than apical margin, PBW/PAW = 1.07–1.20; basal angles rounded or slightly rectangular with an indistinct denticle, not protruding outward; basal fovea with inner and outer grooves faintly defined and partly fused, forming deep depression between them, outer groove slightly shorter than inner one; basal foveal area coarsely punctate; middle area between two basal foveae smooth or very sparsely punctate; area between outer groove and lateral margin slightly convex, forming a weak carina; disc convex, smooth, transversely rugose in some specimens. **Elytra** oblong, EL/EW = 1.33–1.47; basal ridge slightly oblique; shoulder rounded, basal ridge and lateral margin forming an obtuse angle, humeral tooth absent; apical plica absent; basal setigerous pores usually absent, occasionally present in one elytron or both elytra; scutellar striae short, apex free or connected to first stria; intervals feebly convex; microsculpture similar in both sexes, finely isodiametric; third interval often with two setigerous pores on posterior half, adjacent to second stria, sometimes one or two additional pores present; umbilical series on ninth interval sparse in middle, composed of 14–17 pores; striae moderately deep, distinctly punctate. **Ventral side.** Proepisternum sparsely punctate near inner margin, rugose throughout; mesepisternum very sparsely punctate; metepisternum nearly smooth; terminal or penultimate ventrite of males not modified. Tarsomere 5 with one or two pairs of setae ventrally; metatarsomeres without distinct outer furrow. **Male genitalia.** Ventral margin of median lobe near straight at middle, slightly bent downwards near apex; apical orifice opened left-dorsally (Figs 10, 11); apical lamella narrowed in dorsal view, length near two folds of basal width, apex rounded. Right paramere falciform, strongly curved, the obtuse angle between basal portion and apical portion 105–110°; apex acicular or narrow triangular, narrow, sharp (Figs 12–21). Endophallus bent to the ventral left side, major portion of endophallus located at left side of median lobe apex; gp opened to basal-left; gpl large and coniform; gpp large and cap-like, on the ventral side of gp; three groups of lobes recognized: dl on dorsal surface of endophallus, gradually swollen; rl on ventral-right surface of endophallus, divided into two conjoint rounded sub-



Map I. Distributions for *P. singularis*.

lobes; lbl on the ventral-left surface of endophallus, smaller than rl; lal absent (Figs 7–9).

Female genitalia. Gonocoxite II of ovipositor stout, length ca. 1.5 times maximum width; inner and outer margins arched, each with one ensiform setae near middle, apex rounded, with two very short nematiform setae in a groove (Figs 64, 65). Spermatheca short and tubiform, length ca. four times maximum width (Fig. 58).

Distribution. Only known from the eastern section of the Qilian mountains on the border of Qinghai and Gansu provinces (Map 1).

Habitat. This species prefers living in open habitat like the alpine meadows of the Qilian mountains between 3000 m and 4000 m, but a few specimens were also found on the edge of *Picea* forest at ca. 2600 m.

Remarks. *Pterostichus singularis* Tschitschérine was described based on a single male from “Amdo, pres du fleuve Tay-tong-che”, referring to what is now the valley of the Datong River in Menyuan County. Thus, the three specimens we examined from different collections are not type specimens but only subsequently determined by Tschitschérine (1898: 181) although labeled as types by the author. The true holotype was deposited in the collection of ZIN.

Pterostichus balthasari Jedlička was described based on five specimens from “Liangchow” without an original fixation for holotype. In the collection of NMPC, we examined three specimens in accordance with the original literature. We designate the male bearing a “type” label as the lectotype herein, for the taxonomic purpose of fixing the species name to a single specimen and preventing further confusion. The type locality “Liangchow” refers to what is now Wuwei City in Gansu Province. The exact type locality could be the north slope of Mt. Qilian Shan in Wuwei territory.

Comparing with specimens of *P. singularis* determined by Tschitschérine, the types of *P. balthasari* are nearly identical but the basal angles of the pronotum are more

rounded and the type locality is further north. We studied specimens from several localities of the Qilian mountains and found that the northern population (Wushaoling, Lenglongling, Datong Shan) usually has a rounded or a slightly rectangular pronotal basal angle, but the southern population (Laji Shan) generally has a rectangular basal angle of the pronotum; however, a few specimens from Laji Shan also have rounded pronotal basal angles. Moreover, there is no significant difference in the male genitalia between the different localities, both for the median lobe and right paramere. Thus, we synonymize *P. balthasari* with *P. singularis*.

Variations. This species is widely distributed in the eastern section of the Qilian mountain range and is sometimes locally abundant. We studied many specimens from the five branches of the Qilian mountain range: Wushaoling, Lenglongling, Daban Shan, Datong Shan, and Laji Shan. In addition to the above variations of the basal angle, three more variations exist geographically or individually as follows:

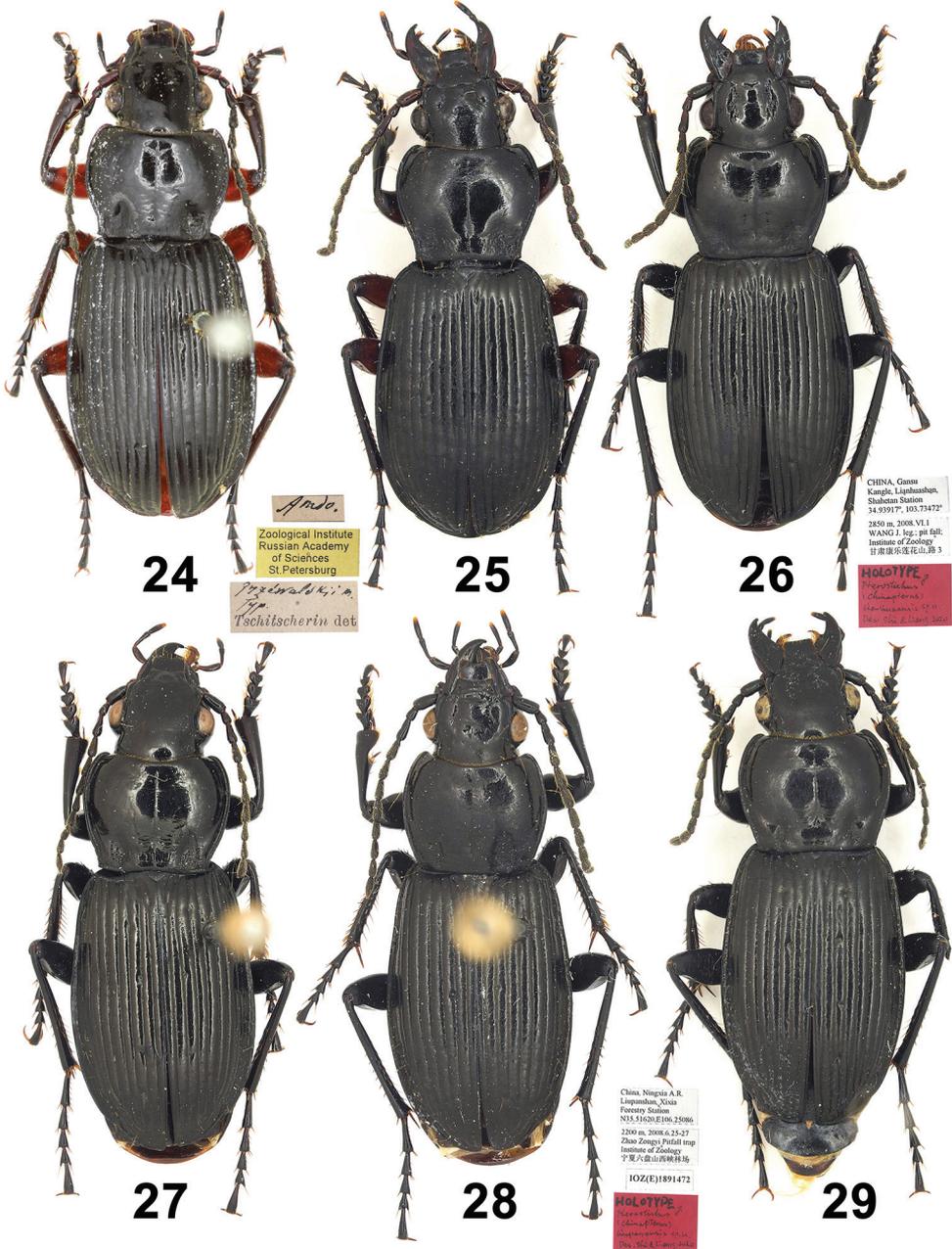
- (1) elytral dorsal pores on third interval. For ca. two-thirds of the examined specimens, two setigerous pores are present on the third elytral interval. For the other one-third, one or two additional pores are present anterior to the first pore or between the first and second pores.
- (2) elytra basal pore. For most specimens there is no basal pore on the elytra, but occasionally, a basal pore is present on one elytron or on both elytra. The proportion of individuals with elytra basal pores is larger in the population from Laji Shan than in the others.
- (3) shape of right paramere. The length of the right paramere varies individually as well as geographically. Statistically, the northeastern populations (Wushaoling, Lenglongling, Datong Shan) have a longer right paramere with the apex usually more elongate and acicular as in Figs 17–21. In contrast, the southern (Laji Shan) populations usually have shorter right paramere with the apex less elongate or narrowly triangular as in Figs 12–14. But, this individual variation with a long acicular right paramere is also present in some specimens from the southern localities (Figs 15, 16).

***Pterostichus (Chinapterus) przewalskyi* Tschitschérine, 1888**

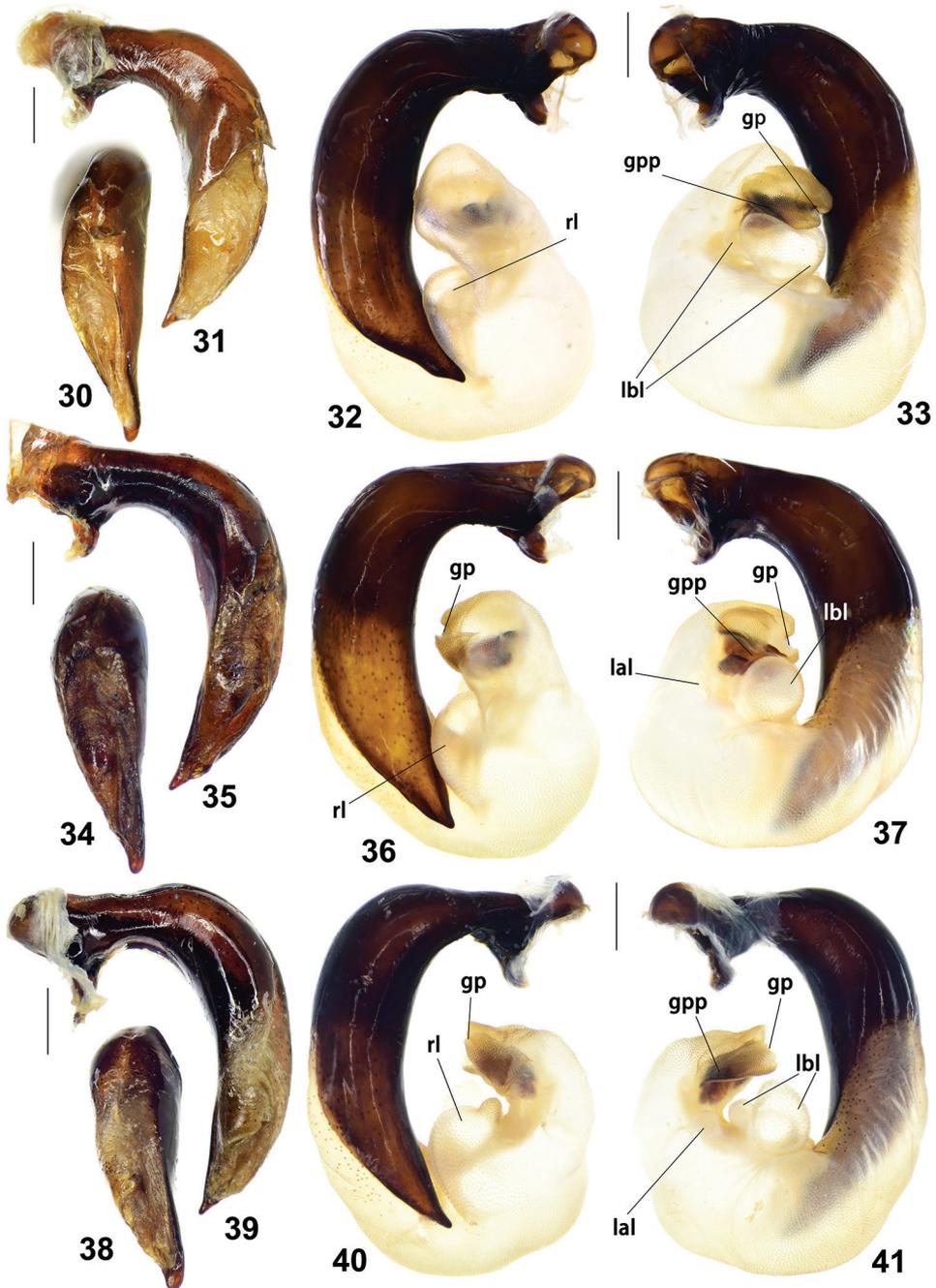
Habitus, Figs 24, 25; male genitalia, Figs 30, 33, 42, 43, 44, 47–51; female genitalia, Figs 59–61

Pterostichus przewalskyi Tschitschérine 1888: 362 (syntypes in ZIN; type locality: Amdo); Jedlička, 1962: 289 (sg. *Oreophilus*); Sciaky, 1996: 437 (sg. *Sinoreophilus*).

Type locality. From the original description, the type localities are “Amdo: près des rivières Tala-tchu et By-tchu, aux sources du Jangtsekiang”. By-tchu refers to the Buqu River in Qumarléb County of Qinhai Province, and Tala-tchu probably refers to the



Figures 24–29. Habitus of *Pterostichus* (*Chinapterus*) spp. **24** Lectotype of *P. przewalskyi*, male (ZIN) **25** *P. przewalskyi*, male, LT: Hongxing (IZAS) **26** Holotype of *P. lianhuaensis* sp. nov. (IZAS) **27** Paratype of *P. lianhuaensis* sp. nov., male (IZAS) **28** Holotype of *P. liupanensis* sp. nov. (IZAS) **29** Paratype of *P. liupanensis* sp. nov., male (IZAS).



Figures 30–41. male genitalia of *Pterostichus* (*Chinapterus*) spp. **30–33** *P. przewalskyi*; **30–31** median lobe of aedeagus, dorsal and left lateral view, Lectotype (ZIN) **32, 33** endophallus, right and left lateral view, LT: Jigzhi (IZAS) **34–37** *P. lianhuashensis* sp. nov. **34, 35** median lobe of aedeagus, dorsal and left lateral view, Holotype (IZAS) **36, 37** endophallus, right and left lateral view, Paratype, LT: Lianhuashan (IZAS) **38–41** *P. liupanensis* sp. nov. **38, 39** median lobe of aedeagus, dorsal and left lateral view, Holotype (IZAS) **40, 41** endophallus, right and left lateral view, Paratype, LT: Liupanshan, Xixia (IZAS). Scale bars: 0.5 mm, abbreviations as stated in text.

Derqu River in Chindu County, but the detailed locality was not labeled for any examined type so the precise type locality for the lectotype is unclear.

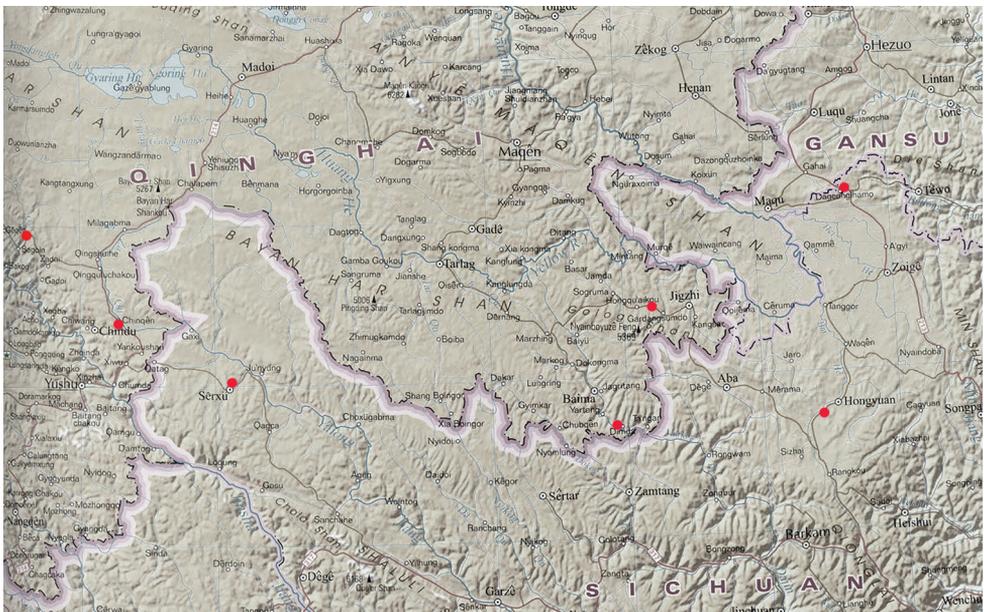
Type series. **Lectotype** of *Pterostichus przewalskyi* Tschitschérine (designated herein), male (ZIN) [Figs 24, 30, 31, 47], Amdo / Przewalskii m. Typ. Tschitscherin det / Zoological Institute Russian Academy of Sciences, St. Petersburg [yellow label]. **Paralectotypes** of *Pterostichus przewalskyi* Tschitschérine, 1 male (ZIN), N. E. Thibet, 1884, Przewalsky / Przewalskii m. typ. Tschitscherin det / Zoological Institute, Russian Academy of Sciences, St. Petersburg [yellow label]. 1 female (NMPC), N.E. Thibet, 1884, Przewalsky. / przewalskii m., typ., Tschitscherin det / Type [red label] / przewalskii, typ., Tsch., Det. Tschitscherin [pink label].

Non-type material. 1 female (IZAS), China, N Sichuan prov., Hongyuan, ca. 4200 m, 21.7–3.8.1991, J. Kalab leg. 1 male (IZAS) [Figs 42, 51], Ch-NW Sichuan, ±3700 m, 32.59N, 98.06E, 3+15/7, SERXÜ env. 1995, alpine meadow, Jaroslav Turna leg. 1 female (IZAS), Qinghai, Baima county, Makehe, Meilanggou, 2013.VI.28, D 3500 m, Chen Jin leg. 2 males (IZAS) [Figs 25, 44, 50], Sichuan, Zoigê county, 8km W. of Hongxing, wetland, 3236 m, 34.1236N, 102.6545E, under rock, 2016.VII.25, Shi HL lgt. 3 males and 1 female (IZAS) [Figs 32, 33, 49], Qinghai, Jigzhi county, E. of Luanshitou pass; alpine meadow; 4091 m; 33.4008N, 101.2537E; 2017.VIII.2, pitfall trap, SHI HL, LU ZB, ZHU PZ & YAN WF leg. 1 male (IZAS) [Figs 43, 48], Qinghai, Jigzhi county, Luanshitou pass; alpine meadow; 4212 m; 33.3986N, 101.2432E; 2017.VIII.2, under stone, SHI HL, LU ZB, ZHU PZ & YAN WF leg. 8 females (IZAS) [Figs 59–61], Qinghai, Chidu county, 2 km S of Zhenqin; alpine wetland, 4329 m, 33.3908N, 97.2977E, 2017.VII.27, under stone, SHI HL, LU ZB, ZHU PZ & YAN WF leg.

Diagnosis. Femora reddish brown. Pronotum cordate; lateral margins strongly sinuate before basal angles; basal angles right-angled, clearly pointed outwards. Elytral basal fovea depressed between inner and outer grooves; basal pore present; third interval often with two setigerous pores. Fifth tarsomere glabrous ventrally; right paramere strongly elongate and bent, apex rounded, not declined to dorsum.

Description. BL 12.0–13.4 mm, BW 4.8–5.6 mm. Robust, black, femora reddish brown except black apex; elytra slightly shiny. **Head** large, frons smooth or very sparsely punctate; genae short, less than one-third length of eyes; eyes prominent. **Pronotum** cordate; widest slightly before middle, PW/PL = 1.33–1.41; lateral margins largely rounded before the middle, strongly sinuate before basal angles; one mid-lateral seta present at apical third; basal margin slightly wider than apical margin, PBW/PAW = 1.02–1.12; basal angles rectangular, clearly protruding outwards; basal foveae deep, inner and outer grooves faintly defined, inner groove straight, distant from basal margin, outer groove shorter than inner one, extending to basal margin; basal fovea depressed between inner and outer grooves, coarsely punctate in basal fovea; area between outer groove and lateral margin hardly convex; disc convex, smooth, slightly transversely rugose; apical angle rounded, not protruding. **Elytra** oblong, EL/EW = 1.42–1.45; basal ridge slightly oblique; shoulder rounded, basal ridge and lateral margin forming an obtuse angle, humeral tooth small and obtuse; apical plica indistinct; basal setigerous pores present; scutellar striae complete; intervals slightly convex; microsculpture simi-

lar in both sexes, finely isodiametric; third interval usually with two setigerous pores, at basal two-fifths and two-thirds respectively, occasionally with one or three pores on one elytron, all adjacent to second stria; ninth interval with umbilical series regularly arranged, slightly sparser in the middle; striae deep, indistinctly punctate. Fifth tarsomere glabrous ventrally; meso- and metatarsomere I and II with outer groove. Terminal ventrite shallowly depressed and finely rugose in males. **Male genitalia.** Ventral margin of median lobe nearly straight at middle, gradually bent downwards near apex; apical orifice opening left-dorsally; apical lamella small, rounded triangular, length sub-equal to basal width, apex rounded (Figs 30, 31); apical lamella slightly twisted, forming a continuously curved dorsal-left surface (Figs 42–44). Right paramere strongly elongate and curved, the obtuse angle between basal portion and apical portion 100–105°; apex slightly thick, well rounded, not or weakly bent to dorsum (Figs 47–51). Endophallus bent to the ventral side of aedeagus, major portion of endophallus located at ventral side of median lobe apex; gp opened to basal-dorsum; gpl large and coniform; gpp large and cap-like, on the ventral side of gp; two groups of lobes recognized: rl on ventral-right surface of endophallus, large, rounded or apex a little pointed; lbl on ventral-left surface of endophallus, divided into two clearly separated sub-lobes, the basal one large and nearly rounded, the apical one much smaller than the basal one; lal absent (Figs 32, 33). **Female genitalia.** Gonocoxite II of ovipositor slightly slender, length ca. 2.5 times maximum width; inner and outer margins near straight, each with one ensiform setae before middle, apex narrowly rounded, with two very short nematiform setae in a groove (Figs 60, 61). Spermatheca moderately long and tube-like, length ca. 15 times maximum width (Fig. 59).



Map 2. Distributions for *P. przewalskyi*.

Distribution. Qinghai (southeast part), Sichuan (northwest part). Probably also in southwest Gansu (Map 2).

Habitat. This hygrophilous species tends to live in wet habitats such as wetlands or the banks of seasonal streams on alpine meadows.

Remarks. This species was described based on an unspecified number of specimens from “Amdo: près des rivières Tala-tchu et By-tchu” collected by Przewalsky in 1884. In the collection of ZIN, we examined two males which matched with the original literature. We designated the male with its genitalia dissected as the lectotype herein, for the taxonomic purpose of fixing the species name to a single specimen and preventing further confusion.

Sciaky (1996) assigned this species to the subgenus *Sinoreophilus* due to external similarities but this species has its right paramere strongly elongated and the elytral microsculpture is similar in both sexes, supporting a close relationship to *P. singularis*. So, we herein moved it from the subgenus *Sinoreophilus* to the subgenus *Chinapterus*.

***Pterostichus (Chinapterus) lianhuaensis* sp. nov.**

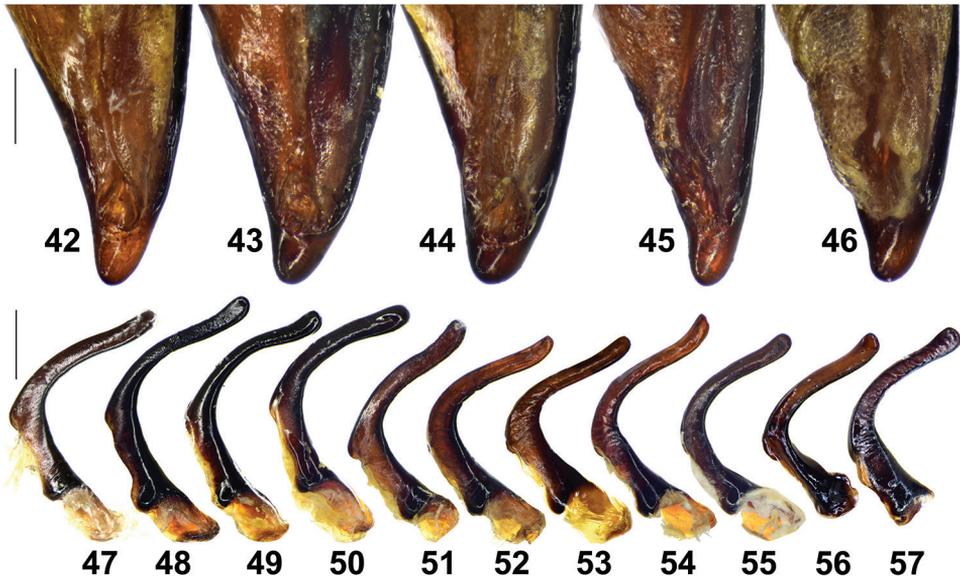
<http://zoobank.org/DE1CB5E1-EA91-4EDE-A244-70FC63F5DCFD>

Habitus, Figs 26, 27; male genitalia, Figs 34–37, 45, 52–54; female genitalia, Figs 61, 62

Type series. Holotype: male (IZAS) [Figs 26, 34, 35, 45, 52], CHINA, Gansu, Kangle, Lianhuashan, Shahetan station 34.93917N, 103.73472E / 2850 m, 2008.VI.1, WANG J. leg.; pit fall; Institute of Zoology. **Paratypes:** 1 male and 1 female (IZAS), 2012, VI, 21 D 2960 m, China, Gansu, Kangle, Lianhuashan, 34.93577N, 103.75054E / Morii leg., Inst. of Zoology, CAS. 1 male and 2 females (IZAS) [Figs 27, 36, 37, 53, 62, 63], 2012, VI, 22. D 2960 m, Gansu, Kangle, Lianhuashan, 34.91943N, 103.72860E / Liang Hongbin, Sota leg., Inst. of Zoology, CAS. 1 male and 1 female (IZAS) [Fig. 54], CHINA, Gansu, Kangle, Lianhuashan, Shahetan station 34.93917N, 103.73472E / 2850 m, 2008.VII.6, WANG J. leg.; pitfall trap; Institute of Zoology.

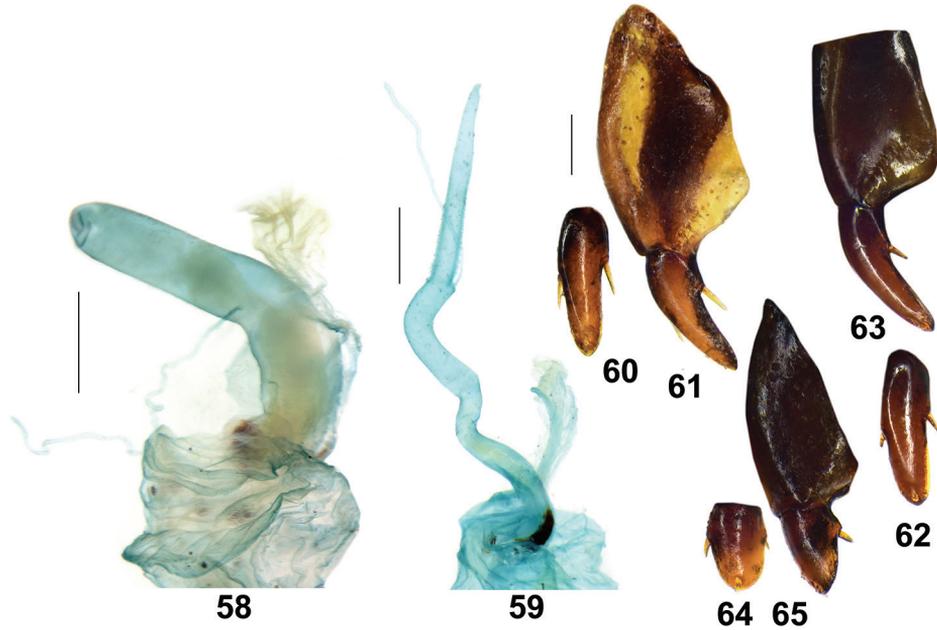
Diagnosis. Femora black; pronotum cordate, lateral margins strongly sinuate before basal angles, which clearly pointed outwards; basal foveae convex between inner and outer grooves; elytral basal pore present, third interval often with three setigerous pores; fifth tarsomere with one or two pairs of fine setae ventrally; right paramere strongly elongated and bent, apex slightly bent to dorsum, angulate at dorso-apical end.

Description. BL 12.3–13.6 mm, BW 5.0–5.5 mm. Robust, black, femora completely black, elytra slightly shiny. Head large, frons smooth or very sparsely punctate; genae short, less than one-third length of eyes; eyes prominent. **Pronotum** cordate; widest slightly before middle, PW/PL = 1.31–1.40; lateral margins largely rounded before middle, strongly sinuate before basal angles; one mid-lateral seta present at apical one-third; basal margin slightly wider than apical margin, PBW/PAW = 1.02–1.13; basal angles rectangular, clearly protruding outwards; basal foveae narrow and deep, inner groove well present, apex reaching basal third of pronotum, outer groove obsolete; basal fovea convex between inner and outer grooves, not convex between outer groove and lateral margin, basal foveal area coarsely punctate; disc convex, smooth, finely



Figures 42–57. male genitalia of *Pterostichus* (*Chinapterus*) spp. **42–46** Apex of median lobe, dorsal left view **42** *P. przewalskyi*, LT: Serxü (IZAS) **43** *P. przewalskyi*, LT: Jigzhi (IZAS) **44** *P. przewalskyi*, LT: Hongxing (IZAS) **45** *P. lianhuaensis* sp. nov. Holotype (IZAS) **46** *P. liupanensis* sp. nov. Holotype (IZAS) **47–57** right paramere, inner face **47–51** *P. przewalskyi* **52–54** *P. lianhuaensis* sp. nov. **55–57** *P. liupanensis* sp. nov. **47** Lectotype (ZIN) **48** LT: Jigzhi (IZAS) **49** LT: Jigzhi (IZAS) **50** LT: Hongxing (IZAS) **51** LT: Serxü (IZAS) **52** Holotype (IZAS) **53** Paratype, LT: Lianhuashan (IZAS) **54** Paratype, LT: Lianhuashan, Shahetan (IZAS) **55** Holotype (IZAS) **56** Paratype, LT: Liupanshan, Longtan (IZAS) **57** Paratype, LT: Liupanshan, Xixia (IZAS). Scale bars: 0.5 mm (**42–45**, **47–57**); 0.2 mm (**46**).

transversely rugose on basal half; apical angles rounded, not protruding. *Elytra* oblong, EL/EW = 1.36–1.46; basal ridge slightly oblique; shoulder rounded, basal ridge and lateral margin forming an obtuse angle, humeral tooth small and obtuse; apical plica indistinct; basal setigerous pores present; scutellar striae complete; intervals slightly convex, microsculpture similar in both sexes, finely isodiametric; third interval usually with three setigerous pores, the basal one at basal seventh, adjacent to third stria, the apical two at basal two-fifths and two-thirds respectively, all adjacent to second stria, occasionally with four or five pores on one elytron; ninth interval with umbilical series regularly arranged, slightly sparser in middle; striae deep, indistinctly punctate. Fifth tarsomere with one or two pairs of setae ventrally; meso- and metatarsomere I and II with outer groove. Terminal ventrite shallowly depressed and finely rugose in males. **Male genitalia.** Ventral margin of median lobe near straight at middle, gradually bent downwards near apex; apical orifice opened left-dorsally; apical lamella small, rounded triangular, length subequal to basal width, apex rounded, weakly bent to left (Figs 34, 35); apical lamella slightly twisted, forming a continuously curved dorsal-left surface (Fig. 45). Right paramere strongly elongate and curved, the acute angle between basal portion and apical portion 85–90°; apex slightly thick, slightly angulate at dorsal-apical end, slightly bent to dorsum (Figs 52–54). Endophallus bent to the ventral side



Figures 58–65. female genitalia of *Pterostichus* (*Chinapterus*) spp. **58, 59** Female reproductive system **58** *P. singularis*, LT: Pass Xining-Guide (IZAS) **59** *P. przewalskyi*, LT: Zhenqin (IZAS). Scale bar: 0.5 mm. **60–65** Female ovipositor **60, 61** *P. przewalskyi*, LT: Zhenqin (IZAS) **62, 63** *P. lianhuashanensis* sp. nov., Paratype LT: Lianhuashan (IZAS) **64–65** *P. singularis*, LT: Pass Xining-Guide (IZAS) **60, 62, 64** Gonocoxite II, inner view, **61, 63, 65** Gonocoxite I, II, ventral view. Scale basr: 0.2 mm.

of aedeagus, major portion of endophallus located at ventral side of median lobe apex; gp opened to basal-dorsum; gpl large and coniform; gpp large and cap-like, on ventral side of gp; three groups of lobes recognized: rl on ventral-right surface of endophallus, large, near rounded, without projection; lbl on ventral-left surface of endophallus, large and fully round, not divided into sub-lobes; lal on left surface of endophallus, very small, rounded or divided into two small sub-lobes (Figs 36, 37). **Female genitalia** same as that of *P. przewalskyi* (Figs 62, 63).

Distribution. Only known from the type locality, Lianhua Shan mountain, Kangle County, south of Gansu province (Map 3).

Etymology. The name of the new species refers to its type locality, Lianhua mountain.

Remarks. This species is similar to *P. przewalskyi* in having a large body size, lateral margins of the pronotum strongly sinuate before basal angles, but differs from the latter in: (1) femora completely black; (2) basal foveae convex between inner and outer grooves; (3) elytra third interval usually with three pores, the basal one adjacent to the third stria; (4) fifth tarsomere with one or two setae ventrally. In *P. przewalskyi*, femora reddish brown; basal foveae of pronotum depressed between inner and outer grooves; elytral third interval usually with two pores, if with three the basal one adjacent to the second stria; fifth tarsomere glabrous ventrally. The male genitalia of these two species are very similar, with small differences in: (1) apical lamella of aedeagus weakly bent



Map 3. Distributions for *P. lianhuaensis* sp. nov. (red) and *P. liupanensis* sp. nov. (blue).

to left in *P. lianhuaensis* sp. nov. (Fig. 34), almost straight in *P. przewalskyi* (Fig. 30); (2) apex of right paramere slightly angulate at dorsal-apical end in *P. lianhuaensis* sp. nov., completely rounded in *P. przewalskyi*; (3) right paramere more bent in *P. lianhuaensis* sp. nov., forming an acute angle 85–90°, versus 100–105° in *P. przewalskyi*; (4) endophallus with lbl not divided and lal present in *P. lianhuaensis* sp. nov., lbl divided into two sub-lobes and lal absent in *P. przewalskyi*.

We noticed that this new species only has very minute differences from *P. przewalskyi* in the male genitalia. However, considering the stable gaps between their features (especially the external characters) and distributions, we decide to establish a new species but not a new subspecies. A similar situation is also present in the next new species, *P. liupanensis*. Several external differences among these three species are generally of interspecific level in other *Pterostichus* groups, such as the shape of the pronotum base and basal fovea, chaetotaxy on elytral third interval, and setae on the fifth tarsomere.

***Pterostichus (Chinapterus) liupanensis* sp. nov.**

<http://zoobank.org/56C5BFFA-CAD8-41A5-BF61-A39BFEB7B862>

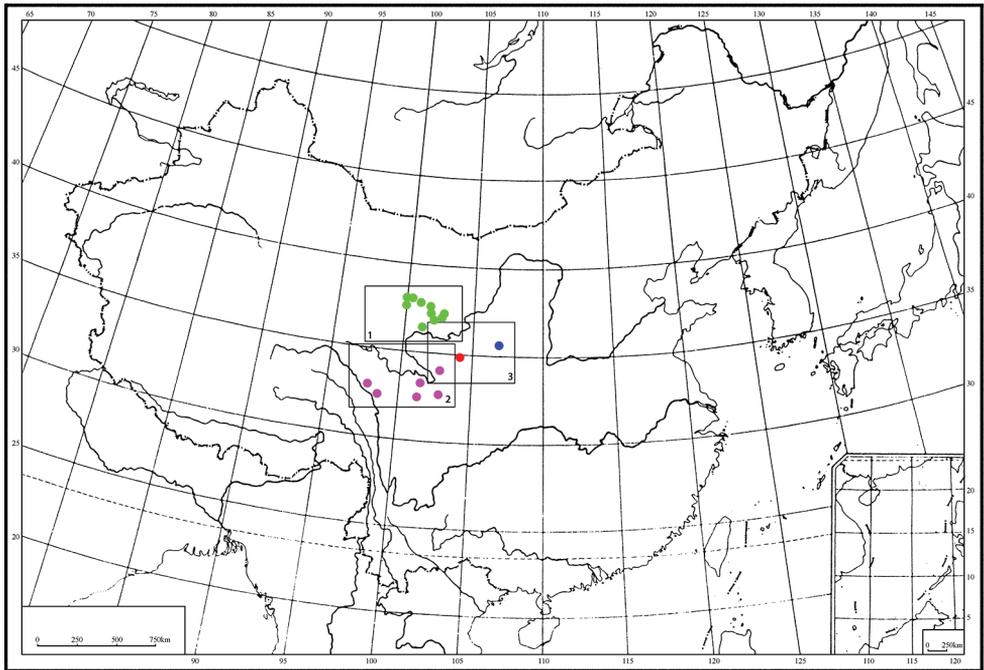
Habitus, Figs 28, 29; male genitalia, Figs 38–41, 46, 55–57

Type series. Holotype: male (IZAS) [Figs 28, 38, 39, 46, 55], China, Ningxia A.R., Liupan Mountain, Xixia Forestry Station, 35.51620N, 106.25086E / 2200 m, 2008.6.25–

27, Zhao Zongyi Pitfall trap, Institute of Zoology. **Paratypes**, 1 male (IZAS) [Fig. 56], China, Ningxia A.R., Liupanshan, Longtan Forestry Station, 35.38982N, 106.34508E / 1936 m, 2008.6.23–25, Lou Qiaozhe, pitfall trap, Institute of Zoology. 1 male (IZAS) [Figs 29, 40, 41, 57], China, Ningxia A.R., Liupanshan, Xixia Forestry Station, 35.49673N, 106.31310E / 1994 m, 2008.6.25N, Lou Qiaozhe collector, Institute of Zoology.

Diagnosis. Femora black; pronotum near quadrate, lateral margins near straight before basal angles, which weakly pointed outward and with a small denticle; basal foveae convex between inner and outer grooves; elytral basal pore present, third interval usually with three setigerous pores; fifth tarsomere glabrous ventrally; right paramere strongly elongated and bent, apex rounded, not bent to dorsum.

Description. BL 12.4–13.2 mm, BW 4.8–5.1 mm. Robust, black, femora black, elytra slightly shiny. Head large, frons smooth or very sparsely punctate; genae short, less than one-third length of eyes; eyes prominent. **Pronotum** near quadrate; widest slightly before middle, PW/PL = 1.33–1.37; lateral margins largely rounded before middle, nearly straight before basal angles; one mid-lateral seta present at apical one-third; basal margin slightly wider than apical margin, PBW/PAW = 1.12–1.16; basal angles rectangular, weakly protruding outwards, with a small denticle; basal foveae narrow and deep, inner groove obviously present, apex reaching basal third of pronotum, outer groove obsolete; basal fovea convex between inner and outer grooves, not convex between outer groove and lateral margin, basal foveal area coarsely punctate; disc convex, smooth, finely transversely rugose at basal half; apical angle rounded, not protruding. **Elytra** oblong, EL/EW = 1.46–1.52; basal ridge slightly oblique; shoulder rounded, basal ridge and lateral margin forming an obtuse angle, humeral tooth small and obtuse; apical plica indistinct; basal setigerous pores present; scutellar striae complete; intervals slightly convex, microsculpture finely isodiametric in males; third interval with three setigerous pores, the basal one at basal seventh, adjacent to third stria, the apical two at middle and apical fourth respectively, all adjacent to second stria; ninth interval with umbilical series regularly arranged, slightly sparser in middle; striae deep, indistinctly punctate. Fifth tarsomere glabrous ventrally; meso- and meta-tarsomeres I and II with outer groove. Terminal ventrite shallowly depressed and rugose in males. **Male genitalia.** Ventral margin of median lobe near straight at middle, obviously bent downwards near apex; apical orifice opened left-dorsally; apical lamella small, rounded triangular, length sub-equal to basal width, apex rounded (Figs 38, 39); apical lamella not twisted with its dorsal surface perpendicular to left surface (Fig. 46). Right paramere strongly elongate and curved, the acute angle between basal portion and apical portion near 90°; apex slightly thick, well rounded, not or weakly bent to dorsum (Figs 55–57). Endophallus bent to the ventral side of aedeagus, major portion of endophallus located at ventral side of median lobe apex; gp opened to basal-dorsum; gpp large and cap-like, on ventral side of gp; three groups of lobes recognized: rl on ventral-right surface of endophallus, large and rounded, with a papillary projection to the apex of endophallus; lbl on ventral-left surface of endophallus, divided into two clearly separated sub-lobes, the apical one very small, same size as lal, the basal one large, same size as rl; lal on left surface of endophallus, very small and rounded (Figs 40, 41).



Map 4. Distributions for *Pterostichus* (*Chinapterus*) spp. *P. singularis* (green), *P. przewalskyi* (violet), *P. lianhuaensis* sp. nov. (red), *P. liupanensis* sp. nov. (blue); black boxes mark area shown in maps 1–3.

Distribution. Only known from the Liupan Shan mountain range, Jingyuan County, Ningxia Huizu Autonomous Region (Map 3).

Etymology. The name of the new species refers to its type locality, Liupan Shan mountain.

Remarks. The new species is similar to *P. lianhuaensis* sp. nov. in having a large body size, black femora, narrow pronotum basal fovea, elytra third interval usually with three pores, but differs from the latter by having: (1) pronotum lateral margins nearly straight before basal angles; and (2) fifth tarsomere glabrous ventrally. In *P. lianhuaensis* sp. nov., pronotum lateral margins strongly sinuate before basal angles; fifth tarsomere with one or two pairs of setae ventrally. The male genitalia of the new species is very similar to that of *P. przewalskyi*, with small differences in: (1) ventral margin of aedeagus more distinctly bent downwards near apex in lateral view in *P. liupanensis* sp. nov. (Fig. 39), evenly and gradually bent downwards in lateral view in *P. przewalskyi* (Fig. 31); (2) apical lamella with dorsal surface perpendicular to left surface in *P. liupanensis* sp. nov., slightly twisted, forming a continuously curved dorsal-left surface in *P. przewalskyi*; (3) right paramere more bent forming an acute angle near 90°, versus 100–105° in *P. przewalskyi*; (4) endophallus with rl projected to the apex of endophallus and lal present, in *P. przewalskyi* rl not or slightly projected to the base of endophallus and lal absent.

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Synopsis of fruit-piercing moths of the genus *Eudocima* (Lepidoptera, Erebidae) from Colombia

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Abstract

In order to provide information about the diversity and distribution of *Eudocima* species in Colombia, 261 specimens deposited in entomological collections were examined and identified. We found seven of the eight species of *Eudocima* recorded in the Neotropics: *E. anguina*, *E. colubra*, *E. collusoria*, *E. memorans* and *E. serpentifera*, all being recorded for the first time from the country. We provide a list of the species, comments on the biology and distribution data, illustrations of the adults, and keys for species identification.

Keywords

Biodiversity, distribution, El Niño-Southern Oscillation (ENSO), entomological collections, fruit pest, taxonomy

Introduction

The fruit-piercing moth genus *Eudocima* Billberg, 1820 (Erebidae, Calpinae) encompasses approximately 50 species distributed throughout tropical and subtropical re-

gions of the world (Zaspel and Branham 2008, Zilli et al. 2017), with eight species occurring in the Neotropics (Zilli and Hogenes 2002). They are generally large-sized and with variably colored patterns, mainly cryptic on the forewings and with bright yellow-orange hindwings, and at least in the Neotropics the species always bear dark spots or bands on the hindwings. Historically, neotropical species of *Eudocima* have been placed in several genera according to differences in their habitus, e.g., *Elygea* Billberg, 1820, *Othreis* Hübner, [1823], *Trissophaes* Hübner, [1823] and *Ophideres* Boisduval, 1832, all now subsumed under *Eudocima*. Like other genera of the subfamily Calpinae, they possess sclerotized and apically sharpened proboscis with tearing hooks, with which they pierce fruits to feed on their juices. Accordingly, unlike other groups of agriculturally important Lepidoptera, it is the adults that damage crops, which in this case takes place due to rotting agents such as fungi and bacteria that penetrate the holes that they leave onto the fruit skin.

In Asian countries and islands of the Pacific, fruit-piercing *Eudocima* are frequently reported as damaging crops, while in the Americas they are only sporadically mentioned as pests (Hernández-Ruiz et al. 2017, Montes et al. 2018), and information about this group is generally scarce.

In Colombia, *E. apta* (Walker, [1858]) and *E. procus* (Cramer, 1777), two species widely distributed in the Neotropics, were recently reported as occasional citrus pests (Montes et al. 2018), but the diversity and distribution of this genus in the country are unknown. Vouchers in biological collections can provide important information about the spatial and temporal distribution of species. In Colombia, many universities and research centers are maintaining biological collections where specimens from monitoring programs and ecological sampling are regularly being deposited. It was therefore expected that these colorful large moths would be well represented in such collections.

The aim of this work is to report information on *Eudocima* from specimen data preserved in collections and produce a checklist and an identification key to species occurring in Colombia. Additionally, we provide information about the environmental variables determining species distribution. This information will facilitate a baseline for planning ecological studies and taking phytosanitary actions in case of the detection of pest species in fruit orchards. Furthermore, the checklist could assist with the resolution of environmental factors determining presence of these moths in cultivations and enable the development of models to forecast their occurrence in agroecosystems.

Material and methods

The checklist presented here collates literature records for Colombia based on Walker ([1858]) and Montes et al. (2018) with specimen data drawn from the following entomological collections:

CEUA Colección de Entomología de la Universidad de Antioquia, Medellín, Colombia

CTNI	Colección Taxonómica Nacional de Insectos “Luis María Murillo” – Agrosavia, Mosquera, Colombia
HNSA	Haus der Natur, Salzburg, Austria
ICN-MHN	Instituto de Ciencias Naturales-Colección de Zoología, Universidad Nacional, Bogotá, Colombia
JFLC	Colección Privada LeCrom, Bogotá, Colombia
MEFLG	Museo Entomológico Francisco Luis Gallego, Universidad Nacional de Colombia, Medellín, Colombia
MHN-UIS	Museo de Historia Natural, Universidad Industrial de Santander, Bucaramanga, Colombia
MLS	Museo de La Salle, Bogotá, Colombia
MPUJ_ENT	Museo Javeriano de Historia Natural, Pontificia Universidad Javeriana, Bogotá, Colombia
MUSENUV	Colección entomológica Universidad del Valle, Cali, Colombia
NHMUK	Natural History Museum, London, UK (historically BMNH, British Museum Natural History)
UNAB	Museo Entomológico Facultad de Agronomía, Universidad Nacional de Colombia, Bogotá, Colombia

For taxonomic identification the original descriptions and the checklist of Zilli and Hogenes (2002) were used as a first guide, subject to comparisons with materials in NHMUK. The generic classification follows Zaspel and Branham (2008).

Relevant information was retrieved wherever possible from specimen labels in order to arrange distribution maps with occurrence data and assess biological and ecological traits of species. The occurrence maps were constructed using ArcMap 10.2 (Esri) and a digital elevation model of the Shuttle Radar Topography Mission, which has a resolution of 250 m (Jarvis et al. 2008).

Specimens were photographed in both dorsal and ventral views with a Camera Canon SX50 HS. The photographs were edited using Adobe Photoshop version 20.0.

Results

A total of 261 fruit-piercing moths of the genus *Eudocima* were studied in this work. They represent seven species. Of these, *E. anguina* (Schaus, 1911), *E. collusoria* (Cramer, 1777), *E. colubra* (Schaus, 1911), *E. memorans* (Walker, [1858]) and *E. serpentifera* (Walker, [1858]) are recorded for the first time from Colombia. The records originate from 15 departments, mostly from the Andean region of the country (Fig. 1).

Key to species of *Eudocima* recorded in Colombia

- 1 Hindwing without marginal band and with two sinuous bands beyond basal dark area *E. procus*
- Hindwing with a black marginal band 2

2	Hindwing with a discal circular spot.....	<i>E. apta</i>
–	Hindwing with a discal band.....	3
3	Discal band of hindwing straight and short.....	<i>E. anguina</i>
–	Discal band of hindwing lobed into an “m”-shape.....	4
4	Discal band of hindwing ending well before wing margin.....	<i>E. serpentifera</i>
–	Discal band of hindwing reaching wing margin.....	5
5	Discal band of hindwing with inner margin nearly straight.....	<i>E. collusoria</i>
–	Discal band of hindwing with inner margin distinctly concave.....	6
6	Forewing crossed by pale transverse lines, postmedial split into more waves before slightly rounded apex.....	<i>E. memorans</i>
–	Forewing crossed by dark transverse lines, postmedial distinct from fairly acute apex.....	<i>E. colubra</i>

Annotated list of Colombian *Eudocima*

Eudocima anguina (Schaus, 1911) (*Trissophaes*)

Fig. 2A, B

Material examined. COLOMBIA. **Cundinamarca:** 1♂; San Francisco; vda. Arrayán, Finca Buena vista; 4.9333, -74.2833; 1520 m; 20 Jul. 2014; L. Tarazona leg.; light trap; UNAB.

Comments. This species is characterized by a short discal band on the hindwings. Schaus (1911) discusses the possibility that *Eudocima anguina* and *Eudocima collusoria* are conspecific, which would make *Trissophaes anguina* Schaus, 1911 a synonym of *Phalaena (Noctua) collusoria* Cramer, 1777; however, Zilli and Hogenes (2002) retained both as valid species. The hostplant and life cycle are unknown.

Distribution. Costa Rica (Schaus 1911) and Colombia.

Remarks. This species is herewith recorded for the first time from Colombia, in the locality of San Francisco, Cundinamarca.

Eudocima apta (Walker, [1858]) (*Ophideres*)

Fig. 2C–F

Material examined. COLOMBIA. **Antioquia:** 1♀; Medellín; 6.2518, -75.5636; Oct. 1993; N. Monsalve leg.; MFLG 46650. 1♂; same locality; Aug. 1967; R. Velez leg.; MFLG 46651. 1♂; Yarumal; vda. Corcovado, Alto de Ventanas; 7.0743, -75.4436; 2020 m; 22–26 Jun. 2015; ICN. **Boyacá:** 1♀; Cerinza; Parque principal; 5.9632, -72.9626; 2750 m; 31 Oct. 2014; E. Corredor leg.; UNAB. **Cauca:** 2♂♂, 1♀; Belalcazar [Páez]; PNN Nevado del Huila, Termales, Ins. Pol. Irlanda; 2.6547, -75.9928; 2800 m; 2 Sep. 1980; C. Bohórquez leg.; light trap; ICN-80 1783, 1783, 1784. **Cundinamarca:** 1♀; Anapoima; Andalucía; 4.5489, -74.5352; 700 m; 14 Sep. 2009; M. Galindo leg.; entomological net; UNAB. 1♂; same locality; 670 m; 1 Nov. 2008; D. Ramirez leg.; entomological net; UNAB. 1♀; Bogotá;

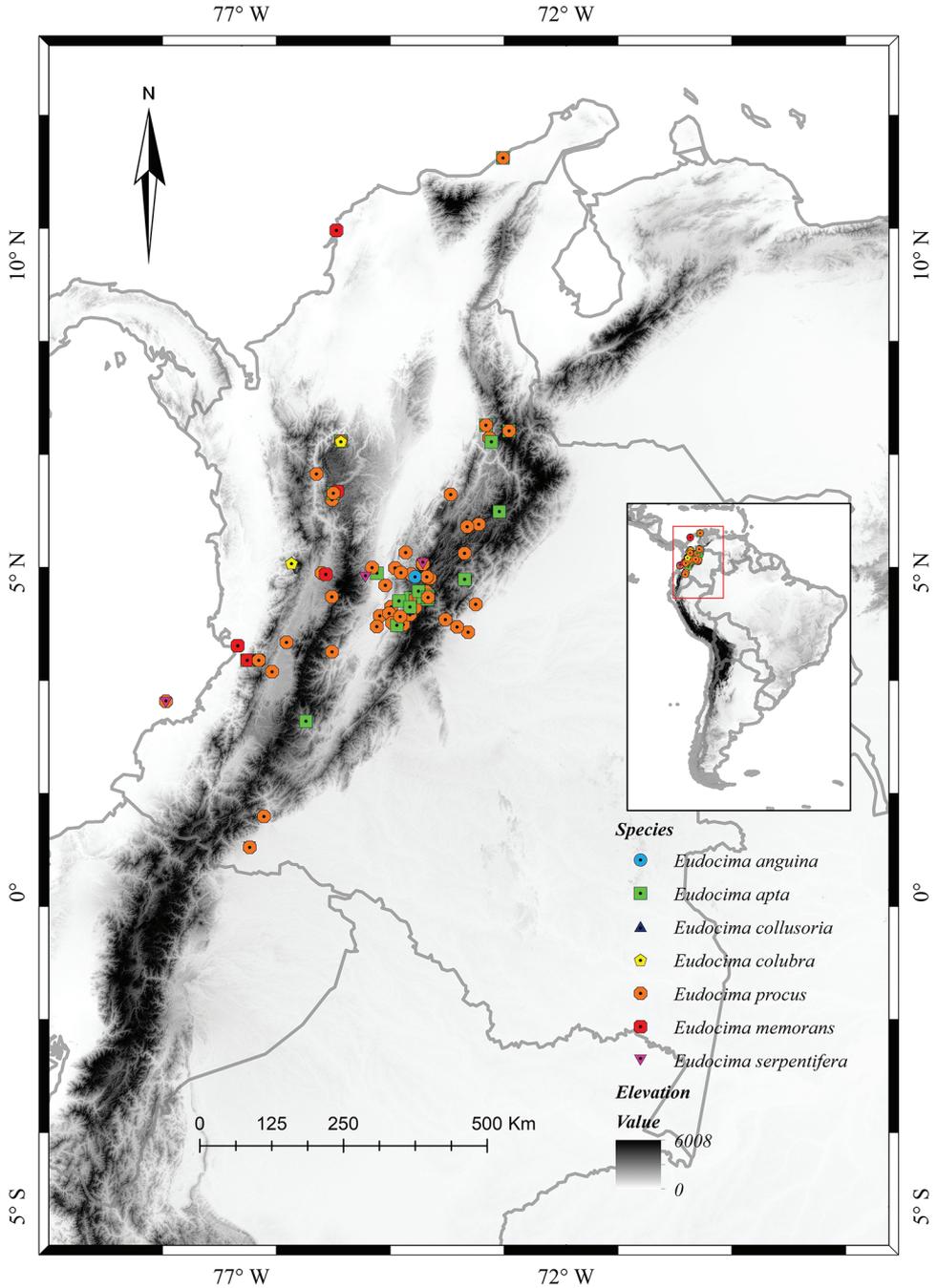


Figure 1. Distribution of *Eudocima* fruit-piercing moths in Colombia.

Barrio Quinta Ramos; 4.5775, -74.0923; 2555 m; 5 Nov. 2015; J. Rincon leg.; hand collecting; UNAB. 1♂, 1♀; Bogotá; Chapinero; 4.6097, -74.0818; 1 Nov. 1963–1 Feb. 1964; S. Restrepo leg.; MPUJ_ENT 0019402, 0019395. 1♀; Bogotá;

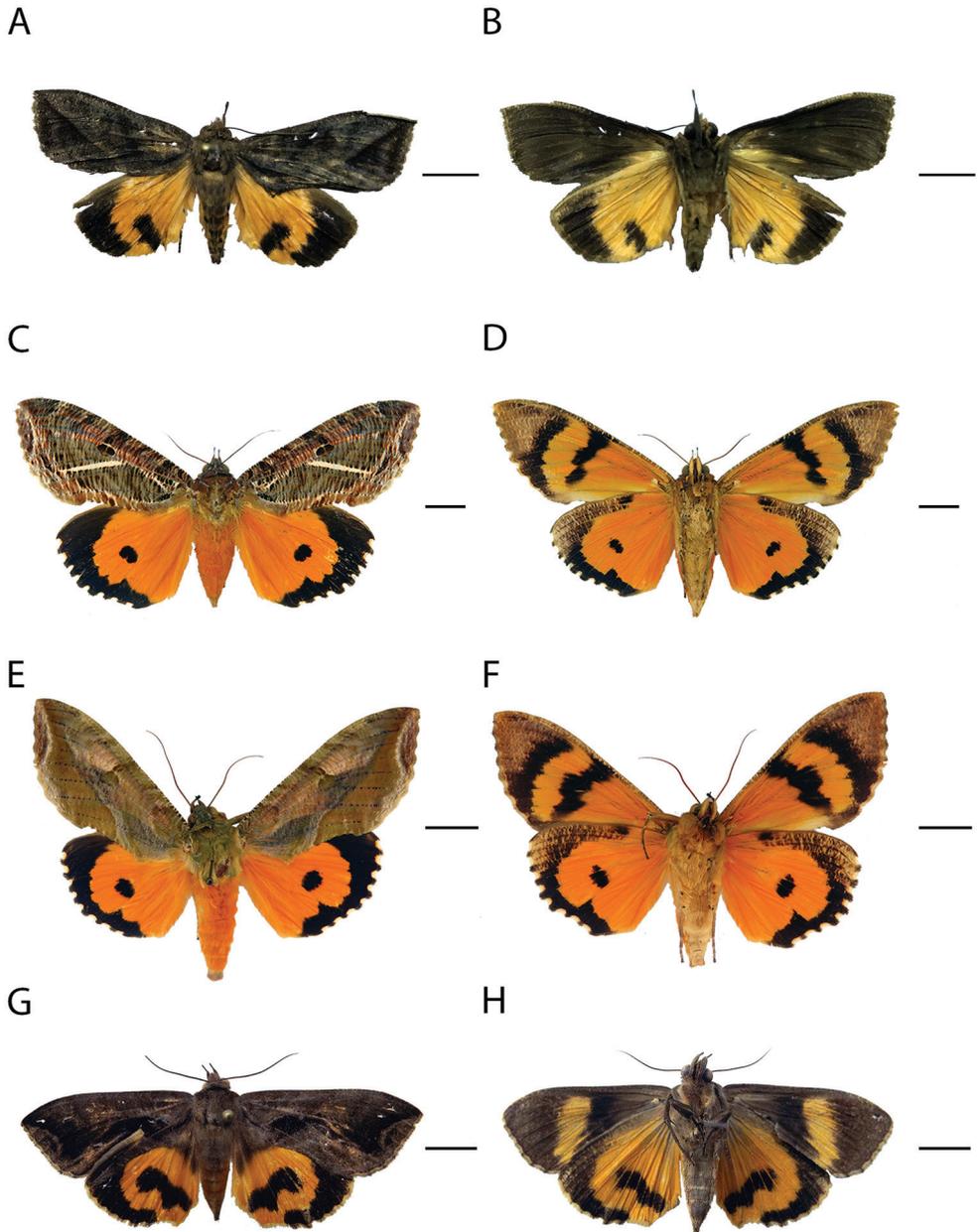


Figure 2. Species of *Eudocima* fruit-piercing moths in Colombia. **A, B** Dorsal and ventral view of *E. anguina* male **C, D** same for *E. apta* female **E, F** same for *E. apta* male **G, H** same for *E. collusoria* female. Scale bars: 1 cm.

Las Villas; 4.6097, -74.0818; 2630 m; 1 Mar. 1985; O. Ricardo leg.; MPUJ_ENT 0019406. 1♂; same locality; 8 Mar. 1985; V. Leonardo leg.; MPUJ_ENT 0019409. 1♂, 1♀; same locality; 17 Mar. 1986–17 Jun. 1988; JFLC. 1♂, 3♀♀;

same locality; NHMUK. 1♂; Bogotá; U. La Salle; 4.6097, -74.0818; 17 Jun. 1977; J. Restrepo leg.; MLS 4684. 1♀; Bogotá; Univ. Nal. Col.; 4.6333, -74.0833; 2562 m; 18 Nov. 2014; Hernández leg.; hand collecting; UNAB. 1♂; same locality; 21 Apr. 2016; V. Ramirez leg.; UNAB. 1♂; same locality; 1 Nov. 2012; F. Ariza leg.; hand collecting; UNAB. 1♂; same locality; 12 Oct. 2016; Jaramillo leg.; entomological net; UNAB. 1♂; same locality; 10 Nov. 2015; L. Lemus leg.; hand collecting; UNAB. 1♂; same locality; 8 Mar. 2012; C. Peña leg.; entomological net; UNAB. 1♀; same locality; 2 Sep. 2014; A. Gamba leg.; hand collecting; UNAB. 1♀; same locality; 10 May 2012; C. Pinilla leg.; hand collecting; UNAB. 1♀; same locality; 12 Nov. 2015; A. Arevalo leg.; hand collecting; UNAB. 1♀; Bogotá; Timiza; 4.6088, -74.1554; 2600 m; 8 Jul. 2015; P. Osorio leg.; CTNI 183. 1♂; Gachalá; vda. Tunja; 4.8924, -73.5066; 1500 m; 1–3 Sep. 2015; ICN. 1♂; Mosquera; 4.7059, -74.2302; 28 Aug. 1979; N. Ruiz leg.; light trap; CTNI 222. 1♀; San Antonio del Tequendama, Santandercito; 4.6, -74.35; 1 May 1960; MPUJ_ENT 0019397. 1♂; Sylvania; 4.4538, -74.3642; 140 m; 19 Nov. 2015; C. Hernández leg.; light trap; UNAB. 2♂♂, 1♀; Soacha, Km. 8, vía-Mosquera; RN Chicaque, Quebrada el Carmen; 4.5921, -74.2763; 2 Ago. 2016.; D. Cualla leg.; MPUJ_ENT 0048742, 0048765, 0048766. **La Guajira:** 1♂; 11.544, -72.9072; ICN. **Norte de Santander:** 2♀♀; Santo Domingo de Silos; Páramo de Berlin; 7.2378, -72.8103; 3171 m; 2 Jul. 2016; J. Montes leg.; hand collecting; MFLG. 1♂; same data; CTNI. **Santander:** 1♀; Floridablanca; 7.0622, -73.0864; 1 Sep. 1980; W. Olarte leg.; MHN-UIS. 1♂, 2♀♀; Rionegro; vda. La Paz, Finca La Esperanza; 7.3247, -73.1751; 1105 m; 5 Jul. 2016; J. Montes leg.; on *Citrus* sp. crop, hand collecting; CTNI. **Tolima:** 1♀; Armero; Hacienda El Dormilón; 4.9887, -74.8813; 180 m; 1 Oct. 2000; G. Fagua leg.; Malaise trap; MPUJ_ENT 0045647. 1♀; Melgar; vda. Aguila Media, Finca Santa Lucia; 4.1667, -74.5667; 1163 m; 4 Mar. 2012; J. Restrepo leg.; hand collecting; UNAB. **Valle del Cauca:** 1♀; Anchicayá; 3.6186, -76.9133; 400 m; 28 Aug. 1967; MUSENUV 14837. 1♀; same locality; 16 Jul. 1977; MUSENUV 14836. Without specific locality: 1♂; MLS 8386. 1♂; MPUJ_ENT 0019412.

Comments. This species is easily distinguished from the other neotropical members of the genus by its circular black discal spot on the hindwings. Janzen and Hallwachs (2009) recorded larvae of *E. apta* as feeding on *Disciphania heterophylla* Barneby and *Cissampelos pareira* L. (Menispermaceae), whereas Van Bael et al. (2004) recorded in Panama *Odontocarya tamoides* Miers (misspelled as *O. lamnoides*), also Menispermaceae, as a host plant. In Colombia, *C. pareira* has a wide distribution, however *O. tamoides* is restricted to the lowlands of the Caribbean Plain, the Pacific region and the Magdalena Valley (Bernal et al. 2019). Adults of *E. apta* have been reported to affect several crops: *Citrus sinensis* [L.] Osbeck (Rutaceae) and genus *Vitis* (Vitaceae) in Cuba and Dominican Republic (Robinson et al. 2010); *Carica papaya* L. (Caricaceae) in Mexico (Hernández-Ruiz et al. 2017). Recently, it was recorded from citrus crops in Colombia (Montes et al. 2018). It has been collected using light traps (Brou 1994, Janzen and Hallwachs 2009).

Distribution. Widespread in the New World, from southern United States and the Caribbean to Brazil, the South Atlantic Islands and north of Chile (Angulo and Jana-Sáenz 1983; Brou 1994, Zilli and Hogenes 2002, Brou and Núñez 2013). Powell and Brown (1990) recorded *E. apta* up to an elevation of 3900 m. In Colombia, it has been recorded in several localities within the eastern cordillera and eastern slope of the central cordillera in a wide elevational range.

Remarks. Traditionally it has been incorrectly identified as *Eudocima materna* (Linnaeus, 1767) (e.g., Costa Lima 1950: fig. 158). However, *E. materna* is distributed in the Old World. Zilli and Hogenes (2002) provided a rationale for considering *E. apta* as a valid species and not a synonym of *E. materna*.

***Eudocima collusoria* (Cramer, 1777) (*Phalaena* (*Noctua*))**

Fig. 2G, H

Material examined. COLOMBIA. **Cundinamarca:** 1♀; Sylvania; Km. 31 Bogotá-Sylvania; 4.4212, -74.3888; 1386 m; 8 May 2016; K. Medina leg.; entomological net; UNAB.

Comments. The “m”-shaped band in the hindwings resembles those of *E. memorans* and *E. colubra*, but it differs in having the inner margin straighter. The forewings do not have pale transverse bands as in *E. memorans*. Lalanne-Cassou and Silvain (2003) report this species in primary forest of French Guiana. The hostplant and life cycle are unknown. See also comments under *E. anguina*.

Distribution. Neotropical (Zilli and Hogenes 2002): Surinam (Cramer 1777), French Guiana (Lalanne-Cassou and Silvain 2003) and Colombia.

Remarks. One male specimen was examined from Cundinamarca. It is recorded for the first time from Colombia.

***Eudocima colubra* (Schaus, 1911) (*Trissophaes*)**

Fig. 3A–C

Material examined. COLOMBIA. **Antioquia:** 1♀; Medellín; 6.2518, -75.5636; May 1984; F. Serna leg.; On a wall; MFLG 46641. 1♀; Yarumal; vda. Corcovado, Alto de Ventanas; 7.0743, -75.4436; 2020 m; 22–26 Jun. 2015; ICN. **Chocó:** 1♂; Río Tamaaná, El Tigre; 5.15, -76.2166; 97 m; 09 Feb.; G.M. Palmer leg.; NHMUK.

Comments. Marked sexual dimorphism in the coloration of forewings. The species has a sinuous band on the posterior wings in the form of an “m”, similar to those of *E. memorans* and *E. collusoria*. Janzen and Hallwachs (2009) record larvae of *E. colubra* as feeding on *Disciphania calocarpa* Standl. (Menispermaceae) in Costa Rica.

Distribution. Costa Rica, Peru (Schaus 1911) and Colombia.

Remarks. Three specimens were examined from the departments of Antioquia and Chocó. It is recorded from Colombia for the first time.

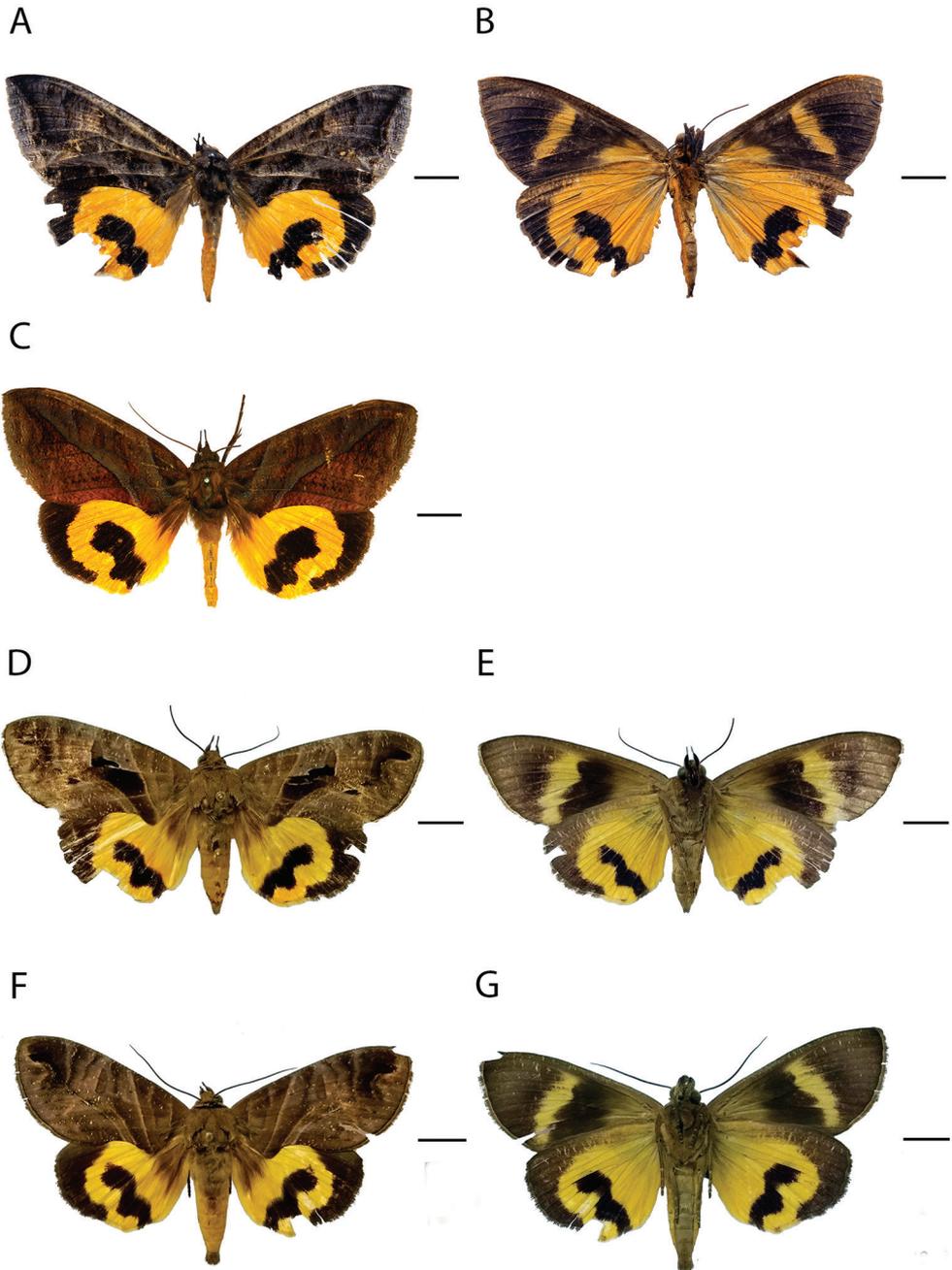


Figure 3. Species of *Eudocima* fruit-piercing moths in Colombia. **A, B** Dorsal and ventral view of *E. colubra* female **C** dorsal for *E. colubra* male **D, E** same for *E. memorans* female **F, G** same for *E. memorans* male. Scale bars: 1 cm.

***Eudocima memorans* (Walker, [1858]) (*Ophideres*)**

Fig. 3D–G

Material examined. COLOMBIA. **Antioquia:** 1♂; Valle de Aburrá; 6.2833, -75.5; May 1953; F. Gallego leg.; MFLG 46653. **Bolivar:** 1♀; Cartagena; 10.3997, -75.5144; L. Cortes leg.; MHN-UIS. **Caldas:** 1♂; Chinchiná; 4.9728, -75.6819; Oct. 1955; F. Gallego leg.; On a road; MFLG 46652. **Cundinamarca:** 1♀; Bogotá; 4.6097, -74.0818; 1 Feb. 1962; MPUJ_ENT 0019396. 2♂♂, 1♀; Pacho; Plaza de Toros; 5.1361, -74.1602; 1740; 7 Jan. 1992, 26 Mar. 1992; G. Patrick leg.; HNSA. **Valle del Cauca:** 1♂, 1♀; Anchicayá; 3.6186, -76.9133; 400 m; 17 Jun. 1977–10 Sep. 1977; Dahners leg.; MUSENUV 14841, 14849. 1♀; R[io] Dagua; 3.8455, -77.0609; W. Rosenberg leg.; NHMUK. 1♂, 1♀; [Valle del] Cauca, Juntas [Río Dagua]; 3.6164, -76.73222; 1897–1898; M. de Mathan leg.; NHMUK.

Comments. The hindwings show an “m”-shaped band with a distinctly sinuous inner margin. Unlike *E. serpentina*, this band reaches the wing margin. Forewing with oblique pale bands. Hostplant and life cycle unknown.

Distribution. Neotropical (Zilli and Hogenes 2002). Described from “the western coast of the Americas” (Walker, [1858]), Brou (2006) suggested that the original specimens probably originated from Ecuador.

Remarks. This species is recorded for the first time from Colombia.

***Eudocima procus* (Cramer, 1777) (*Phalaena* (*Noctua*))**

Fig. 4A–D

Ophideres columbina Guenée, 1852*Ophideres scabellum* Guenée, 1852*Acacallis procax*; Hübner, [1823] [misspelling]

Material examined. COLOMBIA. **Antioquia:** 1♂; Medellín; 6.2518, -75.5636; Apr. 1989; F. Cuartas leg.; entomological net; CEUA. 1♀; same locality; 26 Apr. 1969; F. Mosquera leg.; CTNI 99. 1♂; Medellín; 6.2518, -75.5636; 28 Jun. 1938; J. Gates-Clarke leg.; MFLG. 1♂; same locality; Sep. 1958; F. Gallego leg.; entomological net; MFLG 46647. 1♂; same locality; Oct. 1976; R. Velez leg.; on a door; MFLG 46646. 1♂; same locality; May 1946; F. Gallego leg.; On a wall; MFLG 46645. 1♂; same locality; 1538 m; 28 Mar. 1998; S. Blandon leg.; On a wall; MFLG 46649. 1♂; Sabaneta; Barrio La Doctora; 6.15, -75.5833; 1570 m; May 2005; entomological net; CEUA. 2♀♀; Santa Fe de Antioquia; 6.5569, -75.8281; Nov. 1981; M. Monzón leg.; On Papaya; MFLG 46642, 46643. 1♂; Valle de Aburrá; 6.2833, -75.5; Oct. 1943; F. Gallego leg.; MFLG. 1♂; Valle de Aburrá; 6.2833, -75.5; Feg. 1946; F. Gallego leg.; undergrowth; MFLG 46648. 2♀♀; Yarumal; vda. Corcovado, Alto de Ventanas; 7.0743, -75.4436; 2020 m; 22–26 Jun. 2015; ICN. **Boyacá:** 3♂♂; Arcabuco; vda. Peñas Blancas; 5.723, -73.4678; 2674 m; 17–19 Sep. 2017; ICN. 1♂; Sotaquirá; 5.7618, -73.2859; 9 Aug.

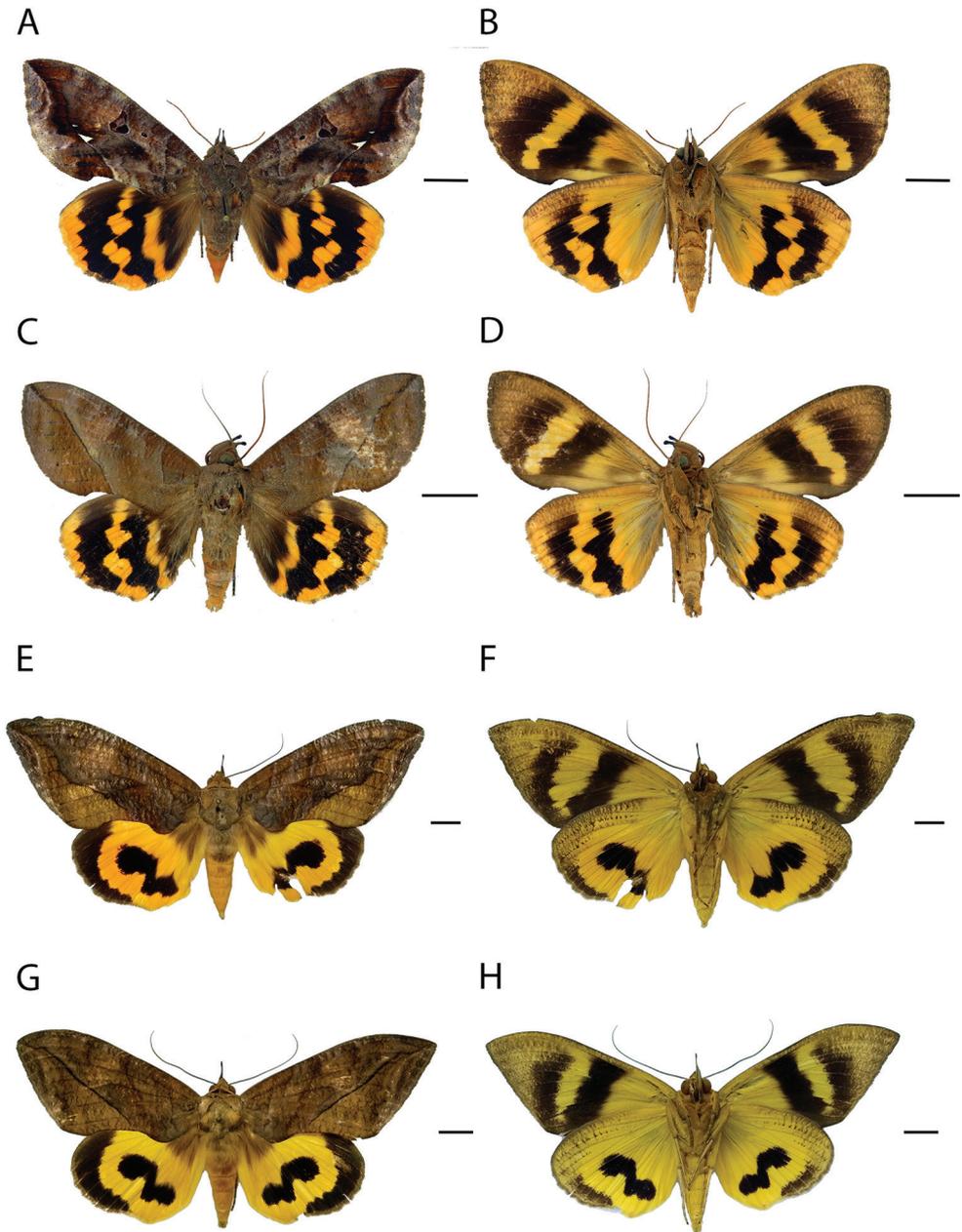


Figure 4. Species of fruit-piercing moths *Eudocima* in Colombia. **A, B** Dorsal and ventral view of *E. procus* female **C, D** same for *E. procus* male **E, F** Dorsal and ventral view of *E. serpentifera* female **G, H** same for *E. serpentifera* male. Scale bar: 1 cm.

1969; J. Alba leg.; UNAB. 1♂; Turmequé; Villa Nely; 5.3062, -73.5088; 2800 m; 27 Apr. 2003; S. Angel leg.; entomological net; UNAB. **Caldas:** 1♀; Florida; 4.9931, -75.7439; Sep. 1963; F. Gallego leg.; On a wall; MFLG 46644. **Cauca:** 1♂; Guapi;

PNN. Gorgona-Poblado; 2.9683, -78.1844; 10 m; 19–22 Oct. 2010; H. Calero leg.; MUSENUV B16. **Cundinamarca**: 1♂; Agua de Dios; 4.3584, -74.69; 1 Jun. 1997; J. Gutierrez leg.; UNAB. 1♀; Beltrán; vda. La Esperanza; 4.8, -74.75; 250 m; 28 Apr. 2012; H. Rojas leg.; hand collecting; UNAB. 1♂; Bogotá; 4.6097, -74.0818; 17 May 1985; J. Cañon leg.; MLS 6677. 1♀; same locality; 18 Jun. 1905; R. Becerra leg.; MLS 8507. 1♂; same locality; 2 Oct. 1970; W. Prieto leg.; MLS 4683. 1♂; same locality; 17 Jul. 1961; J. Berecibar leg.; MPUJ_ENT 0045656. 4♂♂, 4♀♀; Bogotá; Chapinero; 4.6097, -74.0818; 30 Apr. 1962–12 Jun. 1962; E. Carvajalino leg.; MPUJ_ENT 0019404, 0019393, 0019408, 0019403, 0019401, 0045655, 0045657, 0045658. 1♂, 1♀; same locality; 14–17 Apr. 2016; D. Cualla leg.; MPUJ_ENT 0045648, 0045652. 1♂; same locality; Oct. 1972; MPUJ_ENT 0045653. 1♀; same locality; 4.6097, -74.0818; 25 Jul. 2004; D. Corredor leg.; MPUJ_ENT 0019400. 1♂; same locality; 26 Jul. 1949; B. Diez leg.; MPUJ_ENT 0019405. 1♂; same locality; 13 Jun 1965; Amézquita leg.; CTNI 99. 1♀; same locality; 19 Apr. 1977; I. Zenner leg.; CTNI 99. 1♀; same locality; Oct. 1946; CTNI 99. 1♂; same locality; 25 Mar. 1947; CTNI 99. 1♂; same locality; 1 Oct. 1945; CTNI 100. 1♀; same locality; 11 Jun 1986; JFLC. 1♂; same locality; 1 Jul. 1996; J. F. Le Crom leg.; JFLC. 1♀; same locality; Birchall leg.; NHMUK. 1♀; same locality; 1918.; M. Apolinar leg.; NHMUK. 22♂♂, 5♀♀; same locality; NHMUK. 1♀; same locality; 1 Jul. 1967; UNAB. 1♂; same locality; Jul. 1969; UNAB. 1♂; same locality; 8 May 1934; H. Pinzon leg.; UNAB. 1♂; same locality; 20 Nov. 1981; C. Orjuela and E. Mejia legs.; UNAB. 1♂; same locality; 9 May 1993; A. Diego leg.; UNAB. 1♀; same locality; 15 Apr. 1994; A. Tovar leg.; UNAB. 1♀; same locality; 22 Apr. 1984; C. Torres and F. Bernal legs.; UNAB. 1♂; same locality; May 1998; O. Castellanos leg.; UNAB. 1♂; same locality; 6 Mar. 1972; E. Gonzalez leg.; UNAB. 1♀; same locality; 20 Sep. 1975; E. Vargas leg.; UNAB. 1♀; same locality; 10 Apr. 1998; M. Arcos leg.; UNAB. 1♀; same locality; 20 Apr. 1975; A. Alarcon leg.; UNAB. 1♂; same locality; 9 Apr. 1995; L. Palacios leg.; UNAB. 1♂; same locality; 23 Apr. 1975; P. Acevedo leg.; UNAB. 1♂; Bogotá; Engativá; 4.7011, -74.1132; A. Casas leg.; UNAB. 1♂; Bogotá; Univ. Nal. Col.; 4.6333, -74.0833; 2600 m; 1 Feb. 2010; R. Forero leg.; hand collecting; UNAB. 1♂, 1♀; same locality; 8–10 Mar. 2014; A. Gamboa and J. Velásquez legs.; UNAB. 1♂; Cajicá; 4.9128, -74.0526; 17 Jun. 1975; A. Acosta leg.; hand collecting; UNAB. 1♂; same locality; 19 Sep. 1981; J. Rojas leg.; UNAB. 1♂; Fusagasugá; 4.3365, -74.3638; 27 Mar. 1972; L. Espinosa leg.; UNAB. 2♂♂; Gachalá; vda. Tunja; 4.8924, -73.5066; 1500 m; 1–3 Sep. 2015; ICN. 1♂; Girardot; 4.318, -74.835; 23 Nov. 1994.; S. Pulgarin leg.; UNAB. 1♂; Guaduas; Puerto Bogotá, Finca Altavista; 5.0743, -74.5985; MPUJ_ENT 0019410. 1♂; La Palma; 5.3173, -74.43; 14 Jun. 1978; I. Zenner leg.; On *Pinus* sp.; CTNI 99. 1♂; La Vega; 4.9738, -74.3448; 27 May 1969; A. Perez leg.; UNAB. 1♀; same locality; 1969; A. Perez leg.; UNAB. 1♂; same locality; 21. Mar. 1994.; H. Ramirez leg.; UNAB. 2♂♂; Medina; 4.5, -73.3333; 500 m; A. H. Fassl leg.; NHNUK. 1♀; Mosquera; 4.7059, -74.2302; 20 Apr. 1979; I. Zenner leg.; light trap; CTNI 99. 6♂♂, 12♀♀; Pacho; Plaza de Toros; 5.1361, -74.1602; 1740; 12 Jan.-5 Apr. 1992; G. Patrick leg.; HNSA. 1♂; Pandi; 4.1803, -74.471; 12 Nov. 1995; T. Corredor leg.; UNAB. 1♂;

Sibaté; 4.4491, -74.2829; 10 Feb. 1990; I. Posada leg.; UNAB. 2♂♂; Soacha; 4.5794, -74.2168; 19 Mar. 1994, 21 Apr. 1969; UNAB. 2♂♂, 2♀♀; Soacha, Km. 8, vía-Mosquera; RN Chicaque, Quebrada el Carmen; 4.5921, -74.2763; 1 Ago. 2016.; D. Cualla leg.; MPUJ_ENT 0048768–0048771. 1♂; Tabio; 4.9351, -74.1021; Mar. 1986; D. Avellaneda leg.; UNAB. 1♂; Tibacuy; Cerro Quinini; 4.3058, -74.5164; Jun 1998; J. F. Le Crom leg.; JFLC. 1♀; Tocaima; 4.4607, -74.6572; 6 Nov. 1993; A. Guerrero leg.; UNAB. 1♂; Villeta; 5.0001, -74.505; 28 Jun 1965; E. Olivos leg.; CTNI 99. 1♀; same locality; 5 Jan. 1982; Bohórquez leg.; UNAB. **La Guajira**: 1♀; 11.544, -72.9072; ICN. **Meta**: 1♂; Villavicencio; 4.142, -73.6266; M. Apolinar leg.; NHMUK. 1♂; same locality; 10 Dic. 1981; G. Rodríguez leg.; UNAB. 1♀; same locality; 4.06, -73.4522; 5 Jun. 2015; O. Vargas leg.; UNAB. 1♂; Ober Río Negro; 4.2602, -73.8105; 800 m; A. H. Fassl leg.; NHMUK. **Norte de Santander**: 2♂♂; Santo Domingo de Silos; Páramo de Berlin; 7.2378, -72.8103; 3171 m; 2 Jul. 2016; J. Montes leg.; hand collecting; MFLG. 1♀; same data; CTNI. **Putumayo**: 2♂♂, 3♀♀; Mocoa; 1.1528, -76.6521; 26 Feb. 1972; MPUJ_ENT 0019398, 0045649–0045651, 0045654. 1♂, 1♀; Orito; 0.6675, -76.873; 26 Feb. 1972; MPUJ_ENT 0045645, 0019399. **Quindío**: 1♀; Río “Nauarco” [Río Navarco]; 4.62, -75.5881; NHMUK. **Santander**: 1♂; Bucaramanga; 7.1253, -73.1197; 1 Aug. 1979; W. Olarte leg.; MHN-UIS. 1♂; same locality; 1 Aug. 1978; W. Olarte leg.; MHN-UIS. 1♀; same locality; 15 May 1998; M. Estupiñán leg.; MHN-UIS. 2♂♂, 1♀; Rionegro; vda. La Paz. Finca La Esperanza; 7.3247, -73.1751; 1105 m; 5 Jul. 2016; J. Montes leg.; on *Citrus* sp. crop, hand collecting; CTNI. 1♀; Vélez; 6.2327, -73.7258; Jul. 1998; E. Espitia leg.; CTNI 99. **Tolima**: 1♂; Chaparral; 3.75, -75.5833; 3 Jul. 1969; J. Bedoya and H. Ruiz legs.; UNAB. 1♂; Espinal; 4.1492, -74.8843; 10 May 1969; Rojas leg.; UNAB. 1♀; Falan; 5.0795, -74.957; 18 Mar. 1990; O. Ferrer leg.; UNAB. 1♂; Melgar; 4.2048, -74.6408; 22 Sep. 1970; Salazar leg.; MLS 4677. 1♂; same locality; 3 May 1969; C. Forero leg.; UNAB. 1♀; same locality; 2 May 1993; S. Avendaño leg.; UNAB. **Valle del Cauca**: 3♂♂, 2♀♀; Anchicayá; 3.6186, -76.9133; 1000 m; 12 May 1975–28 Aug. 1976; MUSENUV 14831–14835. 1♂; Buga; Perímetro urbano; 3.9008, -76.2978; Nov. 1977; R. Torres leg.; MUSENUV 14842. 1♂; Cali; 3.4372, -76.5225; 1000 m; 15 Jun. 1975; MUSENUV 14843. 4♀♀; [Valle del] Cauca, Juntas [Río Dagua]; 3.6164, -76.73222; 1897–1898; M. de Mathan leg.; NHMUK. Without specific locality: 2♂♂, 4♀♀; CTNI 99, MLS 1968, 6674, MPUJ_ENT 0019442, 0019443, 0045646.

Comments. It is easily distinguished from the other species of *Eudocima* by having two sinuous bands on the hindwing, in addition to a black basal band, which confer a somewhat checkered appearance. Caballero et al. (1994, as *O. scabellum*) recorded larvae of *E. proculus* from *Odontocarya tamoides* (= *O. paupera*) (Menispermaceae) in Honduras. Adults were recently observed in Colombia in citrus orchards (Montes et al. 2018).

Distribution. Widely distributed, with records from Central America to southern Brazil (Guenée 1852, Druce 1881–1900, Zilli and Hogenes 2002, Zaspel and Branham 2008). In the present work, specimens from several localities, mainly of the eastern and central cordilleras, were found. Widespread in Colombia.

Remarks. Gallego (1946) reported this species (as *Othereis procus*, genus misspelled) to be frequently found in buildings of Medellín during the first half of the twentieth century. This species seems to be adapted to urban ecosystems as it is frequently attracted to city lights or even to boats near the Brazilian coast (Alves et al. 2019).

***Eudocima serpentifera* (Walker, [1858]) (*Ophideres*)**

Fig. 4E–H

Ophideres raphael Dugès, 1896

Material examined. COLOMBIA. **Antioquia:** 1♂, 1♀; Valle de Aburrá; 6.2833, -75.5; Sep. 1945–Sep. 1952; F. Gallego leg.; MFLG 46654, 46656. **Cauca:** 1♂; Guapi; PNN. Gorgona-Playa Blanca; 2.9484, -78.1842; 52 m; 19–22 Oct. 2010; H. Calero leg.; Van Someren-Rydon Trap; MUSENUV. **Cundinamarca:** 1♀; Bogotá; U. La Salle; 4.6097, -74.0818; 3 Dic. 1973; M. Nicéforo leg.; MLS 4672. 1♂; Pacho; Plaza de Toros; 5.1361, -74.1602; 1740; 7 Mar. 1992; G. Patrick leg.; HNSA. **Putumayo:** 1♂; Orito; 0.6675, -76.873; 26 Feb. 1972; MPUJ_ENT 0019407. **Tolima:** 1♂; Libano; 4.9217, -75.0622; Jul. 1956; F. Gallego leg.; MFLG 46655. **Valle del Cauca:** 2♂♂, 1♀; An-chicayá; 3.6186, -76.9133; 28 Nov. 1975– 20 Nov. 1976; MUSENUV 14846–14848.

Comments. This species has a sinuous “m”-shaped band on the hindwings. Unlike other species with similar pattern on the hindwings such as *E. memorans*, *E. collusoria* and *E. colubra*, in *E. serpentifera* the “m”-shaped band does not reach the wing margin. Janzen and Hallwachs (2009) reported *D. calocarpa* (Menispermaceae) as its hostplant. Adults have been found feeding on *C. papaya* (Caricaceae) and *Citrus* in Mexico (Robinson et al. 2010; Hernández-Ruiz et al. 2017). In Mexico, adults are active from April to November and are commonly collected with light traps (Chamé-Vásquez and Jiménez 2009).

Distribution. Widely distributed in Tropical America. Walker ([1858]) describes this species from the Dominican Republic and Brazil. Additionally, there are occasional records of this species from the southern United States (Brou 2006). In Mexico, it occurs in an elevational range between 150 and 3000 m (Chamé-Vásquez and Jiménez 2009).

Remarks. This species is recorded for the first time from Colombia.

Discussion

Spatial and temporal distribution

The collections examined essentially consist of holdings from the Andean region. It is no surprise then that 94% of records are from the Andes, mainly the eastern mountain chain, with 65%, and 35% solely from Bogotá city. The Caribbean and Pacific regions have only three records each, and most of the Amazon region and Orinoquia are not represented in the sample; *Eudocima* moths are known only from three locations in the Amazonian foothills in the departments of Putumayo and Meta.

Based on collection data from the city of Bogotá, the most common location represented in our sample, it is evident that seasonality of these moths is mainly determined by precipitation. Captures appear to be low in December and January, which are the months of lowest rainfall, and sharply increase during March, when the rainy season begins. Both the annual distribution of precipitation and that of moths show a bimodal pattern (Fig. 5). The relationship between moths and precipitation has frequently been reported (e.g., Bhumannavar and Viraktamath 2012), since with the onset of rainfall the sprouting of host plants increases, and oviposition of hundreds of eggs per female is triggered (Cochereau 1977, Magar et al. 2015).

The known geographical distribution of species of *Eudocima* is considerably expanded with our data. For instance, *E. anguina* was only known from Costa Rica, making the present record the first of this species in South America; *E. collusoria* was only known from Suriname and French Guiana; the record of *E. colubra* was predictable as this was known previously from Costa Rica and Peru; and *E. memorans*, described from the western coast of the Americas, was also found in the eastern mountain chain of Colombia and the Caribbean coast.

The wide distribution of *Eudocima* species is related to both their strong flight capacity (Bhumannavar and Viraktamath 2012) and close relationship with plants of the family Menispermaceae (Fay 1996). The larvae of *Eudocima apta* feed on *Cissampelos pareira* and those of *E. procus* have been recorded from *Odontocarya tamoides*. Both plants are widely distributed latitudinally and at elevations from 0 to 2800 m in the Andean, Pacific and Caribbean regions (Parr et al. 2014), overlapping with the distribution of these moths. On the other hand, the known host plant of *E. serpentifera* and *E. colubra*, namely *Disciphania calocarpa*, is mainly found in Central America and has

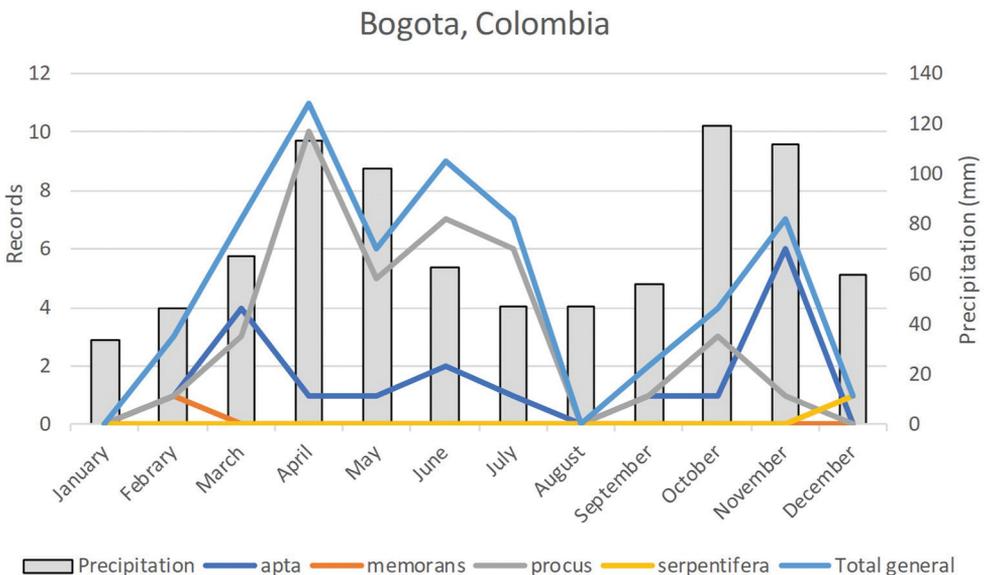


Figure 5. Records of *Eudocima* moths in the city of Bogotá, annual distribution vs precipitation.

only been recorded from Colombia in the humid montane forest of Dagua, Valle del Cauca, on the Pacific coast (Parr et al. 2014).

Perspectives

Research on *Eudocima* moths is intrinsically twofold and may develop along both conservationist and agricultural lines. The larvae of these moths in the Neotropics feed exclusively on wild lianas of the family Menispermaceae (Janzen and Hallwachs 2009). It is expected therefore that breeding populations of these moths are restricted to natural or semi-natural areas with sufficient extent of forest patches, which exposes them to high vulnerability due to the ongoing deforestation. Some species, such as *E. anguina*, *E. collusoria*, *E. colubra* and *E. memorans*, may even be facing a higher risk due to their trophic relationships with just one of few host plants. In fact, these species are already rare in collections.

On the other hand, *Eudocima* moths were recently recorded for the first time as occasional fruit pests in Latin America; *E. apta* and *E. serpentina* on papaya in Mexico (Hernández-Ruiz et al. 2017) and *E. apta* and *E. procius* on citrus in Colombia (Montes et al. 2018). At least in Colombia, damage by these moths was previously unknown by farmers, so many questions now arise about their origin and frequency.

Records of occasional outbreaks of fruit-piercing moths affecting orchards such as those in Colombia and Mexico had already been reported by Cochereau (1977) for New Caledonia in Oceania. Cochereau (1977) observed and monitored changes in *Eudocima phalonia* (Linnaeus, 1763) populations for three years since 1968–1970 and recorded in 1969 that its population increased rapidly with the onset of rains, after a period of drought of several months, and caused damage of more than 90% in citrus production, while the normal rate was around 4% (Cochereau 1973, 1977). The drought event was prompted by the El Niño-Southern Oscillation (ENSO) episode of 1968–1969, which reduced rainfall on the island of New Caledonia (Benoit and Delcroix 2000).

Unusually dry periods such as those recorded by Cochereau (1977) are also known to occur during ENSO events in the Andean region, especially in the eastern mountain range and the Caribbean region of Colombia (Montealegre 2007), where they have the potential to boost populations of fruit-piercing moths. The outbreaks of these moths on citrus orchards recorded from several municipalities in Colombia (Montes et al. 2018) were most likely triggered by the 2014–2016 ENSO event. Van Bael et al. (2004) also reported an outbreak of *E. apta* in Panama on June 1998, which was apparently influenced by the ENSO episode of 1997–1998. In addition, outbreaks of *E. serpentina* have been reported in Honduras during the rainy seasons in 2012 to 2014 and 2016 (Van Dort 2019). Outbreaks of other Lepidoptera taxa in the rainy season following ENSO events have also been recorded in Panama (Van Bael et al. 2004, Srygley et al. 2010, 2014).

During such unusually dry periods several factors may act together and affect the natural control of moths, increasing their populations. In fact, the emergence of parasitoids is known to decrease with increasing temperature and drought (Romo and Tylianakis 2013), and also the rate of parasitoidism was shown to decrease with greater variability in rainfall between years (Stireman et al. 2005). This is likely an outcome of

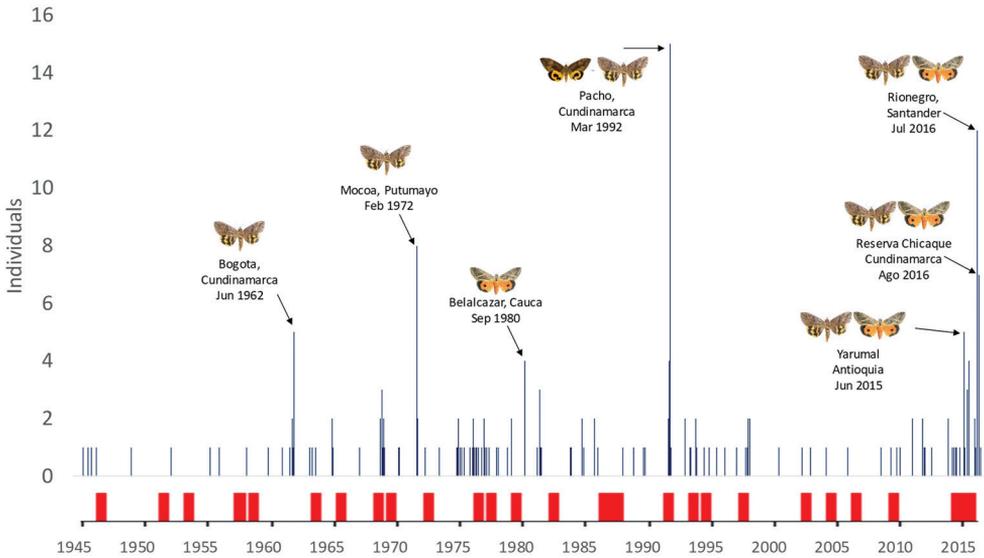


Figure 6. *Eudocima* records found in biological collections in Colombia. Vertical red lines indicate the duration of El Niño-Southern Oscillation ENSO events.

the uncoupling between cycles of hosts and parasitoids, which favors moth outbreaks. Another factor is the unusual sprouting of some plant species after an ENSO event. With the onset of rainfall, the young plant tissue is also of better quality for herbivores, containing a greater amount of leaf nitrogen and lower concentration of secondary defensive compounds such as tannins and phenols (Shure et al. 1998). This allows the development of a greater number of larvae; therefore, the longer the dry season the more luxuriant the vegetation will be, to the advantage of moth populations (Srygley et al. 2010, 2014).

Preliminary evidence therefore suggests a relationship between rainfall following ENSO-related drought and demographic increase of moth populations. That being the case, outbreaks of moth pests such as fruit-piercing *Eudocima* in orchards are expected to become commoner in future reflecting the increased frequency of ENSO events associated with climate change (Timmermann et al. 1999).

Although moth collections do not necessarily match exactly the distribution and abundance of species in the field, in the absence of strongly biasing factors (e.g., a ‘maniac’ collector selectively searching for particular species with exaggerate sampling effort) there is nonetheless an association between the commonness of a species in the field and the number of relevant vouchers deposited in collections. Accordingly, when several specimens of a species with the same locality and date are found, we expect such collection record to somewhat mark a natural population increase. Notably, when our records, which mostly originate from ecological sampling programs, are plotted along a timeline the increase of records matches the end of an ENSO event in most cases (Fig. 6). Remarkably, the high intensity ENSO event between 2014–2016 seems to have markedly increased the number of individuals in collections and outbreaks such as those reported in citrus (Montes et al. 2018).

Collections data provide invaluable information but there are some issues that cannot exclusively be addressed with these. Standardized long-term monitoring and sampling at night at selected sites with light traps, will be necessary to assess population dynamics over more ENSO cycles and to test the association between moth demography and climatic oscillations in the Neotropics. Surveys of host plants of fruit-piercing moths in natural areas will also shed light on several aspects of their biology, such as their life cycle and natural enemies. The importance of this information to preserve *Eudocima* diversity, especially regarding species exclusive of natural habitats, and reducing the damage caused to fruit orchards by pest species is evident.

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Two new *Geranomyia* Haliday (Diptera, Limoniidae) crane flies from Mount Jiulong in China, with an updated key to Chinese species

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Abstract

The genus *Geranomyia* Haliday, 1833 is globally distributed, with 351 known species, of which 26 occur in China. Herein, an overview of the genus *Geranomyia* from Mount Jiulong, Zhejiang, China, is presented. Two new species are described and illustrated. *Geranomyia jiulongensis* **sp. nov.** and *G. subablusa* **sp. nov.** are distinguished from other *Geranomyia* species by the characters of the thorax and male genitalia. An updated key to the *Geranomyia* of China is presented.

Keywords

crane fly, Limoniinae, Limoniini, classification, new species, Zhejiang

Introduction

Geranomyia Haliday, 1833 is a large genus of 351 described species in the family Limoniidae. It is characterized by the following characters: body small or medium-sized (5–9 mm), flagellum with 12 segments, elongate mouthparts, R_{1+2} present, R_2 commonly present, R_4 and R_5 fused to margin, only two branches of Rs present as longitudinal elements (R_3 and R_{4+5}), two branches of M reaching wing margin, and lobe of gonostylus often with two spines (Alexander 1967a; Haliday 1833; Osten Sacken 1869).

The adults of *Geranomyia* species were often found sucking nectar from flowers (Alexander 1948, 1967b; Zhang et al. 2016). Some phenological studies have shown that adults have a long period of activity; for example, adults of *G. canadensis* (Westwood, 1836) were active from April to September, *G. communis* Osten Sacken, 1860 from May to October, and *G. rostrata* (Say, 1823) from April to September (Young 1978; Young and Gelhaus 2000). The habitats of adult flies have been rather frequently discussed in the literature (Alexander 1916, 1919, 1920, 1928a, 1928b, 1948, 1964, 1970a; Englund 1999; Harrison and Barnard 1972; Knab 1910). *Geranomyia advena* (Alexander, 1954) has been found around seeps and adjacent to riffle habitats in streams on Molokai and Hawaii (Englund 1999). The type of *G. annandalei* Edwards, 1913 was collected on the Plain of Gennesaret, near the Sea of Galilee, where it was found on limestone cliffs overhanging a spring (Alexander 1970b).

The habitats of the immature stages have also been extensively investigated. The larvae of *G. canadensis* was found living on the faces of rock exposures, crawling among algae and diatoms (Alexander and Malloch 1920). Rogers (1927) found the immature stages of *G. rostrata* living in wet moss, among the thalli of liverworts and in mats of filamentous algae on wet rocks and shaded seepage areas. Bangerter (1929) found the larvae of *G. caloptera* Mik, 1867 living among saturated mosses on wet banks of streams. The immature stages of *G. diversa* Osten Sacken, 1860 was found in and beneath thick mats of dripping algae on wet, shaded cliffs (Rogers 1930). *Geranomyia argentifera* de Meijere, 1911 and *G. fletcheri* Edwards, 1911 have habitats that are generally similar to the above-mentioned species (Alexander 1931).

Twenty-six species of *Geranomyia* have been previously recorded from China (Oosterbroek 2020), of which five were published by Zhang et al. (2016). Since that publication, further new materials of the genus have become available. Mount Jiulong is located in southwestern Zhejiang, China, with a total area of 200 km². The main peak is 1,724 m high, which is the fourth highest peak in Zhejiang. The area includes more than 6 km² of virgin, typically subtropical, broad-leaf forest. Mount Jiulong is reputed to be a “Biological Gene Pool”, with more than 1,340 species of plants and 149 species of vertebrates. This investigation into *Geranomyia* species on Mount Jiulong, Zhejiang, China, was initiated by the authors together with other entomologists from Zhejiang A&F University in July 2019, and four species of *Geranomyia* were found. In this paper, two new species are described and illustrated, and two known Chinese species are also listed. A dichotomous key to the Chinese species of *Geranomyia* is modified from Zhang et al. (2016) and updated with additional diagnostic characters.

Materials and methods

Specimens for this study were collected on Mount Jiulong, Zhejiang, China, in July 2019 by the authors. Adult crane flies were collected by insect net and at artificial light. Genitalic preparations of males were made by macerating the apical portion of the abdomen in cold 10% NaOH for 12–15 hours. Observations and illustra-

tions were made using a ZEISS Stemi 2000-C stereomicroscope. Photographs were taken with a Canon EOS 77D digital camera through a macro lens. Type specimens of known Chinese species deposited in the National Museum of Natural History, Smithsonian Institution, Washington, DC, USA (USNM), the Natural History Museum, London, UK (NHM) and the Entomological Museum of China Agricultural University, Beijing, China (CAU) were examined. Type specimens of the new species were deposited in the Entomological Museum of Qingdao Agricultural University, Shandong, China (QAU).

The morphological terminology mainly follows McAlpine (1981), and the venation is described after Alexander and Byers (1981). Terminology of the male hypopygium follows Ribeiro (2006). The following abbreviations are used: tg 9 = ninth tergite, tg 10 = tenth tergite, goncx = gonocoxite, c gonst = clasper of gonostylus, l gonst = lobe of gonostylus, aed = aedeagus, pm = paramere, cerc = cercus, hyp vlv = hypogynial valve, mm = millimeter.

Taxonomy

Key to Chinese *Geranomyia*

- 1 Wing patterned with dark brown stigma only 2
- Wing patterned with many spots besides stigma (Figs. 1d, 3d) 6
- 2 Stigma large, covering about 1/2 of distal section of R₁ 3
- Stigma small, covering about 1/3 of distal section of R₁ 4
- 3 Prescutum with three confluent stripes; ovipositor with tip of hypogynial valve near 1/2 way along cercus..... ***G. contrita* (Alexander, 1937) (Guangdong)**
- Prescutum without stripes; ovipositor with tip of hypogynial valve near 3/4 way along cercus... ***G. nigra* Zhang, Zhang & Yang, 2016 (Gansu, Sichuan, Zhejiang, Guanxi, Yunnan, Taiwan)**
- 4 Wing with basal section of CuA₁ at fork of M.....
- ***G. nitida* de Meijere, 1911 (Taiwan; Indonesia)**
- Wing with basal section of CuA₁ more than 1/3 of its own length before (Figs 1d, 3d) or beyond fork of M 5
- 5 Wing with basal section of CuA₁ about 3/4 of its length beyond fork of M; lobe of gonostylus with two short spines directly arising from rostral prolongation ***G. argentifera* (Taiwan, Hainan; Indonesia; Philippines)**
- Wing with basal section of CuA₁ about 1/3 of its length before fork of M; lobe of gonostylus with two long spines arising from a tubercle on rostral prolongation.....
- ***G. gracilispinosa* (Alexander, 1937) (Guangdong; India; Sri Lanka)**
- 6 Wing with spots in costal region except stigma small and weak; seams along cord, m-m and basal section of M₃ almost invisible..... 7
- Wing with spots in costal region large and dark; seams along cord, m-m and basal section of M₃ conspicuous (Figs 1d, 3d) 9

- 7 Prescutum with two stripes ***G. atrostriata* Edwards, 1921 (Taiwan)**
 – Prescutum with three stripes **8**
- 8 Wing with a few distinct spots at base of R.....
 ***G. montana* de Meijere, 1911 (Taiwan; Indonesia)**
 – Wing without conspicuous spot at base of R.....
 ... ***G. sparsiguttata* (Alexander, 1937) (Chongqing, Sichuan, Fujian, Yunnan)**
- 9 Wing with basal section of CuA₁ more than 1/3 of its own length before fork
 of M (Figs 1d, 3d)..... **10**
 – Wing with basal section of CuA₁ less than 1/4 of its length before or beyond
 fork of M..... **16**
- 10 Lobe of gonostylus with two conspicuous tubercles on rostral prolongation
 (Fig. 2a) **11**
 – Lobe of gonostylus with one or no tubercle on rostral prolongation (Fig. 4a)
 **12**
- 11 Prescutum with a narrow brown median stripe; lobe of gonostylus small and
 short, slightly exceeding clasper of gonostylus
 ***G. radialis* (Alexander, 1930) (Zhejiang, Guangxi, Taiwan; Japan)**
 – Prescutum with three broad, dark-brown stripes (Fig. 1c); lobe of gonostylus
 large and long, more than twice length of clasper of gonostylus (Fig. 2a)
 ***G. jiulongensis* sp. nov. (Zhejiang)**
- 12 Lobe of gonostylus with two long and slender spines, one arising from a large
 tubercle on rostral prolongation, other one directly arising from rostral pro-
 longation (Fig. 4a) **13**
 – Lobe of gonostylus not as above..... **14**
- 13 Wing with spot at fork of Rs restricted under Sc, cell r₃ without spot under R₂; lobe
 of gonostylus with two spines at tip and base of rostral prolongation respectively;
 distal part of paramere finger-shaped, lateral margin serrated or jagged
 ... ***G. tenuispinosa* (Alexander, 1929) (Zhejiang, Fujian, Guangdong, Jiangxi)**
 – Wing with spot at fork of Rs covering Sc and reaching costal margin, cell r₃
 with a spot under R₂ (Fig. 3d); lobe of gonostylus with two spines at tip and
 middle of rostral prolongation respectively; distal part of paramere triangular,
 lateral margin smooth (Fig. 4a) ***G. subablusa* sp. nov. (Zhejiang)**
- 14 Wing with a large spot at middle area of cell cua₁
 ***G. maculata* Zhang, Zhang & Yang, 2016 (Taiwan)**
 – Wing without conspicuous spot at middle area of cell cua₁ **15**
- 15 Pleuron of thorax without stripe; spot between first and second large spots in
 costal region very faint; lobe of gonostylus with rostral prolongation pointed
 at apex, middle of rostral prolongation with two subequal spines.....
 ***G. obesistyla* (Alexander, 1940) (Sichuan)**
 – Pleuron of thorax with an ill-defined longitudinal stripe; spot between first and
 second large spots in costal region conspicuous; lobe of gonostylus with rostral
 prolongation blunt, middle of rostral prolongation with two spines, outer spine a
 little longer than inner spine ***G. suensoniana* (Alexander, 1929) (Zhejiang)**

- 16 Wing with Sc₁ ending at about 1/2 to 2/3 of Rs 17
- Wing with Sc₁ ending at more than 3/4 of Rs..... 20
- 17 Wing with spots on origin of Rs and fork of Sc confluent in cell C or nearly so
..... *G. alpestris* (Alexander, 1930) (Taiwan)
- Wing with spots on origin of Rs and fork of Sc distinctly separated..... 18
- 18 Wing with many small dots near M and CuA.....
..... *G. pictorum* (Alexander, 1929) (Taiwan; India)
- Wing without small dot near M or CuA 19
- 19 Prescutum with three broad longitudinal stripes
..... *G. baisensis* Zhang, Zhang & Yang, 2016 (Guangxi)
- Prescutum without evident markings
..... *G. spectata* (Alexander, 1937) (Guangdong)
- 20 Wing heavily patterned, a large spot throughout wing tip, spot on origin of
Rs posteriorly bifurcated
..... *G. apicifasciata* (Alexander, 1930) (Guangdong, Yunnan, Taiwan)
- Wing not as above 21
- 21 Wing without conspicuous spot at base
..... *G. kiangsiana* (Alexander, 1937) (Jiangxi)
- Wing with spot at base 22
- 22 Prescutum with a median longitudinal stripe
..... *G. unifilosa* (Alexander, 1934) (Taiwan)
- Prescutum with three longitudinal stripes 23
- 23 Legs uniformly light brownish ... *G. septemnotata* Edwards, 1916 (Taiwan)
- Legs pale yellow to brownish yellow, with tibiae and tarsi darker, or femora
with tips darker or bases paler 24
- 24 Costal region of wing with a small spot in cell C between second and third
large spots *G. fremida* (Alexander, 1937) (Guangdong)
- Costal region of wing without conspicuous spot in cell C between second and
third large spots 25
- 25 Lobe of gonostylus with two spines.....
..... *G. subradialis* (Alexander, 1937) (Guangdong)
- Lobe of gonostylus with one spine 26
- 26 Lobe of gonostylus with rostral prolongation small, a very long and slender
spine arising from a tubercle on rostral prolongation
..... *G. longispina* Zhang, Zhang & Yang, 2016 (Fujian)
- Lobe of gonostylus with rostral prolongation long and slender, a long and
powerful spine directly arising from rostral prolongation 27
- 27 Male hypopygium with posterior margin of tergite nine deeply and narrowly
notched; clasper of gonostylus small, slender, and nearly straight
..... *G. bifurcula* (Alexander, 1933) (Sichuan)
- Male hypopygium with posterior margin of tergite nine emarginate; clasper
of gonostylus absent.....
..... *G. degenerata* Zhang, Zhang & Yang, 2016 (Guangxi)

***Geranomyia jiulongensis* sp. nov.**

<http://zoobank.org/2E46B202-AA91-4C18-9421-6355DE078719>

Figures 1, 2

Diagnosis. Prescutum yellow with three broad, dark-brown longitudinal stripes. Pleuron of thorax yellow, with a broad, dark-brown stripe. Wing with seven large spots on costal region; Sc_1 ending near fork of R_s , basal section of CuA_1 nearly its length before fork of M . Lobe of gonostylus large with an arched rostral prolongation armed with two basal spines arising from two tubercles.

Description. Male. Body length 5.0–5.3 mm, wing length 5.3–5.5 mm, mouthparts length 2.2–2.3 mm.

Head (Fig. 1b). Black. Setae on head black. Antenna length 1.2–1.3 mm, brownish black. Scape cylindrical. Pedicel nearly globose. Flagellomeres oval, terminal flagellomere with tip knob-like. Mouthparts brownish black with black setae.

Thorax (Fig. 1c). Pronotum yellow with a broad dark brown median stripe. Prescutum yellow, with three broad, dark-brown longitudinal stripes, each lateral stripe about 1/2 length of median stripe. Scutum pale yellow, with a dark-brown longitudinal stripe at middle area, each lobe with a large, dark-brown spot. Scutellum yellow, with two sides and anterior region dark brown, posterior region with a dark-brown spot. Mediotergite brownish black. Pleuron of thorax (Fig. 1a) yellow, with a broad, dark-brown stripe extending from cervical region to mediotergite. Setae on thorax brownish black. Coxae pale yellow; trochanters pale yellow; femora brownish yellow, with fore femur paler; tibiae brownish yellow; tarsi brownish yellow, with terminal three segments darker. Setae on legs brownish black. Wing (Fig. 1d) tinged pale brownish with a brownish-black pattern: seven large spots on costal region; seams along cord, m - and basal section of M_3 ; a spot at fork of R_s ; a very light spot at sub-tip of A_2 . Veins brownish yellow, darker in clouded areas. Venation: Sc long, Sc_1 ending near fork of R_s , Sc_2 at its tip; basal section of CuA_1 nearly its length before fork of M . Halter length 1.1–1.2 mm, pale yellow with base of stem dark brown.

Abdomen (Fig. 1a). Tergites brownish yellow with caudal halves dark brown. Sternites pale yellow. Setae on tergites brown and on sternites white.

Hypopygium (Fig. 2). Posterior margin of ninth tergite slightly emarginate. Gonocoxite slender with an elongate and blunt-apexed ventromesal lobe. Clasper of gonostylus arched at 2/3 of length, tip acute. Lobe of gonostylus large with an arched rostral prolongation armed with two basal spines arising from two tubercles. Paramere stout, wide at base, distal part triangular. Aedeagus long, with two apical lobes.

Female. Body length 5.5–6.4 mm, wing length 5.0–5.8 mm, mouthparts length 2.0–2.5 mm. Similar to male, but tenth tergite (Fig. 1e) brown. Cercus brownish yellow with basal 1/2 brown. Hypogynial valve brownish yellow with tip slightly darker, tip near 2/3 way along cercus.

Type material. Holotype: male (QAU), China: Zhejiang, Suichang, Mount Jiulong, Luohanyuan (28°23'24"N, 118°51'00"E, 517 m), 2019.VII.26, Xingyang Qian. **Paratypes:** 10 males 5 females (QAU), same data as holotype. 1 female (QAU), Chi-

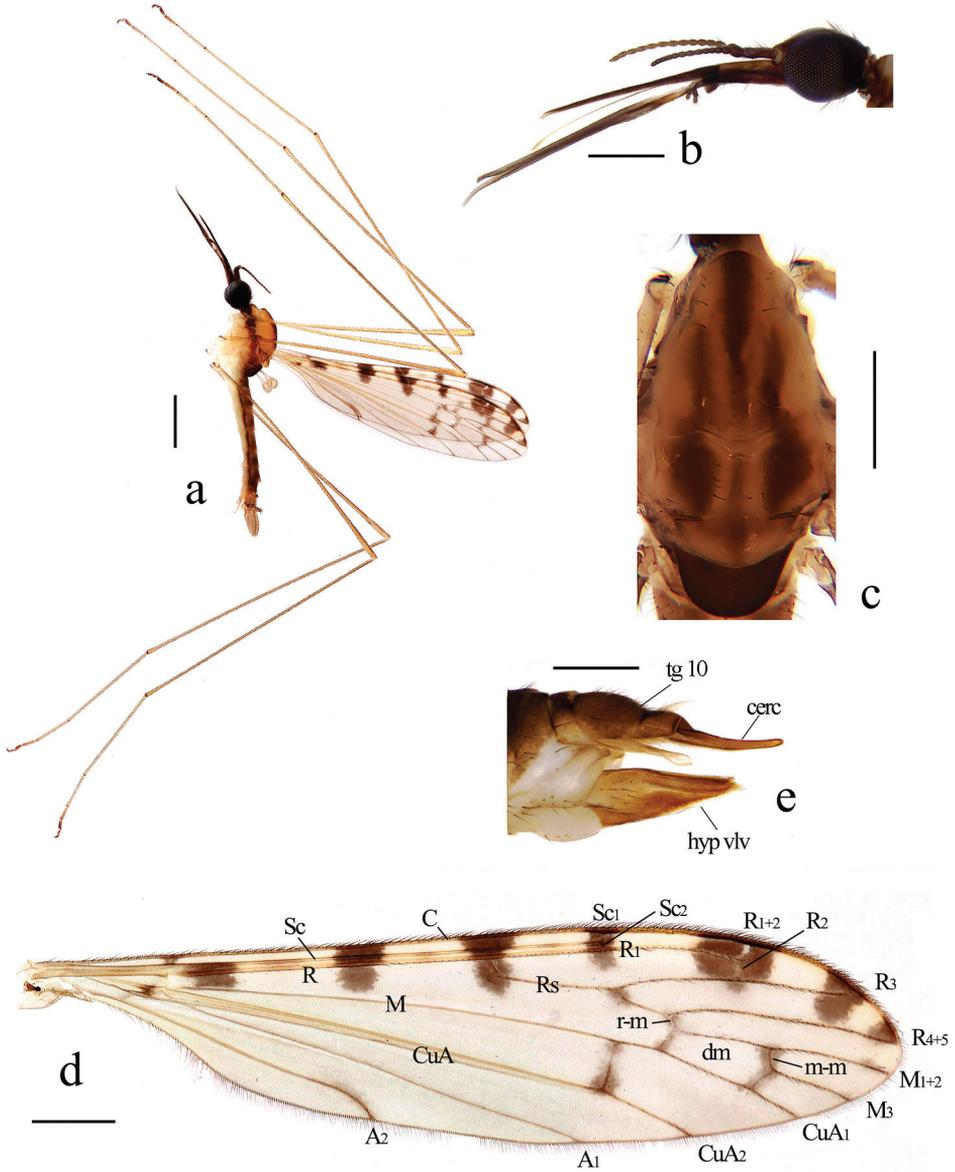


Figure 1. *Geranomyia jiulongensis* sp. nov. **a** Male habitus, lateral view **b** head, lateral view **c** thorax, dorsal view **d** wing **e** ovipositor, lateral view. Scale bars: 1.0 mm (**a**); 0.5 mm (**b–d**); 0.2 mm (**e**).

na: Zhejiang, Suichang, Mount Jiulong, Longkoucun (28°18'11"N, 118°56'42"E, 305 m), 2019.VII.24, Xinyang Qian. 1 male 5 females (QAU), China: Zhejiang, Suichang, Mt. Jiulong, Xikengli (28°20'10"N, 118°55'00"E, 732 m), 2019.VII.25, Xinyang Qian. 1 male (QAU), China: Zhejiang, Suichang, Mount Jiulong, Yanping (28°22'23"N, 118°53'48"E, 667 m), 2019.VII.26, Xinyang Qian. 1 female (QAU),

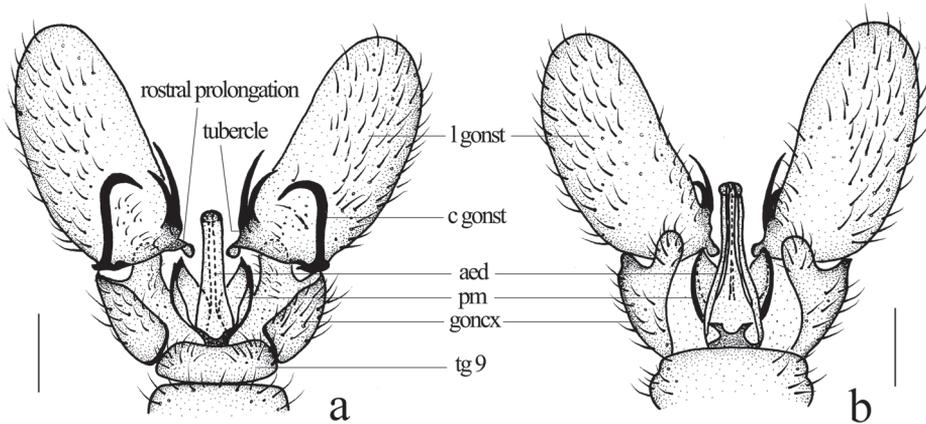


Figure 2. *Geranomyia jiulongensis* sp. nov. **a** male hypopygium, dorsal view **b** male hypopygium, ventral view. Scale bars: 0.2 mm.

China: Zhejiang, Suichang, Mount Jiulong, Zuobieyuan (28°17'10"N, 118°46'42"E, 640 m), 2019.VII.28, Xingyang Qian.

Distribution. China (Zhejiang).

Etymology. The species is named after the type locality, Mount Jiulong.

Remarks. This species is very similar to *G. radialis* but can be distinguished by the prescutum of the thorax having three broad, dark-brown stripes (Fig. 1c) and the lobe of the gonostylus being long and more than twice the length of the gonostylus clasper (Fig. 2a). In *G. radialis*, the prescutum has a narrow brown median stripe, and the lobe of the gonostylus is short and slightly exceeds the gonostylus clasper (Alexander 1930). This new species is also somewhat similar to *G. immobilis* (Alexander, 1932) from the Philippines in its pattern and wing venation but can be easily distinguished from it by the pleuron of the thorax being yellow with a broad dark brown stripe extending from the cervical region to the mediotergite (Fig. 1a) and the lobe of the gonostylus with two spines arising from two tubercles. In *G. immobilis*, the pleuron of the thorax is chiefly dark brown, with the sternopleurite light yellow, and the lobe of the gonostylus has two spines arising from a common tubercle (Alexander 1932).

***Geranomyia subablusa* sp. nov.**

<http://zoobank.org/2F4E8F84-2595-4B4C-9026-6ED380AA499D>

Figures 3, 4

Diagnosis. Prescutum yellow with three broad, brown longitudinal stripes. Pleuron of thorax yellow, with a broad brown stripe. Wing with seven large spots on costal region, with second and third spots combined between C and Sc; Sc₁ ending about 2/5 of Rs; basal section of CuA₁ more than 2/3 of its own length before fork of M. Lobe of gonostylus large with a large rostral prolongation armed with two

long, slender spines, one arising from a large fleshy tubercle, other one directly arising from rostral prolongation.

Description. Male. Body length 6.2–6.5 mm, wing length 6.0–6.3 mm, mouthparts length 2.4–2.5 mm.

Head (Fig. 3b). Brownish black. Setae on head black. Antenna length 1.2–1.3 mm, dark brown. Scape cylindrical. Pedicel nearly globose. Flagellomeres oval, terminal flagellomere with tip knob-like. Mouthparts dark brown, with black setae.

Thorax (Fig. 3c). Pronotum brownish yellow, with a broad, dark-brown, median stripe. Prescutum yellow with three broad, brown, longitudinal stripes; each lateral stripe about $3/4$ length of median stripe. Scutum pale yellow; each lobe with a large brown spot. Scutellum yellow, with brown sides; posterior region with a brown spot. Mediotergite dark brown. Pleuron of thorax (Fig. 3a) yellow, with a broad, brown stripe extending from cervical region to mediotergite. Setae on thorax brownish black. Coxae yellow; trochanters yellow; femora brownish yellow; tibiae brownish yellow; tarsi brownish yellow, with terminal three segments darker. Setae on legs brownish black. Wing (Fig. 3d) tinged with pale brownish with brownish black pattern: seven large spots on costal region, with second and third spots combined between C and Sc; seams along cord, m-m and basal section of M_3 ; spots at fork of Rs and tip of M_{1+2} , M_3 , CuA_1 and A_2 ; a very light and small spot at tip of A_1 . Veins brownish yellow, darker in clouded areas. Venation: Sc long, Sc_1 ending about $2/3$ of Rs, Sc_2 at its tip; basal section of CuA_1 more than $2/3$ of its own length before fork of M. Halter length 1.1–1.2 mm, yellowish white.

Abdomen (Fig. 3a). Tergites brown. Sternites pale yellow. Setae on tergites brown and on sternites white.

Hypopygium (Fig. 4). Posterior margin of ninth tergite emarginate. Gonocoxite stout with a blunt-apexed ventromesal lobe. Clasper of gonostylus arched at $2/3$ of length, tip acute. Lobe of gonostylus large, with a large rostral prolongation armed with two long, slender spines, one arising from a large fleshy tubercle at sub-tip of rostral prolongation, other one directly arising from middle of rostral prolongation. Paramere slender, wide at base, distal part triangular. Aedeagus relatively long, with two apical lobes.

Female. Body length 6.0–7.0 mm, wing length 6.0–6.5 mm, mouthparts length 2.3–2.5 mm. Similar to male, but tenth tergite (Fig. 3e) brown, with tip brownish yellow. Cercus brownish yellow, with basal $1/2$ brown, long. Hypogynial valve brownish yellow, slender, and long, with tip near $2/3$ way along cercus.

Type material. Holotype: male (QAU), China: Zhejiang, Suichang, Mount Jiulong, Luohanyuan (28°23'24"N, 118°51'00"E, 517 m), 2019.VII.26, Xingyang Qian. **Paratypes:** 4 males 10 females (QAU), same data as holotype. 2 males 2 females (QAU), China: Zhejiang, Suichang, Mount Jiulong, Longkoucun (28°18'11"N, 118°56'42"E, 305 m), 2019.VII.24, Xingyang Qian.

Distribution. China (Zhejiang).

Etymology. The name of the new species refers to the *G. ablusa* (Alexander, 1967), as the two species are very similar morphologically.

Remarks. This species is very similar to *G. ablusa* from India but can be distinguished from it by the femora being uniformly brownish yellow (Fig. 3a), the yellowish

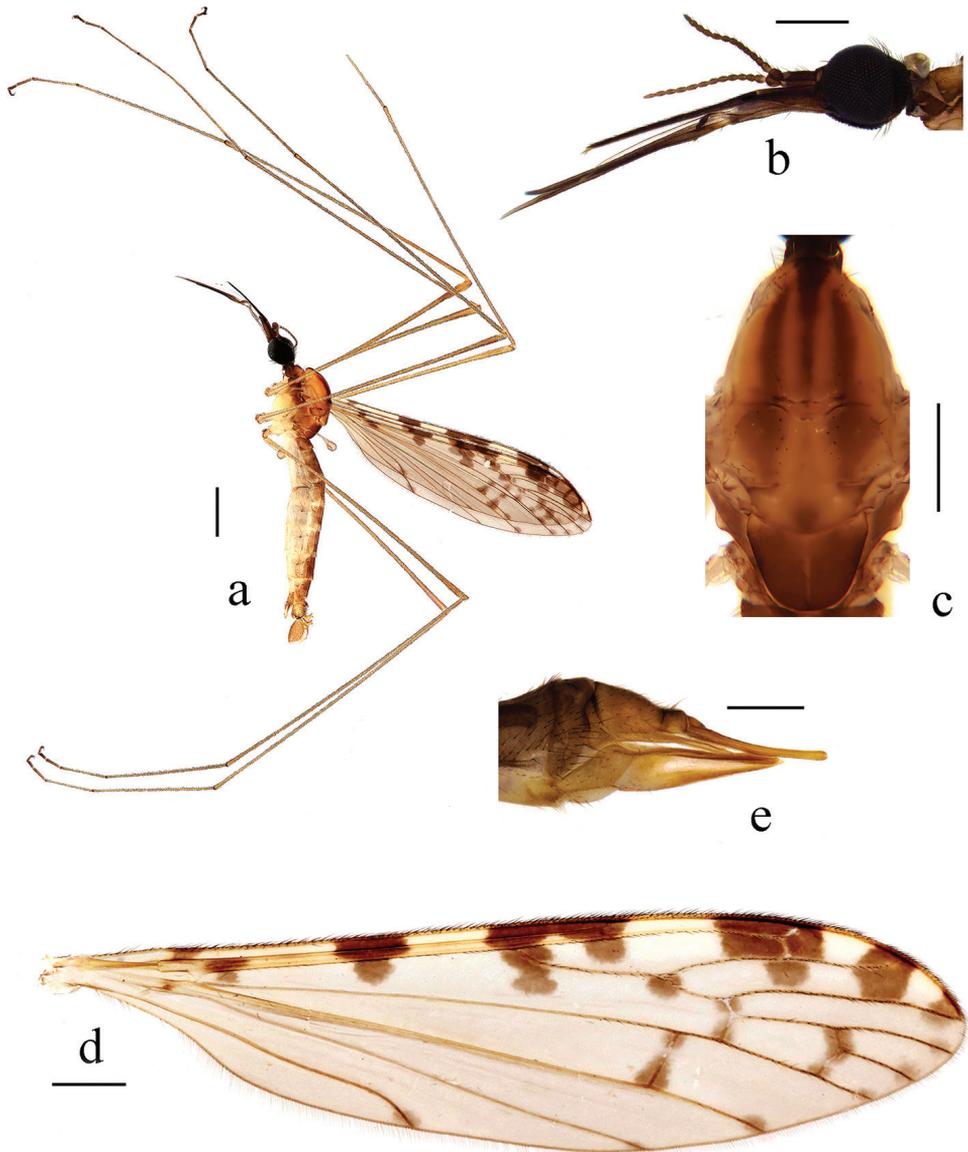


Figure 3. *Geranomyia subablusa* sp. nov. **a** Male habitus, lateral view **b** head, lateral view **c** thorax, dorsal view **d** wing **e** ovipositor, lateral view. Scale bars: 1.0 mm (**a**); 0.5 mm (**b–d**); 0.2 mm (**e**).

white halter, and the aedeagus lacking genital openings near the apical lobes (Fig. 4b). In *G. ablusa*, the femora have vague, pale brown, subterminal rings, the halter is dark brown, and the aedeagus has the genital openings subterminal and lateral in position to the apical lobes (Alexander 1967c).

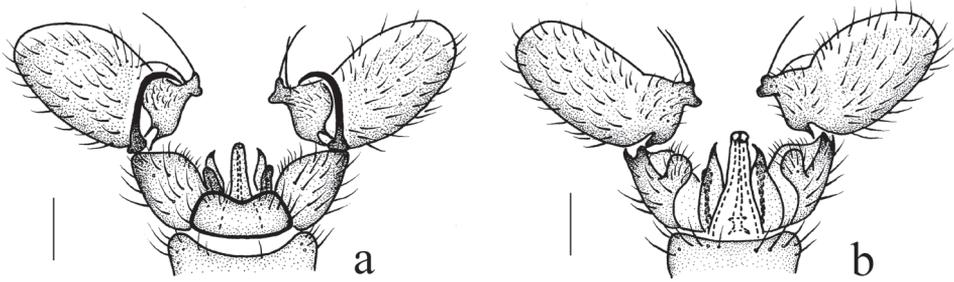


Figure 4. *Geranomyia subablusa* sp. nov. **a** male hypopygium, dorsal view **b** male hypopygium, ventral view. Scale bars: 0.2 mm.

Geranomyia nigra Zhang, Zhang & Yang, 2016

Geranomyia nigra: Zhang et al. 2016: 150. Type locality: Fuxing, Taoyuan, Taiwan (China).

Specimens examined. Holotype: male (CAU), China: Taiwan, Taoyuan, Fuxing (24°48'36"N, 121°20'55"E, 420 m), 2013.VI.10, Wenliang Li (light trap). **Other material:** 2 males 2 females (QAU), China: Zhejiang, Suichang, Mount Jiulong, Luohanyuan (28°23'24"N, 118°51'00"E, 517 m), 2019.VII.26, Xingyang Qian. 1 male 2 females (QAU), China: Zhejiang, Suichang, Mount Jiulong, Longkoucun (28°18'11"N, 118°56'42"E, 305 m), 2019.VII.24, Xingyang Qian.

Distribution. China (Gansu, Sichuan, Yunnan, Zhejiang, Guangxi, Taiwan).

Geranomyia suensoniana (Alexander, 1929)

Limonia (Geranomyia) suensoniana: Alexander 1929a: 330. Type locality: hills south of Ningbo, Zhejiang (China).

Specimens examined. Holotype: male (USNM), China: Zhejiang, hills south of Ningbo, 1925.V.1, E. Suenson. **Other material:** 2 male 4 females (QAU), China: Zhejiang, Suichang, Mount Jiulong, Luohanyuan (28°23'24"N, 118°51'00"E, 517 m), 2019.VII.26, Xingyang Qian.

Distribution. China (Zhejiang).

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Four new species of the subfamily Homoneurinae (Diptera, Lauxaniidae) from southwestern China

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Abstract

Four species of Homoneurinae from southwestern China are described as new to science: *Cestrotus abdominalis* **sp. nov.**, *Cestrotus albifacies* **sp. nov.**, *Phobeticomyia motuoensis* **sp. nov.**, and *Prosopophorella longa* **sp. nov.** An updated key to the species of the genera *Cestrotus*, *Phobeticomyia*, and *Prosopophorella* recorded in China is presented.

Keywords

acalyptrate flies, *Cestrotus*, *Phobeticomyia*, *Prosopophorella*, Oriental region, taxonomy

Introduction

The family Lauxaniidae is a large family of the Acalyptratae. There are more than 170 genera and nearly 2100 described species, distributed worldwide except for Antarctica. The subfamily Homoneurinae of Lauxaniidae was established by Stuckenberg in 1971 (Stuckenberg 1971a) on the basis of studies including 28 genera and more than 780 species worldwide, of which seven genera and 240 species are recorded from China alone.

Among the seven genera of this subfamily in China, *Homoneura* Van der Wulp, 1891 is the largest, containing more than 200 species; Shi and Yang (2014) described 20 species. The genus *Dioides* Kertész, 1915 in China contains six species; Shi et al. (2009a) described five of them. The genus *Noonamyia* Stuckenberg, 1971 (Stuckenberg 1971b) in China

contains seven species: Shi and Yang (2009a) described two species, and we described three species (Li et al. 2020). *Wawu* Evenhuis, 1989 is the smallest genus of the Homoneurinae in China, containing a single species. The three remaining genera of Homoneurinae in China are *Cestrotus* Loew, 1862, *Phobeticomyia* Kertész, 1915, and *Prosopophorella* de Meijere, 1917, containing nine, five, and three species respectively after this research; most of them are distributed in southwestern China, especially Yunnan Province, Hainan Province, and Guangxi Province (Shi et al. 2009c; Shi et al. 2009b; Shi and Yang 2009b).

Southwestern China with a rich biodiversity is located in the Oriental region and includes the Sichuan Basin, Yunnan-Guizhou Plateau, Southern Qinghai-Tibet Plateau and Western Guangxi-Guangdong Hills. It has obvious karst landforms and river valley landforms, large altitude differences and a complex terrain. It encompasses a variety of high-rainfall climates including subtropical monsoon climates, plateau mountain climates, and tropical rainforest climates. There are more than 50 national and provincial nature reserves, each with complete ecological preservation, high vegetation abundance, and rich humus soils and fungi. These are the reasons why most species of Lauxaniidae are distributed in southwestern China.

In this article, four new species are described from this diverse area of China: *Cestrotus abdominalis* sp. nov., *Cestrotus albifacies* sp. nov., *Phobeticomyia motuoensis* sp. nov., and *Prosopophorella longa* sp. nov. An updated key to the species of genus *Cestrotus*, *Phobeticomyia*, and *Prosopophorella* in China, which is based on the keys of Shi et al. (2009c), Shi et al. (2009b), and Shi and Yang (2009b) is presented.

Materials and methods

Genitalia preparations were made by removing and macerating the apical portion of the abdomen in cold saturated NaOH for 6 h, then rinsing and neutralizing them for dissection and study. After examination in glycerin, they were transferred to fresh glycerin and stored in a microvial on a pin below the specimen or moved to an ethanol tube together with the alcohol specimens. Specimens examined were deposited in the Entomological Museum of China Agricultural University, Beijing, China (CAUC).

The general terminology follows Gaimari and Silva (2010) and Shi and Yang (2014).

Taxonomy

Key to species of the genera *Cestrotus*, *Phobeticomyia*, and *Prosopophorella* in China

- 1 Face shining with distinct spherical protuberance, at least half of base dark brown **genus *Phobeticomyia* (Kertész, 1915) 2**
- Face with a median protuberance on ventral margin or slight convex on the middle or convex and with complex bands **6**

- 2 Wing with 1-2 narrow hyaline subapical bands (constricted at middle in some species) in m_1 cell; surstylus not as follows **3**
- Wing without narrow hyaline subapical stripe in m_1 cell; surstylus with one small triangular apical process and one curved inner process with apical tooth..... ***Ph. spinosa* (Sasakawa, 1987)**
- 3 Wing (Fig. 22) with two narrow hyaline subapical bands in m_1 cell, three hyaline spots between R_{2+3} and R_{4+5} ; male genitalia (Figs 26-30): syntergosternite semicircular; hypandrium V-shaped, with a pair of short inner process on sides; gonopod with setulae basally, curved apically ***Ph. motuoensis* sp. nov.**
- Wing with one narrow hyaline subapical band (constricted at middle in some species) in m_1 cell; male genitalia not as above **4**
- 4 Wing with a hyaline spot between *dm-cu* and subapical band in m_1 cell, and with a round median spot near CuA_1 in cua_1 cell **5**
- Wing without hyaline spot between *dm-cu* and subapical stripe in m_1 cell, and no hyaline round median spot near CuA_1 in cua_1 cell..... ***Ph. uncinata* (Shi et al., 2009)**
- 5 Antenna scape and pedicel yellow; surstylus with a small digitiform subapical process and a curved claviform inner process; phallus with a pair of subapical lateral processes and a hooked apical process in ventral view ***Ph. digitiformis* (Shi et al., 2009)**
- Antenna scape and pedicel black; surstylus with a broad apical process, a small bulb-like subapical process and a narrow long curved inner process; phallus with a pair of median teeth and a pair of acute triangular apical processes in ventral view..... ***Ph. lunifera* (de Meijere, 1910)**
- 6 Frons distinctly longitudinally sunken in middle, with one velvet black median spot..... **genus *Prosopophorella* (de Meijere, 1917) 7**
- Frons raised, with velvet rectangular spot and pruinescence **genus *Cestrotus* (Loew, 1862) 9**
- 7 Palpus blackish brown; all femora brown except yellow apically; wing and male genitalia not as follows..... **8**
- Palpus yellow or brownish yellow; mid and hind femora with one brown ventral band at basal 2/3; wing with brown cloud over *r-m* separating from one brown spot over R_1 in subcostal cell and brown spots surrounding *dm-cu*; male genitalia: syntergosternite with short setulae and a pair of ventral processes, epandrium with two pairs of long dorsal setae in ventral view ***Pr. yoshiyasui* (Sasakawa, 2001)**
- 8 Mesonotum with two wide black median stripes, a pair of short black lateral bands behind suture and a narrow grayish white pruinescent band along the rows of dorsocentral setae; tarsi 3–5 pale brown; syntergosternite without ventral process; halter pale yellow..... ***Pr. zhuae* (Shi & Yang, 2009)**
- Mesonotum with one gray pruinescent band and a pair of gray pruinescent bands along the rows of dorsocentral setae; tarsi 3–5 yellow; syntergosternite with a pair of ventral processes; halter white ***Pr. longa* sp. nov.**

- 9 Face with one brown median longitudinal band 15
 – Face without brown median bands..... 10
 10 Scutellum yellow or with yellow pruinescence, without brown spots..... 11
 – Scutellum with gray or yellow pruinescence, with brown spots basally 12
 11 Mesonotum with black trapeziform spot posteriorly; wing 2 times longer than wide..... *C. apicalis* (Hendel, 1920)
 – Mesonotum with two coterminous yellow trapeziform spots present at posterior 1/3, the trapeziform spots basally with two coterminous round brown spots extending to the base of scutellum; wing 2.5 times longer than wide....
 *C. abdominalis* sp. nov.
 12 Scutellum with two brown spots apically
 *C. heteropterus* (Shi et al., 2009)
 – Scutellum without brown spots apically 13
 13 Face yellow with brown spots..... 14
 – Face white without spots..... *C. albifacies* sp. nov.
 14 Mesonotum with brown spots on transverse suture; surstylus with outer process twice as long as wide in ventral view.....
 *C. flavoscutellatus* (de Meijere, 1910)
 – Mesonotum with brown spots on transverse suture large and ensiform posteriorly; surstylus with outer process 4 times longer than wide in ventral view .
 *C. longinudus* (Shi et al., 2009)
 15 Palpus yellow; wing distally lacking marginal spots; surstylus with outer process elongate and blunt distally in lateral view..... *C. liui* (Shi et al., 2009)
 – Palpus black; wing with distal brown marginal spots between R_{2+3} and R_{4+5} and between R_{4+5} and M_{1+2} ; surstylus with outer process distinctly triangular in lateral view..... 16
 16 Wing with a small rhombic hyaline spot in the brown area between R_{2+3} and R_{4+5} ; scutellum with paired elongate brown spots confluent with brown patch on mesonotum; surstylus with inner process strongly arched, similar in size to outer process in ventral view *C. acuticurvus* (Shi et al., 2009)
 – Wing lacking hyaline spot in brown area between R_{2+3} and R_{4+5} ; scutellum with paired elongate brown spots isolated, separated from brown patch on mesonotum; surstylus with inner process not strongly arched, larger than outer process in ventral view *C. obtusus* (Shi et al., 2009)

Species descriptions

Cestrotus abdominalis sp. nov.

<http://zoobank.org/66807266-69FC-49BF-9762-8FD4CE17BFC5>

Figures 1–10

Type material. *Holotype*: ♂ (CAUC), CHINA, Yunnan: Menglun, Lvshilin, 5.V.2009, Tingting Zhang.

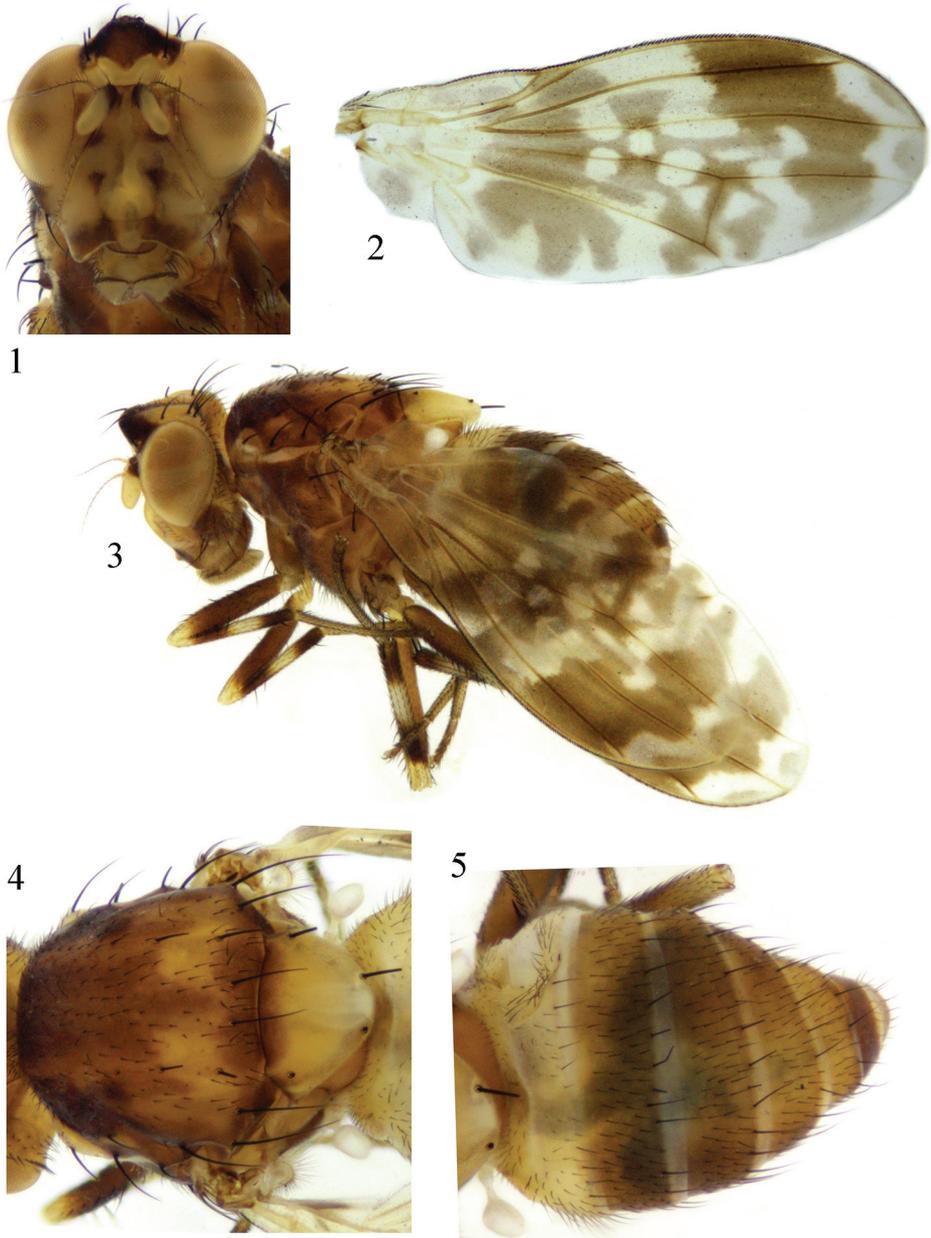
Etymology. Latin, *abdominalis*, referring to the white abdominal tergites I and II of the new species.

Diagnosis. Face pale yellow, with one tubercle on middle and one rounded tubercle near ventral margin. Frons with one black velvet rectangular spot. Antenna yellow except pedicel blackish brown; arista brown except yellow basally, plumose. Thorax brown with gray pruinescence. Mesonotum with a pair of brown median bands and a pair of undulating lateral bands on anterior margin. Legs yellow, tibia with one incomplete brown ring near base and on tip respectively. Wing r_1 cell half apically with broad brown band connected with the subapical band of r_{2+3} cell and r_{4+5} cell. Male genitalia: syntergosternite semicircular; epandrium trapeziform in lateral view; surstylus broad basally, tip slender and curved; hypandrium V-shaped.

Description. Male. Body length 3.8 mm, wing length 3.9 mm. **Female.** Unknown.

Head (Fig. 1) yellow. Face pale yellow, with one tubercle centrally and one rounded tubercle near ventral margin; sides of the central tubercle with one brown spot on dorsal margin and middle respectively, and with a pair of brown lateral longitudinal bands on ventral margin. Frons wider than long and parallel-sided, with one black velvet rectangular spot; ocellar triangle blackish gray, ocellar seta developed, nearly as long as anterior fronto-orbital seta; anterior fronto-orbital seta curved, shorter than posterior fronto-orbital seta. Occiput yellow, with one brown narrow median band extending to ocellar triangle. Parafacial with one triangular brown spot between eye and base of antenna; gena with one brown spot, length of gena and sub-gena about 1/2 eye height. Antenna yellow except pedicel blackish brown; 1st flagellomere about 1.6 times longer than high; arista brown except yellow basally, plumose, the longest ray slightly shorter than 1st flagellomere height. Proboscis yellow except black on margin, with yellow and black setulae; palpus yellow with black setulae.

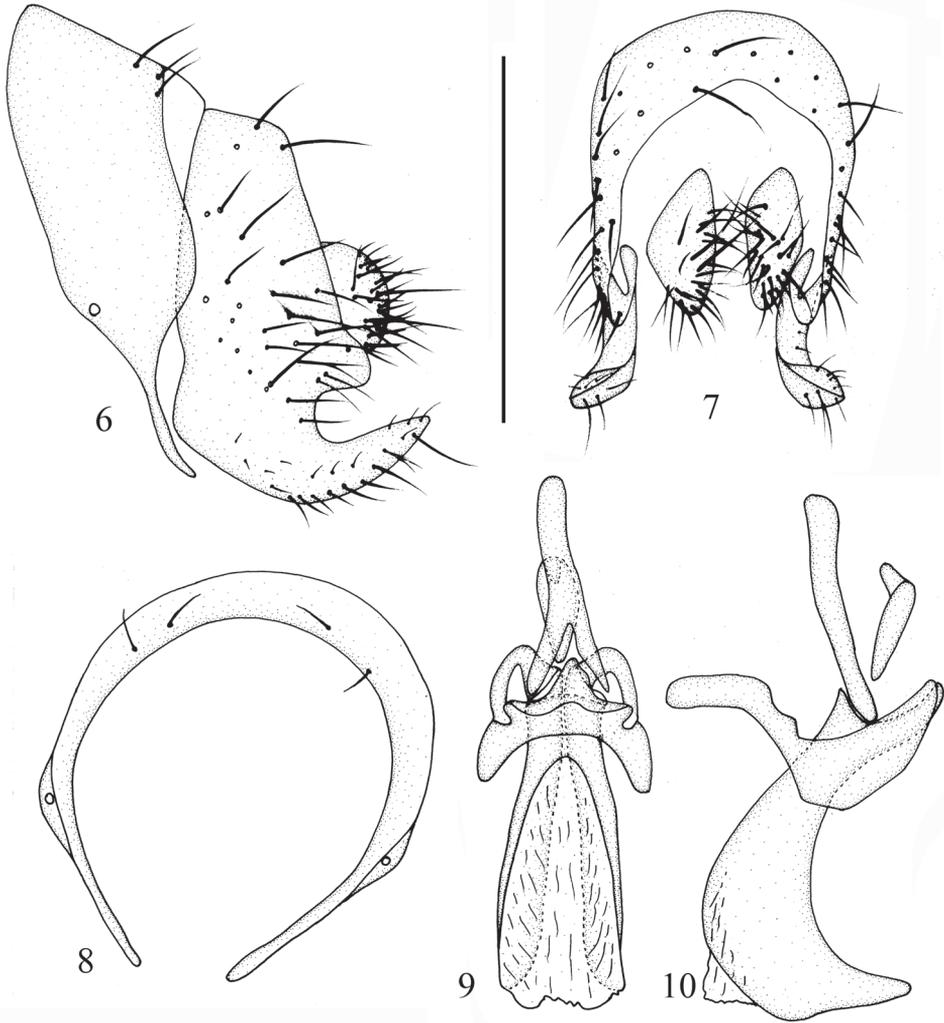
Thorax (Fig. 4) brown with gray pruinescence. Mesonotum with a pair of brown median bands and a pair of undulating lateral bands on anterior margin, a pair of brown lateral spots present behind scutal suture; two coterminous yellow trapeziform spots present at posterior 1/3, the trapeziform spots basally with two coterminous round brown spots extending to base of scutellum. Three dorsocentral setae; acrostichal setulae in six rows; a pair of prescutellar setae. One anepisternal seta, one katepisternal seta. Scutellum yellow. Legs yellow, femur brown except yellow apically, tibia with one incomplete brown ring near base and on tip respectively. Fore femur with six posterior dorsal setae, four posterior ventral setae, seventeen comb-like anterior ventral setae; tibia with one dorsal preapical seta, one short apical ventral seta. Mid femur with eight anterior setae; tibia with one strong dorsal preapical seta, two strong apical ventral setae. Hind femur with preapical anterior dorsal seta; tibia with one dorsal preapical seta, one short apical ventral seta. Wing (Fig. 2) about 2.5 times longer than wide, hyaline; r_1 cell half apically with broad brown band connected with the subapical band of r_{2+3} cell and r_{4+5} cell, form wavy band extending to posterior margin; r_{2+3} cell and r_{4+5} cell with pale brown margin spots; hyaline region of *r-m* surrounded by “+” shape brown spot; *dm-cu* with brown spot, sides of *dm-cu* with hyaline spot; costa with 2nd, 3rd, and 4th sections in proportion of



Figures 1–5. *Cestrotus abdominalis* sp. nov. Male. **1** head, anterior view **2** wing **3** habitus, lateral view **4** thorax, dorsal view **5** abdomen, dorsal view.

6.1 : 2.2 : 1; *r-m* behind middle of the discal cell; ultimate and penultimate sections of M_1 in proportion of 2.1 : 1; ultimate section of CuA_1 about 1/8 of penultimate section. Halter white.

Abdomen (Fig. 5) with gray pruinescence; tergites I and II white, tergites III–IX brown. Male genitalia (Figs 6–10): syntergosternite semicircular, broad half dorsally



Figures 6–10. *Cestrotus abdominalis* sp. nov. Male. **6** syntergosternite and epandrium, lateral view **7** epandrial complex, posterior view **8** syntergosternite, anterior view **9** aedeagal complex, ventral view **10** aedeagal complex, lateral view. Scale bar: 0.5 mm.

and narrow half ventrally. Epandrium trapeziform in lateral view. Surstylus extending from the base of tergite, broad basally, tip slender and curved, surstylus curved outwards in posterior view. Hypandrium V-shaped. Gonopod vestigial. Phallus without apical concave, with a pair of dorsal sclerites, tip of the sclerites slender and curved in lateral view, broad and deep. Phallapodeme shorter than phallus.

Remarks. The new species is similar to *Cestrotus acuticurvus* Shi, Yang & Gaimari, 2009 from China (Yunnan) in having spots on the face and wing, but the latter has a mesonotum with brown trapeziform spots and a *dm-cu* with a brown spot.

Distribution. China (Yunnan).

***Cestrotus albifacies* sp. nov.**

<http://zoobank.org/0501BC02-D746-48BF-BAE7-7FA60F31BF3E>

Figures 11–20

Type material. Holotype: ♂ (CAUC), CHINA, Yunnan: Hekou, Nanxi Town, 132 m, 22.V.2009, Guoquan Wang.

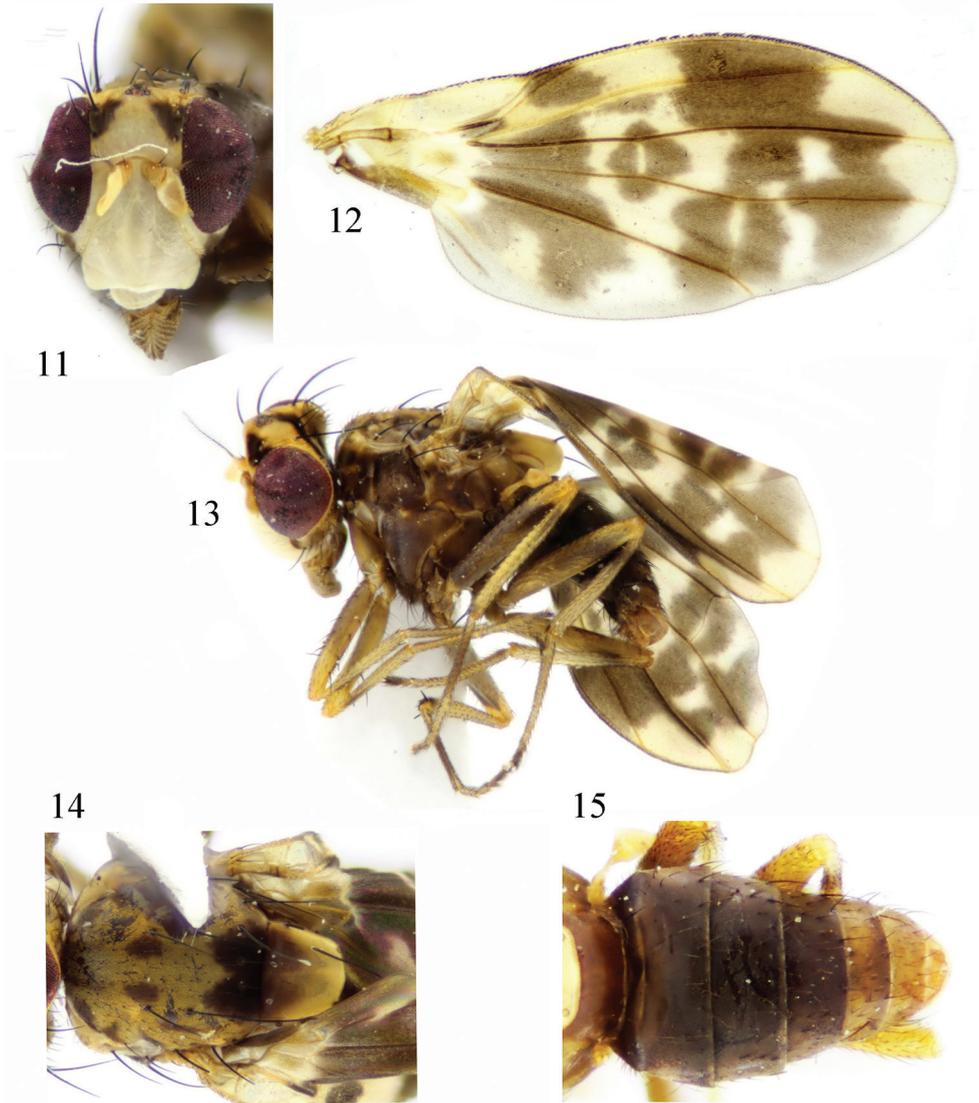
Etymology. Latin, *albifacies*, referring to the new species' white face without any spots or bands.

Diagnosis. Face white, without brown spot or band. Frons with a pair of black velvet triangular spots. Antenna yellow; arista blackish brown except brown basally, plumose. Thorax with yellow pruinescence. Mesonotum with a pair of elliptical brown spots present on scutal suture. Legs yellow, femur brown except yellow apically; tibia with one incomplete brown ring near base. Wing r_{2+3} cell and r_{4+5} cell without margin spot; the hyaline region of *dm-cu* surrounded by two brown spots. Male genitalia: syntergosternite circular; surstylus consisting of one outer process and inner process; hypandrium Y-shaped, inner process longer than phallapodeme.

Description. Male. Body length 3.3 mm, wing length 3.0 mm. **Female.** Unknown.

Head (Fig. 11) yellow. Face white, without brown spot or band. Frons wider than long and parallel-sided, with a pair of black velvet triangular spots; ocellar triangle blackish gray; ocellar setae broken, anterior fronto-orbital seta curved, shorter than posterior fronto-orbital seta. Occiput yellow, with one blackish brown median band extending to ocellar triangle. Gena yellow, with one kidney-shape brown spot; length of gena and sub-gena about 1/2 eye height. Antenna yellow; 1st flagellomere about 1.6 times longer than high; arista blackish brown except brown basally, plumose, the longest ray slightly longer than 1st flagellomere width. Proboscis brown, with yellow and black setulae; palpus yellow with black setulae.

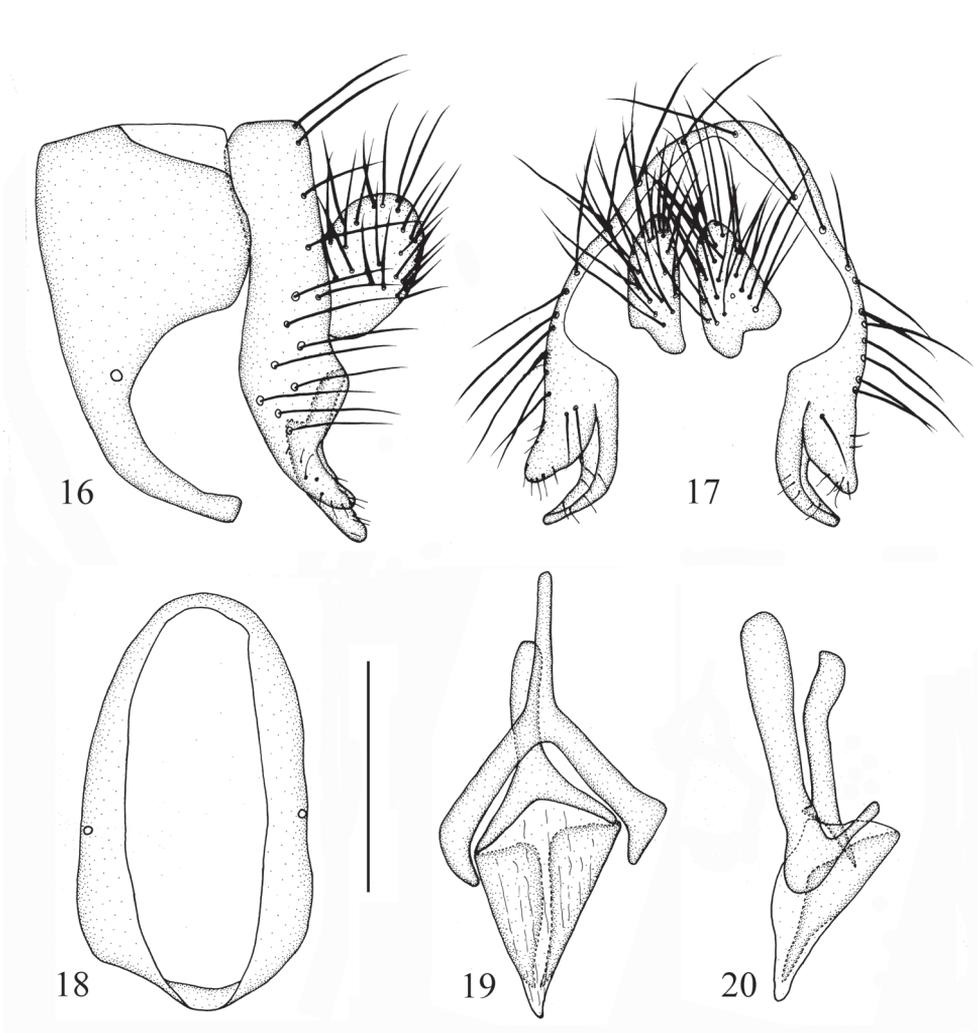
Thorax (Fig. 14) blackish brown with yellow pruinescence. Mesonotum with a pair of brown median bands and a pair of undulating lateral bands on anterior margin, a pair of elliptic brown spots present on scutal suture; one black trapeziform spot present at posterior 1/3, anterior margin of the spot bifurcated. Three dorso-central setae; acrostichal setulae in six rows; a pair of prescutellar setae, shorter than the first dorsocentral seta. One anepisternal seta, one katepisternal seta. Scutellum yellow with gray pruinescence, one brown trapeziform spot present on half basally and connect with the spot of mesonotum, posterior margin of the spot bifurcated. Legs yellow, femur brown except yellow apically; tibia with one incomplete brown ring near base; the fifth tarsus brown. Fore femur with six posterior dorsal setae, four posterior ventral setae, twelve comb-like anterior ventral setae; tibia with one dorsal preapical seta, one short apical ventral seta. Mid femur with eight anterior setae; tibia with one strong dorsal preapical seta, two strong apical ventral setae. Hind femur with preapical anterior dorsal seta; longer than wide, hyaline; r_1 cell half apically with broad brown band connected with the subapical band of r_{2+3} cell and r_{4+5} cell, form wavy band extending to posterior margin; r_{2+3} cell and r_{4+5} cell without margin spot; the hyaline region of *r-m* surrounded by “+” shape brown spot; the hyaline region of



Figures 11–15. *Cestrotus albifacies* sp. nov. Male. **11** head, anterior view **12** wing **13** habitus, lateral view **14** thorax, dorsal view **15** abdomen, dorsal view.

dm-cu surrounded by two brown spots; costa with 2nd, 3rd and 4th sections in proportion of 4.3 : 1.9 : 1; *r-m* behind middle of the discal cell; ultimate and penultimate sections of M_1 in proportion of 2.0 : 1; ultimate section of CuA_1 about 1/7 of penultimate section. Halter yellow.

Abdomen (Fig. 15) with gray pruinescence; tergites I–IV blackish brown, tergites V–IX brownish yellow. Male genitalia (Figs 16–20): syntergosternite circular, broad half dorsally and narrow half ventrally. Epandrium long and narrow in lateral view. Surstylus consisting of one outer process and inner process, the processes similar in



Figures 16–20. *Cestrotus albifacies* sp. nov. Male. **16** syntergosternite and epandrium, lateral view **17** epandrial complex, posterior view **18** syntergosternite, anterior view **19** aedeagal complex, ventral view **20** aedeagal complex, lateral view. Scale bar: 0.2 mm.

shape, rod-like and with setulae, curved in lateral view, inner process longer than outer process in posterior view. Hypandrium Y-shaped, inner process longer than phallapodeme. Gonopod vestigial. Phallus acute apically, without apical concave, with a pair of triangular dorsal sclerites. Phallapodeme as long as phallus.

Remarks. The new species is similar to *Cestrotus heteropterus* Shi, Yang & Gaimari, 2009 from China (Yunnan) in the color of the face and in having spots on the tergite and wing, but the latter has spots on the face and the antennal pedicel brown.

Distribution. China (Yunnan).

***Phobeticomyia motuoensis* sp. nov.**

<http://zoobank.org/13B8BB91-A697-4F68-BA24-207B7A2008F4>

Figures 21–30

Type material. *Holotype*: ♂ (CAUC), CHINA, Tibet: Motuo County, 1100 m, 26.VII.2012, Wenliang Li. *Paratypes*: 1♂ (CAUC), CHINA, Tibet: Motuo County, 1100 m, 28.VII.2012, Wenliang Li; 2♀♀ (CAUC), CHINA, Tibet: Motuo County, 1100 m, 28.VII.2012, Xuankun Li.

Etymology. Latinized, referring to the type locality of the new species.

Diagnosis. Face shining, blackish brown on half basally, yellow on half apically, with a pair of blackish brown trapeziform spots. Frons with two blackish brown velvet longitudinal bands extending to sides of ocellar triangle. Thorax brown with gray pruinescence. Mesonotum with two brown median bands, one gray narrow band between the median bands. Legs blackish brown, hind tibia pale brown, all tibiae with one white ring near tip. Wing brown, with three hyaline spots between R_{2+3} and R_{4+5} . Male genitalia: syntergosternite semicircular; hypandrium V-shaped, with a pair of short inner process on sides, one V-shaped membrane on inferior margin; gonopod with setulae basally, curved apically.

Description. Male. Body length 3.7–3.8 mm, wing length 3.7–3.8 mm. **Female.** Body length 3.8–4.0 mm, wing length 3.9–4.1 mm.

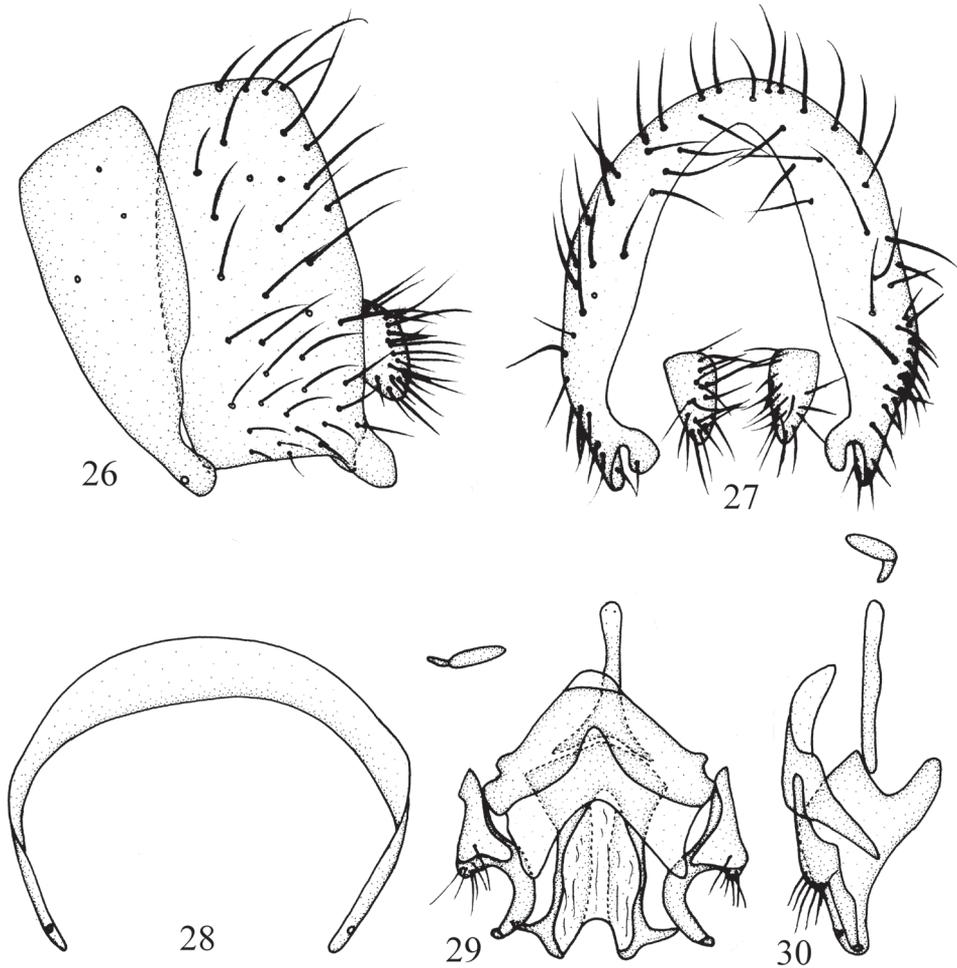
Head (Fig. 21) brownish yellow. Face shining, blackish brown on half basally, yellow on half apically, with a pair of blackish brown trapeziform spots; parafacial black on half basally, yellow on half apically, with silvery pruinescence. Frons yellow, wider than long and parallel-sided, with two blackish brown velvet longitudinal bands extending to sides of ocellar triangle, the bands connected with one W-shape transverse band; ocellar triangle brown, ocellar seta developed, longer than anterior fronto-orbital seta; anterior fronto-orbital seta curved, shorter than posterior fronto-orbital seta. Gena about 1/3 eye height. Antenna yellow except pedicel and scape black; 1st flagellomere about 1.7 times longer than high; arista dark brown except pale brown basally, plumose, the longest ray as long as 1st flagellomere height. A silvery spot present between eye and base of antenna. Proboscis brown, with yellow and black setulae; palpus black with black setulae.

Thorax (Fig. 24) brown with gray pruinescence. Mesoscutum with two brown median bands, one gray narrow band between the median bands; two brown lateral bands behind scutal suture, along rows of dorsocentral setae with one gray narrow band respectively. Three dorsocentral setae, with brown basal spots; acrostichal setulae in eight rows, pubescent; a pair of prescutellar setae, as long as the first dorsocentral seta. One anepisternal seta, two katepisternal seta. Scutellum with brownish yellow pruinescence. Legs blackish brown, hind tibia pale brown, all tibiae with one white ring near tip; fore and hind tibia each with one unobvious white basal ring; tarsi pale yellow, the fifth tarsus brown. Fore femur with eight posterior dorsal setae, five posterior ventral setae, fourteen comb-like anterior ventral setae; tibia with one



Figures 21–25. *Phobeticomyia motuoensis* sp. nov. Male. **21** head, anterior view **22** wing **23** habitus, lateral view **24** thorax, dorsal view **25** abdomen, dorsal view.

dorsal preapical seta, one short apical ventral seta. Mid femur with five anterior setae; tibia with one strong dorsal preapical seta, three apical ventral setae. Hind femur with one weak preapical dorsal seta, one row anterior ventral setae; tibia with one



Figures 26–30. *Phobeticomyia motuoensis* sp. nov. Male. **26** syntergosternite and epandrium, lateral view **27** epandrial complex, posterior view **28** syntergosternite, anterior view **29** aedeagal complex, ventral view **30** aedeagal complex, lateral view.

weak dorsal preapical seta, one short apical ventral seta. Wing (Fig. 22) brown, with one hyaline apical band on outer margin, three hyaline spots present between R_{2+3} and R_{4+5} ; $r-m$ without hyaline spot, the cell in front of $r-m$ with hyaline spot; discal medial cell with two round hyaline spots; $dm-cu$ with one hyaline spot outside, and connected with hyaline apical spot of CuA_1 and hyaline subapical band of m_1 cell; m_1 cell with two hyaline subapical bands, one undulating hyaline along the posterior margin of cua_1 ; subcostal cell with hyaline spot; costa with 2nd, 3rd and 4th sections in proportion of 4.6 : 1.7 : 1; $r-m$ behind middle of the discal cell; ultimate and penultimate sections of M_1 in proportion of 1.4 : 1; ultimate section of CuA_1 about 1/7 of penultimate section. Halter white.

Abdomen (Fig. 25) brown with gray pruinescence. Male genitalia (Figs 26–30): syntergosternite semicircular. Epanthrium near rectangle in lateral view. Surstylus consisting of one short broad outer apical process and one short inner process, the inner process blunt apically and curved in lateral view. Hypandrium V-shaped, with a pair of short inner process on sides, one V-shape membrane on inferior margin. Gonopod with setulae basally, curved apically. Phallus with apical concave and a pair dorsal sclerites, a pair of near apical process present on sides. Phallopodeme shorter than phallus.

Remarks. The new species is similar to *Phobeticomyia lunifera* (de Meijere, 1910) from Indonesia (Java), but the latter has no inner process on the hypandrium, and the phallus has no apical spine.

Distribution. China (Tibet).

***Prosopophorella longa* sp. nov.**

<http://zoobank.org/A0CAF592-59C9-4590-B188-B36C50DA6702>

Figures 31–41

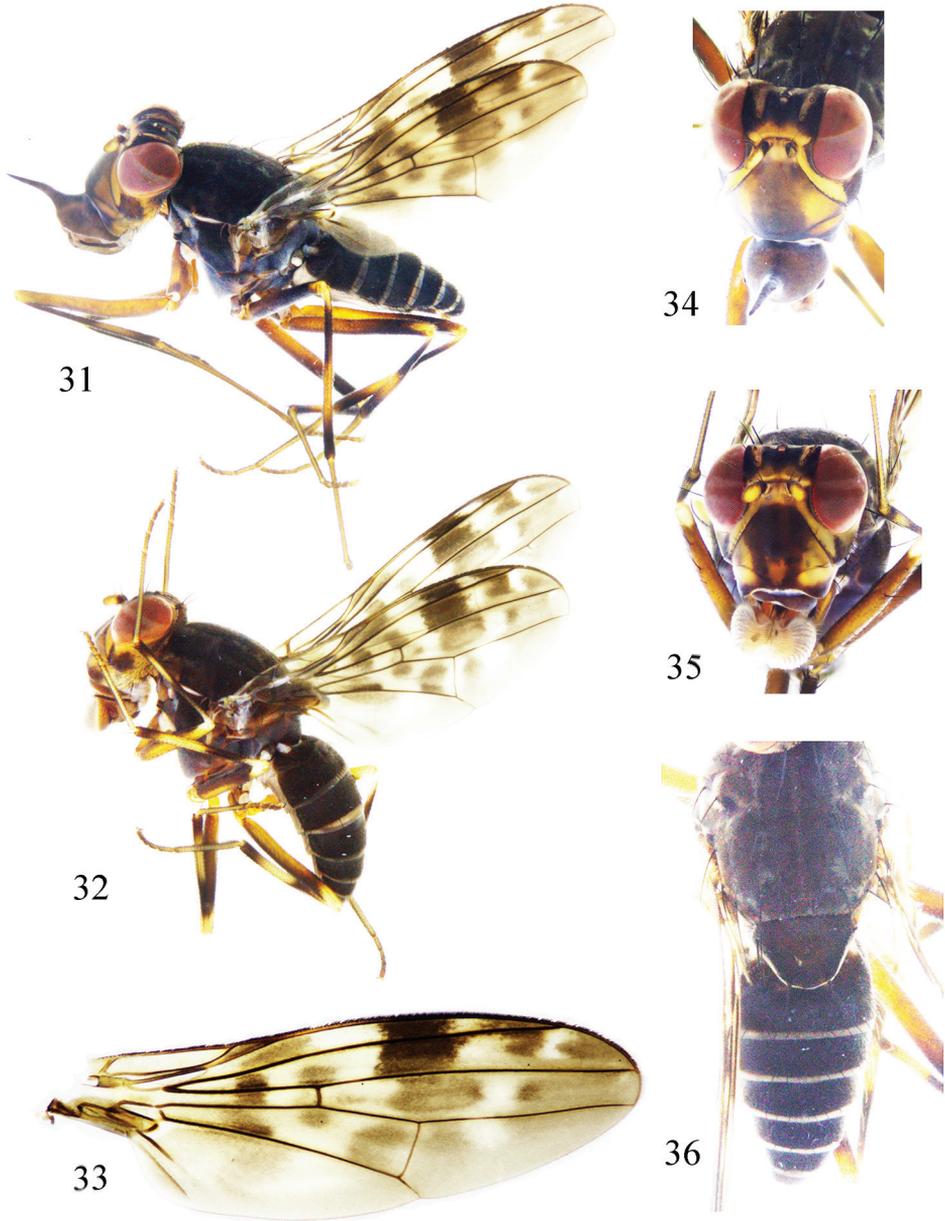
Type material. *Holotype*: ♂ (CAUC), CHINA, Tibet: Motuo County, 1100 m, 26.VII.2012, Xuankun Li. *Paratypes*: (CAUC). 2♀♀ (CAUC), data same as above; 2♀♀ (CAUC), CHINA, Tibet: Motuo County, 1100 m, 26.VII.2012, Wenliang Li.

Etymology. Latin, *longa*, meaning long, referring to the new species' clypeus with one long median process.

Diagnosis. Face brownish yellow, with one brown broad median band on middle. Frons with one yellow W-shape spot on anterior margin. Antenna blackish brown; arista brown, pubescent. With one long median process on male clypeus. Thorax with gray pruinescence. Mesonotum with one narrow gray pruinose band on the middle and a pair of gray pruinose bands along the rows of dorsocentral setae. Legs yellow; tibiae with blackish brown sub-basal ring and apical ring. Wing with one irregular hyaline spot under the tip of R_{2+3} , one hyaline apical spot between R_{4+5} and M_1 . Male genitalia: syntergosternite broad, circular, with a pair of short ventral process; surstylus short, rod-like in lateral view; aedeagal dorsal sclerites consisting of a pair of sclerites, narrow apically.

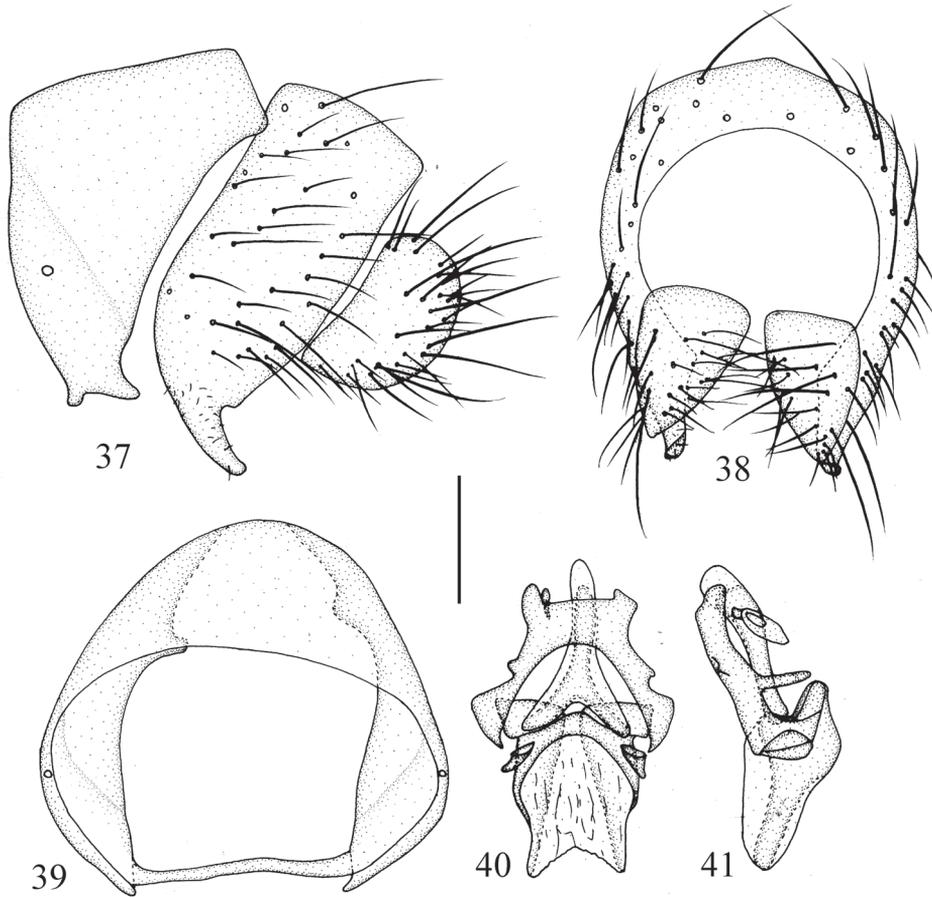
Description. **Male.** Body length 6.5 mm, wing length 6.4 mm. **Female.** Body length 6.5–6.7 mm, wing length 6.4–6.5 mm.

Head (Figs 34, 35) yellow. Face brownish yellow, with one brown broad median band on middle, a pair of triangular blackish brown lateral spots on ventral-lateral angle; parafacial black on inner margin. Frons yellow, wider than long and parallel-sided, with one yellow W-shape spot on anterior margin, two triangular black spots on half apically; the middle with one black velvet rectangular spot extending to vertex, and connected with the triangular black spot on lateral margin; ocellar triangle black, ocellar seta developed, longer than anterior fronto-orbital seta; anterior fronto-orbital seta curved. Occiput yellow, male with one broad brown median band connected with black velvet rectangular spot. Gena yellow, with one brown rectangular spot; gena



Figures 31–36. *Prosopophorella longa* sp. nov. Male. **31** habitus, lateral view **33** wing **34** head, anterior view **36** thorax and abdomen, dorsal view; female. **32** habitus, lateral view **35** head, anterior view.

about 1/3 eye height. Antenna blackish brown, 1st flagellomere yellow except brown on dorsal margin and tip; 1st flagellomere about 1.2 times longer than high; arista brown, pubescent. The black band of inner margin between eye and antenna nearly triangular, connected with the black triangular spot of frons lateral margin. Clypeus black, with



Figures 37–41. *Prosopophorella longa* sp. nov. Male. **37** sytergosternite and epandrium, lateral view **38** epandrial complex, posterior view **39** sytergosternite, anterior view **40** aedeagal complex, ventral view **41** aedeagal complex, lateral view. Scale bar: 0.2 mm.

one long median process. Proboscis yellow except blackish brown apically, with yellow and black setulae; palpus blackish brown with black setulae.

Thorax (Fig. 36) blackish brown with gray pruinescence. Mesonotum with one narrow gray pruinescent band on the middle and a pair of gray pruinescent bands along the rows of dorsocentral setae. Three dorsocentral setae, the most anterior dorsocentral setae near scutal suture; acrostichal setulae in six rows, pubescent; a pair of prescutellar setae, shorter than the first dorsocentral seta. One anepisternal seta, one katepisternal seta. Legs yellow; coxa pale brown; femora brown except yellow apically; tibiae with blackish brown sub-basal ring and apical ring. Fore femur with five posterior dorsal setae, two posterior ventral setae, 27 comb-like anterior ventral setae; tibia with one weak dorsal preapical seta, one short apical ventral seta. Mid femur with eight anterior setae; tibia with one strong dorsal preapical seta, two apical ventral setae. Hind tibia with one dorsal preapical seta, one short apical ventral seta. Wing (Fig. 33) about 3.1–3.3

times longer than wide, hyaline, with one narrow brown sub-basal band connect with gray posterior margin, one broad brown median band extending to *dm-cu*, one brown subapical band connect with gray posterior margin, one hyaline band between brown subapical band and median band; one irregular hyaline spot present under the tip of R_{2+3} , one hyaline apical spot between R_{4+5} and M_1 ; *r-m* and *dm-cu* with narrow hyaline bands, surround by brown cloud-like spot; subcostal cell with brown spot apically, the spot through R_1 ; costa with 2nd, 3rd and 4th sections in proportion of 8.2 : 3.1 : 1; *r-m* behind middle of the discal cell; ultimate and penultimate sections of M_1 in proportion of 2.2 : 1; ultimate section of CuA_1 about 1/8 of penultimate section. Halter white.

Abdomen (Fig. 36) blackish brown. Male genitalia (Figs 37–41): syntergosternite broad, circular, with a pair of short ventral process. Epandrium near rectangle in lateral view. Surstylus short, rod-like in lateral view. Hypandrium V-shaped, with a pair of inner processes and a pair of lateral processes. Gonopod short. Aedeagal dorsal sclerites consisting of a pair of sclerites, narrow apically; apical concave deep.

Remarks. The new species is similar to *Prosopophorella zhuai* Shi & Yang, 2009 from China (Guangxi) in body color, face, wing type and male genitalia. However, tarsi 3–5 of the latter is pale brown and the syntergosternite has no ventral process, whereas tarsi 3–5 in the new species is yellow and the syntergosternite has a pair of ventral processes.

Distribution. China (Tibet).

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A conservation checklist of the amphibians and reptiles of the State of Mexico, Mexico with comparisons with adjoining states

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Abstract

The State of Mexico has a unique combination of geographic characteristics and topography that promotes a high biodiversity. Unfortunately, continued human population growth of the metropolitan areas of Mexico City and Toluca have degraded the environment of the State of Mexico, which threatened its wildlife. An updated checklist of the amphibians and reptiles of the State of Mexico is provided and their conservation status summarized. The State of Mexico has 49 species of amphibians and 101 species of reptiles. The majority of the amphibians (73.5%) and reptiles (70.3%) found in the State of Mexico are endemic to Mexico. Of the amphibian and reptile species in the State of Mexico, 20.1% are IUCN listed (i.e., Vulnerable, Near Threatened, or Endangered), 18.4% are placed in a protected category by SEMAR-NAT (excluding NL and Pr, this last category is equivalent to the LC category of IUCN), and 34.9% are categorized as high risk by the EVS. The importance of forested habitats for the protected amphibians and reptiles in the State of Mexico suggest that management of these habitats to maintain or expand them needs to be considered.

Keywords

checklist, crocodylians, frogs, herpetofauna, lizards, salamanders, snakes, turtles

Introduction

Although relatively small, the State of Mexico bears unique geographic characteristics that combined with its topography create conditions that promote a high level of biodiversity. Unfortunately, these same conditions along with the continued human population growth of the metropolitan area of Mexico City and the city of Toluca have created high water and air pollution levels, deforestation, habitat fragmentation, and low water availability, which threaten the wildlife of this state (Rodríguez Romero et al. 2008; Flores-Villela et al. 2010). For example, atmospheric water in the Valley of Mexico contains heavy metals that are detectable and exceed regulatory limits when condensed (Bautista-Olivas et al. 2014). This is especially important for amphibians and reptiles, which are represented in the State of Mexico by a unique assortment of species. Central Mexico, including the State of Mexico, contains several areas of high endemism for the herpetofauna of Mexico and as such is very important to the conservation of the Mexican herpetofauna (Flores-Villela et al. 2010).

Here, we provide an updated checklist of the amphibians and reptiles documented in the State of Mexico. We also summarize the conservation status of these species with the goal of determining if there are particular taxa of conservative concern in the State of Mexico. In addition, we consider the overlap in species between the State of Mexico and its neighboring states.

Physiographic characteristics of the state

The State of Mexico is the most populous, as well as the most densely populated state in Mexico. It is located in south-central Mexico, in the highest part of the Mexican Altiplano, between 18°22'0.84"N and 20°17'9.24"N, and 100°36'46.8"W and 98°35'48.84"W (Fig. 1). It is bordered by the states of Querétaro and Hidalgo to the north, Morelos and Guerrero to the south, Michoacán to the west, Tlaxcala and Puebla to the east, and surrounds Mexico City on three sides (west, north, and east). The state is relatively small (22,351 km²) and is the seventh smallest Mexican state, representing 1% of the total surface territory of Mexico (modified from Wikipedia – https://en.wikipedia.org/wiki/State_of_Mexico – accessed 21 November 2019).

The topography of the state is highly variable, with the highest mountains in the extreme eastern part of the state along the border with Puebla (Popocatepetl 5,380 m altitude, Iztaccíhuatl 5,203 m, Monte Tláloc 4,120 m), and in the central part of the state (Nevado de Toluca 4,643 m), as well as rugged intermontane valleys, hills and plains, with altitudes ranging from 300 m near the border with Guerrero to 5,380 m on the top of the Popocatepetl Volcano (Fig. 2). The State of Mexico contains two physiographic provinces: a) Eje Neovolcánico, and b) Sierra Madre del Sur (Fig. 3; modified from INEGI 2017). The Eje Neovolcánico comprises most of the state, occupying the central, northern and eastern portions of the state. This province is divided into three sub-provinces: a) Lagos y Volcanes de Anáhuac, which occupies most of the central, north, and east portions of the state, and includes the northern part of the



Figure 1. Map of Mexico with the State of Mexico shown in red (modified from INEGI, 2018a).

Metropolitan Zone of Mexico and the city of Toluca. b) Mil Cumbres, a thin strip running from north to south and lying between the sub-provinces of Lagos y Volcanes de Anáhuac and Depresión del Balsas, and eastern Michoacán. c) Planicies y Sierras de Querétaro e Hidalgo, a small portion at the northern end of the state that borders Querétaro and Hidalgo. The Sierra Madre del Sur comprises the southwestern corner of the state along its border with Guerrero and western-northwestern Morelos, and is divided into two sub-provinces: a) Depresión del Balsas, which is bordered by northern Guerrero, and b) Sierras y Valles Guerrerenses, which is a small area bordering northern Guerrero and western-northwestern Morelos (Fig. 3).

The State of Mexico has a variety of vegetation types (Fig. 4; modified from INEGI 2017). Agricultural Areas that occupy 54.61% of the state's surface area, and are found mainly in the central, northern, and eastern parts of the state, occupying most of the province of the Eje Neovolcánico. Woodlands cover 27.22% of the state's surface area, and are scattered at the higher elevations of the Eje Neovolcánico province, especially the western foothills of the Popocatepetl and Iztaccíhuatl volcanoes, the Sierra de las Cruces – Sierra del Ajusco complex, the area surrounding the Nevado de Toluca Volcano, and most of the Mil Cumbres Subprovince. Woodlands include Oak Forests which are distributed between 1,600 and 2,400 meters above sea level; Pine-Oak Forest, which develops above 2,400 meters altitude; and Pine Forest, which develops in the highest elevations of the state's mountains. At the highest elevations, this forest is surrounded by padded grasses including *Mülhenbergia rigida*, *Stipa ichu*, and *Bouteloa gracilis* among others. Grasslands, covering 12.15% of state's surface area, occur in

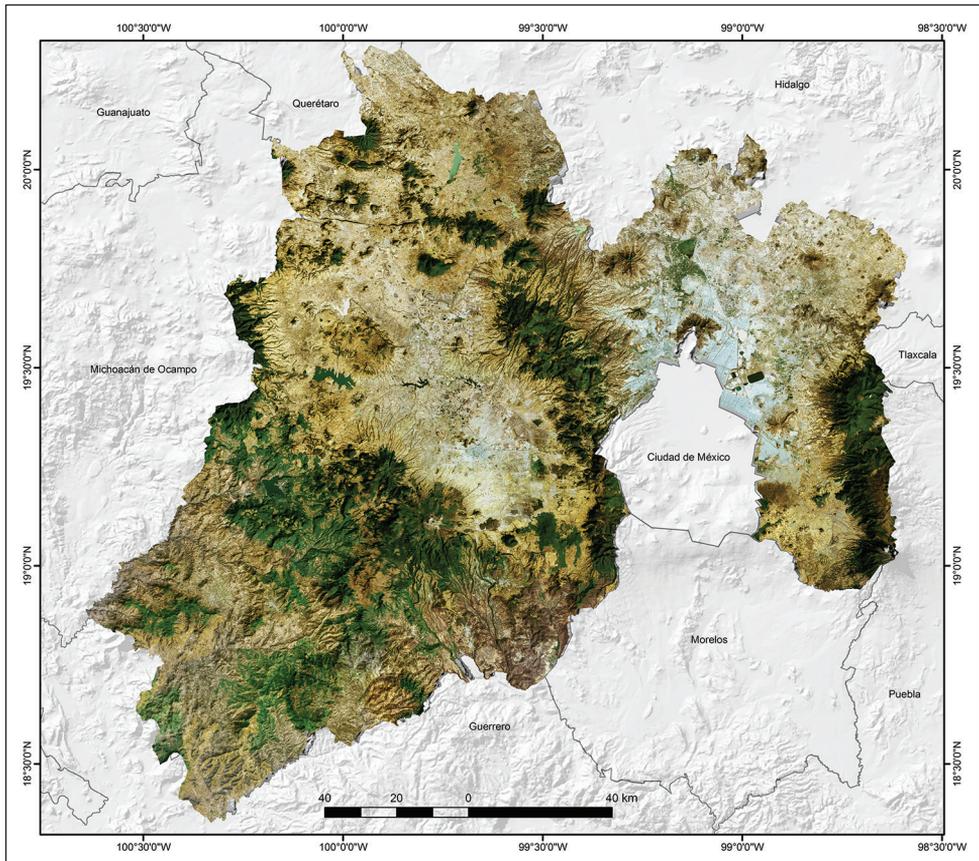


Figure 2. Topographical map of the State of Mexico, Mexico (CONABIO, 1997).

isolated areas in the northern, central, and southwestern parts of the state and they intermingle with Tropical Forests, which are limited to some scattered spots in the Sub-provinces of the Sierra Madre del Sur. Tropical Forest, comprising 5.34% of the state's surface area, is represented by Tropical Deciduous Forest, also called Tropical Dry Forest, that develops between 1,500 and 1,600 m altitude. These forests, although lush, lose their leaves during the dry season (winter-spring), and have dense foliage during the rainy season (summer). Scrubland covers only 0.2% of the state's surface area. The remaining 0.41% is represented by scattered areas lacking vegetation (Fig. 4).

Given the geographical location and diversity of the natural regions in the state, there are several climates in the State of Mexico (Fig. 5; modified from López-Cano et al. 2009; INEGI 2017). A warm sub-humid climate with summer rains and semi-humid with summer rains is found in the Balsas Basin in the extreme southwestern part of the state, covering 20.8% of the state area. The temperate sub-humid with summer rains is found over most of the Lerma Basin and Valley of Mexico, covering most of the state (61.7% of the state). The wet semi-cold climate with abundant rains in summer and sub-humid semi-cold with summer rains is present in the highest mountains of

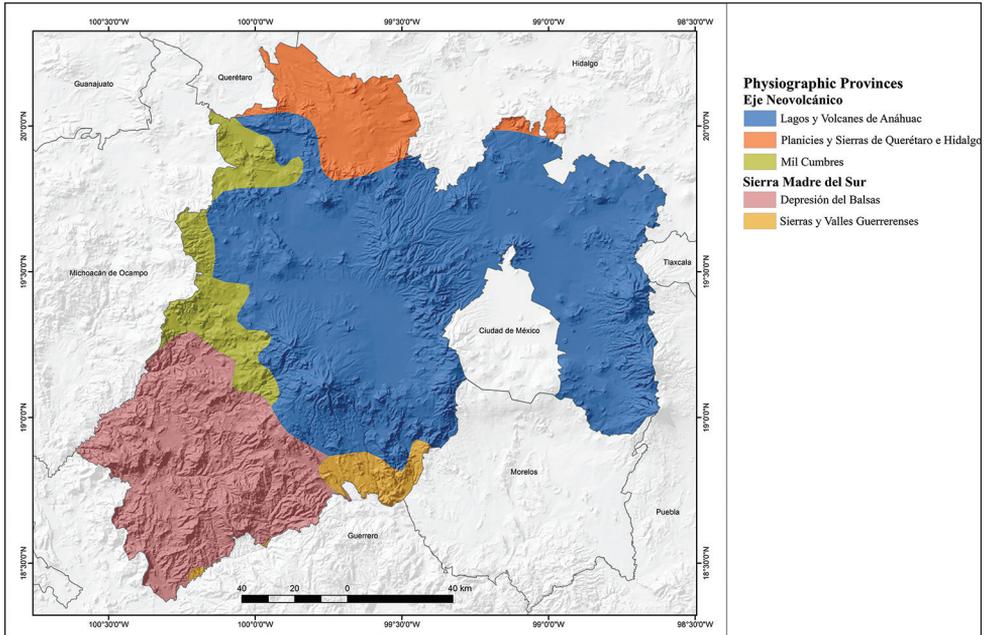


Figure 3. Physiographic provinces of the State of Mexico, Mexico (modified from Cervantes-Zamora et al. 1990).

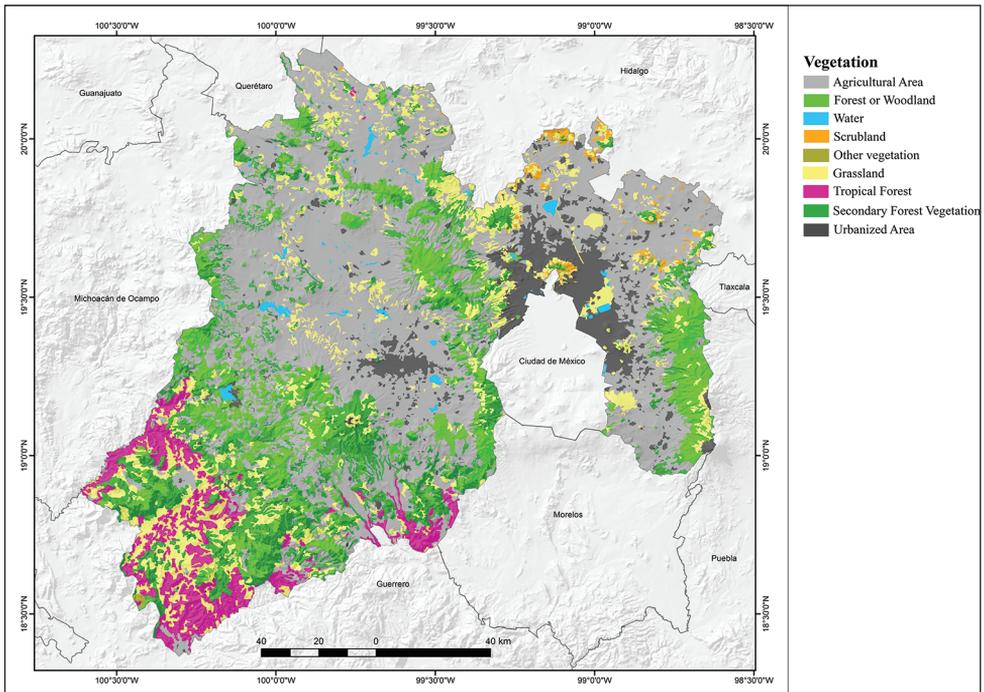


Figure 4. Vegetation map of the State of Mexico, Mexico (modified from Dirección General de Geografía – INEGI 2016).

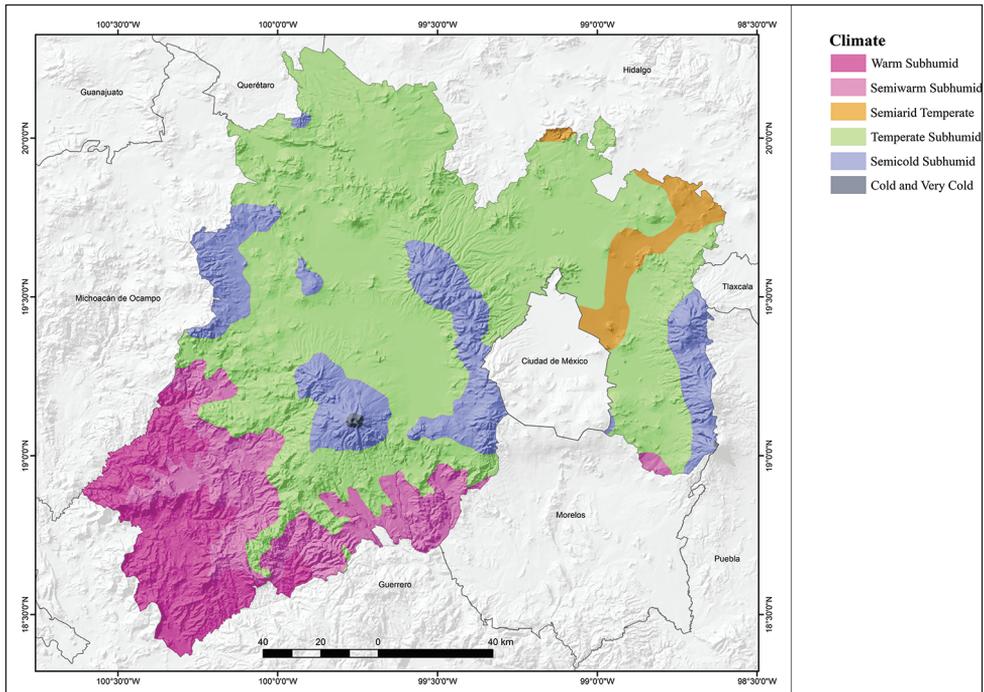


Figure 5. Climate map of the State of Mexico, Mexico (modified from García – Comisión Nacional para el Conocimiento y Uso de la Biodiversidad 1998).

the state (Nevado de Toluca, Sierra Nevada, Sierra las Cruces, Sierra del Ajusco, etc.), covering 11.6% of the state surface. The temperate semi-dry climate is found in the northeast corner of the state, in a strip that runs from the central eastern part of the state, on the northeastern limit of Mexico City to northeastern State of Mexico on the border with Hidalgo, covering 5.7% of the state surface. A Cold climate present on the summits of the Nevado de Toluca, Popocatepetl, and Iztaccíhuatl volcanoes, covering 0.2% of the state's area.

Materials and methods

We compiled our list of amphibians and reptiles of the State of Mexico from our field work over several years, especially within the past 5–10 years, a thorough examination of available literature on amphibians and reptiles in the state, amphibian and reptile records for the State of Mexico in VertNet.org, and amphibian and reptile records for the State of Mexico in Servicio de Descarga de Ejemplares del Sistema Nacional de Información sobre Biodiversidad (SNIB-CONABIO), data bases Amphibians State of Mexico and Reptiles State of Mexico. Amphibian names follow Frost (2019) and AmphibiaWeb (2019) (<http://amphibiaweb.org>) and reptile names follow Uetz and Hošek

(2019). We included species in the list only if we could confirm records by either direct observation or documented museum records or vouchers.

We made species accumulation curves for the total herpetofauna, and amphibians and reptiles separately using the year of the first recorded observation for each species. These curves can estimate the potential species richness of amphibians and reptiles (see Raxworthy et al. 2012). For each species, we recorded conservation status based on the IUCN Red List 2019-2, listing in SEMARNAT (2019), and Environmental Vulnerability Scores (Wilson et al. 2013a, b; Johnson et al. 2015). We determined the number of species found in the State of Mexico that overlapped with neighboring states and Mexico City using recent state lists (Michoacán, Alvarado-Díaz et al. 2013; Hidalgo, Lemos-Espinal and Smith 2015; Puebla, Woolrich-Piña et al. 2017; Guerrero, Palacios-Aguilar and Flores-Villela 2018; Mexico City, Lemos-Espinal and Smith in press; Morelos, Lemos-Espinal and Smith 2020; and Querétaro, Cruz-Elizalde et al. 2019). We did not include the state of Tlaxcala since no comprehensive check list of the amphibians and reptiles of this state currently exists. We generated border lengths with the INEGI state division map for the year 2018 using ArcMap 10.7.1 neighboring polygon tool (June 2019).

Results and discussion

The State of Mexico is home to 150 species of amphibians and reptiles representing 31 families (two introduced: Gekkonidae and Typhlopidae) and 65 genera (two introduced: *Hemidactylus* and *Indotyphlops*) (Table 1; Fig. 6). The herpetofauna of the State of Mexico includes 49 species of amphibians (33 anurans [one introduced], and 16 salamanders), and 101 reptiles (40 lizards [one introduced], 57 snakes [one introduced], and four turtles). The three introduced species are the American Bullfrog (*Rana catesbeiana*), the Common House Gecko (*Hemidactylus frenatus*), and the Brahminy Blindsnake (*Indotyphlops braminus*). Five of the 147 native species of the State of Mexico are endemic to the state: the Delicate-skinned Salamander (*Ambystoma bombypellum*), the Granular Salamander (*Ambystoma granulosum*), the Lake Lerma Salamander (*Ambystoma lermaense*), Roberts' False Brook Salamander (*Pseudoeurycea robertsi*), and the Herrera Alligator Lizard (*Barisia herrerae*). The most species rich families of amphibians in the State of Mexico are Hylidae, Ambystomatidae, and Plethodontidae, whereas the most species rich families of reptiles are Phrynosomatidae and Colubridae (Table 1).

The species accumulation curves for the total herpetofauna, reptiles, and amphibians all show a steep increase in the number of species documented in the State of Mexico in the second half of the 20th century, and that trend appears to be continuing, albeit at a somewhat slower rate in the 21st century (Fig. 7). This suggests that the overall number of amphibians and reptiles in the State of Mexico is likely to increase over time. Indeed, we compiled a list of 21 species (two amphibians, 19 reptiles: Table 2) that potentially occur in the State of Mexico (Table 2). These potential species are distributed mainly along the border with Guerrero (extreme southwest-

Table 1. Amphibians and reptiles of the State of Mexico with distributional and conservation status. Vegetation Type: (1 = Oak Forest; 2 = Pine-oak Forest; 3 = Pine Forest; 4 = Tropical Deciduous Forest; 5 = Grassland; 6 = Scrubland); IUCN Status: (DD = Data Deficient; LC = Least Concern, VU = Vulnerable, NT = Near Threatened; EN = Endangered; CR = Critically Endangered; NE = not Evaluated) according to the IUCN Red List (IUCN 2019); Environmental Vulnerability Score: (EVS – the higher the score the greater the vulnerability: low (L) vulnerability species (EVS of 3–9); medium (M) vulnerability species (EVS of 10–13); and high (H) vulnerability species (EVS of 14–20) (Wilson et al. 2013a,b; Johnson et al. 2015); conservation status in Mexico according to SEMARNAT (2019): (P = in danger of extinction, A = threatened, Pr = subject to special protection, NL – not listed). Global Distribution: 0 = Endemic to the State of Mexico; 1 = Endemic to Mexico; 2 = Shared between the US and Mexico; 3 = widely distributed from Mexico to Central or South America; 4 = widely distributed from the US to Central or South America; IN = Introduced to State of Mexico. Date in which the first record appeared; and Source of the first record.

	Vegetation type	IUCN status	SEMARNAT	EVS	Global distribution	Year of first record	Source
CLASS AMPHIBIA							
ORDER ANURA							
FAMILY BUFONIDAE (5)							
<i>Anaxyrus compactilis</i> (Wiegmann, 1833)	1,2,5,6	LC	NL	H (14)	1	1888	Dugès 1888
<i>Incilius marmoratus</i> (Wiegmann, 1833)	4	LC	NL	M (13)	1	1930	MCZ-A 17755
<i>Incilius occidentalis</i> (Camerano, 1879)	1,2,3,6	LC	NL	M (11)	1	1941	TCWC 6365
<i>Incilius perplexus</i> (Taylor, 1943)	4	EN	NL	M (11)	1	1983	Camarillo-Rangel 1983
<i>Rhinella horribilis</i> (Wiegmann, 1833)	4	LC	NL	L (3)	4	1941	UIMNH 25155
FAMILY CRAUGASTORIDAE (4)							
<i>Craugastor augusti</i> (Dugès, 1879)	2,6	LC	NL	L (8)	2	1942	Taylor 1942
<i>Craugastor hobartsmithi</i> (Taylor, 1937)	2	EN	NL	H (15)	1	1936	UIMNH 18301
<i>Craugastor pygmaeus</i> (Taylor, 1937)	1,2,3	VU	NL	L (9)	3	1992	Camarillo-Rangel and Smith 1992
<i>Craugastor rugulosus</i> (Cope, 1870)	3	LC	NL	M (13)	3	1968	UTEP Herp:7475
FAMILY ELEUTHERODACTYLIDAE (4)							
<i>Eleutherodactylus angustidigitorum</i> (Taylor, 1940)	1,2,3,6	VU	Pr	H (17)	1	1954	TCWC 11158
<i>Eleutherodactylus maurus</i> Hedges, 1989	1,2,3	DD	Pr	H (17)	1	1954	TCWC 11259
<i>Eleutherodactylus nitidus</i> (Peters, 1870)	1,2,3	LC	NL	M(12)	1	1951	AMNH A-55227
<i>Eleutherodactylus pipilans</i> (Taylor, 1940)	4	LC	NL	M (11)	3	1979	MZFC 3764
FAMILY HYLIDAE (9)							
<i>Dryophytes arenicolor</i> (Cope, 1886)	1,2,3,4,5,6	LC	NL	L (7)	2	1921	MCZ A-8367
<i>Dryophytes eximius</i> (Baird, 1854)	1,2,3,6	LC	NL	M (10)	1	1919	AMNH A 13256
<i>Dryophytes plicatus</i> (Brocchi, 1877)	1,2,3,6	LC	A	M (11)	1	1912	MCZ-A 25699
<i>Exerodonta smaragdina</i> (Taylor, 1940)	4	LC	Pr	M (12)	1	1992	Camarillo-Rangel and Smith 1992
<i>Sarcohyala bistrincta</i> (Cope, 1877)	1,2,3	LC	Pr	L (9)	1	1938	UIMNH 17903
<i>Sarcohyala pentheter</i> (Adler, 1965)	4	EN	NL	M (13)	1	2009	Aguilar-Miguel et al. 2009
<i>Smilisca baudinii</i> (Duméril & Bibron, 1841)	1,2,4,6	LC	NL	L (3)	4	1982	CNAR 3912
<i>Smilisca fodiens</i> (Boulenger, 1882)	4	LC	NL	L (8)	2	1968	UTEP H 8448
<i>Tlalocohyla smithii</i> (Boulenger, 1902)	4	LC	NL	M (11)	1	1968	UTEP H 7713
FAMILY LEPTODACTYLIDAE (1)							
<i>Leptodactylus melanonotus</i> (Hallowell, 1861)	4	LC	NL	L (6)	3	1965	ENCB 7687
FAMILY MICROHYLIDAE (1)							
<i>Hypopachus variolosus</i> (Cope, 1866)	4	LC	NL	L (4)	4	1941	ENCB 2905
FAMILY PHYLLOMEDUSIDAE (1)							
<i>Agalychnis dacnicolor</i> (Cope, 1864)	4	LC	NL	M (13)	1	1983	Camarillo-Rangel 1983
FAMILY RANIDAE (7)							
<i>Rana catesbeiana</i> Shaw, 1802	IN	IN	IN	IN	IN	1982	CNAR 17313
<i>Rana forreri</i> Boulenger, 1883	4	LC	Pr	L (3)	3	1940	CNAR 620
<i>Rana montezumae</i> Baird, 1854	1,2,3,5,6	LC	Pr	M (13)	1	1888	Dugès 1888
<i>Rana neovolcanica</i> Hillis & Frost, 1985	1,2,3	NT	A	M (13)	1	2009	MZFC 23392
<i>Rana spectabilis</i> Hillis & Frost, 1985	1,2,3,5,6	LC	NL	M (12)	1	1936	FMNH 110654
<i>Rana tlaloci</i> Hillis & Frost, 1985	1,2,5,6	CR	P	H (15)	1	1979	ENCB 10567

	Vegetation type	IUCN status	SEMARNAT	EVS	Global distribution	Year of first record	Source
<i>Rana zweifeli</i> Hillis, Frost & Webb, 1984	1,2,3,4,5	LC	NL	M (11)	1	1982	ENCB 11912
FAMILY SCAPHIOPODIDAE (1)							
<i>Spea multiplicata</i> (Cope, 1863)	1,5	LC	NL	L (3)	2	1940	UIMNH 27893
ORDER CAUDATA							
FAMILY AMBYSTOMATIDAE (8)							
<i>Ambystoma altamirani</i> Dugès, 1895	1,2,3,5	EN	A	M (13)	1	1895	Dugès 1895
<i>Ambystoma bombypellum</i> Taylor, 1940	2,5	CR	Pr	H (15)	0	1940	Taylor 1940a
<i>Ambystoma granulosum</i> Taylor, 1944	1,2,3,5	CR	Pr	H (14)	0	1944	Taylor 1944
<i>Ambystoma leonae</i> (Taylor, 1943)	2,3,5	CR	A	H (15)	1	1943	Taylor 1943
<i>Ambystoma lermaense</i> (Taylor, 1940)	5	EN	Pr	H (15)	0	1940	Taylor 1940a
<i>Ambystoma ordinarium</i> Taylor, 1940	?	EN	Pr	M (13)	1	22004	Matias-Ferrer and Murillo 2004a
<i>Ambystoma rivulare</i> (Taylor, 1940)	1,2,3,5	DD	A	M (13)	1	1940	Taylor 1940b
<i>Ambystoma velasci</i> Duges, 1888	1,2,3,5,6	LC	Pr	M (10)	1	1888	Dugès 1888
FAMILY PLETHODONTIDAE (8)							
<i>Aquiloerycea cephalica</i> (Cope, 1865)	1,2,3,5	NT	A	H (14)	1	1938	UIMNH 30898
<i>Chiropterorion orculus</i> (Cope, 1865)	1,2,3,5	VU	NL	H (18)	1	1951	MVZ 54646
<i>Isthmura belli</i> (Gray, 1850)	1,2,3,5	VU	A	M (12)	1	1938	UIMNH 30881
<i>Pseudoerycea altamontana</i> (Taylor, 1939)	1,2,3,5	EN	Pr	H (17)	1	1956	UCM 8117
<i>Pseudoerycea leprosa</i> (Cope, 1869)	1,2,3,5	LC	A	H (16)	1	1921	UMMZ 56989
<i>Pseudoerycea longicauda</i> Lynch, Wake, & Yang, 1983	1,2,3,5	EN	Pr	H (17)	1	1983	Lynch et al. 1983
<i>Pseudoerycea robertsi</i> (Taylor, 1939)	1,2,3,5	CR	A	H (18)	1	1939	Taylor 1939
<i>Pseudoerycea tillicixil</i> Lara-Góngora, 2003	1,2,3,5	EN	NL	H (17)	1	2003	Lara-Góngora 2003
CLASS REPTILIA							
SUBORDER LACERTILIA							
FAMILY ANGUIDAE (5)							
<i>Abronia deppii</i> (Wiegmann, 1828)	2	EN	A	H (16)	1	1979	MZFC 6294
<i>Barisia berrenae</i> Zaldivar-Riverón & Nieto Montes de Oca, 2002	2,3	EN	NL	H (15)	0	2002	Zaldivar-Riverón and Nieto Montes de Oca 2002
<i>Barisia imbricata</i> (Wiegmann, 1828)	1,2,3,5,6	LC	Pr	H (14)	1	1888	Dugès 1888
<i>Barisia rudicollis</i> (Wiegmann, 1828)	1,2,3,5	EN	P	H (15)	1	1828	Wiegmann 1828
<i>Gerrhonotus liocephalus</i> Wiegmann, 1828	1,2,3,5	LC	Pr	L (6)	1	1938	FMNH 112024
FAMILY DACTYLOIDAE (1)							
<i>Anolis nebulosus</i> (Wiegmann, 1834)	1,2,4	LC	NL	M (13)	1	1940	UCM 46440
FAMILY GECKONIDAE (1)							
<i>Hemidactylus frenatus</i> Duméril & Bribon, 1836	IN	IN	IN	IN	IN	1998	Casas-Andreu et al. 1998
FAMILY HELODERMATIDAE (1)							
<i>Heloderma horridum</i> (Wiegmann, 1829)	4	LC	A	M (11)	3	1933	MVZ Herp 16434
FAMILY IGUANIDAE (1)							
<i>Ctenosaura pectinata</i> (Wiegmann, 1834)	4	NE	A	H (15)	1	1982	CNAR 3910
FAMILY PHRYNOSOMATIDAE (19)							
<i>Phrynosoma orbiculare</i> (Linnaeus, 1758)	1,2,5,6	LC	A	M (12)	1	1888	Dugès 1888
<i>Sceloporus aeneus</i> Wiegmann, 1828	5,6	LC	NL	M (13)	1	1921	MCZ R-16069
<i>Sceloporus anahuacus</i> Lara-Góngora, 1983	1,2,3	LC	NL	H (15)	1	1979	UCM 52300
<i>Sceloporus bicanthalis</i> Smith, 1937	5	LC	NL	M (13)	1	1937	MCZ R-170033
<i>Sceloporus dugesii</i> Bocourt, 1874	2,5	LC	NL	M (13)	1	1983	CNAR 5006
<i>Sceloporus gadoviae</i> Boulenger, 1905	4	LC	NL	M (11)	1	1996	CNAR 12304
<i>Sceloporus grammicus</i> Wiegmann, 1828	1,2,3,6	LC	Pr	L (9)	1	1888	Dugès 1888
<i>Sceloporus horridus</i> Wiegmann, 1834	4	LC	NL	M (11)	1	1951	AMNH R-71351
<i>Sceloporus megalopidurus</i> Smith, 1934	4	VU	Pr	H (14)	1	1971	MCZ R-133166
<i>Sceloporus melanorhinus</i> Bocourt, 1876	4	LC	NL	L (9)	3	1977	MZFC 6312
<i>Sceloporus mucronatus</i> Cope, 1885	2,3,5	LC	NL	M (13)	1	1939	USNM 112207
<i>Sceloporus ochoterrenae</i> Smith, 1934	4	LC	NL	M (12)	1	1992	Camarillo-Rangel and Smith 1992
<i>Sceloporus palaciosi</i> Lara-Góngora, 1983	1,2,3	LC	NL	H (15)	1	1976	USNM 245337
<i>Sceloporus pyrocephalus</i> Cope, 1864	4	LC	NL	M (12)	1	1982	CNAR 3900
<i>Sceloporus scalaris</i> Wiegmann, 1828	5,6	LC	NL	M (12)	1	1888	Dugès 1888

	Vegetation type	IUCN status	SEMARNAT	EVS	Global distribution	Year of first record	Source
<i>Sceloporus spinosus</i> Wiegmann, 1828	1,2,5,6	LC	NL	M (12)	1	1922	MVZ 8851
<i>Sceloporus sugillatus</i> Smith, 1942	1,2,3	LC	NL	H (16)	1	1939	UIMNH 10753
<i>Sceloporus torquatus</i> Wiegmann, 1828	1,2,3,5,6	LC	NL	M (11)	1	1888	Dugès 1888
<i>Urosaurus bicarinatus</i> (Duméril, 1856)	4	LC	NL	M (12)	1	1930	MCZ R-33686
FAMILY PHYLLODACTYLIDAE (1)							
<i>Phyllodactylus lanei</i> Smith, 1935	4	LC	NL	H (15)	1	1981	CNAR 3550
FAMILY SCINCIDAE (6)							
<i>Marisora brachypoda</i> (Taylor, 1956)	4	LC	NL	L (6)	3	1882	USNM 12718
<i>Plestiodon brevirostris</i> (Günther, 1860)	1,2,3	LC	NL	M (11)	1	1942	KUNHM 25937
<i>Plestiodon copei</i> (Taylor, 1933)	1,2,3	LC	Pr	H (14)	1	1932	USNM 92547
<i>Plestiodon dugesii</i> (Thomiot, 1883)	1,2,3	VU	Pr	H (16)	1	1954	KUNHM 38080
<i>Plestiodon indubitus</i> (Taylor, 1933)	1,2,3	NE	NL	H (15)	1	1932	UIMNH 22701
<i>Plestiodon lynxe</i> (Wiegmann, 1834)	1,2,3	LC	Pr	M (10)	1	1974	UTA 4182
FAMILY TEIIDAE (5)							
<i>Aspidoscelis communis</i> (Cope, 1878)	4	LC	Pr	H (14)	1	2009	Aguilar-Miguel et al. 2009
<i>Aspidoscelis costatus</i> (Cope, 1878)	4	LC	Pr	M (11)	1	1941	ENCB 6757
<i>Aspidoscelis deppii</i> (Wiegmann, 1834)	4	LC	NL	L (8)	3	1977	MZFC 5884
<i>Aspidoscelis gularis</i> (Baird & Girard, 1852)	4	LC	NL	L (9)	4	1930	MCZ Herp R-33685
<i>Aspidoscelis sackii</i> (Wiegmann, 1834)	4	LC	NL	H (14)	1	1966	ENCB 4285
SUBORDER SERPENTES							
FAMILY BOIDAE (1)							
<i>Boa sigma</i> Smith, 1943	4	NE	NL	H (15)	1	1985	Camarillo-Rangel et al. 1985
FAMILY COLUBRIDAE (21)							
<i>Conopsis biserialis</i> (Taylor & Smith, 1942)	1,2,3,6	LC	A	M (13)	1	1932	Taylor and Smith 1942
<i>Conopsis lineata</i> (Kennicott, 1859)	1,2,3,6	LC	NL	M (13)	1	1859	Kennicott 1859
<i>Conopsis nasus</i> (Günther, 1858)	1,2,3,6	LC	NL	M (11)	1	1921	MCZ R-16128
<i>Drymarchon melanurus</i> (Duméril, Bibron & Duméril, 1854)	4	LC	NL	L (6)	3	1975	ENCB 9028
<i>Drymobius margaritiferus</i> (Schlegel, 1837)	4	LC	NL	L (6)	3	1939	MCZ R-45575
<i>Lampropeltis polyzona</i> Cope, 1860	1,2,3,4,5	LC	NL	L (7)	1	1943	ENCB 2205
<i>Leptophis diplotropis</i> (Günther, 1872)	4	LC	A	H (14)	1	1978	CNAR 3264
<i>Masticophis mentovarius</i> (Duméril, Bibron & Duméril, 1854)	4	LC	A	L (6)	3	1960	KUNHM 67691
<i>Oxybelis aeneus</i> (Wagler, 1824)	4	LC	NL	L (5)	4	1985	Camarillo-Rangel et al. 1985
<i>Pituophis deppii</i> (Duméril, 1853)	1,2,3,4,6	LC	A	H (14)	1	1853	Duméril 1853
<i>Pituophis lineaticollis</i> (Cope, 1861)	1,2,3,4,5	LC	NL	L (8)	3	1940	UIMNH 36223 reported by Duellman 1960
<i>Pseudoficimia frontalis</i> (Cope, 1864)	4	LC	NL	M (13)	1	1951	AMNH R-71359
<i>Salvadora bairdi</i> Jan & Sordelli, 1860	1,2,3,4,5,6	LC	Pr	H (15)	1	1888	Dugès 1888
<i>Salvadora mexicana</i> (Duméril, Bibron & Duméril, 1854)	4	LC	Pr	H (15)	1	1982	CNAR 3908
<i>Senticolis triaspis</i> (Cope, 1866)	1,2,4,5	LC	NL	L (6)	3	1943	ENCB 2207
<i>Tantilla bocourti</i> (Günther, 1895)	1,2,5	LC	NL	L (9)	1	1960	KUNHM 67723
<i>Tantilla calamarina</i> Cope, 1866	4	LC	Pr	M (12)	1	1981	UTEP H-13999
<i>Tantilla deppii</i> (Bocourt, 1883)	4	LC	A	M (13)	1	1977	CNAR 1751
<i>Tantilla rubra</i> Cope, 1875	1,2,3,5	LC	Pr	L (5)	3	2009	Aguilar-Miguel et al. 2009
<i>Trimorphodon biscutatus</i> (Duméril, Bibron & Duméril, 1854)	4	NE	NL	L (7)	3	1983	Camarillo-Rangel 1983
<i>Trimorphodon tau</i> Cope, 1870	4	LC	NL	M (13)	1	1943	ENCB 2206
FAMILY DIPSADIDAE (12)							
<i>Conopsis vittatus</i> Peters, 1860	4	LC	NL	M (11)	3	2004	Matias-Ferrer and Murillo 2004c
<i>Diadophis punctatus</i> (Linnaeus, 1766)	1,2,3,6	LC	NL	L (4)	2	1937	MZFC 2307
<i>Enulius flavitorques</i> (Cope, 1868)	4	LC	NL	L (5)	3	1951	AMNH R-71357
<i>Geophis bicolor</i> Günther, 1868	4	DD	Pr	H (15)	1	1992	Camarillo-Rangel and Smith 1992
<i>Geophis sieboldi</i> (Jan, 1862)	4	DD	Pr	M (13)	1	1991	MZFC 36
<i>Imantodes gemmistratus</i> (Cope, 1861)	4	LC	Pr	L (6)	3	1951	AMNH R-71361
<i>Leptodeira maculata</i> (Hallowell, 1861)	4,6	LC	Pr	L (7)	1	1965	CNAR 1102

	Vegetation type	IUCN status	SEMARNAT	EVS	Global distribution	Year of first record	Source
<i>Leptodeira septentrionalis</i> (Kennicott, 1859)	4	LC	NL	L (8)	4	1992	Camarillo-Rangel and Smith 1992
<i>Leptodeira splendida</i> Günther, 1895	4	LC	NL	H (14)	1	1976	CNAR 3770
<i>Rhadinaea hesperia</i> Bailey, 1940	4	LC	Pr	M (10)	1	1973	ENCB 7829
<i>Rhadinaea laureata</i> (Günther, 1868)	1,2,3	LC	NL	M (12)	1	1952	KUNHM 39966
<i>Rhadinaea taeniata</i> (Peters, 1863)	1,2	LC	NL	M (13)	1	1979	CNAR 3543
FAMILY ELAPIDAE (3)							
<i>Micrurus brauni</i> Schmidt & Smith, 1943	1,2	LC	Pr	L (8)	3	1954	KUNHM 50701
<i>Micrurus laticollaris</i> Peters, 1870	4	LC	Pr	H (14)	1	1986	ENCB 12924
<i>Micrurus tener</i> Baird & Girard, 1953	1,4	LC	NL	M (11)	2	1943	ENCB 2204
FAMILY LEPTOTYPHLOPIDAE (2)							
<i>Epictia bakewelli</i> (Oliver, 1937)	4	NE	NL	NE	1	1985	Camarillo-Rangel et al. 1985
<i>Rena maxima</i> (Loveridge, 1932)	4	LC	NL	M (11)	1	1960	KUNHM 67639
FAMILY NATRICIDAE (7)							
<i>Storeria storerioides</i> (Cope, 1866)	1,2,3	LC	NL	M (11)	1	1938	UIMNH 18771
<i>Thamnophis cyrtopsis</i> (Kennicott, 1860)	1,2,3,4,6	LC	A	L (7)	4	1892	USNM 19003
<i>Thamnophis eques</i> (Reuss, 1834)	1,2,3,4,6	LC	A	L (8)	2	1904	USNM 46599
<i>Thamnophis melanogaster</i> (Wiegmann, 1830)	1,2,3,6	EN	A	H (15)	1	1888	Dugès 1888
<i>Thamnophis pulcherrimus</i> (Cope, 1885)	1,2,3,4	LC	NL	H (15)	1	1888	Dugès 1888
<i>Thamnophis scalaris</i> Cope, 1861	1,2,3,5	LC	A	H (14)	1	1888	Dugès 1888
<i>Thamnophis scaliger</i> (Jan, 1863)	1,2,3,5,6	VU	A	H (15)	1	1939	UMMZ 85367
FAMILY TYPHLOPIDAE (1)							
<i>Indotyphlops bnaminus</i> (Daudin, 1803)	IN	IN	IN	IN	IN	1997	CNAR 11307
FAMILY VIPERIDAE (10)							
<i>Crotalus aquilus</i> Klauber, 1952	1,2,3,4,6	LC	Pr	H (16)	1	1982	CNAR 4246
<i>Crotalus atrox</i> Baird & Girard, 1853	5	LC	Pr	L (9)	2	2004	Matias-Ferrer and Murillo 2004b
<i>Crotalus culminatus</i> Klauber, 1952	4	NE	NL	H (15)	1	1888	Dugès 1888
<i>Crotalus molossus</i> Baird & Girard, 1853	1,2,3,6	LC	Pr	L (8)	2	1888	Dugès 1888
<i>Crotalus polyicticus</i> (Cope, 1865)	1,2,3,4	LC	Pr	H (16)	1	1888	Dugès 1888
<i>Crotalus rarus</i> Cope, 1865	1,2,3,4,6	LC	A	H (14)	1	1938	UIMNH 19186
<i>Crotalus scutulatus</i> (Kennicott, 1861)	5	LC	Pr	M (11)	2	1967	ENCB 3853
<i>Crotalus tlaloci</i> Bryson, Linkem, Dorcas, Lathrop, Jones, Alvarado-Días, Grünwald & Murphy, 2014	1,2,3,4	NE	NL	H (16)	1	2014	Bryson et al. 2014
<i>Crotalus transversus</i> Taylor, 1944	2,3	LC	P	H (17)	1	1973	KUNHM 159362
<i>Crotalus triseriatus</i> (Wagler, 1830)	1,2,3,4,6	LC	NL	H (16)	1	1940	MVZ 36745
ORDER TESTUDINES							
EMYDIDAE (1)							
<i>Trachemys venusta</i> (Gray, 1855)	4	NE	NL	M (13)	3	1939	MCZ R-45542
FAMILY GEOEMYDIDAE (1)							
<i>Rhinoclemmys rubida</i> (Cope, 1870)	4	NT	Pr	H (14)	1	1983	Camarillo-Rangel 1983
FAMILY KINOSTERNIDAE (2)							
<i>Kinosternon hirtipes</i> (Wagler, 1830)	1,4,5,6	LC	Pr	M (10)	2	1888	Dugès 1888
<i>Kinosternon integrum</i> LeConte, 1854	4	LC	Pr	M (11)	1	1888	Dugès 1888

ern State of Mexico), Hidalgo and Querétaro (northern State of Mexico), Morelos (southern State of Mexico), and Puebla (eastern State of Mexico), and are based on distributional records appearing in Vertnet.org, the Sistema Nacional de Información sobre Biodiversidad (SNIB-CONABIO) for all six neighboring states and Mexico City, Dixon and Lemos-Espinal (2010) for Querétaro; and Lemos-Espinal and Dixon (2016) for Hidalgo. We are convinced that as more herpetological work is done in the areas near the borders between the State of Mexico and its neighboring states, these potential species will likely be documented in the State of Mexico.

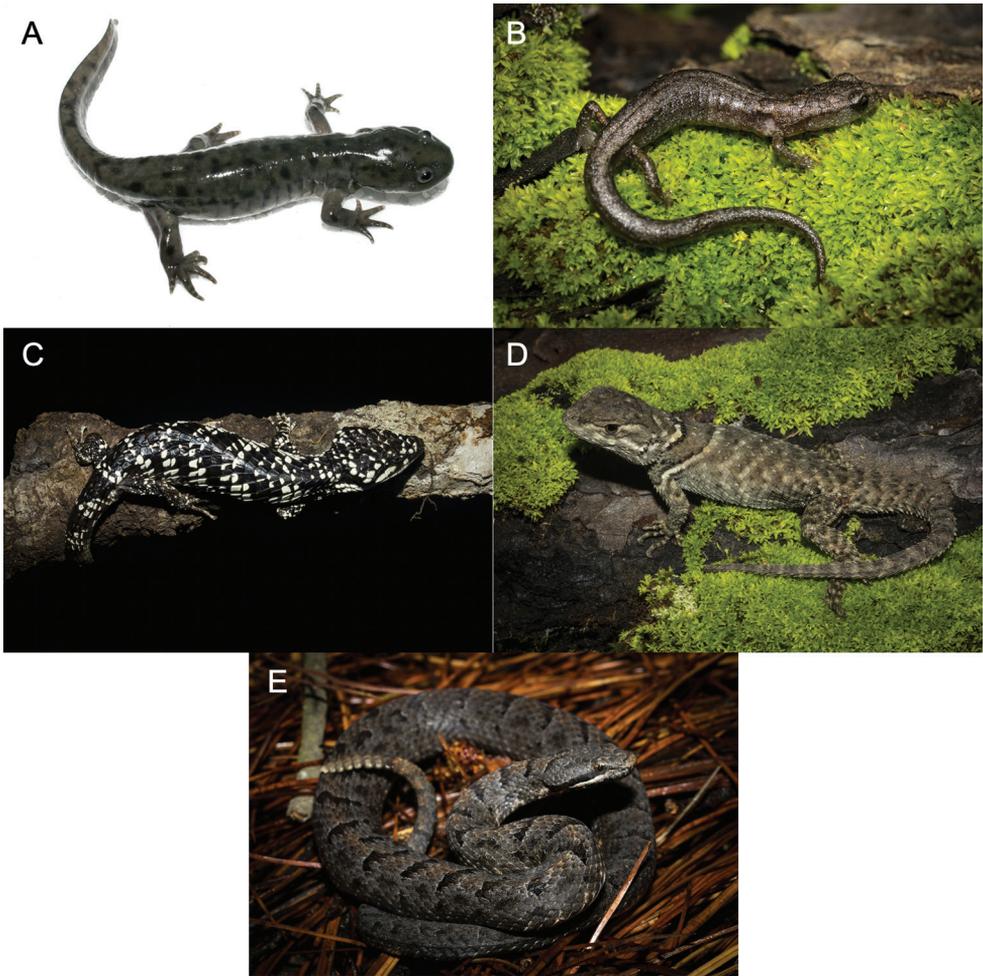


Figure 6. **A** *Ambystoma lermaense* **B** *Chiropetrotriton orculus* **C** *Abronia deppii* **D** juvenile *Sceloporus sugillatus* **E** *Crotalus transversus*. Photos by Eric Centenero-Alcalá

General distribution

Thirty-six of the 49 species of amphibians found in the State of Mexico are endemic to Mexico, four of them to the State of Mexico (*Ambystoma bombypellum*, *A. granulosum*, *A. lermaense*, and *Pseudoeurycea robertsi*); twelve are species found mainly along the Eje Neovolcánico of central Mexico; seven are species typical of the Pacific Coast, including the Balsas Depression; three are species characteristics of the Mexican Plateau; seven more are species with a widely distributional patterns in the Mexican Plateau, the Sierra Madre Occidental, Sierra Madre Oriental, Sierra Madre del Sur, and Eje Neovolcánico; and the remaining three are represented by scattered populations in the Mexican Plateau, Sierras Madres, and Eje Neovolcánico (Table 1). Of the 13 amphibian species not endemic to Mexico, four are found in the United States and Mexico,

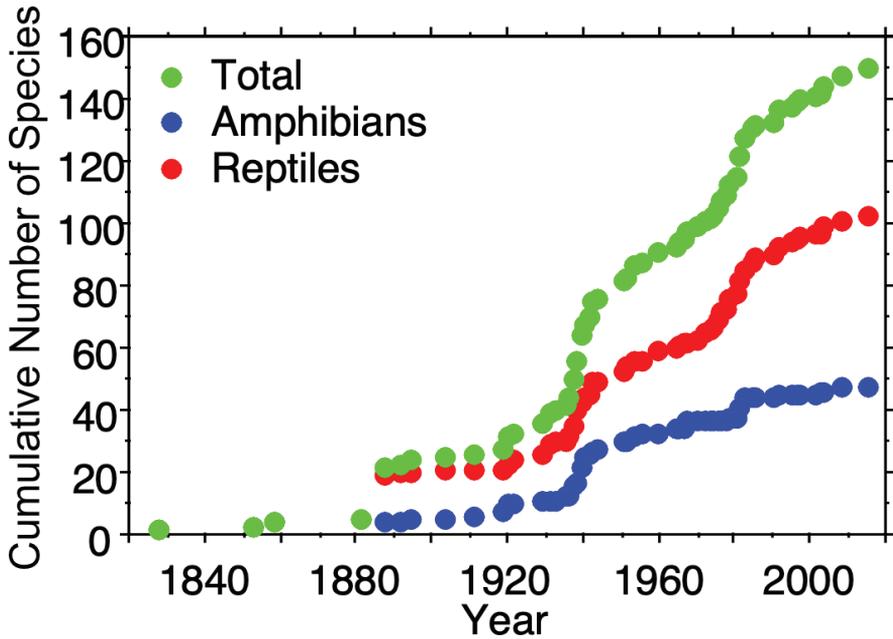


Figure 7. Species accumulation curves for total herpetofauna, amphibians, and reptiles of the State of Mexico, Mexico.

five range from Mexico to Central or even South America, three more are found from southern United States to Central or South America, and one is introduced (Table 1). Thirty-three of the 40 species of lizards that occur in the state are endemic to Mexico; one is endemic to the State of Mexico (*Barisia herrerae*); six are restricted to localities in central Mexico in the State of Mexico, Morelos, Puebla, and Mexico City; ten are typical of the Mexican Pacific Coast; two are limited to the Eje Neovolcánico of central Mexico; six are limited to the central-south part of Mexico, in the Eje Neovolcánico and Sierra Madre del Sur; two are typical of the Mexican Plateau, occurring also in the Eje Neovolcánico or the Sierra Madre del Sur; and six occur in both the Sierra Madre Occidental and Sierra Madre Oriental, and in the Eje Neovolcánico. Of the seven species of lizards found in the State of Mexico but that are not endemic to Mexico, one is found in the United States and Mexico, four are distributed from Mexico to Central America, one is distributed from the United States to Central America, and one is introduced (Table 1). Thirty-six of the 57 species of snakes that inhabit the State of Mexico are endemic to Mexico. Of the 21 snake species not endemic to Mexico that are found in the State of Mexico, six are found in the United States and Mexico, ten range from Mexico to Central or even South America, four are found from central or southern United States to Central or South America, and one is introduced (Table 1). Two of the four species of turtles found in the State of Mexico are endemic to Mexico, one is a species found in the United States and Mexico, and one is distributed from Mexico to Central America (Table 1).

Table 2. List of amphibian and reptile species that potentially occur in the State of Mexico.

	Region in the State of Mexico where it likely occurs
CLASS AMPHIBIA	
ORDER ANURA	
Family Craugastoridae	
<i>Craugastor rhodopsis</i> (Cope, 1867)	southern
Family Hyliidae	
<i>Scinax staufferi</i> (Cope, 1865)	southern
CLASS REPTILIA	
ORDER SQUAMATA	
SUBORDER AMPHISBAENIA	
Family Bipedidae	
<i>Bipes canaliculatus</i> Latreille, 1801	extreme southwestern
SUBORDER LACERTILIA	
Family Anguidae	
<i>Gerrhonotus ophiourus</i> Cope, 1867	eastern and southern
Family Eublepharidae	
<i>Coleonyx elegans</i> Gray, 1845	extreme southwestern
Family Phrynosomatidae	
<i>Phrynosoma asio</i> Cope, 1864	extreme southwestern
<i>Sceloporus minor</i> Cope, 1885	northern
<i>Sceloporus siniferus</i> Cope, 1870	extreme southwestern
<i>Sceloporus utiformis</i> Cope, 1864	extreme southwestern
Family Phyllodactylidae	
<i>Phyllodactylus bordai</i> Taylor, 1942	extreme southwestern
<i>Phyllodactylus tuberculatus</i> Wiegmann, 1834	extreme southwestern
Family Teiidae	
<i>Holcosus sinister</i> (Wiegmann, 1834)	extreme southwestern
SUBORDER SERPENTES	
Family Colubridae	
<i>Ficimia publia</i> (Cope, 1866)	extreme southwestern
<i>Lampropeltis ruthveni</i> Blanchard, 1920	northern
<i>Mastigodryas melanolomus</i> (Cope, 1868)	extreme southwestern
<i>Sonora michoacacensis</i> (Dugès, 1884)	western and southwestern
Family Dipsadidae	
<i>Pseudoleptodeira latifasciata</i> (Günther, 1894)	extreme southwestern
<i>Tropidodipsas zweifeli</i> (Liner & Wilson, 1970)	extreme southwestern
Family Loxocemidae	
<i>Loxocemus bicolor</i> Cope, 1861	extreme southwestern
Family Viperidae	
<i>Agkistrodon bilineatus</i> Günther, 1863	extreme southwestern
ORDER TESTUDINES	
Family Kinosternidae	
<i>Kinosternon scorpioides</i> (Linnaeus, 1766)	western and southwestern

Habitat types

In the State of Mexico, the percentage of herpetofaunal species found in the Oak (51.7%), Pine-oak (55.8%), Pine (44.9%), and Tropical Deciduous Forest (51.7%) vegetation types are relatively equal (Table 1). However, the Grassland (29.9%) and Scrubland (23.8%) vegetation types have relatively fewer species. This pattern of the observed percentage of species in each habitat type is the same for amphibians and reptiles individually in the Oak, Pine-oak, and Pine Forests; and in the Scrubland. However, the Tropical Deciduous Forest contains a higher percentage of reptiles (80.3%)

than for amphibians (19.7%), which might be due to the dry conditions of this vegetation type. The percentage of species found in the Grassland is the same for amphibians as for reptiles (50.0% for both), perhaps due to the high altitude grasslands that intermingle with Pine Forest in the State of Mexico, and these grasslands often traverse streams which host important populations of hylids, ranids, ambystomatids, anguids, phrynosomatids, colubrids, and vipers in the State of Mexico.

Conservation status

Of the amphibian and reptile species in the State of Mexico, 20.1% are IUCN listed (i.e., Vulnerable, Near Threatened, or Endangered), 18.4% are placed in a protected category by SEMARNAT (excluding NL and Pr, this last category is equivalent to the LC category of IUCN), and 34.9% are categorized as high risk by the EVS (Table 3; Fig. 8). For amphibians, 41.7% are IUCN listed, 20.8% are protected by SEMARNAT, and 33.3% are at high risk according to the EVS (Table 3; Fig. 8). For reptiles, 8.8% are listed by the IUCN, 17.2% are protected by SEMARNAT, and 35.7% are at high risk according to the EVS (Table 3; Fig. 8). These results suggest that many amphibians found in the State of Mexico are at risk and of relatively high conservation concern at both the global and national scale. However, the reptiles found in the State of Mexico are less at risk according to the global and national assessments of the IUCN and SEMARNAT, respectively; but the EVS suggests they may be at higher risk than the IUCN and SEMARNAT assessments suggest. Based on our review of the conservation statuses of the herpetofauna found in the State of Mexico, we have identified several families that include species of particular conservation concern. These families include Craugastoridae, Eleutherodactylidae, Ambystomatidae, Plethodontidae, Helodermatidae, Iguanidae, Phrynosomatidae, Colubridae, Natricidae, and Viperidae (Table 3). Because the conservation statuses we reviewed are developed and applied at a species wide level, we believe that the conservation status of specific taxa in the State of Mexico may not be accurately reflected by these measures. Additional state level assessments are needed, especially for species in the families we have identified as being at a particularly high level of risk.

We summarized the conservation status of amphibian and reptile taxa in each vegetation type found in the State of Mexico to determine the vegetation types that support species of particular conservation concern (Table 1). For IUCN listings, 43.3% of amphibian species in the Oak Forest are listed in a protected category; 48.5% in the Pine-oak Forest; 50.0% in the Pine Forest; 13.3% in the Tropical Deciduous Forest; 59.1% in the Grassland; and 16.7% in the Scrubland. For SEMARNAT listings of amphibian species, 30.0% in the Oak Forest are listed in a protected category; 30.3% in the Pine-oak Forest; 34.6% in the Pine Forest; 0% in the Tropical Deciduous Forest; 36.4% in the Grassland; and 16.7% in the Scrubland. For EVS, 40.0% of amphibian species in the Oak Forest of the State of Mexico were in the high category, 45.5% in the Pine-oak Forest, 42.3% in the Pine Forest, 0% in the Tropical Deciduous Forest, 54.5% in the Grassland, and 25.0% in the Scrubland. For IUCN listings, 8.9% of reptile species in

Table 3. Summary of native species present in the State of Mexico by family, order or suborder, and class. Status summary indicates the number of species found in each IUCN conservation status in the order DD, LC, VU, NT, EN, CR (see Table 1 for abbreviations; in some cases species have not been assigned a status by the IUCN and therefore these may not add up to the total number of species in a taxon). Mean EVS is the mean Environmental Vulnerability Score; scores ≥ 14 are considered high vulnerability (Wilson et al. 2013a, b) and conservation status in Mexico according to SEMARNAT (2019) in the order NL, Pr, A, P (see Table 1 for abbreviations).

Scientific name	Genera	Species	IUCN	\bar{x} EVS	SEMARNAT
			DD, LC, VU, NT, EN, CR		NL, Pr, A, P
CLASS AMPHIBIA					
ORDER ANURA	15	32	1,24,2,1,3,1	10.3	20,9,2,1
Bufonidae	3	5	0,4,0,0,1,0	10.4	5,0,0,0
Craugastoridae	1	4	0,2,1,0,1,0	11.25	4,0,0,0
Eleutherodactylidae	1	4	1,2,1,0,0,0	14.3	2,2,0,0
Hylidae	5	9	0,8,0,0,1,0	9.3	6,2,1,0
Leptodactylidae	1	1	0,1,0,0,0,0	6	0,1,0,0
Microhylidae	1	1	0,1,0,0,0,0	4	0,1,0,0
Phyllomedusidae	1	1	0,1,0,0,0,0	13	0,1,0,0
Ranidae	1	6	0,4,0,1,0,1	11.2	2,2,1,1
Scaphiropodidae	1	1	0,1,0,0,0,0	3	1,0,0,0
ORDER CAUDATA	5	16	1,2,2,1,5,5	14.8	2,7,7,0
Ambystomatidae	1	8	1,1,0,0,2,4	13.5	0,5,3,0
Plethodontidae	4	8	0,1,2,1,3,1	16.1	2,2,4,0
SUBTOTAL	20	48	2,26,4,2,8,6	11.8	22,16,9,1
CLASS REPTILIA					
ORDER SQUAMATA	40	95	2,79,3,0,4,0	11.5	53,25,15,2
SUBORDER LACERTILIA	13	39	0,32,2,0,3,0	12.4	25,9,4,1
Anguidae	3	5	0,2,0,0,3,0	13.2	1,2,1,1
Dactyloidae	1	1	0,1,0,0,0,0	13	1,0,0,0
Helodermatidae	1	1	0,1,0,0,0,0	11	0,0,1,0
Iguanidae	1	1	0,0,0,0,0,0	15	0,0,1,0
Phrynosomatidae	3	19	0,18,1,0,0,0	12.4	16,2,1,0
Phyllodactylidae	1	1	0,1,0,0,0,0	15	1,0,0,0
Scincidae	2	6	0,4,1,0,0,0	12	3,3,0,0
Teiidae	1	5	0,5,0,0,0,0	11.2	3,2,0,0
SUBORDER SERPENTES	27	56	2,47,1,0,1,0	11	28,16,11,1
Boidae	1	1	0,0,0,0,0,0	15	1,0,0,0
Colubridae	13	21	0,20,0,0,0,0	10	12,4,5,0
Dipsadidae	7	12	2,10,0,0,0,0	9.8	7,5,0,0
Elapidae	1	3	0,3,0,0,0,0	11	1,2,0,0
Leptotyphlopidae	2	2	0,1,0,0,0,0	11	2,0,0,0
Natricidae	2	7	0,5,1,0,1,0	11.5	2,0,5,0
Viperidae	1	10	0,8,0,0,0,0	13.8	3,5,1,1
ORDER TESTUDINES	3	4	0,2,0,1,0,0	12	1,3,0,0
Emydidae	1	1	0,0,0,0,0,0	13	1,0,0,0
Geoemydidae	1	1	0,0,0,1,0,0	14	0,1,0,0
Kinosternidae	1	2	0,2,0,0,0,0	10.5	0,2,0,0
SUBTOTAL	43	99	2,81,3,1,4,0	11.6	54,28,15,2
TOTAL	63	147	4107,7,3,12,6	11.7	76,44,24,3

the Oak Forest are listed in a protected category; 12.5% in the Pine-oak Forest; 12.5% in the Pine Forest; 3.8% in the Tropical Deciduous Forest; 9.1% in the Grassland; and 8.7% in the Scrubland. For SEMARNAT listings of reptile species, 22.2% in the Oak Forest are listed in a protected category; 25.0% in the Pine-oak Forest; 25.6% in the Pine Forest; 15.0% in the Tropical Deciduous Forest; 18.2% in the Grassland; and 34.8% in the Scrubland. For EVS, 42.2% of reptile species in the Oak Forest of the State of Mexico were in the high category, 45.8% in the Pine-oak Forest, 53.8% in the Pine Forest, 35.0% in the Tropical Deciduous Forest, 22.7% in the Grassland, and

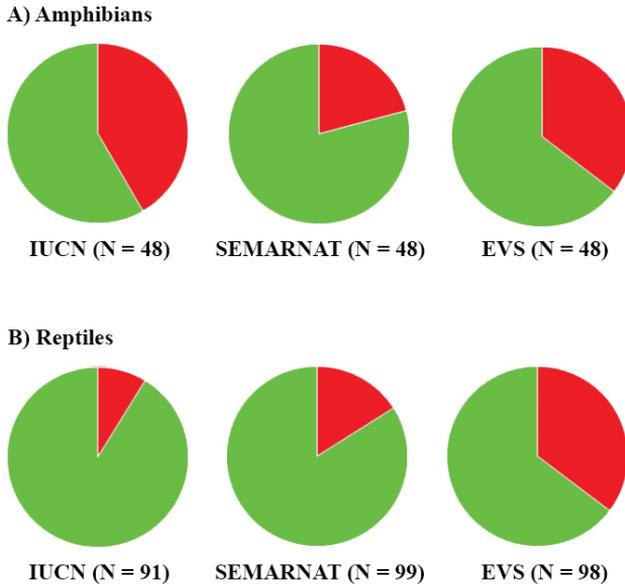


Figure 8. Proportion of **A)** amphibians and **B)** reptiles listed in protected categories on the IUCN Red List, SEMARNAT, and high EVS for the State of Mexico. Green is proportion in Data Deficient and Least Concern (IUCN); Not Listed and Subject to Special Protection (we regarded the category of Subject to Special Protection in SEMARNAT equivalent to Least Concern in IUCN) (SEMARNAT); or low or medium EVS. Red is percentage in protected categories or high EVS. N is the number of species assessed.

34.8% in the Scrubland. Given the apparent importance of forested habitats in terms of protected amphibian and reptile species in the State of Mexico, efforts to maintain or expand such habitats, perhaps by reforestation, is a management strategy that needs to be considered. Indeed, Sánchez-Jasso et al. (2013) found that reforested woodlands in the State of Mexico supported a relatively high richness of vertebrates.

Comparison with neighboring states

Overall, the State of Mexico shares the most species (76.9%) with Michoacán (Table 4). The State of Mexico also shares the most amphibian species with Michoacán (72.9%), including 87.5% of its anuran species, and 43.8% of its salamander species. These two states are especially important for salamanders in the family Ambystomatidae and contribute 11 of the 14 species of the regional pool, only lacking *A. mexicanum* (endemic to Mexico City), *A. taylori* (endemic to Puebla), and *A. subsalsum*. For reptiles, the State of Mexico shares 78.8% of its reptile species with Michoacán. The similarity between these two states is due to the long border between them (241 km, INEGI 2018) and the fact that the larger Michoacán contains essentially all of the vegetation types present in the State of Mexico. In contrast, the state that shares the second highest number of species with the State of Mexico is the small state of Morelos. Morelos, along with the State of Mexico and Mexico City,

Table 4. Summary of the numbers of species shared between the State of Mexico and neighboring Mexican states (not including introduced species). The percent of the State of Mexico species shared by a neighboring state are given in parentheses. – indicates either the State of Mexico or the neighboring state has no species in the taxonomic group, or none of that specific taxon is shared between the states, thus no value for shared species is provided.

Taxon	State of Mexico	Michoacán	Morelos	Puebla	Guerrero	Hidalgo	Querétaro	Mexico City
CLASS AMPHIBIA	48	35 (72.9)	33 (68.8)	27 (56.3)	26 (55.3)	20 (41.7)	16 (33.3)	16 (33.3)
ORDER ANURA	32	28 (87.5)	26 (81.3)	23 (71.9)	23 (71.9)	16 (50.0)	13 (40.6)	8 (25.0)
Bufonidae	5	5 (100)	5 (100)	5 (100)	4 (80.0)	3 (60.0)	3 (60.0)	1 (20.0)
Craugastoridae	4	3 (75.0)	4 (100)	3 (75.0)	4 (100)	1 (25.0)	1 (25.0)	1 (25.0)
Eleutherodactylidae	4	3 (75.0)	3 (75.0)	1 (25.0)	2 (50.0)	1 (25.0)	1 (25.0)	–
Hylidae	9	8 (88.9)	7 (77.8)	7 (77.8)	7 (77.8)	5 (55.6)	3 (33.3)	3 (33.3)
Leptodactylidae	1	1 (100)	0	1 (100)	1 (100)	1 (100)	–	–
Microhylidae	1	1 (100)	1 (100)	1 (100)	1 (100)	1 (100)	1 (100)	–
Phyllomedusidae	1	1 (100)	1 (100)	1 (100)	1 (100)	–	–	–
Ranidae	6	5 (83.3)	4 (66.7)	3 (50.0)	2 (33.3)	3 (50.0)	3 (50.0)	2 (33.3)
Scaphiopodidae	1	1 (100)	1 (100)	1 (100)	1 (100)	1 (100)	1 (100)	1 (100)
ORDER CAUDATA	16	7 (43.8)	7 (43.8)	4 (25.0)	3 (18.8)	4 (25.0)	3 (18.8)	8 (50.0)
Ambystomatidae	8	4 (50.0)	1 (12.5)	1 (12.5)	1 (12.5)	1 (12.5)	1 (12.5)	2 (25.0)
Plethodontidae	8	3 (37.5)	6 (75.0)	3 (37.5)	2 (25.0)	3 (37.5)	2 (25.0)	6 (75.0)
CLASS REPTILIA	99	78 (78.8)	73 (71.8)	71 (71.7)	65 (65.7)	47 (47.5)	45 (45.5)	43 (43.4)
ORDER SQUAMATA	95	75 (78.9)	71 (74.7)	69 (72.6)	63 (66.3)	44 (46.3)	43 (45.3)	41 (43.2)
SUBORDER LACERTILIA	39	28 (71.8)	29 (74.4)	26 (66.7)	26 (66.7)	12 (30.8)	10 (25.6)	14 (35.9)
Anguidae	5	3 (60.0)	4 (80.0)	2 (40.0)	3 (60.0)	1 (20.0)	1 (20.0)	1 (20.0)
Dactyloidae	1	1 (100)	1 (100)	–	1 (100)	–	–	–
Helodermatidae	1	1 (100)	1 (100)	1 (100)	1 (100)	–	–	–
Iguanidae	1	1 (100)	1 (100)	1 (100)	1 (100)	–	–	–
Phrynosomatidae	19	12 (63.2)	14 (73.7)	15 (78.9)	12 (63.2)	9 (47.4)	7 (36.8)	10 (52.6)
Phyllodactylidae	1	1 (100)	–	–	1 (100)	–	–	–
Scincidae	6	4 (66.7)	4 (66.7)	4 (66.7)	3 (50.0)	1 (16.7)	1 (16.7)	2 (33.3)
Teiidae	5	5 (100)	4 (80.0)	3 (60.0)	4 (80.0)	1 (20.0)	1 (20.0)	1 (20.0)
SUBORDER SERPENTES	56	47 (83.9)	42 (75.0)	43 (76.8)	37 (66.1)	32 (57.1)	33 (58.9)	27 (48.2)
Boidae	1	1 (100)	1 (100)	1 (100)	1 (100)	–	–	–
Colubridae	21	19 (90.5)	19 (90.5)	20 (95.2)	18 (85.7)	13 (61.9)	14 (66.7)	9 (42.9)
Dipsadidae	12	11 (91.7)	8 (66.7)	7 (58.3)	8 (66.6)	5 (41.7)	4 (33.3)	4 (33.3)
Elapidae	3	2 (66.7)	2 (66.7)	2 (66.7)	2 (66.6)	1 (33.3)	1 (33.3)	1 (33.3)
Leptotyphlopidae	2	2 (100)	1 (50.0)	1 (50.0)	2 (100)	1 (50.0)	1 (50.0)	–
Natricidae	7	7 (100)	4 (57.1)	6 (85.7)	3 (42.9)	6 (85.7)	6 (85.7)	7 (100)
Viperidae	10	5 (50.0)	7 (70.0)	6 (60.0)	3 (30.0)	6 (60.0)	7 (70.0)	6 (60.0)
ORDER TESTUDINES	4	3 (75.0)	2 (50.0)	2 (50.0)	2 (50.0)	3 (75.0)	2 (50.0)	2 (50.0)
Emydidae	1	–	–	1 (100)	–	1 (100)	–	–
Geoemydidae	1	1 (100)	–	–	1 (100)	–	–	–
Kinosternidae	2	2 (100)	2 (100)	1 (50.0)	1 (50.0)	2 (100)	2 (100)	2 (100)
TOTAL	147	113 (76.9)	106 (72.1)	98 (66.7)	91 (61.9)	67 (45.6)	61 (41.5)	59 (40.1)

share parts of the Corredor Biológico Chichinautzin, which includes the Lagunas de Zempoala National Park, that hosts a unique assortment of amphibians and reptiles. Moreover, Morelos shares part of the Tropical Deciduous Forest with the southern part of the State of Mexico. Puebla and Guerrero also share a large number of species with the State of Mexico. Hidalgo, Querétaro, and Mexico City share fewer amphibian and reptile species with the State of Mexico. Hidalgo and Querétaro are states whose dominant species are from the Mexican Altiplano and the Sierra Madre Oriental, whereas the dominant species for the State of Mexico are a combination of

species of the Eje Neovolcánico and the Sierra Madre del Sur. The lower number of shared species among these states may also reflect the inherent species richness of the shared habitat types. In addition, the border of Querétaro with the State of Mexico is quite short (95.3 km, INEGI 2018), and although the border of Hidalgo with the State of Mexico is the longest of the other neighboring states (422.3 km, INEGI 2018), most of this border is confined to the subprovince of Llanuras and Sierras de Querétaro e Hidalgo, with a sole contribution of species typical of the Mexican Altiplano. On the other hand, although Mexico City is nearly surrounded by the State of Mexico, its small size (1,485 km²) along with its large urbanized area, results in a small number of species of amphibians and reptiles (63: Lemos-Espinal and Smith, in press), which also results in an equally small number of species shared between Mexico City and the State of Mexico (59). However, 93.7% of the total number of species recorded for Mexico City is shared with the State of Mexico.

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Appendix I

Museum collections included in the VertNet.org database records of the State of Mexico amphibians and reptiles that house specimens of the first record of a species in the State of Mexico.

AMNH	Collection of Herpetology, Herpetology Department, American Museum of Natural History;
CNAR	Colección Nacional de Anfibios y Reptiles, Instituto de Biología, Universidad Nacional Autónoma de México;
ENCB	Escuela Nacional de Ciencias Biológicas, Instituto Politécnico Nacional;
FMNH	Division of Amphibians and Reptiles, Field Museum of Natural History;
MCZ	Collection of Herpetology, Museum of Comparative Zoology, Harvard University Cambridge;
KUNHM	Museum of Natural History, Division of Herpetology, University of Kansas;
MVZ	Museum of Vertebrate Zoology at Berkeley, Herpetological Collection;
MZFC	Museo de Zoología Alfonso L. Herrera, Facultad de Ciencias, UNAM. Colección Herpetológica;
NHM	Natural History Museum, London, Zoological Collection;
TCWC	Collection of Herpetology, Texas Cooperative Wildlife Collection, Texas A&M University;
UCM	Collection of Herpetology, University of Colorado Museum;
UIMNH	University of Illinois Museum of Natural History Amphibian and Reptile Collection;
UMMZ	Collection of Herpetology, Museum of Zoology, University of Michigan Ann Arbor;
USNM	Collection of Herpetology, Department of Vertebrate Zoology, National Museum of Natural History, Smithsonian Institution;
UTAMM	Merriam Museum, University of Texas Arlington;
UTEP	Collection of Herpetology, Laboratory of Environmental Biology, Biological Science Department, University of Texas – El Paso.

