RESEARCH ARTICLE



A redescription of Syncarpa composita (Ascidiacea, Stolidobranchia) with an inference of its phylogenetic position within Styelidae

Naohiro Hasegawa¹, Hiroshi Kajihara²

Department of Natural History Sciences, Graduate School of Science, Hokkaido University, Kita 10 Nishi
8 Kitaku, Sapporo, Hokkaido 060-0810, Japan 2 Faculty of Science, Hokkaido University, Kita 10 Nishi
8 Kitaku, Sapporo, Hokkaido 060-0810, Japan

Corresponding author: Naohiro Hasegawa (uuuuu-hasegawa@eis.hokudai.ac.jp)

Academic editor: <i>Tito Lotufo</i> Received 25 December 2018 Accepted 6 May 2019	Published 24 June 2019
- http://zoobank.org/2183A9EC-C4B7-4863-B03B-EB5346D7B95E	

Citation: Hasegawa N, Kajihara H (2019) A redescription of *Syncarpa composita* (Ascidiacea, Stolidobranchia) with an inference of its phylogenetic position within Styelidae. ZooKeys 857: 1–15. https://doi.org/10.3897/zooKeys.857.32654

Abstract

Two species of styelid colonial ascidians in the genus *Syncarpa* Redikorzev, 1913 are known from the northwest Pacific. The valid status of the lesser known species, *Syncarpa composita* (Tokioka, 1951) (type locality: Akkeshi, Japan), is assessed here. To assess the taxonomic identity of *S. composita*, we compared one of the syntypes and freshly collected topotypes of *S. composita* with a syntype of *S. oviformis* Redikorzev, 1913 (type locality: Ul'banskij Bay, Russia). Specimens of *S. composita* consistently differed from the syntype of *S. oviformis* in the number of oral tentacles, the number of size-classes of transverse vessels, and the number of anal lobes. In this paper, *S. composita* is redescribed as distinct from *S. oviformis*, and its phylogenetic position inferred within Styelidae based on the 18S rRNA and cytochrome *c* oxidase subunit I gene sequences. In our phylogenetic tree, *Syncarpa* formed a well-supported clade together with *Dendrodoa* MacLeay, 1824. In *Syncarpa* and *Dendrodoa*, a single gonad is situated on the right side of the body, which is unique among Styelidae, and thus can be a synapomorphy for this clade.

Keywords

Chordata, COI, phylogeny, Sea of Okhotsk, taxonomy, Urochordata

Introduction

Syncarpa Redikorzev, 1913 is a member of the ascidian family Styelidae and consists of two species, *Syncarpa composita* (Tokioka, 1951) and *S. oviformis* Redikorzev, 1913. The two nominal species *S. corticiformis* Beniaminson, 1975 and *S. longicaudata* Skalkin, 1957, all from the Northwest Pacific, have been synonymized with *S. oviformis* by Sanamyan (2000). This genus is defined by the following four characters: *i*) colonial, with zooids reproducing asexually, *ii*) a single, well-developed fold is present on each side of the pharynx, *iii*) a single gonad is situated on the right side of the body, and *iv*) the gonad has several branches. *Syncarpa composita* is only known by the original description based on material from Akkeshi, Japan (Tokioka 1951). It was originally placed in a new monotypic genus *Syndendrodoa* Tokioka, 1951, which has been synonymized with *Syncarpa* by Nishikawa (1995).

The phylogeny of ascidians including styelids has been investigated by Zeng et al. (2006), Pérez-Portela et al. (2009), Tsagkogeorga et al. (2009), Alié et al. (2018), and Delsuc et al. (2018). Among these, Alié et al.'s (2018) analysis was based on 4908 genes and included 16 OTUs from Styelidae. It recovered Styelidae as monophyletic with maximum branch-support values, which turned out to be sister to part of paraphyletic Pyuridae. Alié et al.'s (2018) phylogeny showed three major clades for Styelidae: i) Polyzoinae + Botryllinae, ii) *Dendrodoa + Polycarpa + Polyandrocarpa zorritensis* (Van Name, 1931), and iii) *Astrocarpa + Styela*. However, no member of *Syncarpa* has ever been placed on a phylogenetic context in any of the previous studies.

The aims of this study are to assess the taxonomic identity of *S. composita* based on type specimens and freshly collected topotypes andto infer the species' phylogenetic position among Styelidae. In this paper, we redescribe the species and present the results of a multi-gene molecular analysis.

Materials and methods

Eleven topotype colonies of *S. composita* were freshly collected by dredging, snorkeling, and SCUBA diving in the type locality, Akkeshi Bay, at depths of 3–5 m in June, August, and September 2017, and July 2018 (Table 1). One of the colonies was photographed underwater and in the laboratory with a Nikon COOLPIX AW130 digital camera. The live colonies were anesthetized with menthol; then a part of a zooid was cut off along with the tunic from each colony and preserved in 99% EtOH for DNA extraction. The colonies were preserved in 10% formalin-seawater for morphological observation; zooids were removed from the colonies and then dissected for morphological examination. Larvae for histological observation were dehydrated in an ethanol series, cleared in xylene, embedded in paraffin wax, sectioned at 5 µm thickness, and stained with hematoxylin and eosin. After sections were mounted on glass slides in Entellan New (Merck, Germany), they were observed under an Olympus BX51

Family	Species	Sampling date Sampling site GenBank accession number				Catalog number
		18S COI				
	Botrylloides violaceus	30 Mar 2017	Oshoro Bay	LC432326	LC432331	ICHUM 5826
	Styela clava	26 Aug 2017	Shukutsu	LC432329	LC432334	ICHUM 5827
	Styela plicata	10 Jul 2017	Moroiso Bay	LC432328	LC432333	ICHUM 5828
		25 Jun 2017		-	-	ICHUM 5815
		25 Jun 2017		-	accession number Catalog number COI - 26 LC432331 ICHUM 5826 29 LC432334 ICHUM 5827 28 LC432333 ICHUM 5828 - ICHUM 5815 - ICHUM 5816 25 LC432330 ICHUM 5817 - ICHUM 5818 - ICHUM 5819 - ICHUM 5820 - ICHUM 5819 - ICHUM 5820 - ICHUM 5823 - ICHUM 5824 - ICHUM 5825 27 LC432332 ICHUM 5829	
		2 Aug 2017		LC432325		ICHUM 5817
		7 Sep 2017]		-	ICHUM 5818
Styendae		7 Sep 2017		-	ccession number Catalog number COI - LC432331 ICHUM 5826 LC432333 ICHUM 5827 LC432333 ICHUM 5827 LC432333 ICHUM 5827 LC432333 ICHUM 5816 - ICHUM 5816 LC432330 ICHUM 5816 LC432330 ICHUM 5817 - ICHUM 5818 - ICHUM 5819 - ICHUM 5820 - ICHUM 5821 - ICHUM 5822 - ICHUM 5823 - ICHUM 5824 - ICHUM 5824 - ICHUM 5825 LC432332 ICHUM 5829	
	Syncarpa composita	7 Sep 2017	Akkeshi Bay	-	-	number Catalog number COI - \$432331 ICHUM 5826 \$432333 ICHUM 5827 \$432333 ICHUM 5827 \$432333 ICHUM 5827 \$432333 ICHUM 5828 - ICHUM 5815 - ICHUM 5816 \$432330 ICHUM 5817 - ICHUM 5818 - ICHUM 5819 - ICHUM 5820 - ICHUM 5821 - ICHUM 5821 - ICHUM 5823 - ICHUM 5823 - ICHUM 5823 - ICHUM 5823 - ICHUM 5824 - ICHUM 5825 \$432332 ICHUM 5829
		7 Sep 2017		-	-	ICHUM 5821
		7 Sep 2017		_	-	ICHUM 5822
		7 Sep 2017		-	-	ICHUM 5823
		13 Jul 2018		-	-	ICHUM 5824
		13 Jul 2018		-	-	ICHUM 5825
Pyuridae	Pyura mirabilis	21 Jun 2017	Oshoro Bay	LC432327	LC432332	ICHUM 5829

Table 1. List of specimens newly collected in this study with species, family, sampling date, sampling site, GenBank accession numbers for 18S and COI sequences included in the analysis, and catalog numbers.

compound microscope and photographed with a Nikon D5200 digital camera. These voucher specimens have been deposited in the Invertebrate Collection of the Hokkaido University Museum (ICHUM), Sapporo, Japan. For comparison, specimens deposited in the Seto Marine Biological Laboratory (SMBL), Shirahama, Japan, and the Zoological Institute of the Russian Academy of Sciences (ZIRAS), St. Petersburg, Russia, were also examined.

Total genomic DNA was extracted from a piece of the body wall tissue for eight specimens of *S. composita* as well as one specimen each of *Botrylloides violaceus* Oka, 1927, *Pyura mirabilis* (Drasche, 1884), *Styela clava* Herdman, 1881, and *Styela plicata* (Lesueur, 1823) (Table 1). The tissue was placed in a 1.5 mL tube after air-dried, then mixed with 180 μ L of ATL buffer (Qiagen, Hilden, Germany) and 20 μ L of proteinase K (>700 U/mL, Kanto Chemical, Tokyo, Japan), and incubated at 55 °C for ca. 10 h. To the lysis solution, 200 μ L of ATL buffer (Qiagen) was added and incubated at 70 °C for 10 min; then 210 μ L of 99% EtOH was added. The rest of the DNA extraction was carried out following Boom et al.'s (1990) silica method.

Two gene markers were amplified from the genomic DNA by PCR. The nuclear 18S rRNA (18S) gene was amplified with the primer pair 1F/9R (Giribet et al. 1996). The mitochondrial cytochrome *c* oxidase subunit I (COI) gene was amplified with the primers Sty_COI_F2 (5'-TTTGCCTTTAATAGTAAGAAGTCC-3') and Sty_COI_R1 (5'-CATCAAAACAGATGCTGATA-3') for *S. composita* and with the primer pair LCO1490/HCO2198 (Folmer et al. 1994) for the other ascidians. PCRs were performed in a 10- μ L total reaction volume with 3 μ L of each primer pair (10 μ M), 0.5 μ L of TaKaRa Ex *Taq* (TaKaRa, Kusatsu, Japan), 10 μ L of 10 × Ex *Taq* Buffer (TaKaRa), 8 μ L of dNTP mixture (TaKaRa), 1 μ L of extracted DNA, and 68.5 μ L of deionized water. Thermal cycling condition was 94 °C for 2 min; 35 cycles of 94 °C for

45 sec, 52 °C for 90 sec (for 18S) or 55 °C for 50 sec (for COI), and 72 °C for 55 sec; then 72 °C for 5 min. Amplification was verified by electrophoresis in 1% agarose gel. The PCR products were purified through enzymatic reaction with 24 mU/ μ L of Exonuclease I (TaKaRa) and 4.9 mU/ μ L of Shrimp Alkaline Phosphatase (TaKaRa). The purified PCR products were sequenced directly with a BigDye Terminator ver. 3.1 Cycle Sequence Kit (Applied Biosystem, Foster, CA, USA) and 3730 Genetic Analyzer (Applied Biosystems), using the same primer pairs for amplification, as well as the following internal primers for 18S: 3F, 5R (Giribet et al. 1996); and 2, bi (Whiting et al. 1997). Base calling was performed with GeneStudio Professional Edition ver. 2.2.0.0 (GeneStudio, Suwanee, GA, USA).

To infer the phylogenetic position of *S. composita*, 18S and COI sequences of 24 species of Styelidae were obtained from GenBank (Table 2). For 18S, alignment was carried out by MAFFT ver. 7 using the *E-INS-i* strategy (Katoh and Standley 2013); ambiguous sites were removed by using Gblocks ver. 0.91b (Castresana 2002). For COI, nucleotide sequences were manually edited by MEGA ver. 5.2.2 (Tamura et al. 2011) so that translated amino acid sequences were aligned straightforward without indels. 18S and COI sequences were concatenated by using MEGA ver. 5.2.2 (Tamura et al. 2011).

Family	Species	GenBank accession number				
		185	COI			
	Botrylloides chevalense	-	KX650764			
	Botrylloides giganteus	-	HF922627			
	Botrylloides leachii	MG009583	KY235402			
	Botrylloides niger	-	KP254541			
	Botrylloides perspicuus	-	KY235404			
	Botryllus schlosseri	FM244858	AY600987			
	Dendrodoa aggregata	AJ250774	-			
	Dendrodoa grossularia	L12416	FJ528650			
	Distoma variolosus	FM897308	FJ528652			
	Eusynstyela hartmeyeri	FM897309	_			
	Metandrocarpa taylori	AY903922	-			
Studidaa	Pelonaia corrugata	L12440	-			
Styendae	Polyandrocarpa anguinea	-	KY111428			
	Polyandrocarpa misakiensis	AF165825	_			
	Polyandrocarpa zorritensis	FM897311	KX138505			
	Polycarpa aurata	FM897312	FJ528646			
	Polycarpa tenera	FM897313	FJ528655			
	Polyzoa opuntia	FM897314	FJ528647			
	Stolonica socialis	FM897317	-			
	Styela canopus	-	KU905887			
	Styela gibbsii	AY903923	HQ916447			
	Styela montereyensis	L12443	FJ528638			
	Symplegma rubra	FM897315	FJ528648			
	Symplegma viride	DQ346655	_			
Pyuridae	Halocynthia roretzi	AB013016	AB024528			

Table 2. List of species obtained from GenBank included in the phylogenetic analysis with accession numbers for 18S and COI sequences.

Bayesian inference (BI) was performed using MrBayes ver. 3.2.2 (Huelsenbeck and Ronquist 2001; Ronquist and Huelsenbeck 2003). The best-fit substitution models selected by PartitionFinder ver. 2.1.1 (Lanfear et al. 2016) for BI were GTR+I+G for 18S and GTR+G for all the three codon positions of COI. Each Markov chain was initiated from a random tree and run for 5×10^6 generations; trees were sampled every 100 generation from the chain. Burn-in fraction was set to be 0.25. A consensus of sampled trees was computed using the "sumt" command, and the posterior probability (PP) for each interior branch was obtained to assess the robustness of the inferred relationships. Values of run convergence indicated that sufficient amounts of trees and parameters were sampled (average standard deviation of split frequencies = 0.009823; average estimated sample size of tree lengths = 205.35; potential scale reduction factor of tree lengths = 1.005). Run convergence was also assessed with Tracer ver. 1.6 (Rambaut et al. 2014) to see if the effective sample size of each parameter exceeded 200. Maximum Likelihood (ML) analysis was performed by RAxML ver. 8.2.3 (Stamatakis 2014). One thousand fast-bootstrap replicates were conducted to evaluate nodal support.

Systematics

Family Styelidae Sluiter, 1895 Genus *Syncarpa* Redikorzev, 1913

Syncarpa composita (Tokioka, 1951)

Syndendrodoa composita Tokioka, 1951: 14–16, fig. 11. *Syncarpa longicaudata* Skallin, 1957: 297–298, figs a, b.

Material examined. Thirteen specimens: SMBL 104 (syntypes, two colonies); ICHUM 5815–5825 (non-types, each represented by a single colony).

Comparative material examined. ZIRAS 508-911, one of the syntypes of *Syn-carpa oviformis* Redikorzev, 1913.

Description. Colonies ca. 30–50 mm (40 mm and 50 mm in syntypes) in thickness and ca. 40–130 mm (45 mm and 100 mm in syntypes) in diameter. Tunic grayish violet to black or red in life, tough and leathery; zooids more or less protruded and thus externally discernible from each other (Fig. 1A–C). Zooids 12–50 mm long (21 mm and 22 mm in syntypes) and ca. 8 mm wide (Fig. 1D). Posterior extension of zooids varying in length within the colony and among different colonies; while main zooid length (L_a) varied from 9 mm to 20 mm, posterior extension length (L_b) varied from 3 mm to 22 mm among 20 zooids from 11 colonies, with L_b/L_a ratio being 0.33–1.83 (Fig. 1E, Table 3). Siphons four-lobed, reddish in life, close together. Approximately 30 oral tentacles present (Fig. 2A), comprised of larger and smaller ones alternating almost regularly. Approximately 30 atrial tentacles present and ca. 0.3 mm long. Ciliated aperture of the dorsal tubercle C-shaped, with its interval directing leftward (Fig. 2B).



Figure 1. *Syncarpa composita* (Tokioka, 1951). **A, B, D, E** ICHUM 5817 **C** SMBL 104 (syntype). **A** Live colony **B** intact colony **C** preserved colony **D** intact zooid **E** zooid showing length from top of siphon to end of stomach (L_y) and from end of stomach to posterior end of zooid (L_y).

colonies of Swidt 104 was	illeasureu.		
Catalog number	L _a (mm)	L _b (mm)	L _b / L _a
ICHUM 5817	9	3	0.33
ICHUM 5821	11	4	0.36
SMBL 104	15	7	0.47
ICHUM 5817	12	6	0.5
ICHUM 5820	14	7	0.5
ICHUM 5819	9	5	0.56
ICHUM 5821	12	7	0.58

Table 3. Comparison of the posterior extension length and the ratios of L_a to L_b . Each zooid from two colonies of SMBL 104 was measured.

ICHUM 5820	14	7	0.5
ICHUM 5819	9	5	0.56
ICHUM 5821	12	7	0.58
SMBL 104	11	7	0.64
ICHUM 5818	14	9	0.64
ICHUM 5825	19	15	0.79
ICHUM 5822	10	8	0.8
ICHUM5819	11	9	0.82
ICHUM 5818	14	12	0.86
ICHUM 5824	22	23	1.05
ICHUM 5823	13	14	1.08
ICHUM 5825	19	25	1.32
ICHUM 5824	20	30	1.5
ICHUM 5823	13	20	1.54
ICHUM 5820	18	29	1.61
ICHUM 5822	12	22	1.83



Figure 2. *Syncarpa composita* (Tokioka, 1951). **A, B, D, E** ICHUM 5817 **C** SMBL 104. **A** Zooid opened dorsally **B** ciliated groove (rotated 90 degrees anti-clockwise and enlarged view of the white square of **A**) **C** magnification of inner surface of pharynx, showing large (indicated by an asterisk) and small (indicated by an arrow) transverse vessels **D** outer surface of pharynx, viewed from right side **E** magnification of white square in **D**, showing 'shortcut' of large transverse vessel (asterisk) above pharyngeal fold and 'detour' of small transverse vessel (arrowed) along pharyngeal fold.



Figure 3. *Syncarpa composita* (Tokioka, 1951). **A, B** ICHUM 5817 **C** ICHUM 5824. **A** Zooid opened dorsally, with pharynx removed **B** stomach internal surface **C** tadpole larva.

Prepharyngeal band consisting of a single lamina running close to the ring of oral tentacles; prepharyngeal band V shaped around the dorsal tubercle. Neural ganglion close to dorsal tubercle. Dorsal lamina smoothly margined. One pharyngeal fold and one reduced pharyngeal fold present on each side of pharynx with formula:

L D. 0 (7–8) 2 (2) 3 V. R D. 0 (7) 2 (3) 3 V.

Thirteen-twenty stigmata per mesh between endostyle and first longitudinal vessel from endostyle. Transverse vessels comprised of larger and smaller ones almost regularly alternating antero-posteriorly (Fig. 2C); when running across each pharyngeal fold (as well as reduced pharyngeal fold) on outer surface of pharynx, larger ones always taking a 'shortcut' and bridging over fold valley, while smaller ones 'detour' and go along valley (Fig. 2D, E). Parastigmatic vessels present. Stigmata straight. Gut located on left side (Fig. 3A). Alimentary system occupying approx. half of the left side of body; intestinal loop J-shaped. Esophagus short and slightly curved; its length being one-third of stomach (Fig. 3A). Stomach spindle-shaped, shorter than onethird of body length and has no plication or striation on its outer surface; stomach lying almost parallel to longitudinal axis of body (Fig. 3A), with its internal wall having at least 22 well-defined, regularly arranged, parallel, longitudinal folds (Fig. 3B). Intestine gently curving from pyloric part. Anus lying almost beneath atrial aperture. Diameter of intestine almost uniform from pylorus to anus. Anus without lobes. Gonad with 2–5 branches, situated only on right side of body (Fig. 3A). Ovaries spherical, occupying medial side of gonad; oviduct slightly bending at its end to peripharyngeal cavity before opening on right side of body at almost same level as pylorus. Male follicles located laterally within gonad, surrounding ovaries. Many endocarps present on inner surface of body wall (Fig. 3A).

Hatched tadpole larvae found in peripharyngeal cavity of ICHUM 5824 and 5825; trunk spindle-shaped, ca. 1 mm in length (Fig. 3C). Three adhesive papillae arranged in triangle. Approximately 35 elongated ampullae discerned on anterior half of trunk surface. Photolith present in cerebral vesicle but invisible from the outside (Fig. 4). Tail twice as long as trunk.

Remarks. Syncarpa composita and S. oviformis are different in terms of the number of oral tentacles, the number of size-classes of transverse vessels, and the number of anal lobes (Table 4). In addition, the transverse vessels in S. composita alternate 'shortcut' and 'detour' when crossing the valley of pharyngeal folds, while all the transverse vessels in S. oviformis make a shortcut and bridge over the valley of pharyngeal folds (Fig. 5A, B). Based on the consistent, discontinuous differences discovered in the present

Character	Species								
	S. com	iposita	S. corticiformis	S. longicaudata	S. oviformis				
Source	Tokioka	Tokioka present		Skalkin (1957)	Redikorzev	Sanamyan			
	(1951)	study	(1975)		(1913)	(2000)			
Zooid length (mm)	12	12-50	15	40	10	10-30			
Zooid width (mm)	8	8	5	7.5	4	4-8			
Posterior extension of	-	-/+	-	+	-	-			
zooid long (+) or short (-)									
Number of oral tentacles	30	30-35	20	30-35	20-25	20-25			
Number of size-classes of	of size-classes of ? 2		1 2		1*	?			
transverse vessels									
Stomach internal wall	?	+	+	+	+	+			
present (+) or absent (-)									
Intestinal loop	?	J-shaped	J-shaped	J-shaped	J-shaped	J-shaped			
Number of anal lobes	0	0	2	0	2	2			
Number of gonadal	2-5	2–5	4	3	2	2-4			
branches									
Locality Akkeshi Bay Al		Akkeshi Bay	Kunashiri	South Kuril	Ul'banskij	Sea of			
			Island	Islands	Bay	Okhotsk			

Table 4. Comparison of four species of *Syncarpa*. The number of size-classes of transverse vessels in *S. oviformis* (indicated by an asterisk) was newly confirmed in this study. Sanamyan (2000) concluded that *S. corticiformis* and *S. longicaudata* were junior synonyms of *S. oviformis*.



Figure 4. *Syncarpa composita* (Tokioka, 1951), ICHUM 5824, cross section of a tadpole larva, showing photolith.

study, we conclude to leave *S. composita* as a valid species as opposed to *S. oviformis*, until molecular data settle the issue of conspecificity.

Syncarpa composita and S. longicaudata were supposed to be differentiated by the ratio of the lengths of the zooid's main body (L_a) to its posterior extension (L_b) , expressed as L_b/L_a (Fig. 1E). The values of this character for S. composita and S. longicaudata, based on the original figures (Tokioka 1951, figs 11.2, 11.3; Skalkin 1957, fig. a), are 0.40 and 1.00, respectively. In this study, however, we discovered that the L_b/L_a values could vary from 0.33 to 1.83 even intra-colonially in S. composita (Table 3), completely encompassing the character state of S. longicaudata. Although S. longcaudata has been considered a junior synonym of S. oviformis, we think that it is more similar to S. composita (Table 4). Extensive population genetic studies on potentially different populations of these species from the Northwest Pacific would help to improve our understanding of the taxonomy of this genus.



Figure 5. *Syncarpa oviformis* Redikorzev, 1913, ZIRAS 508-911 (syntype). **A** Outer surface of pharynx, viewed from right side **B** magnification of white square in **A**, showing that all transverse vessels make 'shortcuts' and bridge across the pharyngeal fold.

Phylogeny. In the phylogenetic tree, *Syncarpa* formed a well-supported clade together with *Dendrodoa* (Fig. 6). These two genera have a single gonad positioned on the right side of the body. This feature is likely to represent a synapomorphy for this clade. The only difference between *Syncarpa* and *Dendrodoa* is that the former is colonial while the latter is solitary. The latter currently consists of eight species (Shenkar et al. 2019). Future studies should ascertain the possible reciprocal monophyly of the two genera by analyses with expanded taxon sampling from *Dendrodoa*. If they turn out to be reciprocally non-monophyletic (e.g., *Syncarpa* completely nested within paraphyletic *Dendrodoa*), these two genera can be synonymized so that it consists of both colonial and non-colonial species, just as the diazonid *Rhopalaea* Philippi, 1843.

A clade comprised of *Dendrodoa*, *Polycarpa*, and *Polyandrocarpa zorritensis* was recovered in Alié et al.'s (2018) phylogenomic analysis based on 4,908 genes, in which *Polyandrocarpa zorritensis* was sister to *Polycarpa aurata*, forming a clade sister to *Dendrodoa grossularia*.

Although the nodal support values were generally poor, our tree does not support the three-subfamily classification system: Styelinae consisting of solitary styelid species, Polyzoinae of colonial styelid species without system, and Botryllinae of colonial styelid species with system. Highly reliable molecular analyses and detailed morphological observations including *Syncarpa* would help understanding the systematics of Styelidae.



Figure 6. Phylogenetic relationship of 28 styelid ascidians. ML tree generated from concatenated sequences of 18S (1582 bp) and COI (686 bp). Numbers on nodes indicate bootstrap values and, where applicable, posterior probabilities. Scale bar indicates number of substitutions per site. B, P, and S represented Botryllinae, Polyzoinae, and Styelinae.

Acknowledgments

Sincere thanks are offered to Ms Haruka Yamaguchi, Mr Hidenori Katsuragawa, Mr Shoichi Hamano (Akkeshi Marine Station, Hokkaido University); Mr Daiki Wakita, Dr Kevin Wakeman (Hokkaido University); Mr Hisanori Kohtsuka, Mr Mamoru Sekifuji, and Ms Michiyo Kawabata (Misaki Marine Biological Station, University of Tokyo) for their help in collecting the samples. We are grateful to Dr Yuko Takigawa (Kagawa University); Dr Shigeyuki Yamato (Seto Marine Biological Laboratory, Kyoto University); and Dr Igor Smirnov (Zoological Institute, Russian Academy of Sciences) for their help with specimen loans. Advice and comments given by Dr Teruaki Nishikawa (National Museum of Nature and Science) have been a great help in this study. This study was supported by Research Institute of Marine Invertebrates (FY 2018, No. 6). We thank Dr Keiichi Kakui (Hokkaido University), and the other members of Biodiversity 1 for their help.

References

- Alié A, Hiebert LS, Simion P, Scelzo M, Prünster MM, Lotito S, Delsuc F, Douzery EJP, Dantec C, Lemaire P, Darras S, Kawamura K, Brown FD, Tiozzo S (2018) Convergent acquisition of nonembryonic development in styelid ascidians. Molecular Biology and Evolution 35(7): 1728–1743. https://doi.org/10.1093/molbev/msy068
- Beniaminson TS (1975) Morphology and taxonomic position of ascidians of the genus Syncarpa Redikorzev with a description of Syncarpa corticiformis sp. n. Russian Journal of Marine Biology 3: 29–36.
- Boom R, Sol C, Beld M, Weel J, Goudsmit J, Dillen PW (1990) Improved silica-guanidiniumthiocyanate DNA isolation procedure based on selective binding of bovine alpha-casein to silica particles. Journal of Clinical Microbiology 1999: 615–619.
- Castresana J (2002) Estimation of genetic distances from human and mouse introns. Genome Biology 3(6): 1–7. https://doi.org/10.1186/gb-2002-3-6-research0028
- Delsuc F, Philippe H, Tsagkogeorga G, Simion P, Tilak M, Turon X, López-Legentil S, Piette J, Lemaire P, Douzery EJP (2018) A phylogenomic framework and timescale for comparative studies of tunicates. BMC Biology 16: 39. https://doi.org/10.1186/s12915-018-0499-2
- Folmer O, Black M, Hoeh W, Lutz R, Vrijenhoek R (1994) DNA primers for amplification of mitochondrial cytochrome c oxidase subunit I from diverse metazoan invertebrates. Molecular Marine Biology and Biotechnology 3: 294–299.
- Giribet G, Carranza S, Baguña J, Riutort M, Ribera C (1996) First molecular evidence for the existence of a Tardigrada + Arthropoda clade. Society for Molecular Biology and Evolution 13(1): 76–84. https://doi.org/10.1093/oxfordjournals.molbev.a025573
- Huelsenbeck JP, Ronquist F (2001) MRBAYES: Bayesian inference of phylogenetic trees. Bioinformatics Applications Note 17(8): 754–755. https://doi.org/10.1093/bioinformatics/17.8.754
- Katoh K, Standley DM (2013) MAFFT multiple sequence alignment software version 7: improvements in performance and usability. Molecular Biology and Evolution 30(4): 772–780. https://doi.org/10.1093/molbev/mst010
- Kott P (1985) The Australian Ascidiacea. Part 1: Phlebobranchia and Stolidobranchia. Memoirs of the Queensland Museum 23: 1–440.
- Lanfear R, Frandsen PB, Wright AM, Senfeld T, Calcott B (2016) PartitionFinder 2: new methods for selecting partitioned models of evolution for molecular and morphological phylogenetic analyses. Molecular Biology and Evolution 34(3): 772–773. https://doi.org/10.1093/molbev/msw260
- MacLeay WS (1824) Anatomical observations on the natural group of Tunicata, with the description of three species collected in Fox Channel during the late northern expedi-

tion. Transactions of the Linnean Society of London 14(3): 527–555. https://doi. org/10.1111/j.1095-8339.1823.tb00101.x

- Nishikawa T (1995) Subphylum Urochordata. In: Nishimura S (Ed.) Guide to Seashore Animals of Japan with Color Pictures and Keys, Volume 2. Hoiku-sha, Osaka, 573–608.
- Pérez-Portela R, Bishop JDD, Davis AR, Turon X (2009) Phylogeny of the families Pyuridae and Styelidae (Stolidobranchiata, Ascidiacea) inferred from mitochondrial and nuclear DNA sequences. Molecular Phylogenetics and Evolution 50: 560–570. https://doi. org/10.1016/j.ympev.2008.11.014
- Philippi A (1843) Rhopalaea ein neues Genus der einfachen Ascidien. Archiv für Anatomie, Physiologie und Wissenschatliche Medicin, 45–57.
- Rambaut A, Suchard MA, Xie D, Drummond AJ (2014) Tracer v1.6. http://beast.bio.ed.ac. uk/Tracer
- Redikorzev V (1913) Neue Ascidien. Zoologischer Anzeiger 43: 204–213.
- Redikorzev V (1941) Ascidien der Meere des fernen Osten der Ud.S.S.R. Investigations of the Far Eastern Seas of the USSR 1: 164–212.
- Ronquist F, Huelsenbeck JP (2003) MrBayes 3: Bayesian phylogenetic inference under mixed models. Bioinformatics Applications Note 19(12): 1572–1574. https://doi.org/10.1093/ bioinformatics/btg180
- Sanamyan K (2000) Ascidians from the north-western pacific region 7. Styelidae. Ophelia 53(1): 67–78. https://doi.org/10.1080/00785326.2000.10409436
- Shenkar N, Gittenberger A, Lambert G, Rius M, Moreira da Rocha R, Swalla BJ, Turon X (2019). Ascidiacea World Database. *Dendrodoa* MacLeay, 1824. Accessed through: World Register of Marine Species. http://www.marinespecies.org/aphia.php?p=taxdetails&id=103531 [on 16 April 2019]
- Skalkin VA (1957) A new species of ascidian from the Pacific Ocean Syncarpa longicaudata sp. n. (family Styelidae). Zoologicheskii Zhurnal 36: 297–298.
- Sluiter CP (1895) Tunicaten. In: Semon R (Ed.) Zoologische Forschungsreisen in Australien und den malayischen Archipel. Denkschriften der Medicinisch-Naturwissenschaftlichen Gesellschaft zu Jena 8: 163–186.
- Stamatakis A (2014) RAxML version 8: a tool for phylogenetic analysis and post-analysis of large phylogenies. Bioinformatics 30: 1312–1313. https://doi.org/10.1093/bioinformatics/btu033
- Tamura K, Peterson D, Peterson N, Stecher G, Nei M, Kumar S (2011) MEGA5: molecular evolutionary genetics analysis using maximum likelihood, evolutionary distance, and maximum parsimony methods. Molecular Biology and Evolution 28(10): 2731–2739. https:// doi.org/10.1093/molbev/msr121
- Tokioka T (1951) The fauna of Akkeshi Bay XVIII. Ascidia. Publications from the Akkeshi Marine Biological Station 1: 1–22. [2 pls]
- Tokioka T (1963) Contributions to Japanese ascidian fauna. XX. The outline of Japanese ascidian fauna as compared with that of the Pacific Coasts of North America. Publications of the Seto Marine Biological Laboratory 11(1): 131–156. https://doi.org/10.5134/175319
- Tsagkogeorga G, Turon X, Hopcroft RR, Tilak M, Feldstein T, Shenkar N, Loya Y, Huchon D, Douzery EJP, Delsuc F (2009) An updated 18S rRNA phylogeny of tunicates based on

mixture and secondary structure models. BMC Evolutionary Biology 9: 187. https://doi.org/10.1186/1471-2148-9-187

- Van Name WG (1931) New North and South American ascidians. Bulletin of the American Museum of Natural History 61: 207–255.
- Whiting MF, Carpenter JC, Wheeler QD, Wheeler WC (1997) The Strepsiptera problem: phylogeny of the holometabolous insect orders inferred from 18S and 28S ribosomal DNA sequences and morphology. Systematic Biology 46(1): 1–68. https://doi.org/10.1093/sysbio/46.1.1
- Zeng L, Jacobs MW, Swalla BJ (2006) Coloniality has evolved once in stolidobranch ascidians. Integrative and Comparative Biology 46(3): 255–268. https://doi.org/10.1093/icb/icj035

RESEARCH ARTICLE



Redescription of the Dikraneurini leafhopper Dikrella mella Ruppel & DeLong, 1952 (Hemiptera, Cicadellidae) with a synoptic checklist of leafhoppers on avocado trees in Mexico

J. Adilson Pinedo-Escatel¹, Dmitry Dmitriev²

l Departamento de Botánica y Zoología, CUCBA, Universidad de Guadalajara, km 15.5 carretera Guadalajara-Nogales, Las Agujas, Zapopan, C.P. 45110, Apdo. Postal 139, Jalisco, México 2 Prairie Research Institute, 2204 Griffith Dr., Building 11 Dock A, Champaign, IL 61820, USA

Corresponding author: J. Adilson Pinedo-Escatel (adilson1030@gmail.com)

Academic editor: C.H. Dietrich Received 18 February 2019 Accepted 6 May 2019	Published 24 June 2019

Citation: Pinedo-Escatel JA, Dmitriev D (2019) Redescription of the Dikraneurini leafhopper *Dikrella mella* Ruppel & DeLong, 1952 (Hemiptera, Cicadellidae) with a synoptic checklist of leafhoppers on avocado trees in Mexico. ZooKeys 857: 17–27. https://doi.org/10.3897/zooKeys.857.33910

Abstract

Among leafhoppers (Hemiptera, Cicadellidae), only Typhlocybinae are known in Mexico to inhabit avocado, an important horticultural crop. In this paper, a potential avocado pest, *Dikrella mella* Ruppel & DeLong, 1952, is redescribed and illustrated. Additionally, a detailed checklist and a key for all known species of Typhlocybinae associated with avocado trees in Mexico are provided.

Keywords

Alconeura, Auchenorrhyncha, Empoasca, Empoascini, Idona, Joruma, Typhlocybinae

Introduction

Herbivorous sap-sucking insects are potentially devastating agricultural pests because they not only injure plants directly but may also transmit plant pathogens (Bosco and Marzachi 2016). Most such pests belong to the order Hemiptera (Hogenhout et al. 2008), of which the family Cicadellidae (leafhoppers) (Hemiptera: Auchenorrhyncha) is the most relevant because it comprises around 75% of plant pathogen vector species (Weintraub and Beanland 2006). Within leafhoppers, the subfamily Typhlocybinae is reported to spread several kinds of pathogens effectively due to their high capacity for dispersal. Leafhopper vectors often go unnoticed when transmitting plant diseases, their presence only being detected after disease outbreaks occur (Nault 1979).

Avocado is one of the most important horticultural crops worldwide and Mexico is the main exporter (SAGARPA 2017). Recently five species of leafhoppers were identified as being associated with avocado trees in central Mexico (Quezada-Daniel et al. 2017). All of those species belong to the subfamily Typhlocybinae. Our study of leafhoppers from several entomological collections in Mexico revealed that these species have been widely misidentified. For example, specimens of *Dikrella mella* Ruppel & DeLong, 1952, housed in Mexican collections were often misidentified as *Empoasca* spp., presumably based on superficial resemblance in size and coloration.

The genus *Dikrella* Oman, 1949 was described based on type-species *Dikraneura cockerellii* Gillette, 1895. Oman (1949) also moved 14 species previously placed in *Dikraneura* Hardy, 1850 to *Dikrella*. Today, the genus includes two subgenera: *Readionia* Young, 1952 with four species and *Dikrella* Oman, 1949 with 37 well-defined species and three subspecies. The genus is restricted to the New World. Only one species of the genus is known so far to be a potential vector of diseases of avocado crops.

Dikrella mella Ruppel & DeLong, 1952 was described from four localities in Mexico based on two males and four females. The original description and illustrations lack important details useful for distinguishing the species. Since then, no further information was published on its distribution or host plants. Here we provide a redescription and diagnostic illustrations of this important avocado leafhopper. We also provide a detailed checklist and a key to all known species recorded from avocado trees in Mexico.

Materials and methods

All specimens identified in this study are housed at the Colección Nacional de Insectos, Instituto de Biología, Universidad Nacional Autónoma de México, Mexico (**CNIN**), Colección de Insectos del Instituto de Fitosanidad, Colegio de Postgraduados, Texcoco, Estado de México, Mexico (**CEAM**), Colección de Auchenorrhyncha de Jorge Adilson Pinedo Escatel, Mexico (**CAJAPE**), Colección Entomológica del Centro de Estudios en Zoología, Universidad de Guadalajara, Zapopan, Mexico (**CZUG**), and C.A. Triplehorn Insect Collection, Ohio State University, Columbus, USA (**OSUC**).

Taxonomic criteria and terminology follows mainly Young (1952), Dietrich (2005), and Dmitriev (2010). Techniques for preparation of male genital structures follow Oman (1949) modified such that male abdomens were rinsed with water mixed with alcohol at different concentrations. Label data are given between quotation marks, with a backslash (\) separating the lines on the labels. Images of habitus were taken using a Carl Zeiss camera mounted on a Stemi 2000c stereo-microscope, and illustrations were drawn using a camera lucida attached to a Leica stereo microscope. Subsequently, drawings were digitized and vectorized with Adobe Illustrator and edited in Adobe Photoshop. Measurements were obtained using an electronic vernier.

Taxonomy

Typhlocybinae Kirschbaum, 1868 Dikraneurini McAtee, 1926

Dikrella Oman, 1949

Dikrella (Dikrella) Oman, 1949 Dikrella (Dikrella) Oman, 1949: 83.

Type-species. Dikraneura cockerellii Gillette, 1895

Diagnosis. Slender leafhoppers, overall body coloration usually white to yellowish. Head as wide as pronotum, produced, crown convex. Forewing fourth apical cell short and third narrow. Hind wing submarginal vein complete, three apical cells. Pygofer with process. Aedeagus body elongate or robust usually with a pair of basal process.

Remarks. *Dikrella* differs from *Kunzeana* Oman, 1940 by the distinctly widened basal part of the forewing inner apical cell.

Distribution. Confined to the New World, recorded from: United States, Mexico, Costa Rica, Cuba, Puerto Rico, Panama, Canada, Ecuador, Colombia, Bolivia, and Brazil.

Dikrella (Dikrella) mella Ruppel & DeLong, 1952

Figures 1-8

Dikrella (Dikrella) mella Ruppel & DeLong, 1952: 90

Description of male. Small, delicate. Body slender. Texture of head, pronotum, and mesonotum uniform. General coloration yellowish with orange-gold infusions on pronotum and ventral view, forewing with two black spots on first and fourth apical cell, spots of same diameter but one in fourth cell lighter (Figs. 1 and 2). Head well produced, narrowly rounded apically, lateral margin white, center yellow, distance between eyes (interocular) $1.0 \times$ of eye diameter, coronal suture half as long as crown length. Face without marks, mostly white-yellowish. Frontoclypeus narrow and parallel-sided. Anteclypeus longer than wide. Pronotum large, produced anteriorly, reaching half-length of eye, convex, slightly wider than head, lateral margins slightly convergent distally, white, center yellow. Visible part of mesonotum large, as long as pronotum, apex gold. Forewing well developed, translucent with tiny yellow marks along sides of R, M veins, and apical cells, some yellow pigmentation at base of marginal vein and clavus. Hind wing translucent.

Description of female. Same as male but color somewhat paler overall.

Male genitalia. Pygofer conical, narrowing caudally, longer than wide, with notch on dorsal margin, dorsal process slender curved dorsad arising beyond midlength of pygofer near dorsal notch; ventral process short, straight subapical (Fig. 7). Anal tube broad and membranous. Subgenital plate elongate, wider at base and narrowed toward tip, apex rounded, outer margin striate, inconspicuous setae running on each side of



Figure 1. Dikrella mella Ruppel & DeLong, 1952 male body, dorsal aspect.

plate (Fig. 8). Connective broad and short, almost square (Fig. 6). Style long, base narrow, anterior lobe not developed, preapical lobe very bulky, projected laterad with fine setae apically; apex long, curved and finger-shaped (Fig. 5). Aedeagus with atrium about as long as shaft, dorsal apodeme not developed; shaft long, slender and slightly



Figure 2. Dikrella mella Ruppel & DeLong, 1952 female head, dorsal aspect.

curved dorsad with dorsal preapical gonopore; ventral appendage large, forked close to apex, straight in lateral view; atrium with two long slender processes arising near base of shaft, parallel to each other on ventral side of shaft, divergent at apex (Figs. 3 and 4).

Female genitalia. VII sternite quadrate, ovipositor large, pointed.

Immature stages. Unknown

Measurements. Body size 3.0-3.5 mm

Reported hosts. Avocado (Persea americana)

Type locality. Cuernavaca, Morelos state (Mexico)

Distribution. Mexico: Guerrero (Iguala), Michoacán (Uruapan), Oaxaca (Rancho Monter), Morelos (Cuernavaca; Tetela del Volcán), and Chiapas (Vergel)

Material examined. Holotype \Diamond (OSUC), MEXICO: Cuernavaca Mor. \ X-21-41. \ K. 57 \ DeLong, Good, Caldwell and Plummer \ D. M. DeLong collection; $2\Diamond$ Paratypes (OSUC), MEXICO: Iguala, Guerrero \ IX-11 39 \ D. M. DeLong collection; $1\Diamond$, $2\Diamond$ (CEAM), MEXICO: Morelos, Tetela del Volcán, San Miguel \ 1,962m \ 18°50'27.204"N, 98°44'46.895"W \ 30–Ene–2014 \ ex: *Persea americana* \ sweep net \ R.M. Quezada-Daniel; $1\bigcirc$, $1\Diamond$ (CEAM), MEXICO, Morelos, Tetela del Volcán, Huerta El Calabazo \ 2,195m \ 18°52'3.252"N, 98°44'5.2"W \ 19–Oct–2014 \ ex: *Persea americana* \ sweep net. \ R. M. Quezada-Daniel; $9\Diamond$, $11\bigcirc$ (CAJAPE),



Figure 3–8. *Dikrella mella* Ruppel & DeLong, 1952 male genitalia: 3 aedeagus, lateral view 4 aedeagus, ventral view 5 style, dorsal view 6 connective, dorsal view 7 pygofer, lateral view 8 plate, dorsal view.

MEXICO: Morelos, Tetela del Volcán, San Miguel \ 1,962m \ 18°50'27.204"N, 98°44'46.895"W \ 30–Ene–2014 \ ex: *Persea americana* \ sweep net \ R.M. Quezada-Daniel; 1 (CNIN), MEXICO: Morelos, Tetela del Volcán, San Miguel \ 1,962m \ 18°50'27.204"N, 98°44'46.895"W \ 30–Ene–2014 \ ex: *Persea americana* \ sweep net \ R.M. Quezada-Daniel; 1 (CEAM), MEXICO: Morelos, Tetela del Volcán, San Miguel \ 1,962m \ 18°50'27.204"N, 98°44'46.895"W \ 30–Ene–2014 \ ex: *Persea americana* \ sweep net \ R.M. Quezada-Daniel; 1 (CEAM), MEXICO: Morelos, Tetela del Volcán, San Miguel \ 1,962m \ 18°50'27.204"N, 98°44'46.895"W \ 30–Ene–2014 \ ex: *Persea americana* \ sweep net \ R.M. Quezada-Daniel; 1 (CEAM), MEXICO: Morelos, Tetela del Volcán, San Miguel \ 1,962m \ 18°50'27.204"N, 98°44'46.895"W \ 30–Ene–2014 \ ex: *Persea americana* \ sweep net \ R.M. Quezada-Daniel

Key to Mexican leafhopper pest species on avocado trees (males)

1	Submarginal vein of hind wing extended along apex and connected to vein R2+3
	(Fig. 10) 2
_	Submarginal vein of hind wing not extended along apex, not connected to R2+3
	or absent
2	Forewing with fourth apical cell long, slender, and parallel. Head produced and
	sharply angled, in lateral view, face long and strongly convex. Pronotum, mesono-
	tum, and forewings with many tiny red spots. Aedeagus with posterior preapical
	processes (Fig. 13)
_	Forewing with fourth apical cell distinctly tapered distally. Head sometimes pro-
	duced and angled, in lateral view, face short. Crown, pronotum, mesonotum, and
	forewings sometimes with orange, black or yellow marks but not red. Aedeagus
	with processes, if present, arising near base of shaft
3	Hind wing with apex of vein RP free, connected by crossvein to MA (Fig. 12).
	Crown longer than distance between eyesJoruma krausi
_	Hind wing with RP confluent to MA, r-m crossvein absent. Crown shorter than
	distance between eyes
4	Pygofer with suture close to sternite VIII (Fig. 14). Aedeagus without processes .
	Empoasca angustella
_	Pygofer without suture close to sternite VIII. Aedeagus with pair of basal pro-
	cesses Empoasca deskina
5	Inner apical cell of forewing broader basally than apically. Hind wing with three
	apical cells Dikrella mella
_	Inner apical cell of forewing parallel sided. Hind wing with two apical cells6
6	Pygofer process black (Fig. 15 and 16)7
_	Pygofer process pale (Fig. 17)Idona minuenda
7	Pygofer process extended beyond pygofer apex (Fig. 15)
-	Pygofer process not extended beyond pygofer, visible above dorsal margin (Fig.
	16) Idona gonzalezae
8	Clavus with small spot, not reaching margin and veins (Fig. 11)
-	Clavus with large spot, reaching margin and veins (Fig. 9) Idona dmitrievi

Checklist of leafhoppers associated with avocado trees in Mexico

Alconeura (Hyloidea) candida (Ruppel & DeLong, 1952)

Material examined. 25 $\stackrel{\circ}{\downarrow}$, 2 $\stackrel{\circ}{\circ}$ (CEAM), MEXICO, Morelos, Tetela del Volcán, Huerta El Calabazo \ 2,195m \ 18°52'3.252"N, 98°44'5.2"W \ 19–Oct–2014 \ ex: *Persea americana* \ sweep net \ R. M. Quezada-Daniel.



Figure 9–17. Morphological structures of microleafhopper (Typhlocybinae) species associated to avocado trees in Mexico 9 forewing of *Idona dmitrievi* 10 hind wing of *Idona dmitrievi* 11 forewing of *Idona floresi* 12 hind wing of *Joruma krausi* 13 aedeagus of *Alconeura candida* 14 pygofer of *Empoasca angustella*, lateral view 15 pygofer of *Idona dmitrievi*, lateral view 16 pygofer of *Idona gonzalezae*, lateral view 17 pygofer of *Idona minuenda*, lateral view.

Dikrella (Dikrella) mella Ruppel & DeLong, 1952

Material examined. 13, 23 (CEAM), MEXICO: Morelos, Tetela del Volcán, San Miguel \ 1,962m \ 18°50'27.204"N, 98°44'46.895"W \ 30–Ene–2014 \ ex: *Persea americana* \ sweep net \ R.M. Quezada-Daniel; 12, 13 (CEAM), MEXICO, Morelos, Tetela del Volcán, Huerta El Calabazo \ 2,195m \ 18°52'3.252"N,

98°44'5.2"W \ 19–Oct–2014 \ ex: *Persea americana* \ sweep net. \ R. M. Quezada-Daniel; 9 \Im , 11 \bigcirc (CAJAPE), MEXICO: Morelos, Tetela del Volcán, San Miguel \ 1,962m \ 18°50'27.204"N, 98°44'46.895"W \ 30–Ene–2014 \ ex: *Persea americana* \ sweep net \ R.M. Quezada-Daniel; 1 \Im , 1 \bigcirc (CNIN), MEXICO: Morelos, Tetela del Volcán, San Miguel \ 1,962m \ 18°50'27.204"N, 98°44'46.895"W \ 30–Ene–2014 \ ex: *Persea americana* \ sweep net \ R.M. Quezada-Daniel; 1 \Im (CEAM), MEXICO: Morelos, Tetela del Volcán, San Miguel \ 1,962m \ 18°50'27.204"N, 98°44'46.895"W \ 30–Ene–2014 \ ex: *Persea americana* \ sweep net \ R.M. Quezada-Daniel; 1 \Im (CEAM), MEXICO: Morelos, Tetela del Volcán, San Miguel \ 1,962m \ 18°50'27.204"N, 98°44'46.895"W \ 30–Ene–2014 \ ex: *Persea americana* \ sweep net \ R.M. Quezada-Daniel; 1 \Im

Idona dmitrievi Pinedo-Escatel & Blanco-Rodríguez, 2016

Material examined. 25♀, 16♂ (CEAM), MEXICO, Morelos, Tetela del Volcán, Huerta El Calabazo \ 2,195m \ 18°52'3.252"N, 98°44'5.2"W \ 19–Oct–2014 \ ex: *Persea americana* \ sweep net \ R. M. Quezada-Daniel; 1♂ (CAJAPE), MEXICO, Morelos, Tetela del Volcán, Huerta El Calabazo \ 2,195m \ 18°52'3.252"N, 98°44'5.2"W \ 19–Oct–2014 \ ex: *Persea americana* \ sweep net \ R. M. Quezada-Daniel.

Idona minuenda (Ball, 1921)

Material examined. 13♀, 16♂ (CEAM), MEXICO, Morelos, Tetela del Volcán, Huerta El Calabazo \ 2,195m \ 18°52'3.252"N, 98°44'5.2"W \ 19–Oct–2014 \ ex: *Persea americana* \ sweep net \ R. M. Quezada-Daniel.

Idona floresi Freytag, 2015

Material examined. 1 $\stackrel{\bigcirc}{\rightarrow}$, 1 $\stackrel{\bigcirc}{\rightarrow}$ (OSUC), MEXICO, Michoacán, Salvador Escalante, 03–Aug–2012 \ ex: Aguacate \ Graciela Gonzales Col.

Idona gonzalezae Freytag, 2015

Material examined. 1 $\stackrel{\circ}{\downarrow}$, 1 $\stackrel{\circ}{\circ}$ (OSUC), MEXICO, Michoacán, Salvador Escalante, 03–Aug–2012 \ ex: Aguacate \ Graciela Gonzales Col.

Joruma (Joruma) krausi Ruppel & DeLong, 1953

Material type examined. Holotype ♂ (OSUC), MEXICO: Cuernavaca Mor. \ Mexico III-1945 \ N. L. H. Krause \ D. M. DeLong collection

Additional material reviewed. 12^Q, 25^A (CEAM), MEXICO, Morelos, Tetela del Volcán, Huerta El Calabazo \ 2,195m \ 18°52'3.252"N, 98°44'5.2"W \ 19–Oct–2014 \ ex: *Persea americana* \ sweep net \ R. M. Quezada-Daniel.

Empoasca (Empoasca) deskina DeLong & Guevara, 1954

Material examined. 3° , 9° (CEAM), MEXICO, Morelos, Tetela del Volcán, Huerta El Calabazo \ 2,195m \ 18°52'3.252"N, 98°44'5.2"W \ 19–Oct–2014 \ ex: *Persea americana* \ sweep net \ R. M. Quezada-Daniel.

Empoasca (Empoasca) angustella DeLong, 1952

Material examined. 6, 12, (CEAM), MEXICO, Morelos, Tetela del Volcán, Huerta El Calabazo \ 2,195m \ 18°52'3.252"N, 98°44'5.2"W \ 19–Oct–2014 \ ex: *Persea americana* \ sweep net \ R. M. Quezada-Daniel.

Conclusions

26

Nine species in five genera of typhlocybine leafhoppers are reported from avocado trees in Mexico. None of these species have been tested or confirmed to transmit any disease so far. Species are recorded from Mexican states (Table 1), of which Morelos is the best sampled and is home to seven species. Additional sampling is underway for the purpose of management and monitoring in states with high levels of avocado production within Mexico and will undoubtedly provide additional avocado-associated records.

Table 1. Geographical occurrence of known leafhoppers of the subfamily Typhlocybinae inhabiting avo-cado trees.

	Leafhoppers	;	Distribution					
Genus	Subgenus	Species	Country: state (known localities)					
Alconeura	Hyloidea	candida	Mexico: Morelos (Cuernavaca; Tetela del Volcán)					
Dikrella	Dikrella	mella	Mexico: Morelos (Cuernavaca; Tetela del Volcán), Guerrero (Iguala), Oaxaca (Rancho Monter), and Chiapas (Vergel)					
Idona		dmitrievi	Mexico: Morelos (Tetela del Volcán)					
		minuenda	Mexico: Morelos (Tetela del Volcán), and Tamaulipas (Ciudad Victoria)					
		floresi	Mexico: Michoacán (Uruapan)					
		gonzalezae	Mexico: Michoacán (Uruapan)					
Joruma	Joruma	krausi	Mexico: Morelos (Cuernavaca; Tetela del Volcán), Veracruz (Córdoba), and Oaxaca (Chiltepec)					
Empoasca	Empoasca	deskina	Mexico: Morelos (Cuernavaca; Tetela del Volcán), Hidalgo (Jacala), Estado de México (Distrito Federal), and Veracruz (Orizaba)					
		angustella	Mexico: Morelos (Laguna de Zempoala; Tetela del Volcán)					

Acknowledgements

The first author is very grateful to Axel Cristobal P. E. for comments during development of manuscript. We kindly were helped by Christopher Dietrich (Illinois Natural History Survey. USA) and Maria I. Catalano (Centro de Bioinvestigaciones de la Universidad Nacional del Noroeste de la provincia de Buenos Aires) with helpful comments to improve the manuscript. Edith Blanco-Rodríguez helped corroborate identification of the specimens. We also thank curators of collections, Luciana Musetti (OSUC), Harry Brailovsky and M. Cristina Mayorga-Martínez (CNIN), Jose Luis Navarrete-Heredia (CZUG), and Jesus Romero-Nápoles (CEAM) for access to types and other specimens. J.A. Pinedo-Escatel is supported by CONACyT [CVU: 705854] and BEMARENA Ph.D. program of the Universidad de Guadalajara at Centro Universitario de Ciencias Biológicas y Agropecuarias, Zapopan, Jalisco, Mexico. Dmitry Dmitriev is supported by National Science Foundation [NSF 16-39601].

References

- Bosco D, Marzachi C (2016) Insect transmission of phytoplasmas. In: Brown JK (Ed.) Vector-Mediated Transmission of Plant Pathogens. APS PRESS Online. https://doi. org/10.1094/9780890545355.022
- Dietrich CH (2005) Keys to the families of Cicadomorpha and subfamilies and tribes of Cicadellidae (Hemiptera: Auchenorrhyncha). Florida Entomologist 88: 502–517. https:// doi.org/10.1653/0015-4040(2005)88[502:KTTFOC]2.0.CO;2
- Dmitriev DA (2010) Homologies of the head of Membracoidea based on nymphal morphology with notes on other groups of Auchenorrhyncha (Hemiptera). European Journal of Entomology 107: 597–613. https://doi.org/10.14411/eje.2010.069
- Hogenhout SA, Ammar el-D, Whitfield AE, Redinbaugh MG (2008) Insect vector interactions with persistently transmitted viruses. Annual Review of Phytopathology 46: 327–359. https://doi.org/10.1146/annurev.phyto.022508.092135
- Nault LR (1997) Arthropod transmission of plant viruses: a new synthesis. Annals of the Entomological Society of America 90: 521–541. https://doi.org/10.1093/aesa/90.5.521
- Quezada-Daniel RM, Bautista-Martínez N, González-Santarosa MG, Valdez-Carrasco JM, Pinedo-Escatel JA, Turcios-Palomo LA (2017) Leafhopper Species Associated with Avocados at Morelos, Mexico. Southwestern Entomologist 42: 103–109. https://doi. org/10.3958/059.042.0109
- Ruppel RF, DeLong DM (1952) Some new species of Mexican *Dikrella* (Homoptera Cicadellidae). The Ohio Journal Science 52: 89–95.
- SAGARPA (2017) Planeación Agrícola nacional 2017-2030. Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación. Ciudad de México, México.
- Weintraub PG, Beanland L (2006) Insect vectors of phytoplasmas. Annual Review of Entomology 51: 91–111. https://doi.org/10.1146/annurev.ento.51.110104.151039
- Young DA (1952) A reclassification of western hemisphere Typhlocybinae (Homoptera: Cicadellidae). University of Kansas Science Bulletin 35: 1–217. https://doi.org/10.5962/bhl.part.4327

RESEARCH ARTICLE



A review of the genus Lankaphthona Medvedev, 2001, with comments on the modified phallobase and the unique abdominal appendage of L. binotata (Baly) (Coleoptera, Chrysomelidae, Galerucinae, Alticini)

Yongying Ruan^{1,2}, Alexander S. Konstantinov³, Kaniyarikkal D. Prathapan⁴, Mengna Zhang², Xingke Yang⁵

 College of Agriculture, South China Agricultural University, Guangzhou, Guangdong 510642, China
School of Applied Chemistry and Biological Technology, Postdoctoral Innovation Practice Base, Shenzhen Polytechnic, Shenzhen, Guangdong 518055, China 3 Systematic Entomology Laboratory, USDA, ARS, Washington DC, USA 4 Department of Entomology, Kerala Agricultural University, Vellayani P.O., Trivandrum -695 522, Kerala, India 5 Key Laboratory of Zoological Systematics and Evolution, Institute of Zoology, Chinese Academy of Sciences, Beijing 100101, China

Corresponding author: Yongying Ruan (Yongyingruan@ioz.ac.cn); Xingke Yang (yangxk@ioz.ac.cn)

Academic	editor: Roa	n Beenen		Received	13	March	2019		Accepted 4	i May	2019	Published	25 Ju	une	2019
		htt	p://:	zoobank.org	/FB	352250E	3-DA9E	3-41	B66-BEEC-8-	495518	3 <i>3296B</i>				

Citation: Ruan Y, Konstantinov AS, Prathapan KD, Zhang M, Yang X (2019) A review of the genus *Lankaphthona* Medvedev, 2001, with comments on the modified phallobase and the unique abdominal appendage of *L. binotata* (Baly) (Coleoptera, Chrysomelidae, Galerucinae, Alticini). ZooKeys 857: 29–58. https://doi.org/10.3897/zookeys.857.34465

Abstract

The flea beetle genus *Lankaphthona* Medvedev, 2001 is redescribed and a new species *L. yunnantarsella* **sp. nov.** Ruan, Konstantinov & Prathapan is described. *Longitarsella* Medvedev, 2009, **syn. nov.** and *Philotarsa* Medvedev, 2009, **syn. nov.** are newly synonymized with *Lankaphthona*. *Philotarsa laosica* Medvedev, 2009, **syn. nov.** is synonymized with *Lankaphthona phuketensis* (Gruev, 1989). The following new combinations are proposed: *Lankaphthona binotata* (Baly, 1876), **comb. nov.**; *Lankaphthona costata* (Medvedev, 2016), **comb. nov.**; *Lankaphthona cyanipennis* (Medvedev, 2009), **comb. nov.**; and *Lankaphthona fuketensis* (Gruev, 1989), **comb. nov.**; *Lankaphthona notatipennis* (Medvedev, 2009), **comb. nov.**; and *Lankaphthona phuketensis* (Gruev, 1989), **comb. nov.**; *status restored*. A highly specialized spoon-shaped 'appendage' is discovered on the first abdominal ventrite of males of *Lankaphthona binotata*. Aedeagus of the same species has aberrant sheath-shaped phallobase encircling the median lobe. Morphology and possible function of these structures are discussed. Menispermaceae are newly reported as the host plants of the genus.

Copyright Yongying Ruan et al. This is an open access article distributed under the terms of the Creative Commons Attribution License (CC BY 4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

Keywords

abdominal process, flea beetles, new combinations, new synonyms, sexual dimorphism, spiculum, tegmen

Introduction

Lankaphthona, established by Medvedev (2001) for three new species from Sri Lanka, belongs to a hypothetically monophyletic group of Oriental genera, characterized by a pair of subparallel longitudinal ridges on the first abdominal ventrite. In addition to Lankaphthona, this generic group includes Philogeus Jacoby, 1887, Tegyrius Jacoby, 1887, Lanka Maulik, 1926, Bikasha Maulik, 1931, Parategyrius Kimoto & Gressitt, 1966, Neorthana Medvedev, 1996, Lankanella Kimoto, 2000, Longitarsella Medvedev, 2009, Philotarsa Medvedev, 2009 and Lesagealtica Döberl, 2009. These genera also share the following character states: small to moderate size, body oblong and convex in lateral view, procoxal cavities open, metatibia with distal end outwardly curved and dorsal surface almost flat.

Longitarsella was proposed by Medvedev (2009) as a subgenus of Trachyaphthona Heikertinger (Konstantinov and Prathapan (2008) synonymized Trachyaphthona with Trachytetra Sharp) for two species with elongate first metatarsomere: L. notatipennis Medvedev, 2009 and Thyamis binotata Baly, 1876, with the latter designated as the type species of the subgenus (Medvedev 2009). However, upon specimen examination it became clear that what Medvedev (2009) identified as L. binotata (Baly) is a case of misidentification and, in fact, exactly the same species that Medvedev described (in the same work 60 pages prior) as Philopona (Philotarsa) laosica Medvedev, 2009, which he designated as the type species of Philotarsa (as a subgenus of Philopona).

Longitarsella and Philotarsa share the same type species and therefore are objective synonyms. Additionally, Philotarsa is dramatically different from Philopona Weise and Longitarsella is very different from Trachytetra Sharp, so that discussion on Philopona and Trachytetra is a separate topic in flea beetle taxonomy and nomenclature.

Further studies on *Lankaphthona micheli* Medvedev, 2001 (the type species of *Lankaphthona*), *Longitarsella notatipennis* Medvedev, 2009 and *Philotarsa laosica* confirmed that all three species are clearly congeneric. Since *Lankaphthona* is the oldest available name, *Philotarsa* and *Longitarsella* are here synonymized with it. In addition to the six species treated in this study, Medvedev described two more species of *Longitarsella*: *L. costata* Medvedev, 2016 from Malaysia and *L. cyanipennis* Medvedev, 2017 from Indonesia. Since *Longitarsella* is no longer valid, these species are here transferred to *Lankaphthona*. So far, eight species are not available for this study. Since they cannot be properly treated and included in a species key based on the information provided in the descriptions (Medvedev 2016, 2017), they are treated as species *incertae sedis* here.

Morphological study of *Lankaphthona binotata* unveiled two structures. One of them is previously unknown among leaf beetles: the sheath-shaped phallobase of male genitalia that encircles the aedeagus (Fig. 1H–J), which differs greatly from the usual nar-

row, mostly twig like phallobase in flea beetles. The phallobase of leaf beetles [also termed 'tegmen' (Sharp and Muir 1912; Jolivet et al. 2013), 'spiculum', 'spiculum 1' or 'tegminal apodeme' (Verma 1994, 1996)] is a rather conservative and simple, usually Y-shaped or twig-shaped structure (Sharp and Muir 1912; Chen 1985; Verma 1994, 1996). The ring-shaped phallobase can be found in the genus *Timarcha* (Chrysomelinae) (Sharp and Muir 1912; Jolivet et al. 2013) and rarely in *Chrysolina* (Jolivet et al. 2013). It is considered as a primitive character and usually occurs in basal lineages (e.g., Bruchinae and Donaciinae) of Chrysomelidae and related families (e.g., Cerambycidae) of Chrysomeloidea. In flea beetles, it is usually Y-shaped, and exhibits mild intraspecific variation. In a few flea beetle genera, the shape of the phallobase was used for species identification (Prathapan and Konstantinov 2003; Nadein 2006). However, in *L. binotata*, the phallobase is drastically transformed. Here we describe, discuss and illustrate this unusual structure.

The other structure is a totally unique morphological novelty present only in males – a spoon shaped appendage arising from the first abdominal ventrite (Fig. 3B–E). This unique structure is illustrated and its possible function is discussed.

Material and methods

The male genitalia were dissected and glued to a paper card pinned beneath the specimens; female genitalia were dissected and mounted on slides in Hoyer's medium. After photography, they were glued to paper card pinned beneath the specimens. Photos were taken with digital camera Nikon 5200D attached to a Zeiss Axiostar Plus Microscope. The photos of habitus were taken with the 5X objective lens of the same microscope with extra light source softened by semitransparent paper. Hand drawing of habitus of *Lankaphthona binotata* was painted using water color and Photoshop CS5 (Adobe, San Jose, USA) was used for further rendering. Hand drawings of aedeagus and phallobase of *L. binotata* were entirely composed in Photoshop CS5. The image of *L. binotata* in copula was generated by Autodesk Maya 2014 (Autodesk, Inc., USA) and was edited using Photoshop CS5. Morphological terminology follows Konstantinov (1998). A voucher of the host plant, *Tinospora cordifolia* (Thunb.) Miers (accession number 6488), is deposited in the Calicut University Herbarium, Kerala, India.

Abbreviations of collections:

BMNH	The Natural History Museum (formerly British Museum), London, UK.
IZCAS	Institute of Zoology, Chinese Academy of Sciences, Beijing, China.
KAU	Kerala Agricultural University, Trivandrum, India.
LMCM	Medvedev collection, Moscow, Russia
NHMB	Naturhitorisches Museum, Basel, Switzerland.
TARI	Taiwan Agricultural Research Institute, Taichung, Taiwan, China.
USNM	National Museum of Natural History, Washington DC, USA.

Results

Genus Lankaphthona Medvedev, 2001

Lankaphthona Medvedev, 2001: 162–163. Type species: *Lankaphthona micheli* Medvedev, by original designation.

Philotarsa Medvedev, 2009:147. Type species: *Philotarsa laosica* Medvedev, 2009:147, by original designation. New Synonym.

Longitarsella Medvedev, 2009: 202 (originally as a subgenus of *Trachyaphthona*). Type species: *Philotarsa laosica* Medvedev misidentified as *Lankaphthona binotata* (Baly, 1876) (originally as *Thyamis binotata* Baly, 1876), by original designation. New Synonym.

Distribution. China, Vietnam, Thailand, India, Sri Lanka.

Statistics. 8 species.

Host plants. Adults of *L. nigronotatus*, (Jacoby, 1896) feed on the leaves of Menispermaceae. This is the first report of the host plants of the genus.

Diagnosis. The relationships between the flea beetle genera with subparallel ridges on the first abdominal ventrite are in need of comprehensive reevaluation with a rigorous morphological and molecular phylogenetic study. Lankaphthona closely resembles *Tegyrius* and *Parategyrius* based on preliminary external morphological characters. These three genera share an overall body shape, long first metatarsomere and similar structure of the head. Tegyrius can be separated from Lankaphthona by a very narrow orbit (orbit is generally wider in Lankaphthona), anteromesal ends of antennal calli acutely narrowed and slightly entering into the interantennal space (in Lankaphthona anteromesal ends of antennal calli reach interantennal space, however, does not enter as deep as in the type species of *Tegyrius*, *T. metallicus* Jacoby. This character is difficult to use consistently to separate all known species of *Lankaphthona* and *Tegyrius*); deep sulci delimiting antennal calli (sulci delimiting antennal calli are shallow in *Lankaphthona*); and four labral setae (number of labral setae vary in Lankaphthona from 4 to 14). Lanka can be distinguished from Lankaphthona by the depressed antennal calli separated from each other by the frontal ridge (antennal calli are neither depressed nor separated from each other by the frontal ridge in *Lankaphthona*). In *Philogeus*, antennal calli are separated from each other by the frontal ridge and the bifid claws (in Lankaphthona, the antennal calli are not separated completely from each other, and the claws are appendiculate). In Neorthana, the frontal ridge is almost rectangular in frontal view and forms an abrupt angle with anterofrontal ridge in lateral view (frontal ridge forms a triangular ridge with anterofrontal ridge and never forms an abrupt angle with anterofrontal ridge in lateral view in *Lankaphthona*). In *Bikasha*, the frontal ridge is narrowed anteriorly above the anterofrontal ridge, the elytral punctures are regularly arranged and the first metatarsomere is shorter (frontal ridge is broadened anteriorly forming a triangular ridge with anterofrontal ridge, elytral punctures confused and the first metatarsomere is longer in Lankaphthona). Type material of Parategyrius was not available for our study, but specimens identified as congeneric, examined by us, resemble *Lankaphthona* and hence the former is likely to be a senior synonym of *Lankaphthona*.

Lankaphthona can be easily separated from *Trachytetra* by the following characters: 1) first metatarsomere almost as long as, or longer than, half of metatibia (first metatarsomere much shorter than half of metatibia in *Trachytetra*); 2) longitudinal subparallel ridges present on first abdominal ventrite (absent in *Trachytetra*); 3) antennal calli moderately developed, indistinctly enter into the interantennal space (antennal calli strongly developed, distinctly enter into the interantennal space in *Trachytetra*). Characters separating *Lankaphthona* and *Lankanella* are a few: frontal and anterofrontal ridges merging into each other forming more or less well-defined Y-shaped structure and confused elytral punctures in *Lankaphthona* and arranged in regular rows in *Lankanella*. In *Lankanella*, frontal and anterofrontal ridges more clearly separated from each other forming more or less well-defined T-shaped structure and the elytral punctures are regularly arranged.

Lankaphthona superficially resembles Aphthona Chevrolat in having similar characters of head and body shape. However, Lankaphthona can be easily differentiated from Aphthona by the longer first metatarsomere, presence of antebasal transverse impression on pronotum and the subparallel ridges on first abdominal ventrite. Lankaphthona can be confused with Longitarsus Latreille due to the general body shape and the elongate first metatarsomere, and there are also several species of Longitarsus having black maculation on elytra (e.g. Longitarsus transversalis Chen, 1935 from Northern India, Longitarsus bimaculatus (Baly, 1874) from China and Japan). However, Lankaphthona can be separated from Longitarsus by the shape of the frontal ridge and antennal calli, the presence of the antebasal transverse impression on the pronotum and paired intercoxal subparallel ridges on the first abdominal ventrite (both the antebasal transverse impression on the pronotum and the subparallel intercoxal ridges or the appendage on first abdominal ventrite are absent in Longitarsus).

Among other Oriental genera, *Doeberlnotus* Prathapan, Konstantinov & Ruan, 2017 and *Sanckia* Duvivier, 1891 have elongate first metatarsomere. *Lankaphthona* can be differentiated from *Doeberlnotus* by the smooth pronotum and body color without metallic luster (pronotum bumpy and body color metallic in *Doeberlnotus*); from *Sanckia* by the glabrous body surface, presence of antebasal groove on pronotum and confused elytral punctation (in *Sanckia*, body surface is covered with dense hair, antebasal transverse impression of pronotum is absent and the elytral punctures are arranged in regular lines.

Description. Small, oblong to oval, convex in lateral view; length 1.5–2.4 mm; 1.6–1.9 times longer than wide, width 0.8–1.3 mm. Color non-metallic, straw brown to red-brown to black.

Head hypognathous. In lateral view, vertex and antennal calli as well as frontal ridge separately form convex lines, meeting point of frontal ridge and antennal calli concave in lateral view. In frontal view, vertex moderately convex, minutely punctate, with obtusely angulate anterior margin. Supraorbital pore situated adjacent to orbital sulcus, with adjacent minute setiferous pores. Antennal callus transverse to oblique, 1-2 times wider than long, separated from vertex. Antennal callus as high as vertex or lower; often a little lower near supracallinal sulcus, much lower near antennal socket than near supracallinal sulcus. Supracallinal sulci distinct, not deep, shallower than orbital sulcus. Anteromesal ends of antennal calli not distinctly angulate, reach up to or slightly entering into interantennal space; antennal calli separated by dorsal end of frontal ridge or narrowly to broadly connected to each other. Supracallinal sulcus transverse to oblique, mostly convex, rarely concave. Midcranial suture absent. Orbit well differentiated from antennal callus by supraorbital sulcus. Subgenal suture well developed along base of mandible. Eye anterolateral, inner margin weakly concave near antennal socket, gently diverging ventrad, vertical diameter 1.2-1.4 times transverse diameter. Distance between eyes 3.0-4.0 times diameter of a socket, 0.9-1.4 times transverse diameter of one eye. Diameter of antennal socket 2.3-4.5 times distance between eye and adjacent socket. Distance between antennal sockets 0.8–1.0 times diameter of a socket. Frontal ridge and anterofrontal ridge together form a triangular ridge, flat anteriorly. Frontoclypeal suture with a row of setae. Antenna filiform, reaching beyond middle of elytra or longer. First and second antennomeres thick, next four or five thin, distal ones slightly thickened. First antennomere longer than second or third separately, little shorter than second and third combined. Labrum with 4-14 setiferous pores arranged irregularly or regularly in transverse row. Maxilla with apical plapomere pointed, shorter or longer than penultimate palpomere. Penultimate palpomere distinctly widened.

Pronotum 1.1-1.6 times wider than long. Antebasal transverse impression sinuate in middle, merge with posterior margin laterally. Almost absent in Lankaphthona micheli Medvedev, however, traces of antebasal transverse impression evident laterally. Width of pronotum anteriorly subequal to width posteriorly. Lateral margin evenly and gently curved. Anterolateral callosity about two times longer than wide, convex and oblique in dorsal view, forms obtuse denticle at pore, pore situated at posterodorsal face of callosity. Posterolateral callosity slightly or strongly protruding, with pore situated laterally. Posterior margin weakly, but distinctly bisinuate, forming lobe in middle. Pronotal punctures minute to small, apparently greater than those on vertex. Anterior coxal cavities open behind. Intercoxal prosternal process extending beyond coxa, apical margin convex, convexly raised along top; apex widened, often with preapical depressions. Shortest width of intercoxal prosternal process more than shortest distance between anterior margin of prosternum and coxal cavity. Prosternum 1.5-1.6 times as long as mesosternum, 0.6 times as long as metasternum. Distance between anterior margin of prosternum to end of prosternal intercoxal process 2.8-6.3 times width of prosternal intercoxal process; width of prosternal intercoxal process 1.2-2.7 times minimum distance between anterior margin of mesosternum to coxal cavity.

Elytra basally wider than pronotum, with basal callus not distinct, without depression posteriorly; humeral callus with or without depression mesally. Elytral punctures confused, fine yet stronger than those on pronotum. Elytral epipleuron extending beyond 3/4 of elytron, hardly reaching apex, subhorizontal to outwardly oblique with maximum width subequal to that of midfemur. Hind wings fully developed. Visible

part of mesoscutellum flat, triangular with broadly rounded apex. Mesosternal intercoxal process depressed anteriorly, raised in posterior half. Distance between anterior margin of mesosternum to end of intercoxal mesosternal process 0.8–1.2 times width of mesosternal intercoxal process; width of mesosternal intercoxal process 2.6–4.0 times minimum distance between anterior margin of mesosternum to coxal cavity. Metasternum with anterior margin strongly convexly arched, convexly raised posteriorly, forming paired protuberances raised much above level of metacoxa, as is typical in other genera of the group.

Pro- and mesotibiae dorsally convex, without apical spine. Metafemur robust with anterior margin strongly convex, posterior margin weakly convex. Metatibia in dorsal view distinctly, but weakly curved, with apex directed outwardly. Metatibia almost straight or weakly curved in lateral view; in dorsal view gradually widening from proximal end till it narrows preapically; dorsally convex proximally, turning flat beyond proximal 1/3; distinctly margined both mesally and laterally. Lateral margin apically with row of pointed bristles, row of bristles being much shorter than that on lateral margin. Spinules absent on both lateral and mesal margins. Metatibial spine positioned at middle of apex, pointed, shorter than width of metatibial apex. Tarsal articulation on metatibia visible in lateral view, on callosity flanked by flat sclerite on either side. First metatarsomere as long as or longer than half of metatibia, subequal to or longer than next three combined, ventral side densely covered with dense capitate setae. Second metatarsomere apparently longer than third. Third metatarsomere deeply bilobed. Claw appendiculate, apparently shorter than metabitial spine.

Intercoxal part of first abdominal ventrite raised, subparallel ridges on first abdominal ventrite weakly to well developed. Apical tergite of female without longitudinal groove along middle.

Spermatheca with distinct pump, receptacle and duct. Duct not coiled. Receptacle cylindrical, longer than wide, longer than pump.

Sexual dimorphism. In *Lankaphthona*, males can be differentiated from females by the apex of the last abdominal ventrite tri-lobed and incised (evenly convex in female). In *L. nigronotata* (see Fig. 8H) and *L. micheli*, males have much longer antennae than females. A spoon like appendage arising from the first abdominal ventrite in males of *L. binotata* (Fig. 3B–E), is absent in females.

One of the most common characters to separate males and females in flea beetles is the enlarged first protarsomere in males. However, the first protarsomere is not sexually dimorphic in *Lankaphthona*, as males and females have more or less the same sized first protarsomere.

Variation. The maculation on elytra is highly variable in most species of *Lankaph-thona*. It could be indistinct or entirely absent in some cases. The color of maculation varies from brown to black in different individuals of the same species. The body color also varies from pale yellow to light brown in some species.

Remarks. *Trachyaphthona* Heikertinger, 1924 was synonymized with *Trachytetra* Sharp, 1886 by Konstantinov and Prathapan (2008: 413). However, Medvedev (2009)

treated *Trachyaphthona* as a valid genus name without justification. Here we consider it as a junior synonym of *Trachytetra*.

In most flea beetle genera, the number of labral setae is usually conservative and considered as a more or less reliable generic character. In most cases, there are four (e.g., *Lanka*, *Tegyrius*) or six (e.g., *Chaetocnema* Stephens, *Bikasha*) labral setae. However, the number of labral setae varies greatly in *Lankaphthona*. For instance, there are seven pairs of setae in *Lankaphthona nironotata*, five pairs in *L. micheli* and two pairs in *L. yunnantarsella* sp. nov.

Key to the species of Lankaphthona

1	Body red brown. Apex of aedeagus in ventral and dorsal views broad, gently narrowed preapically, with emarginate apical margin (Fig. 4F)
_	Body straw brown to yellow brown to dark brown, without tinge of red; apex of aedeagus in ventral and dorsal views narrowed and convex or angulate (Figs
	1D, IE, 5G, 6D, 7D)
2	In lateral view, aedeagus almost straight, only bent ventrally near apex (Figs
	6D, 7E)
_	Aedeagus curved along length in lateral view (Figs 1F, 1G, 5H)4
3	Antennae extremely long, about as long as body; sides of aedeagus parallel in
	ventral view, apex tri-lobed (Fig. / F)
	L. yunnantarsella Ruan, Konstantinov & Prathapan, sp. nov.
_	Antennae moderately long, about $3/4$ the body length; aedeagus with sides
	slightly sinuate in ventral view (Fig. 6D); apex with acute denticle, not tri-lobed
	(Fig. 6D) L. phuketensis Gruev, 1989, status restored, comb. nov.
4	Male with highly specialized spoon-shaped abdominal appendage on first ab-
	dominal ventrite (Fig. 3); intercoxal longitudinal ridges on first abdominal
	ventrite obsolete, almost invisible; eyes not enlarged, distance between eyes
	to transverse diameter of eye in frontal view ratio: $2.49-2.55$
	Male without abdominal appendage on first abdominal ventrite; intercoxal
	longitudinal ridges on first abdominal ventrite well developed; eyes strong-
	ly enlarged, vertex and frons obviously narrowed, distance between eyes to
5	Antennomeres 2 and 4 charter then entennomere 2 (Fig. 9H), magulation
)	present on posterior part of elytral suture (Fig. 5 D. E).
	L_{n} nigronotata (Jacoby, 1896), comb. nov.
_	Antennomeres 3 and 4 longer than antennomere 2: elytral suture without
	maculation

Notes: *Lankaphthona costata* (Medvedev, 2016) comb. nov. (incertae sedis) and *L. cyanipennis* (Medvedev, 2017) comb. nov. (incertae sedis) are not treated here.
1. *Lankaphthona binotata* (Baly, 1876), comb. nov. Figs 1–3, 8G

Thyamis binotata Baly, 1876: 583. Type locality: China, Shanghai. Type depository: BMNH. Lectotype designated by Konstantinov and Lingafelter (2002: 214).
Aphthona binotata: Chen 1934: 368.
Zipangia binotata: Konstantinov and Lingafelter 2002: 214.
Trachyaphthona (Longitarsella) binotata: Medvedev 2009: 202.

Distribution. China: Shanghai (Baly 1876), Jiangsu (Ruan and Yang 2015), Fujian (new record).

Description. Body entirely yellow to yellow brown, each elytron with a black round spot (with indistinct margin) slightly behind middle. Body oval, slightly elongated in dorsal view, dorsum convex in lateral view. Body length: 1.90–2.20 mm. Body width: 1.10–1.20 mm. Body length to width ratio: 1.80–1.85. Pronotum width to length ratio: 1.75–1.80. Pronotum width at base to width at apex ratio: 1.00–1.05. Elytron length (measured along suture) to width of both ratio: 1.25–1.30. Length of elytron to length of pronotum ratio: 3.30–3.40. Width of elytra at base (measured in middle of humeral calli) to width of pronotum at base ratio: 1.10–1.15.

Vertex without punctures, except 2–3 on each side near supraorbital sulcus. Frontal ridge moderately developed, not wide, slightly convex. Sides of frontal ridge without sulci or large punctures, slightly sloping. Antennal calli obliquely elongated, sub-triangular, closely conjoined; lower part narrowed, slightly entering interantennal space. Top of frontal ridge acute, slightly produced between antennal calli. Frontal ridge in lateral view moderately convex. Width of frontal ridge to antennal sockets (counting surrounding ridges) ratio 1.05–1.15. Eyes moderately large, distance between eyes (just above antennal sockets) to transverse diameter of one eye in frontal view ratio: 2.45–2.55. Longitudinal diameter of eye to transverse diameter of eye in frontal view ratio: 2.10–2.15. Distance between antennal sockets to transverse diameter of one antennal socket ratio: 1.05–1.15. Supraorbital and orbital sulci moderately developed. Supraantennal, supracallinal sulci shallow. Frontolateral sulcus obsolete. Orbit wide, as wide as diameter of one antennal socket.

Antennae filiform, moderately long, about 0.8 times body length. Proportions of antennomeres as follows: 12:6:7:8:9:9:10:12:11:10:13. Antennomere 1 almost as long as next two combined. Antennomere 2 robust, slightly shorter than 3 and 4. Length to width of antennomere 9 ratio: 2.30–2.40. Length to width of antennomere 10 ratio: 2.00–2.05. Length to width of antennomere 11 ratio: 2.55–2.60.

Pronotum almost rectangular. Pronotal disc slightly convex. Base of pronotum with a shallow antebasal impression. Pronotal punctures sparse, shallow and minute. Diameter of pronotal punctures 3–4 times smaller than distance between adjacent punctures. Pronotal punctures nearly as large as elytral ones. Anterolateral callosity of pronotum well developed, truncate and elongate, facing anterolaterally. Pronotum parallel sided, not converging forward; lateral margin obviously explanate, slightly sinuate.



Figure I. *Lankaphthona binotata*. Individuals collected in Pingtang island, Fujian Pro., China. **A** Habitus, male **B** prothorax, dorsal view **C** head, frontal view **D** aedeagus, ventral view **E** ventral view of aedeagus, hand drawing, showing sheath-shaped phallobase **F** aedeagus, lateral view **G** aedeagus, hand drawing, lateral view, showing sheath-shaped phallobase **H** phallobase mounted on slide, dorsal view **I** ventral view of phallobase, hand drawing, showing sclerotization **J** dorsal view of phallobase, hand drawing, showing sclerotization.

Elytron without impressions or ridges. Elytral humeral callus moderately developed. Elytral punctures minute, confused.

Length (not counting trochanter) to maximum width of metafemur ratio: 1.90– 1.95. Length to width of metatibia in lateral view ratio: 5.80–5.90. Width of metatibia at base to width at apex in dorsal view ratio: 0.45–0.50. Length of metatibia to length



Figure 2. *Lankaphthona binotata*. **A** Habitus, hand drawing **B** a hypothetical mating diagram: abdominal appendage serving as an auxiliary structure assists the process **C** male abdominal ventrites **D** female abdominal ventrites **E** vaginal palpi **F** spermatheca **G** tignum **H** Hind wing.

of first metatarsomere ratio: 2.0–2.2. Length of metafemur to metatibia ratio: 1.05–1.10. Length of first metatarsomere to that of second metatarsomere ratio: 2.10–2.20.

Intercoxal ridges on first abdominal ventrite obsolete in both male and female; males with a spoon-shaped appendage arising near hind margin of first abdominal ventrite, produced anteriorly (Fig. 3). Numerous elongate setae present on lateral margin of appendage.



Figure 3. *Lankaphthona binotata*, showing spoon-shaped abdominal appendage on first abdominal ventrite. **A** Ventral view of male **B** lateral view of abdominal appendage **C** ventral view of abdominal appendage **D**, **E** close-up view of appendage (mounted on slide and photographed under a light microscope).

Aedeagus of male robust, oval in cross section. In lateral view, aedeagus robust and sinuate, with apex slightly bent dorsally. Aedeagus, in ventral view, gradually narrowed near apex, apical denticle absent. Ventral groove on aedeagus poorly developed. Phallobase (i.e., tegmen, spiculum) of male genitalia sheath-shaped, encircling middle of aedeagus. Phallobase with a longitudinal sclerotized rod-shaped apodeme in middle, produced anteriorly beyond anterior margin of sheath-like part (Fig. 1I–J: anterior apodeme) and a transverse sclerotization on posterior margin, both together forming a 'Y' shaped sclerotization.

Receptacle of spermatheca cylindrical. Spermathecal pump shorter and smaller than receptacle. Basal part of spermathecal duct (between spermathecal gland and receptacle) wide and coiled, longer than receptacle. Apex of spermathecal pump wide, rounded. Lateral margins of vaginal palpus more or less parallel to each other. Vaginal palpus widened near base, weakly sclerotized from base to middle, moderately sclerotized distally. Tignum spear-shaped.

Variability. Depth of pronotal antebasal transverse impression and length of first metatarsomere vary slightly between individuals.

Only a single type of elytal maculation – a round spot with indistinct margin near middle of each elytron – was observed in our study.

Type material. \bigcirc (BMNH), labels: 1) Type H.T.; 2) Baly coll.; 3) *Aphthona binotata* Baly \bigcirc ; 4) A. Warchalowski det. 1965; 5) *Thyamis binotata* Baly, Shanghai.

Material. $4\overset{\circ}{\oslash}4^{\bigcirc}$ (IZCAS, preserved in ethanol), CHINA, Fujian, Pingtan Island, 5.VI.2014, alt. 200 m, leg. Yongying Ruan; $2\overset{\circ}{\oslash}3^{\bigcirc}$ (USNM, dry specimens), China, Fujian, Pingtan Isl., WP-449, 25°33.252'N, 119°52.253'E, 5.vi.2014, h = 202 m.

Remarks. Lankaphthona binotata resembles L. yunnantarsella Ruan, Konstantinov & Prathapan, sp. nov. due to the similarity in elytral maculation. However, L. binotata can be separated from the latter by the much shorter antennae, eyes not prominently enlarged and males with abdominal appendage on first abdominal ventrite.

This species was originally published by Baly (1876) in *Thyamis*. Subsequently, it was placed in *Aphthona* by Chen (1934). Konstantinov and Lingafelter (2002) transferred it to *Zipangia* after they studied the type material. Medvedev (2009) misidentified it and used misidentified specimens as the type for the newly erected subgenus *Longitarsella* (in genus *Trachytaphthona*). Despite the studies of authors mentioned above, the sheath-shaped phallobase and the highly specialized abdominal appendage on the first abdominal ventrite of males remained unknown prior to this study. We have dissected five males and it turns out that both structures are rather stable in shape.

2. Lankaphthona micheli Medvedev, 2001

Fig. 4

Lankaphthona micheli Medvedev, 2001: 163. Type Locality: "Kandy, Sri Lanka". Type depository: Naturhistorisches Museum, Basel, Switzerland (NHMB).

Distribution. Sri Lanka.

Description. Body rufous brown, except labrum, fore- and middle legs, hind tibia and tarsi lemon yellow. Body broadly oblong in dorsal view, dorsum convex in lateral view. Body apparently larger in female, 1.74–1.84 mm in length, 1.10–1.12 mm in width. Body length to width ratio: 1.55–1.67. Pronotum width to length ratio: 1.40–1.52. Pronotum width at base to width at apex ratio: 1.06–1.13. Elytron length



Figure 4. *Lankaphthona micheli*. **A** Habitus, dorsal view **B** habitus, ventral view **C** pronotum, dorsal view **D** head, frontal view **E** intercoxal ridges on first abdominal ventrite, indicated by arrow **F** aedeagus, ventral view **G** aedeagus, lateral view **H** spermatheca **I** vaginal palpi **J** tignum.

(measured along suture) to width of both ratio: 1.28–1.45. Length of elytron to length of pronotum ratio: 2.96–3.48. Width of elytra at base (measured in middle of humeral calli) to width of pronotum at base ratio: 1.32–1.37.

Vertex with minute and shallow moderate sized punctures. Supraorbital pore adjacent to orbital sulcus, surrounded by shallow groove. Supracallinal sulcus convex, shallow; suprafrontal, supraantennal sulci shallow but more vivid than supracallinal; midfrontal sulcus short, shallow and broader. Antennal callus subtriangular, posteriorly higher than anteriorly, hardly raised above level of vertex, anterior ends slightly enter into interantennal space. Proximal end of frontal ridge narrowed, produced between anterior ends of antennal calli. Frontal ridge well developed, convexly raised between antennal sockets, forms strongly arched convex line in lateral view. Frontal ridge anteriorly flat, forming flat, triangular anterofrontal ridge, raised laterally, flat above clypeus. Antennal socket close to eye. Width of frontal ridge to antennal sockets (counting surrounding ridges), ratio 0.40–0.55. Eyes strongly convex. Distance between eyes (just above antennal sockets) to transverse diameter of eye in frontal view ratio: 0.96–1.80. Longitudinal diameter of eye to transverse diameter of eye in frontal view ratio: 1.39–1.40. Distance between antennal sockets to transverse diameter of one antennal socket ratio: 0.72–0.90. Labrum with about five pairs of irregularly arranged setiferous pores bearing long setae.

Antennae filiform, rather long, about 0.69 times body length in female and 0.82 times body length in male. Proportions of antennomeres as follows: 10: 6.5–8: 4.7–6.7: 7.1–7.3: 8.2–10: 8.7–10: 10–10.6: 10.6–10.7: 10.7–1.18: 10–10.6: 14–15.3. Antennomere 2 robust, 3 shorter and thinner than 2, 4–6 each longer than preceding one. Antennomere 6–9 subequal; 10 shorter than 9. Length to width of antennomere 9 ratio: 2.00–2.22. Length to width of antennomere 10 ratio: 1.64–2.00. Length to width of antennomere 11 ratio: 2.33–2.74.

Pronotum convex, with mixture of shallow, small and minute punctures. Antebasal transverse impression obsolete, leaving an evident trace. Posterior margin weakly bisinuate with lobe in middle. Pronotal punctures distinctly smaller than those on elytra. Anterolateral callosity convex, elongate, with seta bearing pore on upper posterior face. Lateral margin posteriorly narrowed. Posterolateral callosity not protruding.

Elytral punctures irregular, distance between adjacent punctures about 1–3 times diameter of a puncture. Humeral callus well developed, with weak depression posteriorly.

Length (not counting trochanter) to maximum width of metafemur ratio: 1.85– 1.94. Length to width of metatibia in lateral view ratio: 5.17–5.60. Width of metatibia at base to width at apex in dorsal view ratio: 0.46–0.60. Length of metafemur to metatibia ratio: 1.72–1.87. Length of first metatarsomere to length of second metatarsomere ratio: 2.57–3.60.

Intercoxal subparallel ridges on first abdominal ventrite well developed (Fig. 4E), barely reaching middle of ventrite. Males without appendage on first abdominal ventrite. Last abdominal ventrite in male with circular depression towards posterior margin, posterior margin with lobe in middle. Last ventrite in female with convex posterior margin as in most flea beetles, apical circular depression and lobe absent.

Aedeagus characteristic: in ventral view, deeply channeled along middle, gently narrowed preapically, apex unusually broad and emarginated in middle; nearly straight in lateral view with apex very slightly curved dorsad. Spermatheca with receptacle about 2.8 times longer than wide, narrowed at distal 1/4, outer margin concave, inner margin convex; pump widened medially, apex rounded without denticle; duct strongly bent towards receptacle, not coiled. Vaginal palpi strongly sclerotized posteriorly than

anteriorly; lateral membranous area shorter and narrower than posterior sclerotization. Tignum gently curved; proximal end broadened and lightly sclerotized, distal sclerotization arrow-head shaped.

Type material. Paratype: ♂ (NHMB), labels: 1) Sri Lanka, Kandy, 600 m 1–18.6.1991, N. M. Kolibac leg.; 2) Paratype: *Lankaphthona micheli* m. L. Medvedev det. 1998.

Material. 4 \mathcal{J} , 1 \mathcal{Q} (3 in KAU, 2 to be transferred to USNM) SRI LANKA, Central Prov., 10 km south from Kandy, Uda Peradeniya Vill. Env., 07°15.087'N, 80°37.108'E, 720 m, 24.ii.2013, S. Saluk coll.

Remarks. Medvedev (2001), in his original description of the genus, has stated that the pronotum in *Lankaphthona* is devoid of antebasal transverse impression. However, the pronotum has a very weak antebasal transverse impression that is hard to discern. *Lankaphthona micheli* can be distinguished from other members of the genus by the red-brown color (all others are yellow brown), feeble antebasal transverse impression on pronotum (well developed in other species) and the unique shape of the aedeagus. The apex of the aedeagus in ventral view is broad and emarginate in *L. micheli*, while the same is narrowed and convex in all other species.

3. Lankaphthona nigronotata (Jacoby, 1896), comb. nov.

Figs 5, 8H

Longitarsus nigronotatus, Jacoby, 1896: 259. Type locality: Myanmar (=Burma), Tharrawaddy. Type depository: BMNH.

Distribution. China: Yunnan (new record); Myanmar (Jacoby 1896), India (Maulik 1926).
 Host plants. *Tinospora cordifolia* (Thunb.) Miers (Menispermaceae). Adults feed on the leaves. This is the first report of a host plant of *L. nigronotata*.

Description. Body pale yellow to yellow brown. Each elytron with three brown to black spots: a round one at middle, a longitudinal one on sutural margin near apex and a round one on apex. Legs fulvous, apex of metafemur dorsally brown to black. Body oval, slightly elongate in dorsal view; dorsum convex in lateral view. Body length: 2.00–2.10 mm. Body width: 1.10–1.20 mm. Body length to width ratio: 1.70–1.80. Pronotum width to length ratio: 1.65–1.75. Pronotum width at base to width at apex ratio: 1.10–1.20. Elytron length (measured along suture) to width of both ratio: 1.25–1.35. Length of elytron to length of pronotum ratio: 3.35–3.45. Width of elytra at base (measured in middle of humeral calli) to width of pronotum at base ratio: 1.30–1.40.

Vertex impunctate, except few shallow punctures near eyes. Antennal calli obliquely elongate, sub-triangular, conjoined. Supracallinal, supraantennal and supraorbital sulci well developed, suprafrontal sulcus weak. Frontal ridge proximally acute, produced between antennal calli. Frontal ridge moderately developed, slightly convex. Frontal ridge in lateral view moderately convex. Antennal socket close to eye. Width of frontal ridge to antennal sockets ratio: 0.85–0.90. Eyes strongly enlarged. Distance between eyes (just above antennal sockets) to transverse diameter of eye in



Figure 5. Lankaphthona nigronotata. A Pronotum, dorsal view, paratype, female B head, frontal view, holotype, female C intercoxal ridges on first abdominal ventrite, holotype, female D holotype habitus, female E paratype habitus, female F lateral view of paratype G aedeagus, ventral view, specimen from Yunnan H aedeagus, lateral view, specimen from Yunnan I apex of aedeagus, ventral view J vaginal palpi K spermatheca L abdomimal ventrites, male, red arrow indicates intercoxal ridges on first abdominal ventrite M labrum, male, showing numerous setae on surface.

frontal view ratio: 1.30–1.40. Longitudinal diameter of eye to transverse diameter of eye in frontal view ratio: 1.65–1.75. Distance between antennal sockets to transverse diameter of one antennal socket ratio: 1.20–1.30. Labrum with about 14 (7 pairs) setiferous pores; 10 long setae arranged in transverse row, additional 4 short ones placed above them.

Antennae filiform, long, about 0.7–0.8 times body length; longer and slender in male. Proportions of antennomeres as follows: 14:7:5:5:11:12:13:14:14:13:15 (measured in male). Antennomere 2 robust, antennomeres 3 and 4 short, subequal, following antennomeres elongate. Length to width of antennomere 9 ratio: 4.90–5.00 (measured in male). Length to width of antennomere 10 ratio: 4.60–4.70 (measured in male). Length to width of antennomere 11 ratio: 4.95–5.05 (measured in male).

Pronotum rectangular, slightly convex; base with distinct, slightly sinuate antebasal impression; punctures sparse, shallow and minute. Diameter of pronotal punctures 3–4 times smaller than distance between adjacent ones. Pronotal punctures nearly as large as elytral ones. Anterolateral callosity of pronotum obliquely truncate. Basal margin slightly convex in middle.

Elytral humeral callus moderately developed. Impressions or ridges absent on elytron. Elytral punctures minute, irregularly arranged.

Length to width of metafemur ratio: 1.95–2.00. Length to width of metatibia in lateral view ratio: 5.65–5.75. Width of metatibia at base to width at apex in dorsal view ratio: 0.40–0.50. Length of metatibia to length of first metatarsomere ratio: 1.80–2.20. Length of metafemur to metatibia ratio: 1.15–1.25.

Subparallel intercoxal longitudinal ridges on first abdominal ventrite hardly reach proximal 1/3 of ventrite.

Aedeagus robust, oval in cross section. Aedeagus in ventral view gently narrowed in middle, apex abruptly narrowed, apical denticle absent; ventral longitudinal groove poorly developed. Aedeagus in lateral view evenly curved with apex bent ventrally.

Receptacle of spermatheca cylindrical, parallel sided. Spermathecal duct wide, strongly curved near middle forming loop towards receptacle. Spermathecal pump shorter and smaller than receptacle, cylindrical, slightly narrowed from base to apex. Vaginal palpus weakly sclerotized anteriorly and medially, strongly sclerotized distally. Vaginal palpus narrowing from base to middle, slightly widening towards apex.

Variability. The elytral spots vary from barely visible, to highly prominent in specimens from Yunnan, China. The aedeagus very slightly varied in shape even in the specimens collected at the same place and time. In the specimens from India, the aedeagus in ventral view with middle part not much narrowed as the specimens from Yunnan.

Type Material. Holotype: \bigcirc (BMNH), labels: 1) Jacoby coll. 1909-28a; 2) Type H.T.; 3) \bigcirc ; 4) *Longitarsus nigronotatus* type Jac.; 5) Tharrawaddy; 6) Examined K. Prathapan 2005.

Paratypes: 4° (BMNH), labels: 1) Tharrawaddy; 2) *Longitarsus nigronotatus* type Jac.; 3) Cotype; 4) $^{\circ}$; 5) Examined K. Prathapan 2005.

Material. CHINA, $13^{\circ}_{\circ}1^{\circ}_{\circ}$ (IZCAS), labels: 1) Yunnan, Xishuangbanna, Menglun, botanical garden, lvshilin, 2009.XI.17, Guo Tang & Zhiyuan Yao leg., 21°54.609'N, 101°17.090'E, 643 m, IZCAS; 2) *Lankaphthona nigronotata* (Jacoby), det. Ruan, 2017; $8^{\circ}_{\circ}2^{\circ}_{\circ}$ (IZCAS), labels: 1) Yunnan, Xishuangbanna, Menglun, 2011. viii, 1088 m; 2) *Lankaphthona nigronotata* (Jacoby), det. Ruan, 2017.

INDIA, Karnataka, 1 ♂ (KAU), labels: 1) Karnataka, Bangalore, 916 m, 17.iv.2000, Prathapan coll., 2) *Lankaphthona nigronotata* (Jacoby), det. Prathapan, 2019; 1 ♂ (KAU), labels: 1) Kerala, Chinnar WLS, 10.vi. 2010, Prathapan coll., 2) *Lankaphthona nigronotata*

(Jacoby), det. Prathapan, 2019; 2 \checkmark (KAU), labels: 1) Kerala, Nelliampathy SeetharGundu, 10°33'21"N, 75°42'53.9"E, 1053 m, 30.x.2010, Prathapan coll., 2) *Lankaphthona nigronotata* (Jacoby), det. Prathapan, 2019; 1 \circlearrowright (KAU), labels: 1) Vellayani, 8.iv.2010, Prathapan coll., 2) *Lankaphthona nigronotata* (Jacoby), det. Prathapan, 2019; 2 \heartsuit (KAU), labels: 1) Kerala, Vellayani, 29. vii.2010, Prathapan coll., 2) Host: Tinospora cordifolia, 3) *Lankaphthona nigronotata* (Jacoby), det. Prathapan, 2019; 1 \heartsuit (KAU), labels: West Bengal, Kalyani, 2–4. xii. 2009, Prathapan coll., 2) *Lankaphthona nigronotata* (Jacoby), det. Prathapan, 2019; 1 \circlearrowright , 2 \heartsuit (KAU), labels: West Bengal, Santhi Niketan, 18.xi.2007, Prathapan coll., 2) *Lankaphthona nigronotata* (Jacoby), det. Prathapan, 2019.

Remarks. Lankaphthona nigronotata was originally described in Longitarsus. However, this is not a member of Longitarsus as evidenced by the prominent antebasal impression on pronotum, explanate lateral pronotal margin, anteromesal ends of antennal calli entering interantennal space and the subparallel intercoxal ridges on the first abdominal ventrite. Lankaphthona nigronotata closely resembles L. notatipennis Medvedev, 2009, however, it can be separated from the latter by the presence of maculation on posterior part of sutural margin and the apex of the elytra as well as the antennomeres 3 and 4 shorter than antennomere 2.

4. Lankaphthona notatipennis (Medvedev, 2009), comb. nov.

Trachyaphthona (Longtitarsella) notatipennis Medvedev, 2009: 202. Type locality: Thailand, Khao Sok. Type depository: Medvedev collection.

Distribution. Thailand.

Remarks. Currently, we do not have access to the type specimens.

We have examined several specimens from Malaysia and India that are very similar to *Longtitarsella notatipennis*, except for the shape of the aedeagus, which is slightly different from the description provided by Medvedev (2009). The aedeagus is gradually widened from base to rounded apex in the specimens at our disposal, however, according to the original description and illustration provided by Medvedev (2009), the aedeagus is gradually narrowed from base to rounded apex. Hence the types should be examined to ensure identity of the species.

5. *Lankaphthona phuketensis* (Gruev, 1989), status restored, comb. nov. Fig. 6

Longitarsus phuketensis Gruev, 1989: 97. Type locality: Thailand, Phuket Island. Type depository: Gruev Collection, Bulgaria.

Philotarsa laosica Medvedev, 2009:147. Type locality: Laos, Lhammomuang Prov., Ban Khoungham (Nanin). Type depository: L. Medvedev Collection, Russia. New Synonym.

Lankaphthona binotata: Medvedev, 2009: 202 (misidentification)

Distribution. Laos, Thailand.

Description. Body pale yellow to yellow brown. Each elytron with three brown to black markings: elongate one in middle, a longitudinal one on sutural margin and a round one near elytral humeral calli. Legs fulvous, metafemur dorsally brown to black. Body oval, slightly elongate in dorsal view; dorsum convex in lateral view. Body length: 2.2–2.4 mm. Body length to width ratio: 1.88. Pronotum width to length ratio: 1.66. Pronotum width at base to width at apex ratio: 1.22. Elytron length (measured along suture) to width of both ratio: 1.43. Length of elytron to length of pronotum ratio: 3.53. Width of elytra at base (measured in middle of humeral calli) to width of pronotum at base ratio: 1.27.

Vertex impunctate, except few shallow punctures near eyes. Antennal calli obliquely elongate, sub-triangular, conjoined, entering interantennal space. Supracallinal, supraantennal, suprafrontal and supraorbital sulci well developed. Frontal ridge proximally acute, in lateral view moderately convex, produced between antennal calli. Antennal socket close to eye. Eyes strongly enlarged. Frontal and anterofrontal ridges merge gradually.

Antennae filiform, long, about 0.7–0.8 times body length. Antennomere 2 robust, as long as antennomere 3, slightly shorter than 4, following antennomeres elongate. Length to width of antennomere 9 ratio: 4.11 (measured in female). Length to width of antennomere 10 ratio: 3.77 (measured in female). Length to width of antennomere 11 ratio: 3.81 (measured in female).

Pronotum rectangular, slightly convex; base with distinct, slightly sinuate antebasal impression; punctures sparse, shallow and minute. Diameter of pronotal punctures 3–4 times smaller than distance between adjacent ones. Pronotal punctures smaller than elytral ones. Anterolateral callosity of pronotum obliquely truncate. Basal margin slightly convex in middle.

Elytral humeral callus moderately developed. Elytron without impressions or ridges. Elytral punctures small, irregularly arranged.

Length to width of metatibia in dorsal view ratio: 5.17. Width of metatibia at base to width at apex in dorsal view ratio: 0.39. Length of metatibia to length of first metatarsomere ratio: 1.98.

In ventral view, aedeagus sinuate at sides, dilated before apex, abruptly narrowed near apex, with acute apical denticle. In lateral view, aedeagus straight from base to subapex, with apex bent ventrad.

Type material. Holotype of *Philotarsa laosica* Medvedev, 2009: ♀ (LMCM), labels: 1) Laos, Khammouang Prov., Ban Khounkham (Nahin), 18°13'N, 104°31'E, 200 m, 9.vi.2005, leg. O. Gorbunov.

The type material of *Longitarsus phuketensis* Gruev, 1989 is unavailable to this study. Species concept is based on the author's (Gruev, 1989) descriptions and illustrations on habitus and aedeagus of holotype.

Remarks. Medvedev (2009: 202) synonymized *Longitarsus phuketensis* Gruev with *Lankaphthona binotata* (Baly). However, as we mentioned above, in the same work Medvedev (2009) erroneously identified a species that he described as *Philotarsa laosica* as



Figure 6. *Lankaphthona phuketensis* (Gruev, 1989) (= *Philotarsa laosica* Medvedev, 2009). **A–C** and **E–I** are photo of holotype of *Philotarsa laosica*, female. **A** Habitus, dorsal view **B** habitus, lateral view **C** habitus, frontal view **D** shape of aedeagus, hand drawing, based on illustration provided by Gruev (1989) **E** metatibia and metatarsomere, dorsal view **F** head, antennae and pronotum, dorsal view, Holotype **G** head, showing supraantennal calli, dorsal view **H** head, frontal view **I** pronotum, dorsal view.

L. binotata. Based on the original description and illustration of the habitus and aedeagus of the type provided by Gruev (1989), it is evident that *Longitarsus phuketensis* is clearly different from *Lankaphthona binotata* and can be separated by the following characters: apical and basal spots present on elytron (apical and basal spots on elytron are absent in *Lankaphthona binotata*); aedeagus straight from base to subapex in lateral view, with acute apical denticle in ventral view (in *Lankaphthona binotata*, aedeagus curved ventrally from base to near apex, without acute apical denticle); body length slightly larger (2.40 mm in *Longitarsus phuketensis*, 1.90–2.20 mm in *Lankaphthona binotata*).

Based on Medvedev's suggestion of the synonymy of *Longitarsus phuketensis* and *Philotarsa laosica* (erroneously identified as *L. binotata*) and our observations of the holotype of *Philotarsa laosica*, we here synonymize *Philotarsa laosica* Medvedev, 2009 with *Longitarsus phuketensis* Gruev, 1989.

Lankaphthona phuketensis is close to L. notatipennis in the similar pattern of maculation on elytron (e.g., having apical and basal spots), the type localities of the two species are also very close to each other. But L. phuketensis can be differentiated from L. notatipennis by the aedeagus straight from base to near apex in lateral view, with acute apical denticle in ventral view (in L. notatipennis, aedeagus curved ventrally from base to near apex, without acute apical denticle in ventral view).

6. Lankaphthona yunnantarsella Ruan, Konstantinov & Prathapan, sp. nov. http://zoobank.org/22ABFD57-B137-42B1-A5D9-646535A5D0B8 Figs 7, 8A–F

Type Locality. China: Yunnan (Xishuangbanna).

Etymology. The name is derived from the type locality and the elongate first metatarsomere of this species.

Distribution. China: Yunnan.

Diagnosis. *Lankaphthona yunnantarsella* Ruan, Konstantinov & Prathapan, sp. nov. is close to *L. binotata* (Baly) due to the similarity in body color and elytral maculation. However, it can be separated from *L. binotata* (Baly) by the strongly enlarged eyes, narrow vertex and frons, longer antennae and the absence of abdominal appendage on first abdominal ventrite in male.

Description. Body pale yellow to yellow; meso- and metasternum and apex of metafemur dark brown dorsally; two brown to black spots with indistinct margin present on each elytron: one situated at middle and other at base on mesal side of humerus. Body oval, slightly elongate in dorsal view, dorsum convex in lateral view. Body larger in female, 1.70–2.10 mm in length, 0.80–1.10 mm in width. Body length to width ratio: 1.85–1.95. Pronotum width to length ratio: 1.65–1.75. Pronotum width at base to width at apex ratio: 1.05–1.10. Elytron length (measured along suture) to width of both ratio: 1.30–1.35. Length of elytron to length of pronotum ratio: 3.15–3.25. Width of elytra at base (measured in middle of humeral calli) to width of pronotum at base ratio: 1.30–1.40.

Vertex without punctures, except 2–3 on each side near supraorbital sulcus. Frontal ridge moderately developed, evenly convex. Sides of frontal ridge without sulci or punctures, oblique. Antennal calli obliquely elongate, sub-triangular, conjoined, well delimited with supracallinal, midfrontal, supraantennal, and suprafrontal sulci. Top of frontal ridge acute, produced between antennal calli. Frontal ridge in lateral view mod-



Figure 7. *Lankaphthona yunnantarsella* sp. nov. **A** Holotype habitus, male, dorsal view (A_1) and lateral view (A_2) **B** paratype, prothorax, dorsal view **C** paratype, head, frontal view **D** paratype, aedeagus, ventral view **E** paratype, aedeagus, lateral view **F** paratype, apex of aedeagus, ventral view **G** paratype, abdominal ventrites of male, ventral view **H** paratype, showing longitudinal intercoxal ridges on first abdominal ventrite of male.

erately convex. Antennal socket close to eye. Width of frontal ridge to antennal sockets (counting surrounding ridges) ratio 0.50–0.60. Eyes strongly enlarged. Distance between eyes (just above antennal sockets) to transverse diameter of eye in frontal view ratio: 1.50–1.60. Longitudinal diameter of eye to transverse diameter of eye in frontal view ratio: 2.00–2.10. Distance between antennal sockets to transverse diameter of one antennal socket ratio: 0.85–0.95. Labrum with four setiferous pores bearing long setae.



Figure 8. A–F *Lankaphthona yunnantarsella* Ruan, Konstantinov & Prathapan, sp. nov. **G** *L. binotata* (Baly) **H**₁–**H**₂ *L. nigronotata* (Jacoby). **A** Paratype habitus, female, dorsal view **B** paratype habitus, female, lateral view **C** paratype, spermatheca **D** paratype, vaginal palpi **E** paratype, tignum **F** paratype, male antenna **G** male antenna **H** antenna, female (**H**₁) and male (**H**₂).

Antennae filiform, rather long, about 0.9 times body length in female and 1.0 times body length in male. Proportions of antennomeres as follows: 13:7:8:9:12:11:15:15:15:14:19. Antennomere 2 robust, shorter than antennomere 3 and 4, following antennomeres slender. Length to width of antennomere 9 ratio: 5.85–5.90. Length to width of antennomere 10 ratio: 3.65–3.70. Length to width of antennomere 11 ratio: 5.50–5.55.

Pronotum more or less rectangular, slightly convex, antebasal transverse impression poorly to well developed. Pronotal punctures shallow and minute, slightly larger near antebasal transverse impression. Diameter of pronotal punctures 3–4 times smaller than distance between them. Pronotal punctures nearly as large as elytral ones. Anterolateral callosity of pronotum well developed, truncate and elongate, facing anterolaterally. Lateral margins of pronotum slightly sinuate, not converging anteriorly, with lateral margin obviously explanate. Pronotal base slightly convex at middle.

Elytral humeral callus moderately developed. Impressions or ridges absent on elytron. Elytral punctures minute, confusedly arranged. Elytra at base wider than pronotum.

Length (not counting trochanter) to maximum width of metafemur ratio: 1.95–2.00. Length to width of metatibia in lateral view ratio: 5.65–5.75. Width of metatibia at base to width at apex in dorsal view ratio: 0.45–0.50. Length of metatibia to length of first metatarsomere ratio: 1.80–1.90. Length of metafemur to metatibia ratio: 1.15–1.25. Length of first metatarsomere to length of second metatarsomere ratio: 2.50–2.55.

Subparallel intercoxal ridges on first abdominal ventrite short, not reaching proximal 1/3 of ventrite. Males without appendage on first abdominal ventrite.

Aedeagus nearly parallel sided in ventral view, with basal part slightly wider; apex tri-lobed, with sulci between middle and lateral lobes (Fig. 7F). Ventral groove present. In lateral view, aedeagus almost straight with base and apex very slightly curved ventrally.

Variability. The number and position of elytral spots are consistent in all the specimens studied: one situated near middle and the other at the base on mesal side of humerus. However, spots varied from brown to black and poorly visible (e.g., in holo-type, Fig. 7A) to distinctly prominent (e.g., in paratype, female, Fig. 8A, B). The basal spot on the mesal side of the humerus is almost invisible in the holotype, but for a trace of brown maculation. In female, an additional longitudinal spot present near lateral margin of elytra, merging with the middle spot.

Type material. Holotype: ♂ (IZCAS), labels: 1) Yunnan, Xishuangbanna, Menglun, botanical garden, lvshilin, 2009.xi.17, Guo Tang & Zhiyuan Yao leg., 21°54.609'N, 101°17.090'E, 643 m, IZCAS; 2) Holotype, *Lankaphthona yunnantar-sella* sp. nov. Des. Ruan, Konstantinov & Prathapan, 2018.

Paratypes: 2 $end{d}$ (1 in TARI, 1 to be transferred to USNM), labels: 1) Yunnan, Xishuangbanna, Menglun, botanical garden, lvshilin, 2009.xi.17, Guo Tang & Zhiyuan Yao leg., 21°54.609'N, 101°17.090'E, 643 m, IZCAS; 2) Paratype, *Lankaphthona yunnantarsella* sp. nov. Des. Ruan, Konstantinov & Prathapan, 2018; 1 $end{d}$ 1eq (IZCAS), labels: 1) Yunnan, Xishuangbanna, Menglun, 2011.viii, 1088 m; 2) Paratype, *Lankaphthona yunnantarsella* sp. nov. Des. Ruan, Konstantinov & Prathapan, 2018.

Remarks. The specimens of *L. yunnantarsella* sp. nov. Ruan, Konstantinov & Prathapan and *L. nigronotatus* were collected from the same location in Yunnan province, China. Hence it is very easy to confuse these two species due to their similarity in body shape, color and elytral maculation. However, they can be carefully separated based on external characters. In *L. yunnantarsella* antennae are about 0.9–1.0 times body length, antennomere 2 shorter than antennomere 3 and 4 and each elytron with two dark spots (in males), one situated at middle and the other basally on mesal side of

humerus. In *L. nigronotatus*, antennae are about 0.8 times body length, antennomere 2 longer than antennomere 3 and 4; and elytron with three dark spots: one situated at middle, one elongate spot on sutural margin near apex and the third one at apex.

Discussion

Sheath-shaped phallobase of *L. binotata* (Fig. 1D–J)

The phallobase exhibit very limited variation within or between genera in flea beetles. However, it offers distinct but highly stable variation between family groups of Chrysomeloidea and Cerambycoidea. Hence it is extensively used in phylogenetic studies on higher classification of leaf beetles and allied families (e.g. Chen 1985; Verma 1996). Chen (1985) identified four types of male genitalia in Chrysomeloidea (*sensu lato*): cerambycid, megalopodid, sagrid, chrysomelid and eumolpid.

According to Crowson (2013), the sheath-like phallobase has evolved polyphyletically in many families of Coleoptera (e.g., Histeridae, Buprestidae, Bostrychidae and Trogossitidae). Within Chrysomeloidea, gutter-shaped fused lateral lobes encircling median lobe have been reported in the bruchid genus *Caryopemon* Jekel (Li et al. 2016). However, in Chrysomelidae, the phallobase is long, slender and T- or Y- shaped (Verma et al. 1996) and is the basic structure in most subfamilies (e.g., Chrysomelinae, Galerucinae, Synetinae, Cassidinae). The structure of the phallobase in *L. binotata* is more primitive and closely resembles a modified abdominal sternite rather than a regular T- or Y-shaped chrysomelid phallobase. The sheath-like phallobase of *T. binotata*, which apparently is a homoplasy, indicates that the phallobase can be modified and highly specialized even in highly evolved species or genera.

The chrysomelid phallobase plays a vital role in the reversal of the aedeagus as both protractor and retractor muscles of aedeagus are attached to it (Verma 1994, 1996). Apparently, the sheath-like phallobase (spiculum) too performs the same function.

The shape of the phallobase in *L. binotata* also indicates that it is a modified true abdominal sternite or tergite. As the structure has an anteriorly produced sclerotized rod-shaped apodeme in middle (Fig. 1I–J: anterior apodeme), it supports the theory that the phallobase of Coleoptera has originated from sternite 9 with a 'median anterior apodeme' (Crowson 2013).

Abdominal appendage of *L. binotata* (Fig. 3)

Several secondary sexual characters are known in flea beetles. The most common ones are the following: the larger body size in female; sexually dimorphic shape of posterior margin of last visible abdominal ventrite and pygidium; and first protarsomere much more enlarged in males than in females in many genera (Konstantinov and Lingafelter 2002). 'Abdominal appendages' are present in specific groups of chrysomelids, especially Galerucini. For instance, in males of *Pseudoluperus tuberculatus* (Blake) (Galaerucini), two short and simple lamellae are present on the second abdominal ventrite; males of *Scelida* Chapuis also has odd ventral appendages (Riley et al. 2002); in *Hoplasoma* Jacoby, some species tend to have 1 or 2 pairs of processes on abdominal ventrite (Bezděk and Zhang 2007; Bezděk 2014). Mohamedsaid and Furth (2011) reported that there are 66 species from 18 different genera of Galerucini having lamella-shaped abdominal ornaments.

Such specialized abdominal appendages are rare in flea beetles. There are two Australian flea beetle (Alticini) genera *Axillofebra* Samuelson and *Profebra* Samuelson with extra structures on procoxa, which are produced over part of the trochantero-femoral articulation (Samuelson 1969), but these structures are simple and do not seem to be specialized.

Morphological structures, similar to that in the male of *L. binotata*, occur in *Haplosomoides* Duvivier (Galerucini). In some species of *Haplosomoides*, the structure is prominent and delicate, and is used as one of the main diagnostic characters to delimit species and species groups (e.g., Lee et al. 2011). Although origin of the abdominal appendages in *Haplosomoides* and *L. binotata* are probably polyphyletic, they are almost morphologically indistinguishable: both are highly specialized, spoon-shaped, with elongate setae on apical part.

The evolutionary significance or function of the spoon-shaped abdominal appendage still remain unexplained. The true function of the structure should be tested empirically. However, as it is currently only known in males, we presume that it is related to copulation, most probably as an auxiliary structure in the mating process (shown in Fig. 2B).

Acknowledgements

This research was supported by the Grants from the National Natural Science Foundation of China to Yongying Ruan (Grant No. 31802004) and Shihong Jiang (Grant No. 31772511).

Mention of trade names or commercial products in this publication is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the USDA; USDA is an equal opportunity provider and employer.

References

- Baly JS (1874) Catalogue of the phytophagous Coleoptera of Japan, with descriptions of the species new to science. Transactions of the Entomological Society of London 6: 161–217. https://doi.org/10.1111/j.1365-2311.1874.tb00164.x
- Baly JS (1876) Descriptions of a new genus and of new species of Halticinae. Transactions of the Entomological Society of London 28: 581–602. https://doi.org/10.1111/j.1365-2311.1876. tb01931.x

- Bezděk J (2014) A revision of *Hoplasoma acuminatum* and *H. thailandicum* species groups, and re-definition of *H. unicolor* species group (Coleoptera: Chrysomelidae: Galerucinae). Zootaxa 3794: 419–434. https://doi.org/10.11646/zootaxa.3794.3.5
- Bezděk J, Zhang L (2007) Taxonomical changes in the genera *Hoplasoma* and *Haplosomoides* (Coleoptera: Chrysomelidae: Galerucinae). Acta Entomologica Musei Nationalis Pragae 47: 189–193.
- Biondi M, D'Alessandro P (2010) Genus-group names of Afrotropical flea beetles (Coleoptera: Chrysomelidae: Alticinae), annotated catalogue and biogeographical notes. European Journal of Entomology 107(3): 401–424. https://doi.org/10.14411/eje.2010.049
- Chen S (1934) Revision of the Halticinae (Col. Chrysomelidae) of Yunnan and Tonkin. Sinensia Nanking 5: 225–416.
- Chen S (1935) Coleoptera Halticinae de la collection du Museum recueillis par le Dr. J. Harmand au Sikkim. Bulletin de la Societe Entomologique de France Paris 40: 75–80.
- Chen S (1985) Phylogeny and classification of the Chrysomeloidea. Entomography 3: 465–475.
- Crowson RA (2013) The biology of the Coleoptera. Academic Press, 802 pp.
- Döberl M (2009) Nomenclatorial notes on Palaearctic Coleoptera (Curculionidae, Cerambycidae, Chrysomelidae). Entomologische Blaetter fuer Biologie und Systematik der Kaefer 105: 19–23.
- Döberl M (2010) Alticinae. In: Löbl I, Smetana A (Eds) Catalogue of Palaearctic Coleoptera Vol. 6. Apollo Books, Stenstrup, 491–563.
- Duvivier A (1891) Diagnoses de Phytophages madégasses. Annales de la Société Entomologique de Belgique 35: 238–245; 313–321; 423–424.
- Gruev B (1989) *Longitarsus phuketensis* sp. n. from Thailand (Coleoptera, Chrysomelidae: Alticinae). Entomological Review of Japan 44(2): 97–98.
- Heikertinger F (1924) Die Halticinen genera der Palaearktis und Nearktis. Bestimmungstabellen (Monographic der palaearktischen Halticinen: Systematischer Teil.-Zweites Stuck). Koleopterologische Rundschau 11: 25–48.
- Jacoby M (1896) Descriptions of the new genera and species of phytophagous Coleoptera obtained by Mr. Andrews in India. Part II. Chrysomelinae, Halticinae and Galerucinae. Annales de la Société Entomologique de Belgique 40: 250–304. https://doi.org/10.5962/bhl.part.2024
- Jolivet P, George P, Verma K (2013) *Timarcha* Latreille: A strange beetle and a living fossil. Terrestrial Arthropod Reviews 7(1): 3–20. https://doi.org/10.1163/18749836-06041071
- Kimoto S (2000) Descriptions of some new genera and species of Chrysomelidae (Coleoptera) from Thailand, Laos, and Vietnam. Serangga 5(1): 1–39.
- Konstantinov AS (1998) Revision of the Palearctic species of *Aphthona* Chevrolat and cladistic classification of the Aphthonini (Coleoptera: Chrysomelidae: Alticinae). Memoirs on Entomology International. Vol. 11. Associated Publishers, Gainesville, 429 pp.
- Konstantinov AS, Lingafelter SW (2002) Revision of the Oriental species of *Aphthona* Chevrolat (Coleoptera: Chrysomelidae). Entomological Society of Washington, 349 pp.
- Konstantinov AS, Prathapan KD (2008) New generic synonyms in the Oriental flea beetles (Coleoptera: Chrysomelidae). Coleopterists Bulletin 62: 381–418. https://doi. org/10.1649/1089.1

- Lee C-F, Bezděk J, Staines CL (2011) A review of the genus *Haplosomoides* Duvivier, 1890 in Taiwan and Japan (Coleoptera: Chrysomelidae: Galerucinae). Zoological Studies 50(1): 118–138.
- Li Y, Omar, YM, Zhang R (2016) Taxonomic studies on the genus *Caryopemon* =(Coleoptera: Chrysomelidae: Bruchinae) of China and Myanmar with some new host plants. Florida Entomologist 99(2): 257–263. https://doi.org/10.1653/024.099.0215
- Maulik S (1926) The fauna of British India, including Ceylon and Burma, Chrysomelidae (Chrysomelinae and Halticinae). Taylor and Francis, London, 441 pp.
- Maulik S (1931) Coleoptera, Chrysomelidae, Eumolpinae, Galerucinae and Halticinae. Percy Sladen Trust Expedition to the Indian Ocean in 1905. Transactions of the Linnaean Society of London 2nd Series Zoology 19: 241–260. https://doi.org/10.1111/j.1096-3642.1931. tb00128.x
- Medvedev LN (2001) Chrysomelidae of southern Asia (Coleoptera). Entomologica Basiliensia 23: 159–191.
- Medvedev LN (2009) Alticinae of Indochina. KMK Scientific Press, Moscow, 224 pp.
- Medvedev LN (2016) New and poorly known Oriental Chrysomelidae (Insecta: Coleoptera) in the collection of the Naturkundemuseum Erfurt. Vernate 35: 347–365.
- Medvedev LN (2017) New leaf beetles (Coleoptera: Chrysomelidae) from New Guinea. In: Telnov D, Barclay MVL, Pauwels OSG (Eds) Biodiversity, biogeography and nature conservation in Wallacea and New Guinea. Volume III. The Entomological Society of Latvia, Riga, 419–426. [658 pp., 172 pls]
- Mohamedsaid MS, Furth DG (2011) Secondary sexual characteristics in the Galerucinae (Sensu stricto) (Coleoptera: Chrysomelidae). ISRN Zoology, 60 pp. https://doi. org/10.5402/2011/328670
- Nadein KS (2006) A significance of the tegmen structure for classification of the genus *Psylliodes* Latreille, 1829 (Coleoptera: Chrysomelidae: Psylliodina). Trudy Russkogo Entomologicheskogo Obshchestva 77: 250–254.
- Prathapan KD, Konstantinov AS (2003) The flea beetle genus *Aphthona* Chevrolat (Coleoptera: Chrysomelidae) of southern India, with descriptions of seven new species. Proceedings of the Entomological Society of Washington 105(1): 154–179.
- Prathapan KD, Ruan Y, Konstantinov AS (2017) *Doeberlnotus*, a new genus of flea beetles from India (Coleoptera: Chrysomelidae: Galerucinae: Alticini). Entomologische Blätter und Coleoptera 113(1): 201–206. https://doi.org/10.12976/jib/2017.5.5
- Riley EG, Clark SM, Flowers RW, Gilbert AJ (2002) Chrysomelidae Latreille 1802. In: Arnett RH, Thomas MC, Skelley PE,Frank JH (Eds) American Beetles, Volume II: Polyphaga: Scarabaeoidea through Curculionoidea. CRC Press, 617–691.
- Ruan Y, Yang X (2015) Subfamily Alticinae Chûjô, 1953. In: Yang X, Ge S, Nie R, Ruan Y, Li
 W (Eds) Chinese leaf beetles. Science Press, Beijing, 307–464.
- Samuelson GA (1969) Alticinae of new guinea. 3. Schenklingia and allies (Coleoptera: Chrysomelidae). Pacific insects 11(1): 33–47.
- Sharp D (1886) On New Zealand Coleoptera, with descriptions of new genera and species. Transactions Royal Dublin Society 2(iii): 351–454.

- Sharp D, Muir F (1912) The comparative anatomy of the male genital tube in Coleoptera. Transactions of the Royal Entomological Society of London 60(3): 477–642. https://doi. org/10.1111/j.1365-2311.1912.tb03107.x
- Verma KK (1994) 'Retournement' of the aedeagus in Chrysomelidae (Coleoptera). In: Jolivet PHA, Cox ML, Petitperre E (Eds) Novel aspects of the biology of Chrysomelidae, Kluwer Academic Publishers, The Netherlands, 355–362. https://doi.org/10.1007/978-94-011-1781-4_29
- Verma KK (1996) Inter-subfamily relations among Chrysomelidae (Coleoptera) as suggested by organization of the male genital system. In: Jolivet PHA, Cox ML (Eds) Chrysomelidae Biology, vol. 1, SPB Academic Publishing, The Hague, The Netherlands, 317–351.

RESEARCH ARTICLE



A new genus of Pelecotominae from Mexico, with notes on the genera *Clinops* and *Scotoscopus* and the description of new species (Coleoptera, Ripiphoridae)

Michael S. Engel^{1,2,3}, Zachary H. Falin¹, Jan Batelka⁴

I Division of Entomology, Natural History Museum, 1501 Crestline Drive – Suite 140, University of Kansas, Lawrence, Kansas 66045-4415, USA 2 Department of Ecology & Evolutionary Biology, University of Kansas, Lawrence, Kansas 66045, USA 3 Division of Invertebrate Zoology, American Museum of Natural History, Central Park West at 79th Street, New York, New York 10025-5192, USA 4 Department of Zoology, Faculty of Science, Charles University, Viničná 7, 128 43 Praha 2, Czech Republic

Corresponding author: Jan Batelka (janbat@centrum.cz)

Academic editor: Aaron Smith	Received 27 March 2019	Accepted 11 May 2019	Published 25 June 2019
http://	/zoobank.org/27E52E85-0B31-	445E-BC90-C7D5D17C429A	

Citation: Engel MS, Falin ZH, Batelka J (2019) A new genus of Pelecotominae from Mexico, with notes on the genera *Clinops* and *Scotoscopus* and the description of new species (Coleoptera, Ripiphoridae). ZooKeys 857: 59–84. https://doi.org/10.3897/zooKeys.857.34938

Abstract

Taxonomic notes are provided on species of the uncommonly encountered ripiphorid subfamily Pelecotominae. *Zapotecotoma sumichrasti* gen. et sp. nov., is described from southern Mexico based on a unique male likely collected in the later part of the mid-19th Century. The discovery of additional species of the South African genus *Clinops* Gerstaecker permit a revised diagnosis and distinction of the group from the eastern Mediterranean genus *Scotoscopus* Brenske and Reitter, resurrected status. Two new species of *Clinops* are established: *Clinops inexpectatus* sp. nov. (northeast of Durban near Swaziland) and *C. perpes*sus sp. nov. (region of Durban), and *Scotoscopus spectabilis* (Schaufuss) is newly recorded for the Peloponnese in Greece.

Keywords

distribution, Greece, Mexico, South Africa, taxonomy, Tenebrionoidea

Introduction

The ripiphorid subfamily Pelecotominae is one of the earliest diverging lineages of wedge-shaped beetles, only the Ptilophorinae being more basal in the phylogeny of Ripiphoridae (Falin 2003; Batelka et al. 2016a). Pelecotominae are infrequently encountered beetles with most of their scant diversity (hitherto 14 modern species in eight genera: table 1) found in the New World tropics, and other species scattered from eastern North America, central and southern Europe, Turkey, South Africa, Japan, mainland Malaysia, and New Zealand (Falin 2003; Batelka 2009). Where known, species are parasitoids of the larvae of wood-boring beetles (Ptinidae [formerly Anobiidae] and Cerambycidae) (Hudson 1934; Watt 1983; Kuschel 1990; Švácha 1994; Batelka 2005; Lawrence et al. 2010). Not surprising given its phylogenetic position, Pelecotominae are known from as far back as the mid-Cretaceous, and from a diversity of species largely preserved in amber from northern Myanmar (Batelka et al. 2016b, 2018; Hsiao and Huang 2018). All other Cretaceous species of Ripiphoridae belong to the more derived subfamily Ripidiinae (e.g., Falin and Engel 2010; Batelka et al. 2016b, 2018; Cai et al. 2018).

The subfamily has been generally characterized by Falin (2003) who incorporated therein the former Micholaeminae which otherwise rendered the more traditionally restricted Pelecotominae paraphyletic. Inclusive of the micholaemines, the subfamily can be distinguished from other Ripiphoridae by the long and slender body form with fully developed elytra, protibiae shorter than the protarsi, labrum connected to the frontoclypeus, presence of a small dorso-ventral phragma on the inner aspect of the anterior edge of the mesepisternum, and a U-shaped excavation on the ventral margin of the fossa of the pronotum (the latter two serving as synapomorphies for the clade according to Falin 2003). The genera are poorly understood owing to a dearth of available material and are generally characterized by an intermingling of features relating to the tibial spur formula, form of the pretarsal claws, and form of the maxillary palpomeres. Although some degree of relationship was recovered in the morphological analyses of Falin (2003), considerable phylogenetic work remains to be undertaken, particularly once additional material is discovered, proper dissections undertaken, and ideally both sexes for the various genera characterized (presently, the majority of species are known only from one sex).

Herein we provide various notes on Pelecotominae. First, we describe a new genus and species from southern Mexico, thereby allowing us to update the tabulation of known diversity within the subfamily (Table 1). In addition, we clarify the diagnosis of the genus *Clinops* Gerstaecker, and describe two new species of this southern African genus. In clarifying the identity of *Clinops*, we resurrect the genus *Scotoscopus* Brenske and Reitter for a species known to occur in Greece and Turkey.

Materials and methods

Morphological terminology and the format for descriptions generally follow that used elsewhere for Pelecotominae (e.g., Falin 2003; Batelka 2005, 2009; Batelka et al. 2016b) and more generally for Ripiphoridae (e.g., Lawrence et al. 2010). In reporting

Genus	No.	Spur	Distribution
	Species	Formula	
Allocinops Broun, 1921	1	1-2-2	New Zealand
Ancholaemus Gerstaecker, 1855a	2	0-1-2	Brazil, Ecuador (Galapagos Islands)
† <i>Burmitoma</i> Batelka, Engel, & Prokop, 2018	1	0-2-2	Myanmar (Cenomanian)
Clinopalpus Batelka, 2009	1	0-0-1	mainland Malaysia
Clinops Gerstaecker, 1855a	3	0-0-2	South Africa
† <i>Flabellotoma</i> Batelka, Prokop, & Engel, 2016b	1	0-0-0	Myanmar (Cenomanian)
Micholaemus Viana, 1971	1	0-1-2	Argentina
Pelecotoma Fischer von Waldheim, 1809	3	1-1-1	eastern North America, central Europe, Japan
†Plesiotoma Batelka, Engel, & Prokop, 2018	1	1-2-2	Myanmar (Cenomanian)
Rhipistena Sharp, 1878	3	2-2-2	New Zealand
Scotoscopus Brenske & Reitter, 1884	1	0-2-2	Greece, Turkey
Sharpides Kirkaldy, 1910	1	2-2-2	New Zealand
†Spinotoma Hsiao & Huang, 2018	1	?	Myanmar (Cenomanian)
Zapotecotoma gen. nov.	1	0-1-1	southern Mexico

Table 1. Currently recognized genera of Pelecotominae (sensu Lawrence et al. 2010). Daggers (†) denote extinct taxa.

specimen label data we have separated information on separate lines of a single label with single slashes (/), and material on separate labels with double slashes (//). Annotations of added information meant to clarify otherwise ambiguous abbreviations or provide further insight into label data is provided in brackets. Material recorded herein is deposited in the following institutions:

MCZ	Museum of Comparative Zoology, Harvard University, Cambridge, Mas-
	sachusetts, USA (P. Perkins).
NHMUK	The Natural History Museum, London, United Kingdom (M. Barclay).
TMSA	Ditsong National Museum of Natural History (formerly the Transvaal
	Museum), Pretoria, South Africa (R. Müller).
ZMUC	Statens Naturhistoriske Museum, Universitetets Zoologiske Museum, Co-
	penhagen, Denmark (A. Solodovnikov).

Systematics

Family Ripiphoridae Laporte Subfamily Pelecotominae Seidlitz

Zapotecotoma gen. nov. http://zoobank.org/958B329B-973A-4D01-9FC7-0DC1E3581C82

Type species. *Zapotecotoma sumichrasti* sp. nov.

Diagnosis. \mathcal{E} : Body slender; head with postocular genae expanded into lobes; compound eye not expanded beyond mandibular base and with a small extra-antennal

sclerotous emargination; antenna with eleven antennomeres; antennomeres I–III simple, IV–X with inner-facing, flabellate, compressed rami, XI similar in shape to preceding rami; ultimate maxillary palpomere cylindrical, not compressed or expanded; distal sensory duct on ultimate maxillary palpomere a small, ovoid point. Lateral aspect of pronotum with a ventrally bowed sulcus; pronotal disc without longitudinal medial impression; mesosternum convex but without distinct medial keel; metepisternum with elytron-receiving carina extending along anterior portion only; posterior aspect of metepimeron narrow. Metacoxa with strongly developed posterior flange; ventral surface of pro- and mesofemora in males without densely setose patch; tibial spur formula 0-1-1; pretarsal claws bifid.

♀: Unknown.

Etymology. The new genus-group name is a combination of Zapotec, the principal indigenous people in the region of the type locality, and *-toma* (derived from the Greek, *tome* or *tomeus*, meaning, "separation", "cutting", or "cutter"), a suffix generally used in the generic names of pelecotomines. The gender of the name is feminine.

Zapotecotoma sumichrasti sp. nov.

http://zoobank.org/DCF375E0-9DC9-4AF4-9F39-B72F1630D911 Figs 1–3

Pelecotominae new genus 1 gen. nov.: Falin 2003: 184.

Diagnosis. As for the genus (*vide supra*).

Description. \mathcal{O} : General size and appearance typical of Pelecotominae. Size 7.38 mm from tip of abdomen to base of antennae, 2.15 mm wide at base of pronotum. Body bicolorous; head, prothorax, mesoscutellum, and majority of elytra orange testaceous; remainder of body dull, dark reddish brown, including patches at apexes of elytra (Figs 1–2).

Head ovoid, approximately 1.1× longer than wide in facial view, medial length 1.67 mm, maximum width (across compound eyes) 1.54 mm. Vertex convex dorsally and posteriorly, as wide as lower face (below compound eyes), rising high above compound eyes in facial view, sloping uniformly to meet and slightly overlap pronotal anterior margin (Fig. 1), with weak medially impressed line, disappearing posteriorly. Dorsal, lateral, and facial aspects of head with fine, semi-decumbent, orange setae, particularly numerous on face between compound eyes and vertex, sparse on genae (Fig. 3); integument dull, with minute, weak, nearly contiguous punctures separated by apparently smooth or faintly imbricate integument (where evident). Compound eye small on middle third of lateral surface of head, finely faceted, emarginate in upper third. Postocular gena expanded into lobe. Frons broad, with antennal torulus laterally directed, antennal toruli separated by distance greater than length of scape, compound eyes separated by distance greater than length. Malar space elongate, more than one-half length of scape, slightly less than basal mandibular width. Man-



Figures 1, 2. Zapotecotoma sumichrasti gen. et sp. nov., holotype male. I lateral habitus 2 dorsal habitus.

dible short, slightly curved, with short, acute subapical tooth. Maxillary palpus long, tetramerous, apical palpomere largest, cylindrical, its apical width approximately one third its maximum length, with acutely rounded apex, not flattened or grossly enlarged (greatly enlarged and flattened in *Ancholaemus* Gerstaecker and *Micholaemus* Viana), distal sensory duct point-like.

Antenna consisting of eleven antennomeres; antennomere I longer than wide, slightly curved to approximate compound eye; antennomere II short, slightly wider than long; antennomere III longer than antennomere II, about as long as apically wide, triangular, apical margin oblique so as to receive base of following antennomere. Antennomeres IV–XI greatly dissimilar from preceding antennomeres; antennomeres IV–X with internally facing, compressed rami; bases of antennomeres IV–X short and of similar lengths; rami IX and X elongate, extending to apex of antennomere XI (apexes of rami IV–VIII damaged and missing and left antenna completely missing so precise structure of all rami uncertain). Antennomere XI expanded, similar in shape to

rami of preceding antennomeres. Total length of antennomere XI nearly $1.6 \times$ length of bases of antennomeres IV–X combined.

Pronotum with suberect to semi-decumbent, fine, orange setae, integument dull, and weakly, indistinctly, and contiguously punctate, with punctures more indistinct posteriorly and integument becoming imbricate. Pronotum triangular in shape, narrowed anteriorly; anterior margin broadly rounded; posterior margin sinuate and generally trilobed, with medial lobe as broad as mesoscutellum and narrowly emarginate, acutely rounded on either side of emargination; lateral margins generally straight, converging apically, convex ventrally to propleurae; propleuron well developed. Pronotal disc without mediolongitudinal carina or impression but with a weak transverse impression near apex and a pair of weak oblique impressions on either side of midline near base; lateral aspect with a ventrally bowed sulcus. Mesonotum obscured by elytra. Mesoscutellum short, flat, parallel-sided, with broadly rounded apex; integumental sculpturing and setation as on pronotal disc. Metanotum obscured by elytra.

Lateral and ventral aspects of pterothorax typical of subfamily. Mesepisternum weakly imbricate, fused with mesosternum, with scattered semi-decumbent setae. Mesepimeron forming prominent, rectangular sclerite separated from mesepisternum by deep sulcus; sculptured and setation as on mesepisternum. Metepisternum an elongate, narrow rectangular sclerite, with sculpturing and setation as on mesepisternum; metasternum massive, weakly imbricate and with semi-decumbent setae more numerous than on metepisternum. Metepimeron approximately parallel-sided except apically upper margin arching ventrally, extending anteriorly to wing base as narrow (slightly more narrow than metepisternum), sclerotized band; weakly imbricate with scattered fine setae.

Legs typical for subfamily; coxae, trochanters, and femora weakly, irregularly, almost indistinctly punctate on otherwise smooth and shining integument with semidecumbent to suberect lightly fuscous setae; metacoxa with strongly developed posterior flange; femora without densely setose patches ventrally; tibiae straight, cylindrical, broadened slightly apically, with apex terminated by dense row of regular, thin, spiniform setae; tibial spur formula 0-1-1. Tarsi 5-5-4, all tarsomeres cylindrical, slightly tapered basally, truncate apically, progressively reducing in diameter; integument and setae similar to tibiae; protarsus longer than protibia. Protarsomere I slightly shorter than combined length of protarsomeres II and III, protarsomere IV slightly shorter than protarsomere V; relative ratios of mesotarsomeres similar except mesotarsomere I subequal to combined length of mesotarsomeres II and III; ratios of metatarsomeres similar. Pretarsal claws bifid, apical ramus sickle-shaped, inner ramus broadly rounded apically.

Elytra elongate, completely covering abdomen, surface imbricate; elytron basal width 1.08 mm, length 6.83 mm; each elytron with four indistinct costae; lateral margins parallel-sided, lateral margin comparatively straight until tapering inward in apical third, medial margin nearly straight until rounding at apex (Fig. 2); apex weakly acuminate.

Abdomen weakly imbricate, with scattered semi-decumbent to semi-erect setae. Q: Latet.

Holotype. ♂, [Mexico:] F. Sumichrast [Francis E. Sumichrast (1828–1882), a famous Mexican collector who supplied biological specimens to many researchers and



Figures 3–5. Details of pelecotomine genera. 3 facial view of *Zapotecotoma sumichrasti* gen. et sp. nov., holotype male 4 facial view of *Clinops perpessus* sp. nov., holotype male 5 inset detail of maxillary palpus of *C. perpessus*.

institutions during the 19th Century] / Isth. [Isthmus] of Tehuantepec // F.C. Bowditch / coll. [Frederick Channing Bowditch (1854–1925) Collection, a wealthy amateur collector of Coleoptera] (MCZ). Unfortunately, the label data are no more specific than referencing the entire isthmus, which encompasses at its narrowest some 124 miles and varied terrain and habitats (e.g., centrally the Selva Zoque, a famous tropical

forest region, ranging to dense jungle swamps in the North). It is therefore unclear as to precisely what environment in which to expect the present species. The specimen was likely collected during the same period in which Sumichrast collected birds from Tehuantepec for the United States National Museum (1868–1871) (Lawrence 1875).

Etymology. The specific epithet honors Francis E. Sumichrast (1828–1882), collector of the holotype and many other fascinating species from southern Mexico during the mid-19th Century.

Genus Clinops Gerstaecker

Clinops Gerstaecker, 1855a: 16. Type species: *Clinops badius* Gerstaecker, 1855, by monotypy.

Diagnosis. Body slender; elytra 3.0–3.4× as long as pronotal disc; coloration light to dark brown, with fine, short golden to light or dark brown setae; head with postocular genae expanded into lobes; compound eye not expanded beyond mandibular base and with a small extra-antennal sclerotous emargination; antenna with eleven antennomeres; male antenna with antennomeres I-III simple, IV-X with inner-facing, flabellate, compressed rami, XI similar in shape to preceding rami; female antenna similar to male with much shorter, pectinate, compressed rami; ultimate maxillary palpomere trapezoidal, apical width slightly less than maximum length, with blunt, truncate apex, not grossly enlarged; distal sensory duct on ultimate maxillary palpomere elongate, strongly oblique. Lateral aspect of pronotum with a ventrally bowed sulcus; pronotal disc without longitudinal medial impression; mesosternum weakly convex, without medial keel; metepisternum without elytron-receiving carina; posterior aspect of metepimeron slightly expanded. Metacoxa with strongly developed posterior flange; ventral surface of pro- and mesofemora in males without densely setose patch; tibial spur formula 0-0-2; pretarsal claws apically bifid, with or without a small, peg-like subsidiary tooth at midlength. Male genitalia with parameres weakly curved with apices widely separated from each other.

Comments. The identity of *Clinops* has presented quite a historical challenge. Gerstaecker (1855a, 1855b) described the tibial spur formula for *Clinops badius* Gerstaecker as 0-?-2 ("*tibiis anticis muticis, mediis–?, posticis bispinosis*"), as both midlegs were missing in his female holotype (Figs 15–16). Falin (2003) proposed a formula of 0-0-2 for the genus, basing his conclusion on a specimen he interpreted as *C. badius* from TMSA (herein recognized as a separate species, *vide C. inexpectatus* sp. nov., *infra*). This interpretation for the genus is followed herein as it is consistent with what little is known of the tibial spur formulas for the three South African species we recognize: *C. badius* 0-?-2, *C. inexpectatus* 0-0-2, and *C. perpessus* sp. nov. 0-0-?. Accordingly, the tibial spur formula for *Clinops* differs from that of *Scotoscopus* Brenske and Reitter (*vide infra*), and the two genera are considered distinct, pending phylogenetic work throughout the subfamily.

There is a possibility that the differences observed between *C. inexpectatus* and *C. perpessus* are only sex differences rather than species distinctions. There are sexual dimorphisms known among pelecotomines, such as differences in the ultimate maxillary

palpomeres of *Ancholaemus* Gerstaecker or color of the pronotal disc in *Scotoscopus*. Nonetheless, we believe the differences in head and pronotal shape reflect features specific to species, particularly as these are not known to be sexually variable in any other pelecotomines. Accordingly, we believe that the material described here represents distinct taxa. Naturally, the discovery of further material from a variety of localities will allow for further testing of this hypothesis.

It is interesting to note that while the form of the pretarsal claws has historically been used as a distinguishing feature for many genera, such as the conditions of bifid or pectinate, and in many cases such a difference does concord with other attributes, there is variation within *Clinops*. Among the species included here are those with strictly bifid claws, i.e., with a subapical ramus (tooth) that opposes the apical terminus of the claw, as well as one (*C. inexpectatus*) that has the typical bifid form coupled with the presence of a smaller, subsidiary tooth at about midlength (Fig 26). It is therefore fascinating that with the addition of more and more such subsidiary teeth one progresses naturally into a pectinate condition. The claw of *Scotoscopus* (*vide infra*: Fig 29) is somewhat similar albeit less pronounced, in that there is at least one, exceptionally short and blunt projection (appearing like a worn tooth) proximal to the initial ramus forming the bifid claw. It will be illuminating to more fully explore the complete ranges of variation in claw structure across the subfamily once more material and more species are discovered, and to develop clear homologies for the various elements distribute in a cladistic framework.

Distribution. The genus is presently recorded only from South Africa. The precise locality from which Gerstaecker's holotype of *C. badius* was collected is not known. Gerstaecker (1855a, 1855b) indicated the type locality only as "Caffraria". This name (properly Kaffraria) was a historical, descriptive term for the southeastern region of the Eastern Cape (in which case the type locality was somewhere more southward coastally from the localities where the other two species were found). The newly described species, *C. inexpectatus* and *C. perpessus*, were collected on the eastern coast of South Africa, the former northeast of Durban toward Swaziland, and the latter somewhere in the region of Durban. Franciscolo (1952: antenna in his fig. 37) reported a female of *"Pelecotoma* sp." from Cape Town, undoubtedly a misidentification for a specimen of *Clinops* (Batelka 2005), but the whereabouts of this specimen is unknown to us. The genus is probably widely distributed in woodlands of South Africa, perhaps escaping the attention of entomologists owing to its parasitoid biology.

Clinops perpessus sp. nov.

http://zoobank.org/B454A4B5-CCC7-4E42-AA5E-3DED1DD0FA53 Figs 4–14

Pelecotominae new genus 2 gen. nov.: Falin 2003: 186.

Diagnosis. Differs from *C. inexpectatus* by the only slightly elevated vertex above the pronotum (greatly elevated in *C. inexpectatus*: cf. Figs 6, 7 vs. Figs 19, 23), more

robust head dorso-ventrally (1.63 mm vs. 1.08 mm in *C. inexpectatus* in which the head appears more flattened), elytral coloration (notably lighter basal two thirds in *C. perpessus*: cf. Figs 6, 7 vs. Figs 19, 20), by the absence of a mediolongitudinal shallow impression (furrow) in basal third of pronotal disc (present in *C. inexpectatus*: cf. Fig. 7 vs. Fig. 20), by the absence of a medioapical emargination to the median lobe of the pronotal posterior border (emargination present in *C. inexpectatus*), by base of pronotal disc wider than the length of the pronotal disc (pronotal disc as wide as long in *C. inexpectatus*), and by the stubbier terminal maxillary palpomere (cf. Fig. 5 vs. Fig. 22). Overall, the species is more similar to *C. badius*, as both species have the scarcely elevated vertex relative to the pronotum (e.g., Figs 6–7, 15–16). *Clinops perpessus* differs from *C. badius* most notably in the shape of the terminal maxillary palpomere (cf. Fig. 5 vs. Fig. 18), the apically darkened elytra (uniformly colored in *C. badius*: cf. Figs 6–7 vs. Figs. 15, 16), the more elongate antennal rami (cf. Fig. 4 vs. Fig. 17), and absence of a medioapical emargination to the median lobe of the pronotal rami (cf. Fig. 4 vs. Fig. 17), and absence of a medioapical emargination to the median lobe of the pronotal rami (cf. Fig. 4 vs. Fig. 17), and absence of a medioapical emargination to the median lobe of the pronotal rami (cf. Fig. 4 vs. Fig. 17), and absence of a medioapical emargination to the median lobe of the pronotal posterior border (emargination present in *C. badius*).

Description. \mathcal{E} : General size and appearance typical of Pelecotominae. Size 9.75 mm from tip of abdomen to base of antennae, 2.54 mm wide at base of pronotum. Body largely dark brown, slightly lighter reddish brown on lateral thirds of pronotum, basal two thirds of elytra, and apical abdominal sterna (Figs 6–7).

Head ovoid, approximately 1.02× longer than wide in facial view, medial length 1.67 mm, maximum width (across compound eyes) 1.63 mm. Vertex convex dorsally and posteriorly, as wide as lower face (below compound eyes), rising high above compound eyes in facial view, sloping uniformly to meet and slightly overlap pronotal anterior margin, with weak medially impressed line, disappearing posteriorly. Dorsal, lateral, and facial aspects of head with fine, decumbent, golden to fuscous setae, particularly numerous on face between compound eyes and vertex, abundant on genae; integument dull, with minute, nearly contiguous punctures separated by apparently smooth to imbricate integument. Compound eye of moderate size, encompassing much of medial third of lateral surface of head, finely faceted, emarginate in upper third (emargination deeper than in Z. sumichrasti, such that compound eye nearly appears bisected in facial view: cf. Figs 3 vs. 4). Postocular gena expanded into lobe. Frons broad, with antennal torulus laterally directed, antennal toruli separated by distance equal to length of scape, compound eyes separated by distance slightly less than maximum compound eye length. Malar space elongate, more than one-half length of scape, slightly less than basal mandibular width. Mandible short, slightly curved, with short, acute subapical tooth. Maxillary palpus long, tetramerous, terminal palpomere largest, trapezoidal, its apical width slightly less than maximum length, with blunt, truncate apex, not flattened or grossly enlarged (greatly enlarged and flattened in Ancholaemus Gerstaecker and Micholaemus Viana), distal sensory duct elongate, strongly oblique.

Antenna consisting of eleven antennomeres; antennomere I longer than wide, slightly curved to approximate curvature of compound eye; antennomere II short, slightly wider than long; antennomere III longer than antennomere II, length approximately 1.3× apical width, apical margin truncate. Antennomeres IV–XI greatly



Figures 6, 7. Clinops perpessus sp. nov., holotype male. 6 lateral habitus 7 dorsal habitus.

dissimilar from preceding antennomeres; antennomeres IV–X with internally facing, compressed rami; bases of antennomeres IV–X short and of similar lengths; rami IX and X elongate, extending to apex of antennomere XI; remaining rami progressively shorter from X to IV. Antennomere XI expanded, similar in shape to rami of preceding antennomeres. Total length of antennomere XI approximately 2× length of bases of antennomeres IV–X combined.

Pronotum with semi-decumbent to decumbent, fine, golden setae except in medial third such setae fuscous, integument dull, and weakly and contiguously punctate, with punctures more indistinct anteriorly and posteriorly, integument becoming imbricate. Pronotum triangular in shape, narrowed anteriorly; anterior margin broadly rounded; posterior margin sinuate and generally trilobed, with medial lobe scarcely broader than mesoscutellum and rounded (not emarginate: distinctly emarginate in *C. inexpectatus, vide infra*); lateral margins generally straight, converging anteriorly, convex ventrally to propleurae; propleuron well developed. Pronotal disc wider at base than length, without mediolongitudinal carina or impression; lateral aspect with a ventrally bowed

sulcus. Mesonotum obscured by elytra. Mesoscutellum (mesoscutellar shield) short, flat, parallel-sided, with broadly rounded apex; integumental sculpturing and setation as on pronotal disc. Metanotum obscured by elytra.

Lateral and ventral aspects of pterothorax typical of subfamily. Mesepisternum weakly and faintly imbricate, with scattered minute punctures, fused with mesosternum, with scattered decumbent setae. Mesepimeron forming prominent, rectangular sclerite separated from mesepisternum by deep sulcus; sculptured and setation as on mesepisternum. Metepisternum an elongate, narrow rectangular sclerite, with sculpturing and setation as on mesepisternum; metasternum massive, weakly imbricate and with decumbent setae more numerous than on metepisternum. Metepimeron slightly expanded posteriorly, extending anteriorly to wing base as narrow (slightly more narrow than metepisternum), sclerotized band; weakly imbricate with scattered setae.

Legs typical for subfamily; coxae, trochanters, and femora weakly, irregularly, almost indistinctly punctate on otherwise smooth integument with decumbent, golden to lightly fuscous setae; metacoxa with strongly developed posterior flange; femora without densely setose patches ventrally; tibiae straight, cylindrical, broadened slightly apically, with apex terminated by dense row of regular, thin, spiniform setae; tibial spur formula 0-0-? (hind legs missing in holotype). Tarsi 5-5-[4, metatarsus presumed to have had four tarsomeres], all tarsomeres cylindrical, very slightly tapered basally, truncate apically; integument and setae similar to tibiae; protarsus longer than protibia. Protarsomere I subequal to combined length of protarsomeres II and III, protarsomere IV less than one-half length protarsomere V; relative ratios of basal mesotarsomeres similar (apical tarsomeres of meso- and metatarsi missing in holotype). Pretarsal claws bifid, apical and inner rami both sickle-shaped and acutely pointed, without any midlength or subsidiary teeth.

Elytra elongate, completely covering abdomen, surface imbricate with minute, weak, nearly contiguous punctures; elytron basal width 1.27 mm, length 8.21 mm; each elytron with four indistinct costae; lateral margins parallel-sided, lateral margin comparatively straight until tapering inward in apical fifth, medial margin nearly straight until rounding at apex; apex weakly acuminate.

Abdomen with terga weakly and faintly imbricate; sterna imbricate with scattered minute punctures, with scattered decumbent, fine setae; male terminalia as depicted in figures 8–14.

 \mathbb{Q} : *Latet*.

Holotype. ∂, [South Africa: KwaZulu-Natal: eThekwini:] Port / Natal / 49 29 [on underside of label] [no collector or date] (NHMUK). The "49 29" on the underside of the label corresponds to the 29th accession of 1849 (M. Barclay, pers. comm.). This accession was a collection of 1627 insects, including 965 Coleoptera, from Port Natal, South Africa collected by Wilhelm Gueinzius (1813–1874), and sold to the Natural History Museum through Samuel Stevens' (1817–1899) auctions at 24 Bloomsbury Street in London during December 1849 (M. Barclay, pers. comm.). Gueinzius, a German naturalist who spent most of his life in present-day South Africa, lived in the area of Port Natal (settled along the Tugela River) from 1841 until late in 1843 when he



Figures 8–11. Male terminalia of holotype of *Clinops perpessus* sp. nov. 8 tergum VII 9 tergum VIII 10 sternum VIII 11 sternum IX.

returned to Cape Town after British troops looted his home during conflict with the Zulus and Boers. He returned to the Natal area in mid-1844 and remained there until shortly before his death. Since the present specimen was auctioned and accessioned in December 1849 it can safely be presumed it was collected sometime between 1844 and this date. A handwritten label from the 19th Century accompanying the specimen reads "closely resembles the figure of *Ancholaemus lyciformis*, but that is from Brazil." The handwriting generally matches that of George C. Champion (1851–1927). The specimen's terminalia were apparently dissected by the late John K. Bouseman (1936–2006) (the sclerites are stored within a genitalia vial along with the specimen), who labeled the specimen "Rhipiphoridae [sic] gen. et sp. nov. $\stackrel{o}{\rightarrow}$ Det. Bouseman '71 [1971]".

Etymology. The specific epithet is taken from the Latin, meaning "suffer with patience" or "endure", and is a reference to the vast time over which this species has awaited description.



Figures 12–14. Male genitalia of holotype of *Clinops perpessus* sp. nov. (tegmen = phallobase + parameres / parameres = lateral lobes, gonoforceps / median lobe = aedeagues). **12** dorsal oblique view **13** lateral oblique view **14** ventral oblique view.

Clinops inexpectatus sp. nov.

http://zoobank.org/73E8653E-4466-4A01-8466-B140D7B2DA59 Figs 19–26

"Clinops badius Gerstaecker": Falin 2003: 175, 439 [misidentification].

Diagnosis. Refer to diagnosis of C. perpessus (vide supra).

Description. \bigcirc : General size and appearance typical of Pelecotominae. Size 10.02 mm from tip of elytra to mandibles, 2.14 mm wide at base of pronotum. Body largely


Figures 15–18. *Clinops badius* Gerstaecker, holotype female. **15** dorsal habitus **16** oblique lateral habitus **17** detail of right antenna **18** maxillary palpus (dissected and mounted by Gerstaecker).

dark brown, slightly lighter reddish brown on humeral parts of elytra, and apical abdominal sterna (Figs 19, 20).

Head hexagonal from facial view, approximately 1.25× longer than wide in facial view, medial length 1.80 mm, maximum width (across compound eyes) 1.08 mm. Vertex convex dorsally and posteriorly, as wide as lower face (below compound eyes),



Figures 19–22. *Clinops inexpectatus* sp. nov., holotype female. 19 lateral habitus 20 dorsal habitus 21 facial view 22 maxillary palpus.

rising high above compound eyes in facial view, sloping uniformly to meet and distinctly overlap pronotal anterior margin. Dorsal, lateral, and facial aspects of head with fine, sparse, golden setae, particularly numerous on face between compound eyes, abundant on genae; integument dull, with deep, nearly contiguous punctures separated by smooth integument. Compound eye of moderate size, length 0.84 mm, width 0.29 mm, encompassing much of medial third of lateral surface of head, finely faceted, emarginate in upper third. Postocular gena expanded into lobe. Frons broad, with antennal torulus laterally directed, antennal toruli separated by distance equal to length of scape, compound eyes separated by distance slightly less than maximum compound eye length. Malar space elongate, more than one-half length of scape, slightly less than basal mandibular width. Mandible short, slightly curved, with short, acute subapical tooth. Maxillary palpus long, tetramerous, apical palpomere largest, trapezoidal, its apical width slightly less than maximum length, with blunt, truncate apex, distal sensory duct elongate, strongly oblique.

Only left antenna without apical antennomere preserved, antenna consisting probably of eleven (10 preserved) antennomeres; antennomere I longer than wide, slightly curved to approximate curvature of compound eye; antennomere II short, distinctly longer than wide, much narrowed in basal third; antennomere III longer and wider than antennomere II, length approximately 1.5× apical width, apical margin as in antennomere II; antennomeres IV–X greatly dissimilar from preceding antennomeres, with internally facing, compressed rami truncated apically, bases short and of similar lengths; rami elongate, about 2.0× as long as their respective base.

Pronotum with fine, golden setae except in medial third such setae fuscous, integument dull, and weakly and contiguously punctate, with punctures more indistinct anteriorly and posteriorly, integument becoming imbricate. Pronotum triangular in shape, narrowed anteriorly, median length 2.30 mm; anterior margin broadly rounded; posterior margin sinuate and generally trilobed, with medial lobe broader than mesoscutellum and distinctly emarginate (rounded in *C. perpessus*); lateral margins generally straight, converging anteriorly, convex ventrally to propleurae; propleuron well developed. Pronotal disc as wide as long, with mediolongitudinal shallow impression in basal third; lateral aspect with a ventrally bowed sulcus. Mesonotum obscured by elytra. Mesoscutellum short, mesoscutellar shield with deep medial furrow, parallelsided, with broadly rounded apex; integumental sculpturing and setation as on pronotal disc. Metanotum obscured by elytra.

Lateral and ventral aspects of pterothorax typical of subfamily. Mesepisternum weakly and faintly imbricate, with scattered minute punctures, fused with mesosternum, with scattered decumbent setae. Mesepimeron forming prominent, rectangular sclerite separated from mesepisternum by deep sulcus; sculptured and setation as on mesepisternum. Metepisternum an elongate, narrow rectangular sclerite, with sculpturing and setation as on mesepisternum; metasternum massive, weakly imbricate and with decumbent setae more numerous than on metepisternum. Metepimeron slightly expanded posteriorly, extending anteriorly to wing base as narrow (slightly more narrow than metepisternum), sclerotized band; weakly imbricate with scattered setae.

Legs typical for subfamily (left front and mid-leg incomplete); coxae, trochanters, and femora weakly, irregularly, almost indistinctly punctate on otherwise smooth integument with decumbent, golden setae; metacoxa with strongly developed posterior flange; femora without densely setose patches ventrally; tibiae straight, cylindrical, broadened slightly apically, with apex terminated by dense row of regular, thin, spiniform setae; tibial spur formula 0-0-2, metatibial spurs well visible. Tarsal formula 5-5-4, all tarsomeres cylindrical, very slightly tapered basally, truncate apically; integument



Figures 23–26. *Clinops inexpectatus* sp. nov., holotype female. 23 lateral detail of head and pronotum 24 dorsal detail of head and pronotum 25 metatarsus 26 detail of metapretarsal claws.

and setae similar to tibiae; protarsus longer than protibia. Protarsomere I subequal to combined length of protarsomeres II and III, protarsomere IV less than one-half length protarsomere V; relative ratios of basal mesotarsomeres similar. Pretarsal claws with apical and inner teeth both sickle-shaped and acutely pointed, with small, peg-like subsidiary tooth at midlength (Fig 26).

Elytra elongate, completely covering abdomen, surface shining with minute, weak, nearly contiguous punctures; elytron basal width 1.15 mm, length 6.10 mm; without costae; lateral margins parallel-sided, lateral margin comparatively straight until taper-

ing inward in apical fifth, medial margin nearly straight until rounding at apex; apex weakly acuminate.

Abdomen with terga weakly and faintly imbricate; sterna imbricate with scattered minute punctures, with scattered decumbent, fine setae, ovipositor shallowly protruded.

♂: Unknown.

Holotype. ♀, S[outh]. Afr[ica].: Zululand / Hluhluwe Game Res. / 28.05. S -32.04 E // 20.11.1992 [20 November 1992]; E.-Y: 2839 / fruittraps, woodysav [?] / leg. Endrödy - Younga // Clinops / badius / Gerstaecker 1855 / Det. ZH Falin [20]'09".

Etymology. The specific epithet is taken from Latin, meaning "unexpected", and refers to the surprise that it was undescribed upon re-examination by JB.

Note. Although the identification label is dated 2009, the specimen was earlier identified and used by ZHF as *C. badius* in Falin (2003).

Genus Scotoscopus Brenske & Reitter, resurrected status

Scotoscopus Brenske & Reitter, 1884: 92. Type species: *Scotoscopus carbonarius* Reitter in Brenske & Reitter, 1884 (= *Clinops spectabilis* Schaufuss, 1872), by monotypy.

Diagnosis. Body slender; elytra 4.0–4.8× as long as pronotal disc, coloration of head, elytra, meso- and metathorax and abdomen dark brown or black, pronotum bright red in males and dark-red with black markings, setae dark, sparsely distributed and indistinct; head with postocular genae expanded into lobes; compound eye not expanded beyond mandibular base and with a small extra-antennal sclerotous emargination; antenna with eleven antennomeres; male antenna with antennomeres I-III simple, III compressed, almost lenticular, IV-X with inner-facing, flabellate, compressed rami, XI similar in shape to preceding rami; female antenna similar to male, antennomere III long and cylindrical, rami much shorter, pectinate, compressed; ultimate maxillary palpomere cylindrical, apical width 3× less than maximum length, with blunt, truncate apex, not grossly enlarged; distal sensory duct on ultimate maxillary palpomere elongate, strongly oblique. Lateral aspect of pronotum with a ventrally bowed sulcus; pronotal disc without longitudinal medial impression; mesosternum weakly convex, without medial keel; metepisternum without elytron-receiving carina; posterior aspect of metepimeron slightly expanded. Metacoxa with strongly developed posterior flange; ventral surface of pro- and mesofemora in males without densely setose patch; tibial spur formula 0-2-2; pretarsal claws bifid, with blunt, small subsidiary tooth proximal to inner bifid ramus (Fig 29). Male genitalia with parametes strongly curved, with apexes overlapping each other.

Comments. Batelka (2005) recognized that the type species of the genus was a junior synonym of *Clinops spectabilis* Schaufuss, and he accordingly synonymized the two genera. However, based on the differences in tibial spur formula between *Clinops (vide supra)* and the type species of *Scotoscopus*, we herein reinstate the genus.



Figures 27–29. *Scotoscopus spectabilis* (Schaufuss), female from Crete. 27 dorsal habitus 28 facial view 29 detail of metapretarsal claws.

Scotoscopus spectabilis (Schaufuss), comb. nov.

Figs 27–33

Clinops spectabilis Schaufuss, 1872: 276.

Scotoscopus carbonarius Reitter in Brenske & Reitter, 1884: 93. Synonymy *vide* Batelka (2005).

Diagnosis. As for the genus (vide supra).

Material examined. 1&, Greece: Pelopónnisos / Taïyetos Mts., 950 – / 1800 m, 15.–19.v.1990 [15–19 May 1990] / Zool. Mus. Copenh. Exp. [p] // Scotoscopus / carbonarius Rtt. / det. C. Wurst 99 [handwritten] (ZMUC).



Figures 30, 31. *Scotoscopus spectabilis* (Schaufuss). **30** lateral detail of head and pronotum (female from Crete) **31** lateral habitus (male from Peloponnese, photograph courtesy of M. Fikáček).

Distribution. Hitherto, the species was known from the holotypes of the two synonymous taxa collected in Turkey (Antakya) and Mount Parnassus (central Greece) and subsequently from approximately a dozen specimens from Crete (Cretan Archipelago, Greece) (Batelka 2005, 2007). This is the first record of the species from the Peloponnese (southern Greece).



Figures 32, 33. *Scotoscopus spectabilis* (Schaufuss), male terminalia (specimen from Crete). 32 lateral, dark-field view 33 dorsal-ventral view. a) parameres, b) apical hook of median lobe, c) base of median lobe, d) phallobase.

Discussion

The study of Pelecotominae, like any rare group of organisms, is hampered by a dearth of information and available material. Several groups are known only from historical type material, one sex, and from little more than type localities. Beyond this, the biology, ecology, and immature stages of most species remains utterly unknown and modeling of ecological niches is presently impossible without a greater variety of collecting localities across diverse habitats. The closest one might come to having sufficient material upon which to base ecological models or explore intraspe-

cific variation would be some of the South American species, such as *Ancholaemus lyciformis* Gerstaecker, where comparatively larger series of specimens are known from a broad range of localities. Otherwise, with such meagre material at hand for Pelecotominae, further exploration and surveys are desperately needed in order to significantly advance our knowledge of this lineage. In the interim, the systematics of the subfamily is improving by slow iterations, to which the present study is but one small step.

Among the many present challenges toward a systematization of the Pelecotominae is the clarification of traits for many species and genera, and whether or not these features are of broader phylogenetic significance. For example, the tibial spur formula has been used to distinguish genera across the subfamily. As shown herein by the revised diagnosis of Clinops, this feature alone has been difficult to interpret. For example, in many taxa the mesotibial spurs are exceedingly small and easily overlooked (particularly if certain specimen preparations obscure a direct view of the inner apical mesotibial articulation), or in older specimens may be damaged and missing, and thereby understandably miscoded as absent, ultimately leading to confusion in the placement of certain specimens and species. More critically, a comprehensive phylogeny of the subfamily is lacking and presently not possible and it therefore remains speculative as to whether this feature (or any of the traits used to recognize genera in the subfamily) will be shown to support clades at any rank, or whether they will prove to be rampantly homoplastic at anything above the level of species. Indeed, once a phylogeny is resolved for the subfamily, it could be discovered that placing an emphasis on tibial spur formula in the circumscription of genera is misguided and does not actually characterize natural groups. Furthermore, the forms of the maxillary palpi and pretarsal claws are more quantitative than qualitative and so likewise require testing in a cladistic framework. This is not to say that the tibial spur formula, pretarsal claw structure, or maxillary palpus form will not ultimately prove to be consistent in a phylogenetic framework and support clades traditionally recognized as genera, merely that in the absence of such a resolved topology their validity is equivocal. Moreover, additional character systems such as the male genitalia remain to be explored comparatively. This is understandable as males are not known for all taxa, but nonetheless represent one of any number of potentially valuable sources of characters. The male genitalia of Pelecotominae are not often figured and, where known, there is comparatively little variation in overall form (e.g., Rivnay 1929; Selander 1957). Nonetheless, a thorough documentation and comparative morphological exploration of pelecotomine genitalia would be worthwhile and may reveal at least a few characters of phylogenetic significance. The same is true for larvae, with few pelecotomine immature stages documented in the literature or in a comparative light (Lawrence et al. 2010). Thus, one of the most important future developments for the study of Pelecotominae is the extensive sampling of taxa in the field so as to build up sufficient material, sexes, and larvae to not only clarify the biology and ecology of these species, but to permit the resolution of relationships and character evolution across the clade.

Acknowledgments

We are grateful to Martin Fikaček (National Museum, Praha) for information and photographs of the specimen of *Clinops* in ZMUC, to the various curators listed in the Materials and methods for the loan of pertinent material, to Max Barclay (NHMUK) for looking up the accession details for the holotype of *C. perpessus*, and to Darren Pollock and Aaron Smith for their helpful comments on the manuscript. The work of JB was supported by the Institutional Research Support grant of Charles University, Prague (No. SVV 260 434 / 2018) and by Charles University Grant Agency (GAUK, No. 1546218). This is a contribution of the Division of Entomology, University of Kansas Natural History Museum.

References

- Batelka J (2005) New synonym of the genus *Clinops* (Coleoptera: Ripiphoridae) with bionomical and distributional notes on *C. spectabilis*. Folia Heyrovskyana, Serie A 13: 27–34.
- Batelka J (2009) Clinopalpus hanae, a new genus and species of ripiphorid beetle from Malaysia (Coleoptera: Ripiphoridae: Pelecotominae). Acta Entomologica Musei Nationalis Pragae 49(1): 239–245.
- Batelka J, Kundrata R, Bocak L (2016a) Position and relationships of Ripiphoridae (Coleoptera: Tenebrionoidea) inferred from ribosomal and mitochondrial molecular markers. Annales Zoologici 66(1): 113–123. https://doi.org/10.3161/00034541A NZ2016.66.1.008
- Batelka J, Prokop J, Engel MS (2016b) New ripiphorid beetles in mid-Cretaceous amber from Myanmar (Coleoptera: Ripiphoridae): first Pelecotominae and possible Mesozoic aggregative behaviour in male Ripidiinae. Cretaceous Research 68: 70–78. https://doi. org/10.1016/j.cretres.2016.08.002
- Batelka J, Engel MS, Prokop J (2018) A remarkable diversity of parasitoid beetles (Ripiphoridae) in Cretaceous amber, with a summary of the Mesozoic record of Tenebrionoidea. Cretaceous Research 90: 296–310. https://doi.org/10.1016/j.cretres.2018.04.019
- Brenske E, Reitter E (1884) Neuer Beitrag zur K\u00e4ferfauna Griechenlands. Deutsche Entomologische Zeitschrift 28(1): 17–100. [2 pls. (pls. I, II)] https://doi.org/10.1002/ mmnd.48018840202
- Broun T (1921) Descriptions of new genera and species of Coleoptera. Bulletin of the New Zealand Institute 1(7): 591–665.
- Cai C-Y, Yin Z-W, Huang D-Y (2018) A new ripiphorid beetle from Upper Cretaceous Burmese amber sheds light on early evolution of the extant subfamily Ripidiinae (Coleoptera: Ripiphoridae). Comptes Rendus Palevol 17(6): 351–356. https://doi.org/10.1016/j. crpv.2017.12.002
- Falin ZH (2003) Phylogenetic analysis and revision of the genera and subfamilies of the Ripiphoridae (Coleoptera). Ph.D. Dissertation; University of Kansas, Lawrence and University Microfilms International, Ann Arbor, xxiv + 535 pp.

- Falin ZH, Engel MS (2010) Notes on Cretaceous Ripidiini and revised diagnoses of the Ripidiinae, Ripidiini, and Eorhipidiini (Coleoptera: Ripiphoridae). Alavesia 3: 35–42.
- Fischer von Waldheim G (1809) Sur deux genres nouveaux de coléoptères. Mémoires de la Société Impériale de Naturalistes de Moscou 2: 293–304. [1pl (pl 18) 18]
- Franciscolo ME (1952) On the systematic position of the genus *Ctenidia* Castelnau, 1840 (Coleoptera). (Contribution XXXIV to the knowledge of the Mordellidae). Proceedings of the Royal Entomological Society of London, Series B, Taxonomy 21(11–12): 155–163. https://doi.org/10.1111/j.1365-3113.1952.tb01038.x
- Gerstaecker [CE]A (1855a) Rhipiphoridum Coleopterorum familiae dispositio systematica. Dissertatio Inauguralis Zoologica quam consensu et auctoritate amplissimi philosophorum ordinis in alma litterarum universitate Friderica Guilelma pro summis in philosophia honoribus rite capessendis die IV. M. Julii a MDCCCLV. Hora XII. Publice defendet auctor A. Gerstaecker, med. Dr. Berolinensis. Schlesinger, Berolini, 36 pp. https://doi.org/10.5962/ bhl.title.68430
- Gerstaecker CEA (1855b) Rhipiphoridum coleopterorum familiae disposito systematica. Friderici Nicolai, Berlin, [i] + 36 pp. [+ 1 pl.] https://doi.org/10.5962/bhl.title.68430
- Hsiao Y, Huang C-L (2018) Spinotoma ruicheni: a new Late Cretaceous genus and species of wedge-shaped beetle from Burmese amber (Coleoptera, Ripiphoridae, Pelecotominae). Cretaceous Research 82: 29–35. https://doi.org/10.1016/j.cretres.2017.10.022
- Hudson GV (1934) New Zealand beetles and their larvae: an elementary introduction to the study of our native Coleoptera. Ferguson and Osborne, Wellington, [iii] + 236 pp. [17 pls]
- Kirkaldy GW (1910) On some preoccupied generic names in insects. Canadian Entomologist 42(1): 8. https://doi.org/10.4039/Ent428-1
- Kuschel G (1990) Beetles in a suburban environment: A New Zealand case study: The identity and status of Coleoptera in the natural and modified habitats of Lynfield, Auckland (1974–1989). DSIR [Department of Scientific and Industrial Research] Plant Protection Report 3: 1–118.
- Lawrence GN (1875) Birds of southwestern Mexico collected by Francis Sumichrast for the United States National Museum. Bulletin of the United States National Museum 4: 1–56.
- Lawrence JF, Falin ZH, Ślipiński S (2010) Ripiphoridae Gemminger and Harold, 1870 (Gerstaecker, 1855). In: Leschen RAB, Beutel RG, Lawrence JF (Eds) Handbook of Zoology, Band 4: Arthropoda, 2 Hälfte: Insecta, Teilband 39: Coleoptera, Beetles, Volume 2: Morphology and Systematics (Elateroidea, Bostrichiformia, Cucujiformia partim). Walter de Gruyter, Berlin, 538–548. https://doi.org/10.1515/9783110911213.538
- Rivnay E (1929) Revision of the Rhipiphoridae of North and Central America (Coleoptera). Memoirs of the American Entomological Society 6: 1–68. [4 pls, + [ii]]
- Schaufuss LW (1872) Beschreibung einiger Käfer. Nunquam Otiosus, Zoologische Mittheilungen 2: 275–278.
- Selander RB (1957) The systematic position of the genus *Nephrites* and the phylogenetic relationships of the higher groups of Rhipiphoridae (Coleoptera). Annals of the Entomological Society of America 50(1): 88–103. https://doi.org/10.1093/aesa/50.1.88
- Sharp D (1878) New Coleoptera from New Zealand. Entomologist's Monthly Magazine 15: 81–83. https://doi.org/10.5962/bhl.part.22016

- Švácha P (1994) Bionomics, behaviour and immature stages of *Pelecotoma fennica* (Paykull) (Coleoptera: Rhipiphoridae). Journal of Natural History 28(3): 585–618. https://doi. org/10.1080/00222939400770271
- Viana M (1971) Micholaeminae, nueva subfamilia de Ripiphoridae y *Micholaemus gerstaeckeri*, nuevo genero y especie de la Republica Argentina. Revista de la Sociedad Entomologica Argentina 33: 69–76.
- Watt JC (1983) The huhu Prionoplus reticularis (Cerambycidae) and other Coleoptera in Acacia. New Zealand Entomologist 7(4): 364–365. https://doi.org/10.1080/00779962.1983 .9722425

RESEARCH ARTICLE



The genus Scutellathous Kishii, 1955 (Coleoptera, Elateridae, Dendrometrinae) in China, with description of three new species

Zhen Liu^{1,2,3}, Shi-hong Jiang²

I School of Applied Chemistry and Biological Technology, Postdoctoral Innovation Practice Base, Shenzhen Polytechnic, Shenzhen, Guangdong 518055, China 2 College of life and environmental sciences, Hunan University of Arts and Science, Changde, Hunan 415000, China 3 College of Natural Resources and Environment, South China Agricultural University, Guangzhou, Guangdong 510642, China

Corresponding author: Zhen Liu (jane@szpt.edu.cn); Shi-hong Jiang (sjiang@szpt.edu.cn)

Academic editor: Hume Douglas Received 10 August 2018 Accepted 8 May 2019	Published 25 June 2019

Citation: Liu Z, Jiang S-h (2019) The genus *Scutellathous* Kishii, 1955 (Coleoptera, Elateridae, Dendrometrinae) in China, with description of three new species. ZooKeys 857: 85–104. https://doi.org/10.3897/zookeys.857.29011

Abstract

Five species of *Scutellathous* Kishii, 1955 are recognized from China, of which three are new. *Scutellathous habenularis* **sp. nov.**, *S. nanlingensis* **sp. nov.**, and *S. quadrata* **sp. nov**. are described and illustrated. A key to species from China, a checklist, and a distribution map are provided. The relationships and comparisons among genera *Athous* Eschscholtz, 1829, *Ohirathous* Han & Park, 2012, *Parathous* Fleutiaux, 1918, and *Scutellathous* Kishii, 1955 are discussed.

Keywords

Athous, catalogue, distribution, Elateroidea, key, new taxa, Ohirathous

Introduction

The genus *Scutellathous* (Coleoptera, Elateridae), as currently defined, is distributed only in East Asia: China (Taiwan), Japan, and Korea. It was erected by Kishii (1955) based on the type species, *Athous comes* Lewis, 1894 from Japan. Kishii (1955) also transferred *S. porrecticollis* (Lewis, 1894) to this genus and described *S. horior*. The latter has been moved to the genus *Stenagostus* Thomson, 1959 (Kishii 2001). Later,

eight species were described in *Scutellathous: S. fujianus* Ôhira, 1963, *S. ozakii* Ôhira, 1992, *S. sasajii* Kishii, 2001, *S. seinoi* Kishii, 2001, *S. shikokuanus* Kishii, 1985, and *S. yakuensis* Nakane & Kishii, 1958 from Japan; *S. spinosus* Platia & Schimmel, 2007 and *S. yamashitai* Arimoto, 1992 from China (Taiwan). There are currently, 10 species recognized within the genus.

Ôhira (1996) synonymized *Scutellathous* under genus *Parathous* Fleutiaux, 1918, known from south-west Asia, based on similarity of the male genitalia, which have simple parameres apices. Kishii (2001) reviewed the Japanese species of *Scutellathous* and argued for genus status because of consistent differences from *Parathous* in the supra-antennal carina, supra-orbital groove, pronotum, pronotal hind angles and elytra.

Scutellathous includes mid-sized beetles (body length: 11–16 mm), resembling the monotypic genus *Ohirathous* Han & Park, 2012 in sharing similar shaped frons (supraantennal carina thickened, overhanging nasale, raised above part of frons immediately posterior to it, ('pentroof shape', *sensu* Kishii 2001)) and broad sub-lateral incisions (Han et al. 2012), but with shorter carinae on hind angles (extending only 1/5 to 1/3 length of pronotum; reaching to 1/2 length in *Ohirathous*), the proportions of antennomere 3 to 2 (antennomere 3 usually over twice longer than 2; it is 1.8 times in *O. nantouensis*), the apical lobed apices of tarsomeres 2 and 3 (*O. nantouensis* lobed from 1st to 4th tarsomeres), the shape of female pronotum (arched laterally, narrowed anteriorly in dorsal view; parallel-sided in *O. nantouensis*) and other characters (Han et al. 2012, 2016).

During our study of the Chinese elaterids, we found three undescribed species from south China. These new species resemble monotypic genus *Ohirathous* Han & Park, 2012 in sharing the 'pentroof' shape of frons and broad sublateral incisions (Han et al. 2012), but should be placed in *Scutellathous* because of its male genitalia (ae-deagus with simple, narrow paramere apices, without apico-lateral expansion at apex, penis gradually narrowed and acute at apex) and the other diagnostic characters mentioned above, and conforming to the generic diagnosis of Han et al. (2016).

Material and methods

The studied specimens are deposited in the following collections:

SZPT School of Applied Chemistry and Biological Technology, Shenzhen Polytechnic, Shenzhen, Guangdong Province, China.
MHBU Museum of Hebei University, Baoding, China.

The terminology used mainly follows Costa et al. (2010), Douglas (2011). The classification follows Cate et al. (2007). Descriptions and measurements were made under a stereomicroscope (Motic SMZ-168). Photographs of types were taken using a digital microscope (LY-WN-YH 3D system) and a Canon 800D camera with a Canon EF 65 mm lens. The genitalia of holotypes and paratypes were macerated in 10% NaOH and photographed in a glycerin jelly.

Measurements: body length was measured along the midline from the anterior edge of the head capsule to the apex of the elytra; the body width was measured across the broadest part (usually across the elytra). The pronotal length was measured along the midline; the pronotal width was measured at the broadest part (usually at the hind angles). The ocular index is obtained by dividing the minimum distance between the eyes by the maximum distance across both eyes and multiplying the quotient by 100 (Becker 1979).

The specimens were mounted on paper points. The genitalia were removed, cleaned and fixed under the body of the specimen in glycerol mounts as described by Prosvirov and Savitsky (2011).

The studied specimens were all collected by hand netting.

Taxonomy

Scutellathous Kishii, 1955

Scutellathous Kishii, 1955: 79 (type species: Athous comes Lewis, 1894: 200 (Sapporo, Japan; by original designation); Ôhira 1970: 22; Gurjeva 1974: 108; Kishii 1987: 91; Park et al. 1993: 179; Suzuki 1999: 113; Kishii 2001: 206; Cate et al. 2007: 172; Han et al. 2016: 72.

Diagnosis. Body length: 11–16 mm; frons triangularly depressed behind supra antennal carina, which is strongly thickened and overhanging labrum and nasale, carina elevated above part of frons immediately posterior to it in dorsal view; supra-orbital groove broadly excavated; antennae serrate from 3rd antennomere; pronotum mostly longer than wide, pronotal disc with weak median depression; hind angles of pronotum unicarinate; sublateral incisions at posterior margin of pronotum small, or toothlike; prosternal sutures not grooved anteriorly; apical end of tarsomeres 2 and 3 lobed beneath; aedeagus with simple and narrow parameres apices, without apico-lateral expansion at apex, penis gradually narrowed and acute at apex (after Han et al. 2016).

Distribution. China, Japan, and Korea.

Remarks. Based on a study of the descriptions and photos of *Athous* (Elateridae, Dendrometrinae) species from North America, we found the *Athous cucullatus* (Say, 1825) species-group shares many characters with *Scutellathous* (Becker, 1979). These include head flattened with triangular depression; frontal carina prominent, well elevated above labrum; eyes large; punctures on pronotum umbillicate; tarsomeres 2-and 3-lobed; and male genitalia with parameres lacking subapical lateral tooth and dorsal carina. However, lobes on tarsomeres 2 and 3 are smaller in *Scutellathous*, the carinae on the pronotal hind angles are present and sharp in all *Scutellathous* (absent or present in *A. cucullatus* group), and base of pronotum with sublateral incisions near hind angles in all *Scutellathous* (some without incisions in *A. cucullatus* group). Further comparison of members of the North American *Athous cucullatus* species group to *Ohirathous* is needed.

Key to the male species of Scutellathous Kishii from China

1	Pronotum with a median furrow (Fig. 7b) or non-furrowed glabrous line
	(Figs 2e, 9a) through the entire length 2
_	Pronotum with a median furrow only on posterior half, never with non-
	furrowed glabrous line
2	Aedeagus with penis reaching beyond parameres (Fig. 8a-d); scutellar shield
	1.5 times longer than wide (Fig. 7f) S. nanlingensis sp. nov.
_	Penis reaching only to apex of parameres (Figs 4a-c, 11e); scutellar shield 1.1
	times longer than wide (Figs 2f, 11b)
3	More pubescent, dorsal pubescence partially hiding integument (Fig. 9a);
	body brown-black; pronotal hind angles convergent posterad (Fig. 10c)
	S. quadrata sp. nov.
_	Less pubescent and more shiny (Fig. 1a); body red-brown; pronotal hind
	angles divergent posterad (Fig. 2e) S. habenularis sp. nov.
4	Elytra with a short spine near humeral angles in dorsal view; antenna falling
	short of pronotal hind angle apex by length of the last antennomere; hind
	angles not divergent posterad
_	Elytra without spine near humeral angles; antenna longer, exceeding apex
	of hind angle of pronotum by at least length of two antennomeres; hind
	angles divergent

Checklist of Scutellathous from China

Scutellathous habenularis sp. nov. [China (Yunnan)] Scutellathous nanlingensis sp. nov. [China (Guangdong)] Scutellathous quadrata sp. nov. [China (Zhejiang)] Scutellathous spinosus Platia & Schimmel, 2007 [China (Taiwan)] Scutellathous yamashitai Arimoto, 1992 [China (Taiwan)]

Scutellathous habenularis Liu & Jiang, sp. nov.

http://zoobank.org/FBAA77C9-3CBF-4DED-812E-98F9E3D13910 Figs 1–5, 12

Type locality. Yunnan, China.

Material examined. Holotype: ⑦ (MHBU), labels: 1) Yunnan Prov., Gaoligong Mts (2000 m, 25°59'8.81"N 98°49'1.40"E) (高黎贡山), 2012.VII.23, leg. Ji-shan Xu et Ling-xiao Chang, Shenzhen Polytechnic; 2) Holotype, *Scutellathous habenularis* sp. nov., Liu et al. 2019; 3) No. 20180353. Paratype: 1♀ (MHBU), labels: 1) Yunnan Prov., Gaoligong Mts (2000 m, 25°59'8.81"N 98°49'1.40"E) (高黎贡山), 2012.



Figure 1. Habitus of *Scutellathous habenularis* sp. nov., holotype, male **a** dorsal view **b** ventral view **c** lateral view.

VII.23, leg. Ji-shan Xu et Ling-xiao Chang, Shenzhen Polytechnic; 2) Paratype, *Scutel-lathous habenularis* sp.nov., Liu et al. 2019; 3) No. 20180354.

Diagnosis. Body bright red-brown, shiny; anterior edge of head truncate in dorsal view; antennae reaching apices of pronotal hind angles, nearly cylindrical from antennomere 6 onward, attached apico-dorsally, antennomere 3 1.8 times as long as 2 and nearly as long as 4; pronotum with hind angles divergent posterad, disc flat medially with only trace of a glabrous non-furrowed longitudinal line, shiny with umbillicate punctures; scutellar shield 1.1 times longer than wide; aedeagus with penis reaching to apex of parameres, penis gradually narrowed to pointed apex.

Scutellathous habenularis is similar to S. yamashitai Arimoto 1992, but is distinguished by the glabrous non-furrowed longitudinal line throughout the length of the

89

pronotum (with shallow median impression only on basal half of the pronotum in *S. yamashitai*), the obtuse anterior angles of the pronotum (acute in *S. yamashitai*), and the penis reaching beyond parameres (penis shorter than parameres in *S. yamashitai*).

Description. Male (holotype). Body (Fig. 1a–c) length 14.8 mm, width 3.5 mm; bright red-brown on head, pronotum (except hind angles), and elytra near scutellar shield; ventral surfaces and legs brown-black, and antennae brown (except antennomere 1–2 brown-black); dorsal pubescence yellow, suberect, shorter, denser, and pointed anterad on pronotum and head, longer, sparser, semi-recumbant, pointed posterad on elytra, ventral pubescence more recumbent and thinner.

Head. Anterior edge truncate in dorsal view (Fig. 2e), spaces between punctures shiny and 1–2 puncture diameters wide, punctures larger, denser, coarser in deep triangular depression (Fig. 2c); eye semi-spherical, ocular index 71; last segment of maxillary palpus 1.6 times longer than wide; antennae (Fig. 3e), reaching apices of pronotal hind angles, antennomeres 3 to 10 weakly serrate, nearly cylindrical from antennomere 6 onward, attached apico-dorsally, antennomere 1 robust, longest and subclavate, antennomere 2 shortest, obconic, 1.4 times longer than wide, antennomere 3 elongated triangular, 1.8 times as long as 2 and nearly as long as 4, antennomere 11 oblong, 5.0 times longer than wide, 1.1 times longer than antennomere 3, proportions of antennomeres as follows: 100; 52; 93; 95; 94; 82; 96; 87; 82; 98.

Thorax. Pronotum (Fig. 2e) nearly 1.2 times longer than wide, parallel-sided in dorsal view, except abruptly concave at anterior end and strongly concave before hind angles, widest at hind angles; disc flat medially with only trace of a glabrous non-furrowed longitudinal line, shiny with umbillicate punctures, spaces between punctures 1 to 2 puncture diameters wide medially (Fig. 3a), strongly umbillicate with interspaces 0.3 puncture diameter wide laterally and posteriorly; hypomera (Fig. 2d) with spaces between punctures narrower than half puncture diameter wide; hind angles (Fig. 2e) divergent, apex upheaved and obtuse, with carina extending only to basal 1/5 of pronotum along sides; sublateral incisions small. Prosternum shiny and sparsely, irregularly punctate, interspaces 1 to 4 times puncture diameters wide; anterior lobe (Fig. 2a) 2.3 times wider than long, with sparse, fine punctures. Prosternal process gradually narrowed to pointed apex. Meso- and meta-ventrites with stronger and denser punctures than those on prosternum, smooth. Metaventrite furrowed medially on anterior 3/4.

Scutellar shield. 1.1 times longer than wide (Fig. 2f), widest posterad, narrowing anterad gradually at sides, hind margin arched, weakly emarginate anteriorly; disc convex with umbillicate punctures medially, spaces between punctures 2–3 puncture diameters wide, strongly rugose-punctate near edges, with short yellow, outwardlyoriented pubescence laterally.

Elytra. Slender (Fig. 1a), 2.7 times longer than wide, 2.8 times longer and 1.1 times wider than prothorax respectively, widest at anterior one-fifth, parallel-sided, gradually narrowing to apex from midlength (Fig. 3b) with punctate striae, interpuncture spaces about 2–3 puncture diameters wide, interstriae slightly elevated, mostly smooth with



Figure 2. *Scutellathous habenularis* sp. nov., holotype, male **a** head, ventral view **b** head, antero-dorsal view **c** head, dorsal view **d** prothorax, ventral view **e** pronotum, dorsal view **f** scutellar shield, dorsal view.

smaller, shallower and sparser punctures than punctures within striae, interpuncture spaces about 3 puncture diameters wide, weakly and transversely rugulose anteriorly.

Legs. Slender (Fig. 3f); tarsomere 3 with a larger lobe beneath than tarsomeres 2, tarsomere 4 shortest; metacoxal plate (Fig. 3c) with mesal parts subparallel-sided, then abruptly strongly narrowed into at lateral one-fourth.

Abdomen. Surfaces of sternites III–VII like metaventrite, with punctures and pubescence more regular and evenly distributed laterally; sternite VII (Fig. 3d) broadly rounded, elongate, 1.7 times wider than long, punctures becoming bigger posteriorly.

Genitalia. Aedeagus (Fig. 4a–c) slender, weakly sclerotized; penis reaching to apex of parameres, gradually narrowed to pointed apex; parameres thin, strongly sinuate laterally at midlength, tapered to rounded apex.

Female. Like male (Fig 5a), except larger (length: 15.9 mm, width: 3.9 mm), antennae shorter (short of pronotal hind angle apices by half length of last antennomere) and pronotum strongly arched laterally and narrowed anteriorly in dorsal view. Bursa copulatrix (Fig. 5b) weakly sclerotized (it dissolved after being macerated in 10% NaOH for 10 hours) with a circular thorny line and without thorny plates. Ovipositor (Fig. 5c) 2.3 times longer than wide, with short styli.

Larva. Unknown.



Figure 3. *Scutellathous habenularis* sp. nov., holotype, male surface of pronotum, dorsal view **b** surface of elytra, dorsal view **c** hind coxae, ventral view **d** sternite VII, ventral view **e** antenna, lateral view **f** hind leg, anterior view.

Etymology. The name of the new species is derived from the Latin "*habenularis*" (Latin for "strip") referring to its hind coxae abruptly and strongly narrowed into a strip at lateral one-fourth part.

Distribution. China: Yunnan (Fig. 12).

Biology. Collected around the elevation of 2000 m in subtropical evergreen forest.

Remarks. Its bursa copulatrix resembles *Ohirathous* in sharing a circular thorny line, but differs in lacking thorny plates. Other characters (carina on hind angles extending only basal 1/5 of pronotal length; antennomere 3 2.1 times as long as 2; shape of male



Figure 4. Aedeagus of *Scutellathous habenularis* sp. nov., holotype, male **a** dorsal view **b** ventral view **c** lateral view.

genitalia; shape of female pronotum; only tarsomeres 2 and 3 lobed beneath) are consistent with the diagnosis of genus *Scutellathous*. Structures of the bursa copulatrix are diverse within *Scutellathous* species – from five thorny plates (*S. comes, S. porrecticollis, S. sasajii, S. shikokuanus*) or four (*S. seinoi*) thorny plates and without thorny line to no thorny plates but with thorny line in *S. habenularis*. The bursa copulatrix structure of *Ohirathous* (a circular thorny line and two thorny plates) falls within the range of variation observed in *Scutellathous* and does not support distinction of *Ohirathous* from *Scutellathous*. Unfortunately, male genitalia of *Ohirathous* is unknown. Further phylogenetic study is needed to understand the monophyly of *Ohirathous* and the relationship between these two genera.

Scutellathous nanlingensis Liu & Jiang, sp. nov.

http://zoobank.org/25E7432B-DB2B-42CB-916A-50C7E0DCA4A5 Figs 6–8, 12

Type locality. Ruyuan Nanling Mts, Guangdong, China.

Material examined. Holotype: ♂ (SZPT), labels: 1) Guangdong Prov., Ruyuan Nanling Mts (961 m, 24°55'31.02"N 113°01'18.33"E) (南岭), 2008.VI–VII, leg. Lei Gao et Kai-xuan Chen; 2) Holotype, *Scutellathous nanlingensis* sp.nov., Liu et al. 2019; 3) No. 20180355.



Figure 5. *Scutellathous habenularis* sp. nov., paratype, female **a** habitus, dorsal view **b** bursa copulatrix (before dissolved macerating in 10% NaOH for 10 hours) **c** ovipositor, dorsal view.

Diagnosis. Antennae barely reaching apices of pronotal hind angles, antennomere 3 2.2 times longer than 2 and 1.1 times longer than 4; pronotum with narrow median furrow throughout length, shiny with fine, weakly umbillicate punctures; scutellar shield 1.5 times longer than wide; punctures on elytra becoming absent near apex; aedeagus with penis reaching beyond parameres, gradually narrowing to obtuse apex.

Scutellathous nanlingensis is similar to *S. sasajii* Kishii, 2001, but can be separated from the latter by the short antennae of male (hardly or just reaching apices of pronotal hind angles; longer in *S. sasajii*, with apical three antennomeres exceeding apices of the hind angles), with narrow median furrow through the length of the pronotum (in *S. sasajii* the pronotum lacks longitudinal furrow), and the longer male penis.

Description. Male (holotype). Body (Fig. 6a–c) length 11.7 mm, body width 3.0 mm; red-brown, head, pronotum, base of elytra, ventral parts of the body and antennae darker, apex of mandible, inner margin of hypomeron, fore and middle coxae, apical parts of legs and elytra paler, more yellowish or reddish; dorsal pubescence yellow, semi-recumbent, longer, sparse and pointed anterad on pronotum and head, pointed



Figure 6. Habitus of *Scutellathous nanlingensis* sp. nov., holotype, male **a** dorsal view **b** ventral view **c** lateral view.

posterad on elytra, ventral pubescence more recumbent, thinner and denser, especially on abdomen.

Head. Anterior edge truncate in dorsal view (Fig. 7b), spaces between punctures shiny and 1 puncture diameter wide, punctures umbillicate and uniform, nearly contiguous in triangular, shallow depression and near supra antennal carina (Fig. 7a); eye, semi-spherical, ocular index 74; last segment of maxillary palpus 2.5 times longer than wide; antennae (Figs 6a, 7j) barely reaching apices of pronotal hind angles, antennomere 3 to 10 moderately serrate, attached apico-dorsally, antennomere 1 robust, longest and subclavate, antennomere 2 shortest, obconic, 1.7 times longer than wide, antennomere 3 elongated triangular, 2.2 times longer than 2 and 1.1 times longer than 4, antennomere 11 oblong, 5.6 times longer than wide, 1.1 times longer than antennomere 3, proportions of antennomeres as follows: 100; 43; 93; 82; 80; 76; 75; 70; 67; 72; 99.

Thorax. Pronotum (Fig. 7b) nearly 1.2 times longer than wide in dorsal view, parallel-sided, except strongly arched anteriorly and weakly concave before hind angles, widest at posterior 1/3 and apices of hind angles; disc broadly flat medially, with nar-



Figure 7. *Scutellathous nanlingensis* sp. nov., holotype, male **a** head, antero-dorsal view **b** pronotum, dorsal view **c** prothorax, ventral view **d** prothorax, lateral view **e** middle leg, dorso-lateral view **f** scutellar shield, dorsal view **g** hind coxae, ventral view **h** surface of elytra, dorsal view **i** surface of pronotum, dorsal view **j** antenna, lateral view.

row median furrow throughout length (Fig. 7b), shiny with fine, weakly-umbillicate punctures, spaces between punctures (Fig. 7i) 1 to 2 puncture diameters wide medially, weakly umbillicate with interspaces 0.5 to 1 puncture diameter wide laterally and posteriorly; hypomera with spaces between punctures 1 to 2 puncture diameters wide; hind angles not divergent, apex acute, with carina reaching basal third of pronotum, gradually approaching side posterad; sublateral incisions long. Prosternum (Fig. 7c, 7d) shiny



Figure 8. Aedeagus of *Scutellathous nanlingensis* sp. nov., holotype **a** dorsal view **b** ventral view **c** lateral view **d** dorsal view (not shrunken).

and sparsely punctate, interspaces 2 to 3 puncture diameters wide; anterior lobe 2.4 times wider than long, with dense, coarse, punctures. Prosternal process (Fig. 7c, 7d) straight in lateral view, abruptly concave behind procoxae and obtusely pointed at apex. Meso- and meta-ventrites smooth with punctures like on prosternum. Metaventrite furrowed medially throughout length, except shallow to absent on the posterior 1/10.

Scutellar shield. (Fig. 7f) 1.5 times longer than wide, parallel-sided, weakly pointed anteriorly, posterior edge arched; disc convex, with small, simple, sparse punctures, spaces between punctures 2–3 puncture diameter wide, with long, yellow outwardly-oriented pubescence.

Elytra. Slender, 2.8 times longer than wide, 2.8 times longer and 1.2 times wider than prothorax, longitudinally oviform, shiny, anterior half nearly parallel-sided, narrowing to apex from midlength, widest at apical third, with deeply-punctate striae, strial punctures elongate, the interpuncture spaces about 1–2 puncture diameters wide (Fig. 7h), the interstriae elevated, smooth with small irregular and sparser punctures, interpuncture spaces about 2 to 3 puncture diameters wide, punctures becoming absent near apex (Fig. 6a).

Legs. Slender (Fig. 7e); tarsomere 3 with longer lobe than tarsomere 2, tarsomere 4 shortest; metacoxal plate (Fig. 7g) with basal half parts subparallel-sided, then gradually narrowing laterally.

Abdomen. Surface (Fig. 6b, 7g) of sternites III-VII like metaventrite, with punctures denser and pubescence shorter; sternites VI–VII missing.

Genitalia. Aedeagus (Fig. 8a-d) with penis reaching beyond parameres, gradually narrowing to obtuse apex; parameres sinuate laterally at midlength, narrowed before rounded pre-apical expansion, apices rounded-acute.

Female. Unknown.

Larva. Unknown.

Etymology. The new species named after Nanling Mts in Guangdong prov., referring to its only known locality.

Distribution. China: Guangdong (Nanling Mts) (Fig. 12).

Biology. Unknown.

Remarks. Genitalia of this specimen is shrunken, membranous parameres apices are folded in (Fig. 8c).

Scutellathous quadrata Liu & Jiang, sp. nov.

http://zoobank.org/FAD53D97-CBB9-439D-A0B3-C509DB413292 Figs 9–11, 12

Type locality. Tianmu (Qianmutian) Mountains, Zhejiang, China.

Material examined. Holotype: $\[dotsel]{ (SZPT), labels: 1) Zhejiang Prov., Tianmu (Qianmutian) Mts (1535 m, 30°23'37.85"N 119°26'25.85"E) (天目山), 2013. VII.1, leg. Jun Xu; 2) Holotype,$ *Scutellathous quadrata* $sp.nov., Liu et al. 2019; 3) No. 20180356. Paratype: <math>\[dotsel]{ (SZPT), labels: 1) Zhejiang Prov., Tianmu (Qianmutian) Mts (1535 m, 30°23'37.85"N 119°26'25.85"E) (天目山), 2013.VII.1, leg. Mei Qin; 2) Paratype,$ *Scutellathous quadrata*sp.nov., Liu et al. 2019; 3) No. 20180358.

Diagnosis. Body brown-black, dorsal pubescence partially hiding integument; anterior edge of head arched anterior-laterally in dorsal view; antennae reaching apices of pronotal hind angles, antennomere attached apico-dorsally near base, more centrally near apex, antennomere 3 2.2 times longer than 2 and 1.1 times longer than 4; pronotum with hind angles convergent posterad, disc with median non-furrowed glabrous line, with simple punctures; scutellar shield as wide as long, anterior edge straight, widest and rounded posteriorly, concave at sides.

Scutellathous quadrata is similar to *S. spinosus* Platia & Schimmel, 2007 (see Schimmel 2007) in body shape and size, but can be separated from the latter by the square-shaped scutellar shield (in *S. spinosus* it is 1.2 times longer than wide, measured from original figure), base without spine near humeral angles of the elytra (with spine in *S. spinosus*), the wholly brown-black body (in *S. spinosus* the body is entirely ferruginous), and the shape of parameres.

Description. Male (holotype). Body (Fig. 9a–c) length 15.7 mm, body width 4.3 mm; brown-black, elytra (red-brown apically) and hypomera brown; antennae and legs brown-black, except tibiae brown; ventral side brown-black; dorsal pubescence pale, semi-recumbant, dense and pointed anterad on pronotum and head, nearly recumbent and pointed posterad on elytra, ventral pubescence more recumbent, longer and denser.

Head. Anterior edge arched anterior-laterally in dorsal view (Fig. 10a), spaces between punctures matt and less than 1 puncture diameter wide, punctures umbillicate and coarser, slightly denser in shallow triangular shallow depression; eyes semi-spherical, ocular index 75; last segment of maxillary palpus 1.5 longer than wide; antennae (Fig. 11c) reaching apices of pronotal hind angles, antennomeres 3 to 10 weakly serrate, attached apico-dorsally near base, more centrally near apex, anten-



Figure 9. Habitus of *Scutellathous quadrata* sp. nov., holotype, male **a** dorsal view **b** ventral view **c** lateral view.

nomere 2 obconic, 1.4 times longer than wide, antennomere 11 oblong, 4.8 times longer than wide, proportions of antennomeres as follows: 100; 45; 99; 95; 101; 90; 90; 89; 79; 71; 100.

Thorax. Pronotum (Fig. 10c) 1.1 times longer than wide; parallel-sided in dorsal view, except slightly arched at anterior one-third and slightly widened before hind angles, widest just before apices of hind angles; disc moderately convex, with weak median non-furrowed glabrous line, hardly visible anteriorly; punctures simple, interspaces 2 to 3 puncture diameters wide medially, punctures larger and weakly umbillicate with interspaces 0.5 to 1 puncture diameter wide laterally and posteriorly; hypomera with spaces between punctures 1 puncture diameter wide; hind angles convergent posterad, apex short and obtuse, carina reaching anterad to basal third of pronotum along sides; sublateral incisions small, tooth-like. Prosternum (Fig. 10d) densely punctate, interspaces 1 to 2 times puncture diameters wide; anterior lobe 2.7 times wider than long, with sparse fine punctures. Prosternal process gradually concave behind procoxae and obtusely pointed at apex. Meso- and meta-ventrites with larger, denser punctures than on prosternum. Metaventrite furrowed medially throughout length.



Figure 10. *Scutellathous quadrata* sp. nov., holotype, male **a** head, dorsal view **b** head, antero-dorsal view **c** pronotum, dorsal view **d** prothorax, ventral view.

Scutellar shield. (Fig. 11b) Length equal to width, straight anteriorly, widest and rounded posteriorly, concave at sides; disc convex with umbillicate punctures, spaces between punctures 2–3 puncture diameters wide medially, rugose-punctate with thick, outwardly-oriented publicate near edges.

Elytra. Together 2.4 times longer than wide (Fig. 9a), 2.6 times longer and 1.1 times wider than prothorax, parallel-sided, gradually narrowing to apex from apical one-third, with punctate striae, strial punctures isodiametric, shallower toward apex; interstriae elevated basally, flat apically, with fine punctures, the interpuncture spaces about 2–3 puncture diameters wide (Figs 9a, 11a).



Figure 11. *Scutellathous quadrata* sp. nov., holotype, male **a** surface of elytra, dorsal view **b** scutellar shield, dorsal view **c** antenna, lateral view **d** hind leg and abdomen, ventral view **e** aedeagus, dorsal view.

Legs. Tarsomere 3 with a longer lobe than tarsomere 2 (Fig. 11d), tarsomere 1 nearly as long as the following 3 tarsomeres together and 1.4 times longer than 5, tarsomere 4 shortest; metacoxal plate (Fig.11d) gradually narrowed laterally, triangularly emarginate basally (tooth-like).

Abdomen. Surface of sternites III–VII like metaventrite, with punctures more regular and dense and recumbent pubescence, interspaces with satin-like metallic sheen (Fig. 11d); sternite VII semicircular, 1.5 times wider than long, punctures evenly distributed.

Genitalia. Aedeagus (Fig. 11e, damaged) with penis gradually narrowing to pointed apex; parameres sinuate laterally near midlength, apical part nearly parallel-sided, apex truncate.

Female. Unknown.

Variability. Body length 14.7-15.7 mm; body width 3.7-4.3 mm.

Larva. Unknown.

Etymology. The name of the new species refers to its quadrate scutellar shield.

Distribution. China: Zhejiang (Tianmu Mts) (Fig. 12).

Biology. Unknown.

Remarks. Unfortunately, aedeagi of both specimens were damaged by poor preservation after prior dissection.

Scutellathous spinosus Platia & Schimmel, 2007

Fig. 12

Scutellathous spinosus Platia & Schimmel, 2007: 59.

Diagnosis. Following Platia and Schimmel (2007): length 13–16 mm, width 3.2–4 mm; red-brown with vague brown-black areas on head and pronotum; frons deeply impressed medio-anteriorly; antennae falling short of pronotal hind angles by about one antennomere, feebly serrate from antennomere 3, antennomere 2 more than twice longer than wide, antennomere 3 subtriangular, 2.5 times longer than 2, and longer than following; pronotum slightly longer than broad, widest at hind angles, disc strongly convex, abruptly sloping posterad, where with a trace of short median furrow, hind angles truncate, not divergent, with a short carina following edge, punctation coarse and variable; scutellar shield 1.2 times longer than wide, gently convex, sparsely punctate; elytra as broad pronotal posterior, 2.5–2.6 times longer than pronotum, base near humeral angles with a short spine.

Distinguished from other *Scutellathous* in China by elytral spine and red-brown colour. Distinguished from *S. yamashitai* by the shorter antennae not reaching the apices of the hind angles of the pronotum and rounded pronotal anterior angles.

Remarks. No additions to the male genitalia except the length (1.75 mm) in original description. But we can see from the original image that the penis is reaching a little beyond the apex of the parameres, gradually narrowed to a pointed apex and the parameres are thick, strongly sinuate laterally at midlength, weakly tapered to a blunt apex.

Distribution. China (Taiwan) (Fig. 12).

Scutellathous yamashitai Arimoto, 1992

Fig. 12

Scutellathous yamashitai Arimoto, 1992: 73.

Diagnosis (after Arimoto 1992). Length 12.6 mm, width 2.8 mm; body almost parallel-sided, flattened and shining dorsally, dark brown; antennae extending beyond apices of hind angles of pronotum by at least apical two antennomeres, antennomere 2 obconic, slightly longer than wide, antennomere 3 elongate triangular, about twice as long as 2 and longer than 4; pronotum as wide as long, with a shallow median impression in basal half, surface smooth and shining, sparsely and evenly punctate, hind angles short, divergent posterad, with carina; scutellar shield subvertical, with the sides somewhat constricted at posterior fourth; elytra about 2.9 times as long as humeral width, striae with coarse, uneven and elongate punctures, interstriae slightly elevated, irregularly punctate and transversely rugose; aedeagus with penis not reaching apex of parameres, apex of parameres depressed and furnished with some short setae.

Scutellathous yamashitai is similar to *S. comes* from Japan, but distinguished from by its darker color, smaller pronotal punctures, and divergent pronotal hind angles (Arimoto 1992).

Remarks. No specimen was available for this study. **Distribution.** China (Taiwan) (Fig. 12).



Figure 12. Distribution map of *Scutellathous* Kishii, 1955 in China. (triangle) *S. spinosus* Platia & Schimmel, 2007; (square) *S. quadrata* Liu & Jiang, sp. nov.; (heart) *S. habenularis* Liu & Jiang, sp. nov.; (circle): *S. nanlingensis* Liu & Jiang, sp. nov.; (star) *S. yamashitai* Arimoto, 1992.

Acknowledgements

We thank Dr. Kôichi Arimoto (Kyushu University, Japan), Dr. Pu Tang (Zhejiang University, China), Dr. Hume Douglas (Agriculture and Agri-Food Canada, Canada) and Prof. Alexander S. Prosvirov (Moscow State University, Russia) for their extensive comments on the manuscript. We are grateful to the collectors for their collecting efforts in the field, and to Prof. Guo-dong Ren (MHBU) for providing specimens for this study. Funding for this study was provided by the National Natural Science Foundation of China (31372231, 31772511) and scientific research project of SZPT (6018K27015).

References

- Arimoto H (1992) Two new Elaterid beetles (Coleoptera, Elateridae) from Taiwan. Elytra, Tokyo 20: 73–78.
- Becker EC (1979) Review of the Western Nearctic species of *Athous* (Coleoptera: Elateridae), with a key to the species north of Panama. The Canadian Entomologist 111: 569–614. https://doi.org/10.4039/Ent111569-5

- Cate PC, Sánchez-Ruiz A, Löbl I, Smetana A (2007) Elateridae. In: Löbl I, Smetana A (Eds) Catalogue of Palaearctic Coleoptera. Vol. 4. Apollo Books, Stenstrup, 89–209. https://doi. org/10.1163/9789004309142_003
- Costa C, Lawrence JF, Rosa SP (2010) Elateridae Leach, 1815. In: Leschen RAB, Beutel RG, Lawrence JF (Eds) Handbook of Zoology Arthropoda: Insecta. Coleoptera, Beetles (Vol. 2) Morphology and Systematics (Elateroidea, Bostrichiformia, Cucujiformia partim). Walter de Gruyter Gmbh & Co. KG, Berlin/New York, 75–103.
- Douglas H (2011) Phylogenetic relationships of Elateridae inferred from adult morphology, with special reference to the position of Cardiophorinae. Zootaxa 2900: 1–45.
- Gurjeva EL (1974) Stroenie grudnogo otdela zhukov-shchelkunov (Coleoptera, Elateridae) I znachenie ego priznakov dlya sistemy semeistva [Thoracic structure of click beetles (Co-leoptera, Elateridae) and the significance of the structural characters for the system of the family]. Entomologicheskoe Obozrenie 53: 96–113.
- Han T, Lee YB, Park SW, Lee S, Park HC (2012) A new genus, *Ohirathous* (Coleoptera, Elateridae, Dendrometrinae) from Taiwan. Elytra, Tokyo, New Series 2: 43–52.
- Han T, Lee S, Park IG, Park H (2016) A taxonomic note on the genus *Scutellathous* Kishii, 1955 (Coleoptera, Elateridae) in Korea. International Journal of Industrial Entomology 33: 72–77. doi: 10.7852/ijie.2016.33.2.72.
- Kishii T (1955) Some new forms of Elateridae in Japan. I. Akitu, Kyoto 4: 77-82.
- Kishii T (1987) A taxonomic study of the Japanese Elateridae (Coleoptera), with the keys to the subfamilies, tribes and genera. T. Kishii, Kyoto, 262 pp.
- Kishii T (2001) Revision of the genus *Scutellathous* from Japan, with descriptions of two new species and taxonomic notes on its relatives (Elateridae, Coleoptera) "Some new forms of Elateridae in Japan (XXXI)". Special publication of the Japan Coleopterological Society 1: 205–214.
- Ôhira H (1970) Elateridae in Japan (V). Nature and Insects 5: 19–24.
- Ôhira H (1996) Notes on some Elaterid-beetles from Hokkaido and its adjacent regions (XIII). Jezoensis, Hokkaido 23: 67–71.
- Park JS, Ku DS, Han KD (1993) Faunistic Study on the Insect from Hamyang-gun and Paemsagol area of Mt Chiri. Report of the Korean Association for Conservation of Nature 31: 158–213.
- Platia G, Schimmel R (2007) Click beetles of Taiwan collected by the expeditions of the Hungarian Natural History Museum in the years 1995 to 2003 (Coleoptera: Elateridae). Annales Historico-naturales Musei Nationalis Hungarici 99: 49–91.
- Prosvirov AS, Savitsky VY (2011) On the significance of genital characters in supraspecific systematics of the elaterid subfamily Agrypninae (Coleoptera, Elateridae). Entomological review 91: 755–772.
- Suzuki W (1999) Catalogue of the Family Elateridae (Coleoptera) of Taiwan. Miscellaneous Reports of the Hiwa Museum for Natural History 38: 1–348.

RESEARCH ARTICLE



A review of some new or little-known species of the genus Gnorimoschema (Lepidoptera, Gelechiidae) from the Palaearctic region

Oleksiy Bidzilya¹, Peter Huemer², Kari Nupponen³, Jan Šumpich⁴

 Institute for Evolutionary Ecology of the National Academy of Sciences of Ukraine, 37 Academician Lebedev str., 03143, Kiev, Ukraine 2 Tiroler Landesmuseen Betriebsges.m.b.H., Natural History Collections, Krajnc-Str. 1, A-6060 Hall in Tirol, Austria 3 Merenneidontie 19 D, FI-02320 Espoo, Finland
National Museum, Natural History Museum, Department of Entomology, Cirkusová 1470, CZ-193 00 Praha 9 - Horní Počernice, Czech Republic

Corresponding author: Oleksiy Bidzilya (olexbid@gmail.com)

Academic editor: E. van Nieukerken	Received 28 February 2019	Accepted 23 April 2019	Published 25 June 2019
------------------------------------	---------------------------	------------------------	------------------------

http://zoobank.org/E719FFD4-3703-4F78-864D-884997162527

Citation: Bidzilya O, Huemer P, Nupponen K, Šumpich J (2019) A review of some new or little-known species of the genus *Gnorimoschema* (Lepidoptera, Gelechiidae) from the Palaearctic region. ZooKeys 857: 105–138. https://doi. org/10.3897/zooKeys.857.34188

Abstract

Six new species of *Gnorimoschema* Busck, 1900 are described: *G. pamira* **sp. nov.** (Tadzhikistan), *G. brachyptera* **sp. nov.** (Russia: Buryatia), *G. altaica* **sp. nov.** (Russia: Altai), *G. tabazhok* **sp. nov.** (Russia, Altai, Tuva), *G. yakovlevi* **sp. nov.** (Russia: Altai, Buryatia), *G. kozlovi* **sp. nov.** (Mongolia). A new synonym is established: *G. mikkolai* Povolný, 1994 **syn. nov.** of *G. radkevichi* Piskunov, 1980. *Gnorimoschema montanum* Povolný, 1966, **sp. rev., stat. nov.** is taken out from synonymy with *G. soffneri* (Riedl, 1965). An annotated check-list of the genus *Gnorimoschema* in the Palaearctic region is provided.

Keywords

New species, new records, new synonym, systematic, distribution, brachyptery, Russia, Siberia, Tadzhikistan, Mongolia, DNA barcoding

Introduction

The Gnorimoschemini is an extremely species rich tribe in the subfamily Gelechiinae. Altogether about 900 species and 44 genera are known world-wide. The tribe is most diverse in the Palaearctic region, where more than 300 species from 21 genera are known (Povolný 2002; Bidzilya and Li 2010; Huemer and Karsholt 2010). The highest generic diversity is found in the Neotropics, with about 180 species known from the Nearctic region (Povolný 2002; Lee et al. 2009; Huemer and Karsholt 2010). Studies on the Oriental, Australian and Afrotropical fauna of Gnorimoschemini are rather fragmentary; however, the tribe is likely less diverse in these regions than in the Holarctic and Nearctic. Despite the progress in the study of Palaearctic Gnorimoschemini in the last decades (Li and Bidzilya 2008; Huemer and Karsholt 2010; Bidzilya and Li 2016), the tribe is still in need of considerable taxonomic and faunistic study especially in central and eastern regions, where the discovery of many new taxa is expected.

The classification of the Gelechiidae is under dispute (Ponomarenko 2005; Karsholt et al. 2013). However, authors generally agree to place Gnorimoschemini in the subfamily Gelechiinae. Within this subfamily the Gnorimoschemini share with Gelechiini synapomorphy such as the conspicuous dilation of the lateral parts of the vinculum (Huemer and Karsholt 2010). Povolný (1964, 2002) did not specify auta-pomorphies for Gnorimoschemini, but defined the tribe mainly by a combination of genitalia characters. Currently, the monophyly of the tribe is supported by the hook-like signum and a lateral zone of microtrichia in the ostial area (Huemer and Karsholt 1999, 2010; Ponomarenko 2005).

The generic classification of Gnorimoschemini is poorly developed. A phylogeny of the tribe proposed by Povolný and Šustek (1988) and based on methods of numerical taxonomy includes seven groups of genera. These groups are rather weakly defined and their taxonomic status remains uncertain. The diagnostic characters of male and female genitalia of *Gnorimoschema* Busck, 1900 were recently discussed (Huemer and Karsholt 2010; Li and Bidzilya 2017). Within the tribe, *Gnorimoschema* is most closely related to the Nearctic genus *Neoschema* Povolný, 1967 and more distantly to the mainly Neotropical genus *Symmetrischema* Povolný, 1967 (Povolný 1991).

Most of the Palaearctic species of *Gnorimoschema* are difficult to separate from other Gnorimoschemini externally and often are confused with other species, e.g. of the genus *Scrobipalpa* Janse, 1951. However, some mainly large-sized species of *Gnorimoschema* are distinguished from other genera by the narrow elongated wings. Additionally, the males can be recognized by the characteristic shape of the uncus and terminal portion of valvae which are usually protruded and clearly visible under a binocular microscope.

The species of *Gnorimoschema* inhabit primarily open landscapes. In the Palaearctic region they are most diverse in xeromontane habitats. Several species are restricted to sand dunes and sandy riverbanks in the northern and central Palaearctic.

Gnorimoschema is most diverse in the Nearctic region where 95 species are known (Lee et al. 2009). The Palaearctic species of the genus were studied intensively by Povolný, who contributed tremendously to the taxonomy and diversity of the genus (Povolný 1966, 1967, 1984, 1992, 1994, 2002). After that, *Gnorimoschema* was later

revised in Europe (Huemer and Karsholt 2010) and China (Li and Bidzilya 2017). As a result, twenty-one species have been recorded from the Palaearctic region, the taxonomic state of several species was clarified and some new synonymies proposed. This contribution aims to describe six additional new species from Tadzhikistan, Russia (Southern Siberia) and Mongolia, to clarify the taxonomic state of some species and to add several new country records. The description of new species is supported morphologically and, for the majority, confirmed by DNA barcodes (mtCOI gene). We also provide an annotated check-list which includes all recent changes in taxonomy and distribution of Palaearctic species of *Gnorimoschema*.

Material and methods

Specimens

Adults were collected by light trapping or by hand netting. Male and female genitalia were dissected and prepared using standard methods (Huemer and Karsholt 1999).

The present contribution is based on material deposited in the following collections:

LMK	Landesmuseum Kärnten, Klagenfurt, Austria
MZH	Finnish Museum of Natural History, Helsinki, Finland
NMPC	National Museum Prague, Czech Republic
NUPP	Research collection of Kari & Timo Nupponen, Espoo, Finland
SMNK	Staatliches Museum für Naturkunde Karlsruhe, Germany
TLMF	Tiroler Landesmuseum Ferdinandeum, Hall in Tirol, Austria
ZIN	Zoological Institute Russian Academy of Sciences, Sankt-Petersburg, Russia
ZMKU	Zoological Museum Kiev Taras Shevchenko National University, Ukraine

Photographic documentation

Pinned specimens were photographed with an Olympus E-410 digital camera attached to an Olympus SZX12 microscope or with Canon 750D and MP-E-65 mm lens. Slide-mounted genitalia were photographed with a Canon EOS 600D digital camera mounted on an Olympus U-CTR30-2 trinocular head combined with a Carl Zeiss microscope body. Sets of 10–20 images were taken for each specimen and assembled to deep-focused images using Helicon Focus 6 and edited in Adobe Photoshop CS5.

DNA Barcoding

DNA barcode sequences of the mitochondrial COI gene – a 658 base-pair long segment of the 5' terminus of the mitochondrial COI gene (*cytochrome c oxidase 1*)

- were obtained from 139 new specimens. Some specimens already sequenced, from private or published data (Mutanen et al. 2016), were also included in our dataset. DNA samples from dried legs were prepared according to prescribed standards using the high-throughput protocol of de Waard et al. (2008). Samples were processed in the Canadian Centre for DNA Barcoding (CCDB, Biodiversity Institute of Ontario, University of Guelph). Sequences were submitted to GenBank. Details of successfully sequenced voucher specimens, including complete geographic data and images, can be accessed in the Barcode of Life Data Systems (BOLD; Ratnasingham and Hebert 2007) in the public dataset "DS-LEPALGNO Lepidoptera of the Palearctic - Gelechiidae/ *Gnorimoschema*" dx.doi.org/10.5883/DS-LEPALGNO.

Degrees of intra- and interspecific variation in the DNA barcode fragments were calculated under the Kimura 2 parameter (K2P) model of nucleotide substitution using analytical tools in BOLD systems v. 4.0 (http://www.boldsystems.org). A neighbour-joining tree of DNA barcode data of currently sequenced Palaearctic taxa was constructed using MEGA6 (Tamura et al. 2013) under the K2P model for nucleotide substitutions.

Furthermore, we checked the congruence of taxonomy with Barcode Index Numbers (BIN) proposed by Ratnasingham and Hebert (2013). This system clusters sequences into so-called Operational Taxonomic Units (OTUs), regardless of their previous taxonomic assignment. It is based on a two-stage algorithm that groups the sequences in a cluster and automatically assigns new sequences. All sequences > 500 bp and covering some other quality requirements are recorded independently of the project origin and assigned to a BIN (Ratnasingham and Hebert 2013). Ultimately, the BIN system is a tried and tested means of checking the concordance between morpho-taxonomically based species determinations and COI sequence data.

Terminology

The descriptive terminology of the genitalia structures generally follows Huemer and Karsholt (2010).

Results

Molecular results

From 139 specimens of *Gnorimoschema* we obtained 113 sequences with 104 barcode sequences longer than 500 bp, which were used for analyses. The sequenced 23 morphospecies all group in different clusters (Fig. 1) and also can be separated at species level. Intraspecific distances range from 0% to 2.98% (mean 0.46%). Distances to the nearest


Figure 1. Neighbour-joining tree of Palaearctic *Gnorimoschema* species (Kimura 2 parameter). Note: the scale bar only applies to internal branches between species. The width of the triangles represents the sample size, and the height the relative genetic variation within the cluster (2× scale bar).

neighbour vary from min. 1.39% to 6.44% (mean 3.96%) (Table 1). All successfully sequenced species, except for a single species pair (*G. brachyptera – G. yakovlevi*), are separated by their BINs (Barcode Index Number) in BOLD (Ratnasingham and Hebert 2013).

Further information on the genetic results can be found under each species.

Species	Mean Intra-Sp	Max Intra-Sp	Nearest Species	Distance to NN
G. altaica	0.63	1.32	G. valesiella	3.29
G. brachyptera	0	0	G. yakovlevi	1.39
G. cinctipunctella	0.51	0.92	G. rufomaculata	2.93
G. epithymella	0.3	0.8	G. jalavai	3.96
G. fuscescens	0.32	0.49	G. rufomaculata	3.6
G. herbichii	1.57	2.98	G. robustella	3.78
G. hoefneri	0.59	1.17	G. rufomaculata	3.44
G. jalavai	0.93	1.39	G. epithymella	3.96
G. montanum	0	0	G. herbichii	4.27
G. nilsi	N/A	0	G. altaica	4.93
G. nordlandicolella	0.69	1.6	G. valesiella	4.14
G. nupponeni	0.15	0.31	G. valesiella	5.6
G. pamira	0	0	G. vastifica	5.26
G. radkevichi	0.1	0.15	G. valesiella	5.57
G. robustella	0.15	0.15	G. herbichii	3.78
G. rufomaculata	N/A	0	G. cinctipunctella	2.93
G. soffneri	N/A	0	G. herbichii	4.52
G. yakovlevi	0.15	0.15	G. brachyptera	1.39
G. steueri	0.89	2.18	G. nupponeni	6.44
G. streliciella	0.05	0.16	G. cinctipunctella	4.11
G. tabazhok	0.16	0.39	G. altaica	4.11
G. valesiella	0.47	0.98	G. altaica	3.29
G. vastifica	N/A	0	G. robustella	4.91

Table 1 COI sequences of *Gnorimoschema* species in the *Palaearctic*. Intraspecific mean K2P (Kimura 2 parameter) divergences, maximum pairwise distances, and distance to the nearest neighbour in percentage.

Descriptions of new species

Gnorimoschema pamira sp. nov.

Figs 2, 3, 20, 34

Material examined. Holotype. TADZHIKISTAN∂; W-Pamir Mts., Pianj/Pamir River by Zugvand village; 37°00'55"N, 72°34'32"E; 2810 m; 25 Jul. 2013; K. Nupponen & R. Haverinen leg.; gen. slide 402/16, O. Bidzilya; TLMF Lep 21646; NUPP.

Paratypes. 2 ♀; same data as for holotype; gen. slide 401/16, O. Bidzilya; TLMF Lep 21647; NUPP.

Description. Adult (Figs 2, 3). Wingspan 15.8–16.0 mm. Head covered with white, brown-tipped scales; segment II of labial palpus white mixed with brown, inner surface white, with brush of modified scales on underside, segment III brown with white base and apex, acute, scape brown, densely mixed with white, flagellum grey, black-ringed; thorax white mottled with brown, tegulae with several brown scales; forewing covered with white, black-tipped scales, oblique narrow white fascia from about 1/8 of costal margin to 1/3 of fold, sub-costal vein mottled with brown to 2/3 length, dorsal margin brown under distal half of fold, brown spot in fold, short black streak edged with brown in mid wing, longer black streak with brown scales beneath



Figures 2–19. Gnorimoschema adults 2 G. pamira sp. nov. – HT, male, Pamir (gen. slide 402/16, O. Bidzilya) 3 G. pamira sp. nov. – PT, female, Pamir (gen. slide 401/16, O. Bidzilya) 4 G. brachyptera sp. nov. – HT, female, Buryatia (gen. slide 160/16, O. Bidzilya) 5 G. brachyptera sp. nov. – PT, female, Buryatia (gen. slide 240/16, O. Bidzilya) 5 G. brachyptera sp. nov. – PT, female, Buryatia (gen. slide 240/16, O. Bidzilya) 8 G. altaica sp. nov. – HT, male, Altai (gen. slide 31/18, O. Bidzilya) 9 G. altaica sp. nov. – PT, female, Altai (gen. slide 31/18, O. Bidzilya) 9 G. altaica sp. nov. – PT, female, Altai (gen. slide 30/18, O. Bidzilya) 10 G. tabazhok sp. nov. – HT, male, Altai I G. tabazhok sp. nov. – PT, male, Altai (gen. slide 1250, P. Huemer)
12 G. tabazhok sp. n. – PT, female, Altai (gen. slide 18595, J. Šumpich) 13 G. tabazhok sp. nov. – PT, female, Altai (gen. slide GP 3_2.1.2019KN) 14 G. yakovlevi sp. nov. – HT, male, Altai (gen. slide 406/16, O. Bidzilya) 15 G. yakovlevi sp. nov. – PT, male, Altai 16 G. yakovlevi sp. nov. – PT, female, Buryatia (gen. slide 69/18, O. Bidzilya) 17 G. kozlovi sp. nov. – HT, male, Mongolia (gen. slide 236/15, O. Bidzilya) 18 G. radkevichi Pisk. – HT, female, Mongolia 19 G. radkevichi Pisk., male, Altai.

on 2/3 length in cell, diffuse white sub-apical fascia at ³/₄ length, costal margin mottled white before apex, fringe white, black-tipped; hindwing and fringe light grey.

Variation. The black pattern of one female paratype is more extensive making the specimen look darker, white basal fascia indistinct (Fig. 3).

Male genitalia (Fig. 20). Uncus sub-rectangular, apex triangular, pointed; gnathos weakly curved, gradually narrowed apically; tegumen narrow, anteromedial emargination triangular, extending to about half length of tegumen; valva broad at basal half, curved and constricted in middle, apex narrow, rounded; sacculus straight, as broad as valva in its narrowest mid length, distal portion narrow, strongly curved inwards, gap to vincular process very narrow; vinculum broad, posterior margin with deep and broad sub-ovate medial emargination, lateral process short, sub-rectangular, posterolateral corner join with the tip of sacculus; saccus broad on base, sub-triangular, apex rounded, not extended beyond top of pedunculus; phallus broad, s-curved, with pointed apex, caecum inflated, slightly exceeding half length of phallus.

Female genitalia (Fig. 34). Papilla analis elongate, sub-ovate, densely covered with short setae; apophysis posterioris twice longer than segment VIII; segment VIII evenly sclerotized, slightly broader than long in middle; sub-genital plates separated by narrow membranous area covered with fine microtrichia, widened anteriorly to rhomboidal, strongly edged sub-ostial membrane; anterior margin of sternum VIII with distinct triangular anteromedial projection; apophysis anterioris 2/3 length of segment VIII, curved before apex; colliculum large, sub-quadrangular, two times as broad as ductus bursae; ductus bursae narrow, about of even width; corpus bursae pear-shaped, about as long as ductus bursae, signum on the left side near entrance of corpus bursae, base small, distal hook long, narrow, nearly straight except for curved and pointed apical fifth.

Diagnosis. The new species can be recognized externally by the rather contrasting, greyish-black forewings with well-developed light brown pattern along veins and near dorsal margin. *Gnorimoschema cinctipunctella* (Erschoff, 1877) is more grey, the light brown pattern is usually less extensive, but some specimens look very similar. *Gnorimoschema tabazhok* is smaller in size (11.0–15.5 mm), more uniformly grey, black spots are less distinct. *Gnorimoschema radkevichi* Piskunov, 1980 is smaller in size (12.0–14.0 mm) and has distinct black or light brown spot in the fold. The male genitalia are well recognizable by the sub-rectangular vincular process. *Gnorimoschema bodillum* Karsholt & Nielsen, 1974 is most similar to the new species regarding the male genitalia, but the vincular process is pointed, triangular rather than sub-rectangular, the sacculus is narrower, the vinculum is deeper emarginated medially and the phallus is narrower. The female genitalia are characterized by the strongly concave and well sclerotized anterior margin of sternum VIII in combination with unmodified sub-genital plate and narrow, straight with slightly curved apex of the signum. *Gnorimoschema bodillum* is similar but anterior margin of sternum VIII is less concave.

Molecular data. BIN BOLD:ADF4416 (n=2). The intraspecific divergence of the barcode region is 0%. The distance to the nearest neighbour *G. vastificum* Braun, 1926 is 4.2% (p-dist). This distance is the proportion (p) of nucleotide sites at which



Figures 20–25. Gnorimoschema male genitalia 20 G. pamira sp. nov. – HT, Pamir (gen. slide 402/16, O. Bidzilya) 21 G. brachyptera sp. nov. – PT, Buryatia (gen. slide 159/16, O. Bidzilya) 22 G. brachyptera sp. nov. – PT, Buryatia (gen. slide 240/16, O. Bidzilya) 23 G. altaica sp. nov. – HT, Altai (gen. slide 31/18, O. Bidzilya) 24 G. tabazhok sp. nov. – PT, Altai (gen. slide 1250, P. Huemer) 25 G. tabazhok sp. nov. – PT, S Ural (gen. slide 43/18, O. Bidzilya) (gen. slide 43/18, O. Bidzilya).

two sequences being compared are different. It is obtained by dividing the number of nucleotide differences by the total number of nucleotides compared. It does not make any correction for multiple substitutions at the same site, substitution rate biases, or differences in evolutionary rates among sites.

Distribution. Tadzhikistan (W Pamir).

Biology. Host plant unknown. Adults were collected by light in late July at an elevation of 2800 m. The collecting site is the edge between a steep rocky slope and riverside sand dunes with plenty of *Salix* (Fig. 43).

Etymology. The species name, a noun in apposition, reflects the distribution of the new species in the Pamir region of Tadzhikistan.

Gnorimoschema brachyptera sp. nov.

Figs 4–7, 21–22, 35–36

Material examined. Holotype. RUSSIA ♀; S-Buryatia, Hamar Daban Mts., Murtoy River, Gusinoe ozero village 6 km NW; 51°11-13'N, 106°10-12'E; 700 m; forest steppe; 27 May 2006; K. Nupponen leg.; gen. slide 160/16, O. Bidzilya; TLMF Lep 21632; NUPP.

Paratypes. 1 ♀, same data as for holotype; gen. slide 122/18, O. Bidzilya; TLMF Lep 21634; NUPP; 1 ♀, same data as for holotype; TLMF Lep 21633; NUPP; 1 ♂; same data as for holotype; gen. slide 159/16, O. Bidzilya; TLMF Lep 21636; NUPP; 1 ♂; same data as for holotype; gen. slide 240/16, O. Bidzilya; TLMF Lep 21635; NUPP; 1 ♂; Chita reg., 23 km N Kyra; 9 Aug. 1994; E. Ivanov leg.; gen. slide 90/15, O. Bidzilya; ZMKU; 1 ♂; same collecting data as for preceding; 10 Aug. 1994; P. Ustjuzhanin leg.; gen. slide 143/14, O. Bidzilya; ZMKU.

Other material. RUSSIA 1 ♂; S-Buryatia, Hamar Daban Mnts., Murtoy River, Gusinoe ozero village 6 km NW; 51°11-13'N, 106°10-12'E, 700 m; forest steppe; 21 Jun. 2002; K. Nupponen leg.; gen. slide 194/16, O. Bidzilya; TLMF Lep 21645; NUPP.

Description. Adult. *Male* (Figs 6, 7). Wingspan 12.8–13.5 mm. Head light grey, frons white; segment 2 of labial palpus white mixed with brown in distal half, inner surface white, with brush of modified scales on lower surface, segment III brown with white medial and apical rings, acute; scape brown with white apex, flagellum blackish-brown grey-ringed; thorax and tegulae covered with white brown-tipped scales; forewing brown, white oblique fascia from about 1/8 of costal margin to half length of the fold, diffuse white pattern in middle of cell, white broad subapical fascia on 3/4–4/5 length, paired black spots edged with brown in fold, small black prolonged spot mixed with brown in middle of cell, few black scales surrounded with brown in the corner of cell, fringe white, black-tipped; hindwing and fringe white.

Variation. The paratype (gen. slide 240/16, O. Bidzilya) appears uniformly brown, white markings and black spots are indistinct (Fig. 7).

Female (Figs 4, 5). Wingspan 11.1–11.3 mm. As male, but hindwing shortened to 2/3–3/4 length of the forewing and stronger narrowed in apical 1/3, apical excavation less distinct, abdomen longer compared to male.



Figures 26–31. of *Gnorimoschema* male genitalia 26 *G. tabazhok* sp. nov. PT, Altai (gen. slide 416/16, O. Bidzilya) 27 *G. tabazhok* sp. nov. – PT, Tuva (gen. slide 319/16, O. Bidzilya) 28 *G. tabazhok* sp. nov. – PT, Altai (gen. slide GP 2_1.1.2019KN) 29 *G. tabazhok* sp. nov. – PT, Altai (gen. slide 19021, J. Šumpich) 30 *G. yakovlevi* sp. nov. – HT, Altai (gen. slide 406/16, O. Bidzilya) 31 *G. yakovlevi* sp. nov. – PT, Altai (gen. slide 1251, P. Huemer).



Figures 32–33. *Gnorimoschema* male genitalia **32** *G. kozlovi* sp. nov. – HT, Mongolia (gen. slide 236/15, O. Bidzilya) **33** *G radkevichi* Pisk. – Altai (gen. slide 441/16, O. Bidzilya).

Male genitalia (Figs 21, 22). Uncus sub-rectangular, apex triangular, pointed; gnathos weakly curved, of even width, apex rounded; tegumen moderately broad, anteromedial emargination triangular, extending to about half length of tegumen; valva broad at basal 1/3, then gradually curved, apex weakly widened, rounded; sacculus short, strongly broadened on base, distal portion narrow, curved inwards at right angle, gap to vincular process narrow, triangular; vinculum broad, posterior margin with broad, shallow sub-triangular emargination, lateral process short, hump-shaped; saccus sub-triangular, gradually narrowed towards rounded or weakly pointed apex, usually not extended beyond top of pedunculus; phallus narrow, straight, with needle-shaped, down-curved apical hook, group of short teeth before apex, caecum inflated, about 1/3 length of phallus.

Variation. Valva varies in width; saccus extended beyond tip of pedunculus in some specimens.

Female genitalia (Figs 35, 36). Papilla analis elongate, sub-triangular, densely covered with short setae; apophysis posterioris 2.5–3 times longer than segment VIII; segment VIII sub-quadrangular; subgenital plates medially strongly edged, separated with broadened posteriorly, membranous area covered with fine microtrichia, posterolateral sclerites sub-triangular, narrowly projecting anteromedially to the base of the apophysis anterioris, placed in middle of sternum VIII; anterior margin of sternum VIII deeply concave, strongly sclerotized, medial opening distinct; apophysis anterioris about as long or slightly longer than segment VIII, straight; colliculum as long as broad; ductus bursae narrow, of even width, but inflated before colliculum; corpus bursae egg-shaped, about as long as ductus bursae, signum near entrance of corpus bursae, base elongated, distal hook weakly curved, apically narrowed.

Diagnosis. The new species can be recognized externally by the contrasting, light grey forewing with black oblique fascia at 1/3, the distinct black markings edged with light brown in cell and in the fold and the white subapical fascia at ³/₄. It resembles North European specimens of *G. herbichii* (Nowicki, 1864) (see Huemer and Karsholt 2010, pl. 1, fig. 2a–d) but the black markings are larger in *G. brachyptera*. The female



Figures 34–36. *Gnorimoschema* female genitalia **34** *G. pamira* sp. nov. – PT, Pamir (gen. slide 401/16, O. Bidzilya) **35** *G. brachyptera* sp. nov. – HT, Buryatia (gen. slide 160/16, O. Bidzilya) **36** *G. brachyptera* **sp. nov.** – PT, Buryatia (gen. slide 122/18, O. Bidzilya).

is well-defined by the brachypterous hindwings. The female of *G. elbursicum* Povolný, 1984 differs in the less contrasting, lighter, grey rather than brown forewing, the smaller size (8.2 mm) and the considerably narrower hindwing. The male genitalia are characterized by the sacculus, which is inflated on base with distal portion inwardly curved at right angle. *Gnorimoschema fuscescens* Li & Bidzilya, 2017 differs in the larger gap between the posterior margin of the vinculum and the distal portion of the sacculus, and the valva with stronger inflated apex. *Gnorimoschema steueri* Povolný, 1975 differs by the longer sacculus, the shorter and broader saccus and the shorter phallus. The medially placed sub-triangular posterolateral sclerites in combination with the long apophysis anterioris (1.5 times longer than length of sternum VIII) and the short signum are characteristic for the female genitalia.

Molecular data. BIN BOLD:ADF2846 (n=2), shared with *G. yakovlevi*. The mean intraspecific divergence of the barcode region is 0.15%. The distance to the nearest neighbour *G. yakovlevi* is 1.44% (p-dist).

Distribution. Russia (Buryatia, Zabaikalskiy krai).

Biology. Host plant unknown. Adults were collected in late May and August in dry steppe slopes with sparse vegetation (Fig. 44) at an elevation of 700–900 m.

Etymology. The species name, an adjective is derived from the Greek *brachýs*, meaning short and the Greek *ptéryx*, meaning wing, referring to the shortened hindwing, the most characteristic feature of this species.

Remarks. An additional male from South Buryatia (gen. slide 194/16, O. Bidzilya) collected in June is larger (14.2 mm) and looks lighter and brighter, having more extensive white pattern and well-developed orange-brown irroration around black spots. We have not found sufficient differences in the male genitalia between this specimen and additional males from the type-series. However, we decided to not include this specimen among the type-series due to the lack of females.

Gnorimoschema altaica sp. nov.

Figs 8, 9, 23, 37

Material examined. Holotype. RUSSIA ♂; Altai Republic, Kosh-Agach Distr., Kurai env. (15 km SW), Dzhangyzkol Lake (or Salagana Lake); 50°10'49"N, 87°44'19"E; 1830 m; coniferous forest/steppe; 24–25 Jun. 2015; J. Šumpich leg.; gen. slide 31/18, O. Bidzilya; NMPC-Lep-0313; NMPC.

Paratypes. 2 \Diamond , 1 \bigcirc ; same data as for holotype; gen. slide 30/18 \bigcirc , O. Bidzilya; NMPC-Lep-0312, NMPC-Lep-0349; NMPC.

Other material. RUSSIA 1^Q; S-Buryatia, Hamar Daban mnts., Murtoy River, Gusinoe ozero village 6 km NW; 51°11-13'N, 106°10-12'E; 700 m; forest steppe; 27 May 2006; K. Nupponen leg.; gen. slide 232/16, O. Bidzilya; TLMF Lep 21639; NUPP.

Description. Adult. *Male* (Fig. 8). Wingspan 11.8 mm. Head covered with white, black-tipped scales, frons white; segment II of labial palpus black mixed with white, inner and upper surface white, with brush of modified scales on underside, segment III



Figures 37–40. *Gnorimoschema* female genitalia **37** *G. altaica* sp. nov. – PT, Altai (gen. slide 30/18, O. Bidzilya) **38** *G. tabazhok* sp. nov. – PT, Altai (gen. slide 222/16, O. Bidzilya) **39** *G. tabazhok* sp. nov. – PT, Altai (gen. slide GP 3_2.1.2019KN) **40** *G. tabazhok* sp. nov. – PT Altai, (gen. slide 18595, J. Šumpich).

black with broad white medial ring and white apex, acute, scape black with white apex, flagellum black, white-ringed; thorax and tegulae black mixed with white; forewing covered randomly with brown and white scales, diffuse black spot mixed with brown

in fold, in middle and in the corner of cell, diffuse white subapical fascia on 3/4 length, fringe white, black-tipped; hindwing and fringe light grey.

Female (Fig. 9). Wingspan 11.4 mm. As male, but darker, black pattern more distinct, subapical white fascia not developed, hindwing shortened to 2/3 length of forewing and stronger narrowed in apical 1/3, apical excavation less distinct than in male.

Male genitalia (Fig. 23). Uncus sub-rectangular, apex triangular, pointed; gnathos weakly curved, of even width, apex rounded; tegumen narrow, anteromedial emargination triangular, extending to about half length of tegumen; valva weakly broadened on base, slightly curved on 1/3, then straight, apex weakly widened, rounded; sacculus short, strongly broadened on base, distal portion narrow, curved inwards at right angle, gap to vincular process narrow, sub-triangular; vinculum broad, posterior margin with broad, shallow sub-triangular emargination, lateral process short, hump-shaped; saccus sub-triangular, gradually narrowed towards rounded apex, not extended beyond top of pedunculus; phallus narrow, straight, with needle-shaped down-curved apical hook, caecum inflated, about 2/3 length of phallus.

Female genitalia (Fig. 37). Papilla analis elongate, sub-triangular, densely covered with short setae; apophysis posterioris 2.5 times longer than segment VIII; segment VIII sub-quadrangular; subgenital plates medially strongly edged, separated with broadened posteriorly, membranous area covered with fine microtrichia, posterolateral sclerites hockey-stick-shaped, narrowly projecting anteromedially to the base of the apophysis anterioris, placed in middle of sternum VIII; anterior margin of sternum VIII weakly concave, strongly sclerotized, medial opening small; apophysis anterioris as long as segment VIII, straight; colliculum broader than long; ductus bursae narrow, of even width, but inflated before colliculum; corpus bursae ovate, about as long as ductus bursae, signum on the left side near entrance of corpus bursae, base elongated, distal hook strongly curved in apical portion.

Diagnosis. Externally *G. altaica* is rather small, uniformly blackish-grey species with indistinct markings and diffuse white subapical fascia on the forewing in the male. *Gnorimoschema valesiella* (Staudinger, 1877) is darker, black rather than blackish-grey, and larger in size (16–18 mm). *Gnorimoschema tabazhok* is greyish brown rather than blackish grey with distinct black spots in cell, and the male is larger in size (13.5–15.5 mm). The male genitalia are similar to those of the previous species except for the shorter and broader saccus. The sub-rhomboidal, prolonged medially placed posterolateral sclerites and narrow strongly curved signum are characteristic for the female genitalia. *Gnorimoschema epithymella* (Staudinger, 1859) differs in the narrower posterolateral sclerites, shorter and basally narrower apophysis anterioris, and weakly curved signum.

Molecular data. BIN BOLD:AAI5506 (n=27), shared with an unrevised species from North America. The mean intraspecific divergence of the barcode region is 0.7%, the maximum distance 2,57% (including North American specimens for the same BIN). The distance to the nearest neighbour *G. contraria* Braun, 1921 from North America is 2.57% (p-dist).

Distribution. Russia (Altai).

Biology. Host plant unknown. Adults were collected in late June in grassy steppe with rock protrusions at an elevation of 1800 m (Fig. 46).

Etymology. The species name, a noun in apposition, reflects the distribution of the new species in the Altai Mountains of Russia.

Remarks. A single female from Buryatia is very close to *G. altaica* in barcode but differs considerably in the female genitalia. Hence, we did not include this specimen among the type series. It is interesting that this female is very similar in barcode to an undescribed species of *Gnorimoschema* from USA and Canada but differs from the latter both externally and in the female genitalia (Nazari, pers. comm.).

Gnorimoschema tabazhok sp. nov.

Figs 10-13, 24-29, 38-40

Material examined. Holotype. RUSSIA 3; Altai Republic, Kosh-Agach District, Tašanta env. (8 km N), bellow "11. station"; 49°44'11"N, 89°20'02"E; 2280 m; rocky steppe, meadows; 1 Jul. 2015; J. Šumpich leg.; NMPC-Lep-0346; TLMF.

Paratypes. RUSSIA – Altai Republic 1 3; 45km N of Ulagan village, Chulyshman Valley; 51°01'03"N, 88°00'39"E; 600 m; grassy steppe, rocks; 27-28 Jun. 2015; J. Šumpich leg.; NMPC-Lep-0344; NMPK; 2 3, 1 2; Kosh-Agach District, Chagan-Uzun env., Krasnaya Gorka Hill; 50°05'00"N, 88°25'15"E; 1870 m; rocky steppe; 29 Jun. 2015; J. Šumpich leg.; NMPC-Lep-0348, NMPC-Lep-0339; gen. slide 19020, J. Šumpich; NMPC; 3 👌; Russia, Kosh-Agach Distr., Tašanta env. (10 km SW), Ulandryk Valley; 49°40'33"N, 89°04'09"E; 2200 m; grassy steppe, rocks; 30 Jun. 2015; J. Šumpich leg.; NMPC-Lep-0345; NMPC; 4 3, 2 2; Altai Mts., Kuraisky hrebet; 50°16-20'N, 87°50-55'E; 2000-2500 m; 26 Jun. 2000; T. & K. Nupponen leg.; gen. slides 222/16 (♀), 409/16, 44/18, O. Bidzilya; 1/2.i.2019 (♂), 3/2.i.2019 (♀) K. Nupponen; NUPP; 1 Å, same collecting data as for preceding; 27 Jun. 2000; gen. slide 1/1.i.2019 K. Nupponen; NUPP; 2 same collecting data as for preceding; 28 Jun. 2000; gen. slides 408/16, O. Bidzilya, 2/1.i.2019 K. Nupponen; NUPP; 1 3; same collecting data as for preceding; 30 Jun. 2000; gen. slide 196/18, O. Bidzilya; NUPP; 1 d; Russia, Altai Republic, Kosh-Agach distr., 10 km NE Kosh-Agach village, Kurai Mts. Range, valley of Tabazhok River; 50°05'N, 88°44'E; 2100 m; 02-04 Aug. 2016; P. Huemer & B. Wiesmair leg.; LMF 2016-020; gen. slide Gel. 1250, P. Huemer; DNA Barcode TLMF 20407; TLMF; 1 👌; Russia, Altai Republic, Northern part of Ukok plateau, Zhumaly riber basin; 2400 m; 04-06 Aug. 2016; P. Huemer & B. Wiesmair leg.; DNA Barcode TLMF Lep 21220; TLMF; 15 👌; Russia, Altai Republic, Kosh-Agach District, Kurai env. (15 km SW), Dzhangyskol (= Salagana) Lake; 50°10'49"N, 87°44'19"E; 1830 m; grassy steppe; 24–25 Jun. 2015; J. Šumpich leg.; NMPC-Lep-0342; gen. slide 19021, J. Šumpich; (NMPC); 3 ♂; Altai Republic, Aktash env.; 50°19'12"N, 87°36'00"E; 1400 m; grassy steppe, rocks; 21 Jun. 2015; J. Šumpich; NMPC-Lep-0343; NMPC. – Tuva Republic 1 👌; 75 km NE of Kosh-Agach, Ak-Chol Lake; 50°16'43"N, 89°36'44"E; 2230 m; rocky steppe, meadows; 2–3 Jul. 2015; J. Šumpich leg.; NMPC-Lep-0333; NMPC; 2 ♂; ca. 25 km W Erzin; 50°16-20'N, 94°54'E; 1250 m; steppe/stony slopes; 7–11 Jun. 1995; J. Jalava & J. Kullberg leg.; gen. slide 319/16, 4/18, O. Bidzilya; MZH. – Chelyabinsk region 1 3; S-Ural, Cheliabinsk district, near Moskovo village; 18 Jun. 1998; T. & K. Nupponen leg.; gen. slide 43/18, O. Bidzilya; NUPP.

Description. Adult. *Male* (Figs 10, 11). Wingspan 13.5–15.5 mm. Head, thorax and tegulae covered with grey black-tipped scales, segment II of labial palpus black mixed with white, outer and upper surface white with rare black scales, with brush of modified scales on underside, segment III black mixed with white, acute, scape black with sparse white-tipped scales, flagellum brown narrowly white-ringed; fore-wing greyish-black, veins and fold mottled with light brown, black touch in fold, black spot surrounded with light brown in middle and in the corner of cell, diffuse white subapical fascia at 3/4, costal margin mottled with white before apex, fringe white brown-tipped; hindwing and fringe light grey.

Variation. Ground colour of the forewing varies from blackish-grey grey to dark brown depending on the amount of brown scales. A single male from South Ural is characterized by the presence of large light brown spots, whereas the blackish-grey pattern is strongly reduced in this specimen.

Female (Figs 12, 13). Wingspan 11.0–12.0 mm. As male, but hindwing shortened to 2/3 of the length of forewing and stronger narrowed in apical 1/3, apical excavation less distinct and abdomen longer compared to male.

Variation. Forewing varies from uniformly greyish-brown with indistinct ochreous spots similar to male to more contrast, lighter appearance, with distinct dark elongated spot in the first third (Fig. 13).

Male genitalia (Figs 24, 29). Uncus moderately narrow, apex triangular, pointed; gnathos short, weakly curved, narrow, of equal width, apex rounded; tegumen broad on basal half, distal half narrow, anteromedial emargination deep, triangular, extending to about half length of tegumen; valva broad in basal third, then curved, distal portion nearly of equal width, apex distinctly broadened, rounded, curved outwardly, extending the top of uncus; sacculus broad at base, distal part narrow, coiled and strongly curved inwards forming about the closed ring; vinculum broad, posterior margin with broad medial emargination and with short, rounded hump-shaped lateral process; saccus moderately narrow, weakly narrowed towards truncate apex, extended to the top of pedunculus; phallus narrow, straight, pointed, with needle-shaped down-curved apical hook, caecum rounded, 3/4 length of phallus.

Variation. The apex of the valva varies from narrow to distinctly inflated; the outer margin of the sacculus is weakly broadened in some specimens; the saccus varies from sub-triangular and apically gradually narrowed to be nearly parallel-sided and sub-rectangular with truncate apex.

Female genitalia (Figs 38–40). Papilla analis elongate, sub-triangular, densely covered with short setae; apophysis posterioris 2.5–3.0 times longer than segment VIII; segment VIII sub-quadrangular; subgenital plates medially strongly edged, separated with broadened posteriorly membranous area covered with fine microtrichia, posterolateral sclerites sub-triangular, narrowly projecting anteromedially to the base of the apophysis anterioris, placed near posterior margin of sternum VIII; anterior margin of sternum VIII deeply concave, strongly sclerotized, medial opening distinct; apophysis anterioris about as long or slightly longer than segment VIII, straight, broadened in basal half; colliculum as long as broad; ductus bursae narrow, of even width; corpus bursae elongated, 3 times as long as broad, about as long as ductus bursae, signum on the right side near entrance of corpus bursae, stout, base elongated, distal hook broad, weakly curved, apically pointed.

Diagnosis. The new species is defined externally by the grey forewing with veins mottled with light brown and distinct black spots in the cell. It differs from G. brachyptera by the absence of a black fascia at 1/4 and the darker forewing with more distinct brown pattern. Gnorimoschema radkevichi differs in the more contrasting forewing with distinct blackish-brown spots and brown pattern along dorsal margin. Gnorimoschema steueri Povolný, 1975 is very similar but can be separated by the absence of white subapical spots and the blackish-brown rather than white subapical costal margin. The male genitalia are characterized by the sacculus, which is strongly curved inwards in the apical half, forming a nearly closed ring. Gnorimoschema hoefneri (Rebel, 1909), G. streliciella (Herrich-Schäffer, 1854) and G. rufomaculata Li & Bidzilya, 2017 are somewhat similar in the shape of sacculus which, however, is medially not broadened, and the valva is widened towards apex in these species. The sub-triangular posterolateral sclerites placed near the posterior margin of segment VIII in combination with the stout, short and broad signum are characteristic for the female genitalia of the new species. Gnorimoschema streliciella is rather similar but the signum is much more slender. Gnorimoschema brachyptera and G. altaica differ by the shape of signum (less curved in G. brachyptera) and shape of posterolateral sclerites (narrow in *G. altaica*).

Molecular data. BIN BOLD:AAD9963 (n=10). The mean intraspecific divergence of the barcode region is 0.14%, the maximum divergence is 0.39%. The distance to the nearest neighbour, an undescribed species of *Gnorimoschema* from North America, is 3.53% (p-dist).

Distribution. Russia (S Ural, Altai, Tuva).

Biology. Host plant unknown. The holotype was collected in early August at an elevation of 2100 m, paratypes were collected from the second half of June to early July in various kinds of rocky steppes and in dry mountain steppes with plenty of *Artemisia* at an elevation between 600–2500 m (Figs 46–48).

Etymology. The species name, a noun in apposition, refers to the type locality – Tabazhok River in the vicinity of Kosh-Agach village in the Altai Mountains.

Gnorimoschema yakovlevi sp. nov.

Figs 14–16, 30–31, 41

Gnorimoschema streliciella (Herrich-Schäffer, 1854) – Li and Bidzilya 2017: 180, figs 14, 38. Misidentification.

Material examined. Holotype. RUSSIA ♂; Altai Mts., Kuraisky hrebet; 50°16-20'N, 87°50-55'E; 2000-2500 m; 27 Jun. 2000; T. & K. Nupponen leg.; gen. slide 406/16, O. Bidzilya; TLMF Lep 21629; NUPP.



Figures 41–42. *Gnorimoschema* female genitalia 41 *G. yakovlevi* sp. nov. – PT, Buryatia (gen. slide 69/18, O. Bidzilya) 42 *G. radkevichi* Pisk. – Buryatia (gen. slide 303/16, O. Bidzilya).

Paratypes. Russia – Altai Republic 2 3; Kuraisky hrebet; 50°16-20'N, 87°50-55'E; 2000–2500 m; 27 Jun. 2000; T. & K. Nupponen leg.; TLMF Lep 21630; NUPP; 5 3; Kosh-Agach distr., 10 km NE Kosh-Agach village, Kurai Mts. Range, valley of Tabazhok River; 50°05'N, 88°44'E; 2100 m; 02–04 Aug. 2016; P. Huemer & B. Wiesmair leg.; TLMF 2016-020; Gel. 12513, P. Huemer, gen. slide 432/16, O. Bidzilya; all TLMF; 1 3; Kosh-Agach Distr., Kurai env. (6,5 km SW); 50°10'35"N,



Figures 43–48. *Gnorimoschema* habitats 43 Tadzhikistan, Pamir by Zugwand, habitat of *G. pamira* sp. nov. 44 Russia, Buryatia, Gusinoe Ozero, habitat of *G. brachyptera* sp. nov. 45 Russia, Altai Mts., steppe near Kurai, habitat of *G. yakovlevi* sp. nov. 46 Russia, Altai Mts., Kurai District, steppe in the surroundings of Dzhangyskol (= Salagana) Lake, habitat of *G. altaica* sp. nov. and *G. tabazhok* sp. nov. 47 Russia, Altai Mts., Ulagan District, Chulyshman Valley, habitat of *G. tabazhok* sp. nov. 48 Russia, Altai Mts., Russia, Altai Mts., Krasnaya Gorka Hill, near Chagan-Uzun, habitat of *G. tabazhok* sp. nov.

87°53'55"E; 1550 m; grassy steppe; 9–10 Jul. 2014; J. Šumpich leg.; NMPC. – **Buryatia Republic** 1 3; Hamar Daban Mts., Murtoy River, Gusinoe ozero village, 6 km NW; 51°11-13'N, 106°10-12'E; 700 m; forest steppe; 19 Jun. 2002; K. Nupponen leg.; TLMF Lep 21628; genitalia in glycerol vial; NUPP; 1 \bigcirc ; pr. Ulan-Ude, 35 km SW Ulan-Ude; 700 m; steppe hill; 17 Jul. 1996; J. Jalava & J. Kullberg leg.; gen. slide 69/18, O. Bidzilya; MZH. **Description.** Adult. *Male* (Figs 14–15). Wingspan 12.1–13.8 mm. Head brown, frons dirty white; segment II of labial palpus brown, outer surface white in basal 1/3–2/3, inner surface white, with brush of modified scales on underside, segment III black with white base half on lower side, acute, scape black with rare white tipped scales, flagellum blackish-brown grey-ringed; thorax and tegulae covered with brown grey-edged apically scales; forewing covered with black white-tipped scales, sub-costal vein and fold mottled with brown to half length, three black spots edged with brown in fold and in cell, black streak in base of fold, distinct white sub-apical fascia on 2/3 length, subapical 1/3 brown except for termen covered with black white-tipped scales, fringe grey; hindwing and fringe light grey.

Female (Fig. 16). Wingspan 11.8 mm. As male, but hindwing narrowed in apical 1/3, apical excavation less distinct compared to male.

Male genitalia (Figs 30–31). Uncus sub-rectangular, apex triangular, pointed; gnathos weakly curved, of even width, apex weakly pointed; tegumen moderately broad, anteromedial emargination triangular, extending to about half length of tegumen; valva broad at basal 1/3, then curved, apex rounded or weakly pointed; sacculus long, straight, as broad as valva in mid length, distal portion narrow, strongly curved inwards and down, gap to vincular process broad; vinculum broad, posterior margin with broad, shallow sub-triangular emargination, lateral process short, hump-shaped; saccus sub-triangular, apex rounded, not extended beyond top of pedunculus; phallus narrow, straight, with needle-shaped down-curved apical hook, group of short teeth before apex, caecum inflated, about 1.5 times shorter than phallus.

Variation. Distal portion of valva varies of even width or with broadened apex; saccus varies in width and length.

Female genitalia (Fig. 41). Papilla analis elongate, sub-triangular, densely covered with short setae; apophysis posterioris 2–2.5 times longer than segment VIII; segment VIII sub-rectangular; subgenital plates medially strongly edged, separated with broad sub-triangular membranous area covered with fine microtrichia, posterolateral sclerites large, inverted drop-shaped, narrowly projecting anteromedially, placed under mid length of posterior margin of sternum VIII; anterior margin of sternum VIII deeply concave, strongly sclerotized, medial opening small; apophysis anterioris about as long as segment VIII, strongly widened in basal 2/3, distal portion narrow, weakly curved; colliculum narrow, twice longer than broad; ductus bursae narrow, weakly broadened in anterior and posterior portion; corpus bursae sub-ovate, twice longer than broad, about as long as ductus bursae, signum near entrance of corpus bursae, base small, distal hook gradually curved, of even width except for narrowed and pointed apex, posterior margin weakly serrated.

Diagnosis. The new species is recognizable by the blackish-brown forewing with distinct narrow white subapical fascia. *Gnorimoschema streliciella* is nearly indistinguishable except for the less extensive brown pattern and the white sub-apical fascia which is usually angled towards apex. The male genitalia are characterized by the down-curved apical portion of the sacculus in combination with the moderately narrow medial emargination of the posterior margin of the vinculum. *Gnorimoschema streliciella* differs in the broader medial emargination of the posterior margin of the posterior margin of vinculum,

and the sacculus which is broader on base, and narrower and longer in the distal portion. The large, inverted drop-shaped posterolateral sclerites in combination with the strongly concave anterior margin of sternum VIII and the apophysis anterioris distinctly widened in basal 2/3 length are characteristic for the female genitalia. *Gnorimoschema hoefneri* differs in the weakly sclerotized anterior margin of sternum VIII, the narrower apophysis anterioris and the shorter signum.

Molecular data. BIN BOLD:ADE8232 (n=2), shared with *G. brachyptera*. The mean intraspecific divergence of the barcode region is 0.15%. The distance to the nearest neighbour *G. brachyptera* is 1.44% (p-dist).

Distribution. Russia (Altai, Buryatia).

Biology. Host plant unknown. Adults were collected in semi-arid, steppe habitats with scattered vegetation (Fig. 45) from mid-June to early August up to an elevation of 2500 m.

Etymology. The new species is named in honour of Prof. Roman Yakovlev (Altai State University, Barnaul, Russia) in recognition of his enormous contribution to the exploration of Lepidoptera in Altai and organization of joint expeditions.

Gnorimoschema kozlovi sp. nov.

Figs 17, 32

Material examined. Holotype. Mongolia ♂; Yuzhno-Gobiisky aimak, 60 km E Talyn-Bilgeh-Bulak spring; 17–19 Aug. 1969; M. Kozlov leg.; gen. slide 236/15, O. Bidzilya; ZIN.

Description. Adult (Fig. 17). Wingspan 11.0 mm. Head white with several brown scales on the neck, segment II of labial palpus brown with white medial belt, upper surface white, with brush of modified scales on underside, segment III black with white medial and apical rind, acute, scape brown with few white scales on apex, flagellum brown white-ringed; thorax and tegulae covered with white brown-tipped scales; forewing yellowish cream in dorsal 1/3 width, costal 2/3 mottled with grey and brown mainly along veins, fold with indistinct light brown streak, fringe white brown-tipped; hindwing and fringe light grey.

Male genitalia (Fig. 32). Uncus moderately narrow, apex triangular, pointed; gnathos long, weakly curved, broadest in middle; tegumen broad in basal half, distally nearly parallel-sided, anteromedial emargination deep, triangular, extending to half length of tegumen; valva broad in basal third, strongly curved before middle, then narrow, weakly sinuate, about of equal width, apex slightly broadened and rounded, not extending the top of uncus; sacculus very long, extending nearly to the top of valva, broad on base, distal portion narrow, with pointed, coiled and downwards curved 1/4; vinculum broad, posterior margin with deep and broad sub-triangular medial emargination, with triangular lateral process and broad membranous lobe; saccus subrectangular, weakly narrowed towards rounded apex, not extended beyond top of pedunculus; phallus moderately broad, gradually curved, with small triangular apical hook, caecum twice shorter than the length of phallus.

Female genitalia. Unknown.

Diagnosis. The new species is characterized by the forewing colour divided into dark brown costal and yellowish-cream dorsal parts. The male genitalia are characterized by a very long sacculus that reaches about ³/₄ length of valva and within the Palaearctis *Gnorimoschema*-species unique phallus with gradually curved distal portion.

Molecular data. Unavailable due to lack of suitable, fresh material.

Distribution. Mongolia.

Biology. Host plant unknown. The holotype was collected in mid-August.

Etymology. The species is named in honour of the Russian hymenopterist and well-known specialist in the family Scelionidae, Mikhail Alekseevich Kozlov, the collector of the holotype of the new species.

Check-list of the genus Gnorimoschema in the Palaearctic region

New regional records are marked with an asterisk *.

Gnorimoschema soffneri (Riedl, 1965)

Lerupsia soffneri Riedl, 1965: 61–62, 80.

Gnorimoschema antiquum Povolný, 1967: 400, figs 5, 22–24, 41. – Karsholt and Nielsen 1974: 91; Huemer and Karsholt 2010: 38.

Distribution. South Europe from Spain to Bulgaria, Turkey, Iraq (Huemer and Karsholt 2010).

Gnorimoschema montanum Povolný, 1966 sp. rev., stat. n.

Gnorimoschema antiquum montanum Povolný, 1966: 402, fig. 6. Gnorimoschema soffneri montanum Povolný, 1966 – Huemer and Karsholt 2010: 38–40.

Remarks. *Gnorimoschema antiquum montanum* was described from the mountains of Afghanistan. It is characterized by its uniformly coloured yellowish to ochreous brown forewing with grey irroration along the veins and costal margin. The status of this taxon was recently discussed, and it was suggested that G. montanum may be a separate species that differs from the related *G. soffneri* and *G. antiquum* by details of the genitalia of both sexes (Li and Bidzilya 2017: 176, figs 7, 31, 32, 54). This suggestion is partially confirmed by DNA barcodes from material collected in Afghanistan which clearly separates *G. montanum* from *G. soffneri* (see Table 1). Even though the sequences are not yet known for *G. antiquum*, we consider the existing evidence sufficient to recognize *G. montanum* as a valid species.

Distribution. Uzbekistan, Iran, Afghanistan (Povolný 2002; Li and Bidzilya 2017).

Gnorimoschema herbichii (Nowicki, 1864)

Bidzilya 2017: 175.

Gelechia herbichii Nowicki, 1864: 17, pl. 1, fig. 6.
Lita pusillella Rebel, 1893: 47.
Gelechia (Lita) tengstroemiella Joannis, 1910: 296. – Povolný 1964: 337.
Lita pazsiczkyi Rebel, 1913: 173. – Povolný 1964: 337.
Lita parentesella Toll, 1936: 407, pl. 49, fig.18.
Phthorimaea tengstroemi Hackman, 1946: 61, figs. 2, 5. – Povolný 1964: 337.
Gnorimoschema herbichi [sic] mongoliae Povolný, 1973: 19, figs. 4, 14, 22. – Li and Bidzilya 2017: 175.
Gnorimoschema herbichi [sic] kamchaticum Povolný, 1977: 218, fig. 14. – Li and

Distribution. Europe from Spain to Belarus, European part of Russia (Kirov region, Udmurtia Republic), Turkmenistan, Uzbekistan, Iraq, Mongolia, Asian part of Russia (Irkutsk region, Buryatia, Zabaikalskiy krai, Chukchi AR, Kamchatka), China (Hebei, Inner Mongolia, Ningxia, Shaanxi, Xinjiang), Canada (Alberta, Yukon, Manitoba) (Povolný 2002; Ponomarenko 2008; Falkovitsh and Bidzilya 2009; Huemer and Karsholt 2010; Nazari and Landry 2012; Bidzilya and Li 2017; Piskunov and Derzhinsky 2018).

Gnorimoschema bodillum Karsholt & Nielsen, 1974

Gnorimoschema bodillum Karsholt & Nielsen, 1974: 91, figs 1-9.

Distribution. Denmark, Germany (Huemer and Karsholt 2010). A record form Taymyr Peninsula of Russia (Bidzilya 2005: 14) should most likely be referred to *G. vastificum* (Kullberg et al. 2013: 130).

Gnorimoschema vastificum Braun, 1926

Gnorimoschema vastificum Braun, 1926: 47.

Distribution. Russia (Arkhangelsk region: Nenetz Autonomous Okrug, Taymyr Peninsula (?)) (Bidzilya 2005; Kullberg et al. 2013), Canada (Northwest Territories, Alaska, Yukon, Alberta, Saskatchewan, Manitoba) (Nazari and Landry 2012), USA (Utah, California) (Powell and Povolný 2001).

Gnorimoschema pamira sp. nov.

Distribution. Tadzhikistan.

Gnorimoschema cinerella Li & Bidzilya, 2017

Gnorimoschema cinerella Li & Bidzilya, 2017: 177, figs 8, 33.

Distribution. China (Yunnan) (Li and Bidzilya 2017).

Gnorimoschema gilvella Li & Bidzilya, 2017

Gnorimoschema gilvella Li & Bidzilya, 2017: 177, figs 9, 55.

Distribution. China (Ningxia) (Li and Bidzilya 2017).

Gnorimoschema nupponeni Huemer & Karsholt, 2010

Gnorimoschema nupponeni Huemer & Karsholt, 2010: 26.

Distribution. Ukraine (Crimea), Russia (Orenburg region) (Huemer and Karsholt 2010), Kazakhstan*.

New records. KAZAKHSTAN 3 ♂; North Mugozhary Mts., Altyndy village 5 km W; 48°55'29"N, 58°18'49"E; 470–520 m; 6 Sep. 2012; K. Nupponen leg.; NUPP.

Gnorimoschema jalavai Povolný, 1994

Gnorimoschema jalavai Povolný, 1994: 57, figs 1, 6.

Distribution. Russia (Altai, Tuva, Irkutsk region, Buryatia, Zabaikalskiy krai, Chukchi AR (Povolný 2002; Ponomarenko 2008), Canada (Yukon) (Landry et al. 2013: 39).

Gnorimoschema robustella (Staudinger, 1871)

Gelechia robustella Staudinger, 1871: 312. *Phthorimaea syrphetopa* Meyrick, 1926: 278. – Povolný 1992: 230.

Distribution. Russia (Arkhangelsk region, Saratov region, Volgograd region, Orenburg region, South of Krasnoyarskiy krai^{*}) (Anikin and Piskunov 1995; Junnilainen et al. 2010; Kozlov et al. 2014); West Kazakhstan (Uralsk, Indersk Lake) (Huemer and Karsholt 2010).

New record. RUSSIA 1 (; [Krasnoyarskiy krai] Minusinsk; 5 Jul. 1924; N. Filipjev leg.; gen. slide 182/18, O. Bidzilya; ZMKU.

Gnorimoschema steueri Povolný, 1975

Gnorimoschema steueri Povolný, 1975: 190, figs 1-3, 6-9.

Distribution. France, Italy, Germany, Austria, Czech Republic, Slovakia (Huemer and Karsholt 2010), Russia (Altai*, Krasnoyarskiy kray, Zabaikalskiy krai) (Bidzilya 2005; Akulov et al. 2018).

New records. RUSSIA 42 3; Altai Republic, Kosh-Agach distr., 17 km NNE Kokorya village, Chikhacheva Mts. Range, Talduair Mt., valley of Sajlyugem River; 50°01'N, 89°14'E; 2200 m; 30 Jul.–2 Aug. 2016; P. Huemer & B. Wiesmair; gen. slides Gel. 1247, P. Huemer; 417/16; 421/16; 423/16, 426/16, 431/16, O. Bidzilya; TLMF; 4 3; Altai Republic, Kosh-Agach distr., 10 km NE Kosh-Agach village, Kurai Mts. Range, valley of Tabazhok River; 50°05'N, 88°44'E; 2100 m; 2–4 Aug. 2016; P. Huemer & B. Wiesmair; TLMF 2016-020; gen. slide 411/16; 424/16; 425/16, O. Bidzilya; TLMF.

Gnorimoschema fuscescens Li & Bidzilya, 2017

Gnorimoschema fuscescens Li & Bidzilya, 2017: 178, figs 11-13, 35-37, 57.

Distribution. Russia (Altai, Zabaikalskiy krai), Kyrgyzstan, Mongolia, China (Gansu, Inner Mongolia) (Li and Bidzilya 2017).

Gnorimoschema brachyptera sp. nov.

Distribution. Russia (Buryatia, Zabaikalskiy krai).

Gnorimoschema altaica sp. nov.

Distribution. Russia (Altai).

Gnorimoschema tabazhok sp. nov.

Distribution. Russia (S Ural, Altai, Tuva).

Gnorimoschema elbursicum Povolný, 1984

Gnorimoschema elbursicum Povolný, 1984: 264, fig. 1.

Distribution. Iran (Elburs Mts.c., Kendevan Pass).

Remarks. The species is known from a single brachypterous female, with genitalia characterized by the unmodified and evenly sclerotized segment VIII (Povolný 1984, 2002: pl. 1, fig. 8; pl. 60, fig. 544).

Gnorimoschema epithymella (Staudinger, 1859)

Gelechia epithymella Staudinger, 1859: 242. Phthorimaea brunneomaculella Hackman, 1946: 60, figs 3, 6. Phthorimaea boernii Amsel, 1952: 123, fig. 29. Gnorimoschema epithymellum kirgisicum Povolný, 1994: 61, figs 3, 8. Subspecies.

Distribution. Europe from Spain to Kola Peninsula, Volga region and Western Caucasus of Russia (Kozlov and Kullberg 2006; Ponomarenko 2008; Karsholt and Huemer 2010), Algeria, Kyrgyzstan (Povolný 2002), Zabaikalskiy krai of Russia (Bidzilya 2005: 15).

Gnorimoschema nilsi Huemer, 1996

Gnorimoschema nilsi Huemer, 1996: 78, figs 1, 3, 5, 6, 11, 12, 17, 18, 21, 22. *Gnorimoschema nordlandicolellum* (Strand, 1902). – Povolný 1998: 337; 2002: 24. *Gnorimoschema nilsi* Huemer, 1996. – Huemer and Karsholt 2010: 49.

Distribution. Austria, France, Italy (Huemer and Karsholt 2010).

Gnorimoschema nordlandicolella (Strand, 1902)

Gelechia (Lita) nordlandicolella Strand, 1902: 21. Gnorimoschema nordlandicolella (Strand, 1902). – Povolný 1966: 397. Gnorimoschema nordlandicolella eucausta (Meyrick, 1929). – Povolný 1967: 77. Phthorimaea ceceonodes Meyrick, 1924: 278. – Povolný 1992: 230. Phthorimaea eucausta Meyrick, 1929: 492. – Povolný 1992: 230. Phthorimaea fennicella Hackman, 1946: 60, figs 1, 4. – Povolný 1992: 230

Distribution. Northern Europe, Turkey, Uzbekistan, mountains of SE Kazakhstan, Kyrgyzstan, Afghanistan*, Russia (Altai, Irkutsk Region, Zabaikalskiy krai, Yakutia) China (Xinjiang) (Povolný 2002; Ponomarenko 2008; Huemer and Karsholt 2010; Bidzilya 2012; Li and Bidzilya 2017).

New record. AFGHANISTAN 1 3; Salang-Pass, N-Seite; 2100 m; 5–11 Jul. 1966; H. Amsel leg.; gen. slide 22/18, O. Bidzilya; SMNK.

Gnorimoschema streliciella (Herrich-Schäffer, 1854)

[no genus] *streliciella* Herrich-Schäffer, 1853: pl. 67, fig. 495. *Gelechia streliciella* Herrich-Schäffer, 1854: 171.

Distribution. Northern and parts of Central Europe (Huemer and Karsholt 2010), Russia (Middle Volga region, Buryatia), China (Inner Mongolia) (Li and Bidzilya 2017).

Gnoriomoschema yakovlevi sp. nov.

Distribution. Russia (Altai, Buryatia).

Gnorimoschema hoefneri (Rebel, 1909)

Gelechia (Lita) hoefneri Rebel, 1909: 331. Gnorimoschema streliciella hoefneri (Rebel 1909). – Povolný 2002: 25. Gnorimoschema hoefneri (Rebel, 1909). – Huemer and Karsholt 2010: 53.

Distribution. Italia, Austria, Slovenia (Huemer and Karsholt 2010).

Gnorimoschema valesiella (Staudinger, 1877)

Lita valesiella Staudinger, 1877: 205. *Gnorimoschema valesiella charcotti* (Meyrick, 1934). – Povolný 1967: 74. *Lita diabolicella* Hartig, 1924: 81. – Povolný 1992: 232. *Phthorimaea charcoti* Meyrick, 1934: 59. – Povolný 1992: 232. *Phthorimaea hackmani* Schantz, 1952: 19. – Povolný 1992: 232.

Distribution. Spain, France, Italy, Switzerland, Austria, Island, Norway, Sweden, Finland, Latvia, Caucasus, Greenland (Huemer and Karsholt 2010), Russia (Kola Peninsula, Altai, Tuva, Buryatia, Zabaikalskiy krai) (Ponomarenko 2008).

Gnorimoschema cinctipunctella (Erschoff, 1877)

Gelechia cinctipunctella Erschoff, 1877: 344.
Gnorimoschema cinctipunctella (Erschoff, 1877). – Piskunov 1988: 362, figs 4, 5.
Gnorimoschema streliciella cinctipunctella (Erschoff, 1877). – Povolný 1992: 232, fig. 11. pl. 3, fig. 4.

Gnorimoschema streliciella (Erschoff, 1877). – Ponomarenko 2008: 328. Gnorimoschema mongolorum Povolný, 1969: 4, pls 1–5, figs 1–10; pl. 32, fig. 31. – Li and Bidzilya 2017: 180.

Distribution. Russia: South Ural (Junnilainen et al. 2010), Altai, South of Krasnoyarskiy krai, Zabaikalskiy krai, Amur Region (Povolný 2002; Ponomarenko 2008; Bidzilya 2009), Mongolia, China (Gansu, Hebei, Inner Mongolia, Ningxia and Qinghai) (Li and Bidzilya 2017).

Gnorimoschema rufomaculata Li & Bidzilya, 2017

Gnorimoschema rufomculata Li & Bidzilya, 2017: 183, figs 21, 22, 46-48, 62, 63.

Distribution. Russia (Buryatia*, Zabaikalskiy krai), China (Ningxia and Inner Mongolia Autonomous Regions), South Korea (Li and Bidzilya 2017).

New records. RUSSIA 3 ♂; S-Buryatia, Hamar Daban Mts., Murtoy River, Gusinoe ozero village 6 km NW; 51°11-13'N, 106°10-12'E; 700 m; forest steppe; 19 Jun. 2002; K. Nupponen leg.; gen. slide 174/16, O. Bidzilya; NUPP.

Gnorimoschema piskunovi Li & Bidzilya, 2017

Gnorimoschema piskunovi Li & Bidzilya, 2017: 184, figs 23, 24, 64, 65.

Distribution. China (Hebei, Shanxi) (Li and Bidzilya 2017).

Gnorimoschema kozlovi sp. nov.

Distribution. Mongolia.

Gnorimoschema radkevichi Piskunov, 1980

Gnorimoschema radkevichi Piskunov, 1980: 388, figs 6, 7. Gnorimoschema mikkolai Povolný, 1994: 60, figs 2, 7. Syn. nov.

Material examined. Holotype of *G. radkevichi*: MONGOLIA ♂; G. Alt. aim., Dutin Daba, 37 km ENE Tsogt; 14 Jul. 1970; malaise trap; V. Zaitzev & E. Narchuk leg.; Mikr. Prep. № 14777; ZIN; RUSSIA 1 ♀; Buryatia, pr. Ulan-Ude; 35 km SW Ulan-

Ude; 17 Jul. 1996; 700 m; steppe hill; J. Jalava & J. Kullberg leg.; gen. slide 303/16, O. Bidzilya; MZH; 6 Å; Altai Republic, Kosh-Agach distr., 10 km NE Kosh-Agach village, Kurai Mts. Range, valley of Tabazhok River; 50°05'N 88°44'E; 2100 m; 2–4 Aug. 2016; P. Huemer & B. Wiesmair leg.; TLMF 2016-020; gen. slide 428/16; 433/16; 441/16, O. Bidzilya; TLMF; 1 Å; same collecting data as for preceding; genitalia in glycerol vial; TLMF; 2 Å, Altai Republic, Aktash village, 50°19'N, 87°36'E; 1400 m; grassy steppe, rocks; 11 Jul. 2014; NMPC-Lep-0337; J. Šumpich leg.; NMPC.

Remarks. Gnorimoschema radkevichi was described from a single male (Fig. 18) collected in Mongolia: pass Dutiin-Daba in Gobi-Altai aimak, 37 km ENE of Tsogt. Gnorimoschema mikkolai was described from a single female collected in Magadan region of Russia: Upper Kolyma River, steppe slopes near Vetrennyi. A female from Buryatia matches the genitalia (Fig. 42) of the holotype of *G. mikkolai*. Males from Altai are identical both externally (Fig. 19) and in the genitalia (Fig. 33) to the holotype of *G. mikkolai* and fully correspond in DNA barcodes with the female holotype of *G. mikkolai* which is therefore formally synonymized with *G. radkevichi*.

Distribution. Russia (Altai*, Buryatia*, Magadan region), Mongolia (Piskunov 1980; Povolný 1994).

Acknowledgements

We are grateful to Paul D.N. Hebert and the entire team at the Canadian Centre for DNA Barcoding (CCDB, Guelph, Canada) for carrying out the sequence analyses. PH is particularly indebted to the Promotion of Educational Policies, University and Research Department of the Autonomous Province of Bolzano - South Tyrol for funding the project "Genetische Artabgrenzung ausgewählter arktoalpiner und boreomontaner Tiere Südtirols". We are grateful to Sergei Sinev (ZIN), Lauri Kaila (MZH) and Christian Wieser (LMK) for their assistance during the study of material deposited in the collection under their care. The authors thank Benjamin Wiesmair (TLMF) and Roman Yakovlev (Altai State University, Barnaul, Russia) for various support and help during field work, Vladimir Olschwang (Ekaterinburg, Russia) for organizing the expeditions to Altai (2000 & 2001) and Buryatia (2002 & 2006), and Aleksander Pototski (Tallinn, Estonia) and Risto Haverinen (Vantaa, Finland) for organizing the expedition to Tadzhikistan (2013) and help during field work. Marko Mutanen (University of Oulu, Finland) and Vazrick Nazari (Canadian National Insect Collection, Ottawa, Canada) kindly gave as access to valuable sequences.

Colin W. Plant (Hertfordshire, England) kindly improved the English language of the final version of the manuscript. We express our gratitude to the referees, Lauri Kaila (Helsinki, Finland) and an anonymous colleague, for their critical reviews and helpful suggestions. The work was supported by the Ministry of Culture of the Czech Republic (DKRVO 2019-2023/5.I.a, National Museum, 00023272, J. Šumpich) and by the State Budget Program "Support for the Development of Priority Areas of Scientific Research" (Code: 6541230) (O. Bidzilya).

References

- Akulov EN, Kirichenko NI, Ponomarenko MG (2018) Contribution to Microlepidoptera Fauna of the South of Krasnoyarsk Territory and the Republic of Khakassia. Entomological review 98(1): 49–75. https://doi.org/10.1134/S0013873818010074
- Anikin VV, Piskunov VI (1995) On the fauna of gelechiid moths (Lepidoptera, Gelechiidae) from the Lower Volga region. Contribution to the knowledge of the Gelechiidae from the European part of Russia. Actias 2(1–2): 3–12.
- Bidzilya OV (2005) On the distribution of Gelechiid-Moths (Lepidoptera, Gelechiidae) in Siberia. Proceeding of the Zoological Museum of Kiev Taras Shevchenko National University 3: 7–19.
- Bidzilya OV (2012) New species and new records of gelechiid-moths from the northern Siberia and Far East of Russia (Lepidoptera, Gelechiidae). SHILAP Revista de Lepidopterologia 160: 419–427.
- Bidzilya OV, Li HH (2010) The genus Scrobipalpa Janse (Lepidoptera, Gelechiidae) in China, with description of 13 new species. Zootaxa 2531: 1–26. https://doi.org/10.11646/ zootaxa.2513.1.1
- Bidzilya OV, Li HH (2016) A review of the genus *Kiwaia* Philpott, 1930 (Lepidoptera, Gelechiidae) in the Palaearctic region. Zootaxa 4098(3): 471–497. https://doi.org/10.11646/ zootaxa.4098.3.3
- de Waard JR, Ivanova NV, Hajibabaei M, Hebert PDN (2008) Assembling DNA Barcodes: Analytical Protocols. In: Martin Cristofre C (Ed.) Methods in Molecular Biology: Environmental Genomics. Humana Press Inc., Totowa, USA, 275–293. https://doi. org/10.1007/978-1-59745-548-0_15
- Falkovitsh MI, Bidzilya OV (2009) A list of gelechiid moths (Lepidoptera, Gelechiidae) of the Southern Kyzylkum. Proceeding of the Zoological Museum of Kiev Taras Shevchenko National University 5: 65–98. [in Russian]
- Junnilainen J, Karsholt O, Nupponen K, Kaitila J-P, Nupponen T, Olschwang V (2010) The gelechiid fauna of the southern Ural Mountains, part II: list of recorded species with taxonomic notes (Lepidoptera: Gelechiidae). Zootaxa 2367: 1–68. https://doi.org/10.11646/ zootaxa.2367.1.1
- Huemer P, Karsholt O (1999) Gelechiidae (Gelechiinae: Teleiodini, Gelechiini). In: Huemer P, Karsholt O, Lyneborg L (Eds) Microlepidoptera of Europe, Stenstrup 3: 1–356.
- Huemer P, Karsholt O (2010) Gelechiidae II (Gelechiinae: Gnorimoschemini). In: Huemer P, Karsholt O, Nuss M (Eds) Microlepidoptera of Europe, Stenstrup 6: 1–586.
- Karsholt O, Mutanen M, Lee S, Kaila L (2013) A molecular analysis of the Gelechiidae (Lepidoptera, Gelechioidea) with an interpretative grouping of its taxa. Systematic Entomology 38: 334–348. https://doi.org/10.1111/syen.12006
- Kozlov MV, Kullberg J, Dubatolov VV (2006) Lepidoptera of the Taymyr Peninsula, northwestern Siberia. Entomologica Fennica 17: 136–152.
- Kozlov MV, Kullberg J, Zverev VE (2014) Lepidoptera of Arkhangelsk oblast of Russia: a regional checklist. Entomologica Fennica 25(3): 113–141.
- Kullberg J, Filippov BYu, Zubrij NA, Kozlov MV (2013) Faunistic notes on Lepidoptera collected from arctic tundra in European Russia. Nota lepidopterologica 36(2): 127–136.

- Landry J-F, Nazari V, de Waard JR, Mutanen M, Carlos Lopez-Vaamonde C, Huemer P, Hebert PDN (2013) Shared but overlooked: 30 species of Holarctic Microlepidoptera revealed by DNA barcodes and morphology. Zootaxa 3749(1): 1–93. https://doi.org/10.11646/ zootaxa.3749.1.1
- Lee S, Hodges RW, Brown RL (2009) Checklist of Gelechiidae (Lepidoptera) in America north of Mexico. Zootaxa 2231: 1–39.
- Li HH, Bidzilya O (2008) A review of the genus *Ephysteris* Meyrick, 1908 from China, with descriptions of two new species (Lepidoptera: Gelechiidae). Zootaxa 1733: 45–56. https://doi.org/10.3897/nl.41.23395
- Li H, Bidzilya O (2017) Review of the genus *Gnorimoschema* Busck, 1900 (Lepidoptera, Gelechiidae) in China. Zootaxa 4365(2): 173–195. https://doi.org/10.11646/zootaxa.4365.2.4
- Mutanen M, Kivela SM, Vos RA, Doorenweerd C, Ratnasingham S, Hausmann A et al. (2016) Species-Level Para- and Polyphyly in DNA Barcode Gene Trees: Strong Operational Bias in European Lepidoptera. Systematic Biology 65(6): 1024–1040. https://doi.org/10.1093/ sysbio/syw044
- Nazari V, Landry J-F (2012) Gnorimoschemini fauna of Alberta (Lepidoptera: Gelechiidae). Report prepared for the Alberta Lepidopterists' Guild. AB, Edmonton, 117 pp. Available from: http://www.albertalepguild.ca/projects/faunal-inventories/ [accessed 22 February 2019]
- Piskunov VI (1980) An addition to the fauna of the gelechiid and anarsiid moths (Lepidoptera: Gelechiidae, Anarsiidae) of Mongolia and North China. Nasekomye Mongolii 7: 386–395 [in Russian]
- Piskunov VI (1988) Results of study of the type specimens of gelechiid moths (Lepidoptera, Gelechiidae) from the collection of the Zoological Museum, Moscow State University, and the Zoological Institute, Academy of Sciences of the USSR. Entomologitcheskoe obozrenie 67, 360–368. [in Russian, English abstract]
- Piskunov VI, Derzhinsky YeA (2018) New Findings of Gelechiid Moths (Lepidoptera: Gelechiidae) in the Republic of Belarus. Vesnik Vitsebskaga dzjarzhaunaga universiteta, Bijalogia 4(97): 69–79 [in Russian]
- Ponomarenko MG (2005) Gelechiid moths of the Palaearctics: functional morphology of the male genitalia, phylogeny and taxonomy (Lepidoptera, Gelechiidae). Meetings in memory of N. A. Kholodkovsky 58(1), St. Petersburg, 1–139 [in Russian, English abstract]
- Ponomarenko MG (2008) Gelechiidae. In: Sinev SYu (Ed.) Katalog Cheshuekrylyh (Lepidoptera) Rossii (Catalogue of the Lepidoptera of Russia), KMK Scientific Press, St. Petersburg-Moscow, 87–106, 327–329. [in Russian, English abstract]
- Povolný D (1964) Gnorimoschemini trib. nov. eine neue Tribus der Familie Gelechiidae nebst Bemerkungen zu ihrer Taxonomie (Lepidoptera). Acta entomologica bohemoslovaca 61: 330–359. [3 pls]
- Povolný D (1966) Die taxonomisch geklärten palaearktischen Gnorimoschema-Arten (Lep., Gel.) nebst Beschreibung einer neuen Art. Arkiv för Zoologi 18(15): 393–404. [pls 1–11]
- Povolný D (1967) Genitalia of some nearctic and neotropic members of the tribe Gnorimoschemini (Lepidoptera, Gelechiidae). Acta entomologica Musei Nationalis Pragae 37: 51–127.
- Povolný D (1984) Drei neue Arten des tribus Gnorimoschemini (Lepidoptera, Gelechiidae) aus Asien. Nota lepidopterologica 7(3): 264–270.

- Povolný D (1992) A critical review of the Palaearctic taxa of Gnorimoschema Busck (Lepidoptera, Gelechiidae). Acta entomologica bohemoslovaca 89: 217–233.
- Povolný D (1994) New taxa and records of *Gnorimoschema* Busck and *Gobipalpa* Povolný from Palearctic Asia (Lepidoptera, Gelechiidae). Entomologica Fennica 5(1): 57–64.
- Povolný D (1998) New taxa and new faunistic records of the tribe Gnorimoschemini from Nearctic Region (Lepidoptera, Gelechiidae). Stapfia 55: 327–347.
- Povolný D (2002) Iconographia tribus Gnorimoschemini (Lepidoptera, Gelechiidae) Regionis Palaearcticae. František Slamka Publ., Bratislava, 110 pp. [16 colour pls, 87 pls]
- Povolný D, Šustek Z (1988) Versuch einer numerisch-taxonomischen Lösung der phylogenetischen Beziehungen im Rahmen der gelechioiden Tribus Gnorimoschemini (Lepidoptera). Stapfia 16: 209–247.
- Powel JA, Povolný D (2001) Gnorimoschemine moths of costal dune and scrub habitats in California (Lepidoptera: Gelechiidae). Holarctic Lepidoptera 8 (Suppl. 1): 1–51.
- Ratnasingham S, Hebert PDN (2007) BOLD: The Barcode of Life Data System (http://www. barcodinglife.org). Molecular Ecology Notes 7: 355–364. https://doi.org/10.1111/j.1471-8286.2007.01678.x
- Ratnasingham S, Hebert PDN (2013) A DNA-based registry for all animal species: the Barcode Index Number (BIN) system. PLoS ONE 8: e66213. https://doi.org/10.1371/journal.pone.0066213
- Tamura K, Stecher G, Peterson D, Filipski A, Kumar S (2013) MEGA6: Molecular Evolutionary Genetics Analysis version 6.0. Molecular Biology and Evolution 30: 2725–2729. https://doi.org/10.1093/molbev/mst197

RESEARCH ARTICLE



Amphibians of Santa Teresa, Brazil: the hotspot further evaluated

Rodrigo Barbosa Ferreira^{1,2}, Alexander Tamanini Mônico^{1,3}, Emanuel Teixeira da Silva^{4,5}, Fernanda Cristina Ferreira Lirio¹, Cássio Zocca^{1,3}, Marcio Marques Mageski¹, João Filipe Riva Tonini^{6,7}, Karen H. Beard², Charles Duca¹, Thiago Silva-Soares³

1 Programa de Pós-Graduação em Ecologia de Ecossistemas, Universidade Vila Velha, Campus Boa Vista, 29102-920, Vila Velha, ES, Brazil 2 Department of Wildland Resources and the Ecology Center, Utah State University, Logan, UT, USA 3 Instituto Nacional da Mata Atlântica/Museu de Biologia Prof. Mello Leitão, 29650-000, Santa Teresa, ES, Brazil 4 Laboratório de Herpetologia, Departamento de Zoologia, Instituto de Ciências Biológicas, Universidade Federal de Minas Gerais, Avenida Antônio Carlos, 6627, Pampulha, Belo Horizonte, MG, Brazil 5 Centro de Estudos em Biologia, Centro Universitário de Caratinga, Avenida Niterói, s/n, Bairro Nossa Senhora das Graças, 35300-000, Caratinga, MG, Brazil 6 Department of Organismic and Evolutionary Biology, Harvard University, 26 Oxford St, Cambridge, MA, USA 7 Museum of Comparative Zoology, Harvard University, 26 Oxford St, Cambridge, MA, USA

Corresponding author: Rodrigo Barbosa Ferreira (rodrigoecologia@yahoo.com.br)

Academic editor: A. Cr	rottini Received 4 October 2018 Accepted 20 April	2019 Published 25 June 2019
		42CC1

Citation: Ferreira RB, Mônico AT, da Silva ET, Lirio FCF, Zocca C, Mageski MM, Tonini JFR, Beard KH, Duca C, Silva-Soares T (2019) Amphibians of Santa Teresa, Brazil: the hotspot further evaluated. ZooKeys 857: 139–162. https://doi.org/10.3897/zookeys.857.30302

Abstract

A checklist of the amphibians of Santa Teresa municipality, in southeastern Brazil is presented based on fieldwork, examination of specimens in collections, and a literature review. This new amphibian list of Santa Teresa includes 108 species, of which 106 (~98%) belong to Anura and two (~2%) to Gymnophiona. Hylidae was the most represented family with 47 species (43%). Compared to the previous amphibian lists for Santa Teresa, 14 species were added, 17 previously reported species were removed, and 13 species were re-identified based on recent taxonomic rearrangements. Of the 14 species added, 11 (79%) were first recorded during our fieldwork and specimen examination. It is also the first list of caecilians for Santa Teresa. This list suggests that Santa Teresa has 0.16 species per km² (i.e., 108 species/683 km²), one of the highest densities of amphibian species in the world at a regional scale. This richness represents 78% of the

136 anurans from Espírito Santo state and 10% of the 1,080 amphibians from Brazil. We highlight the need for long-term monitoring to understand population trends and develop effective conservation plans to safeguard this remarkable amphibian richness.

Keywords

Anura, Atlantic Forest, Caecilians, Diversity, Espírito Santo, Inventory

Introduction

Species checklists provide a scientific value to areas by identifying the richness that is threatened given anthropogenic actions. The Brazilian Amphibian Conservation Action plan recognizes that species lists are a scientific priority for many areas across Brazil (Verdade et al. 2012). For instance, Brazil's Atlantic Forest is one of the most threatened global biodiversity hotspots and remains under-sampled given the high number of new species recently described (Lourenço-de-Moraes et al. 2014, Ferreira et al. 2015, Marciano-Jr et al. 2017). The Atlantic Forest has currently 12% of its historical range, which has resulted in the replacement of continuous forest to small remnants surrounded by human settlements, pastures, plantations, and roads (Ribeiro et al. 2009, Tabarelli et al. 2010). Thus, compiling data regarding the biodiversity of this tropical forest is a conservation priority, especially because several studies have detected changes and declines of some species (Heyer et al. 1988, Weygoldt 1989, Carvalho et al. 2017).

The Atlantic Forest harbors 625 anuran species and 14 caecilians (Rossa-Feres et al. 2017). The state of Espírito Santo, southeastern Brazil harbors 136 (22%) species listed for Atlantic Forest. The state's most sampled area is the municipality of Santa Teresa, which comprises high functional and phylogenetic diversity of amphibians (Almeida et al. 2011, Campos et al. 2017, Lourenço-de-Moraes et al. 2019). There are conflicting reports regarding the species composition and richness in this area. The first species list for Santa Teresa recorded 102 anuran species (Rödder et al. 2007). However, the state list of anurans mentioned 92 species for Santa Teresa (Almeida et al. 2011). In recent years, new species have been described for Santa Teresa (e.g., Lourenço-de-Moraes et al. 2014, Ferreira et al. 2015, Taucce et al. 2018), some species have been reported for the first time in the area (Simon and Peres 2012), and there have been many taxonomic changes (e.g., Pimenta et al. 2014, Walker et al. 2016), indicating the need to update the species list of this anuran diversity hotspot.

Santa Teresa is also a hotspot for several other taxa, such as plants (Thomaz and Monteiro 1997), birds (Simon 2000), butterflies (Brown and Freitas 2000), and small mammals (Passamani et al. 2000). Due to its remarkable biological importance, it is essential to keep the species lists updated. Here, we present an updated species list of the amphibians for Santa Teresa based on many years of fieldwork, examination of specimens from scientific collections, and literature review.

Materials and methods

Study area

The municipality of Santa Teresa has 683 km² and is located in the mountainous region (altitude range: ~120–1099 m a.s.l.) of Espírito Santo state, southeastern Brazil (19°56'14"S, 40°35'52"W; Figure 1). Santa Teresa encompasses the southern portion of Bahia Coastal Forests ecoregion, and northern portion of Serra do Mar ecoregion in the Atlantic Forest (Olson et al. 2001, Scaramuzza et al. 2011, Campos and Lourençode-Moraes 2017, Silva et al. 2018).

The predominant vegetation types are montane and sub-montane rainforests (Rizzini 1979), characterized by non-deciduous trees with lead buds without protection against drought (Brasil 1983). Santa Teresa was mostly forested until the arrival of European settlers in 1874. Currently, the municipality has 42% of its original forest cover inside and surrounding three protected areas: the Reserva Biológica Augusto Ruschi (3,598 ha), the Estação Biológica de Santa Lúcia (440 ha), and the Parque Natural de São Lourenço (22 ha) (SOS Mata Atlântica and Inpe 2013). Outside these protected areas, forest remnants are in private properties and mostly restricted to hilltops while the valleys are dominated by different types of human-modified matrix (e.g., coffee plantations, *Eucalyptus* spp. plantations, abandoned pastures, and settlements; Ferreira et al. 2016).

The climate of Santa Teresa is classified as oceanic climate without dry season and with temperate summer (Cfb) according to Köppen classification (Alvares et al. 2013). Mean annual precipitation is 1,868 mm with highest rainfall in November and lowest in June, when the mean rainfall is less than 60 mm (Mendes and Padovan 2000). Mean annual temperature is 20 °C (range: 14.3–26.2 °C, Thomaz and Monteiro 1997).

Data sampling

The species list presented in this study has been compiled in part using field surveys conducted by the authors from 2006 to 2019, and also through the evaluation of specimens in zoological collections (see Appendix I) and a literature review.

During field surveys, we conducted intensive sampling across Santa Teresa using audio and visual searches inside bromeliads, in the leaf litter, and in water bodies (see Dodd 2010). We released easily identified and extensively vouchered (> 30 specimens) species but took those species with more complex identification back to laboratory. To do this, we kept amphibians in moist plastic tubes or plastic bags to prevent dehydration. Some specimens were euthanized by ventral application of 7.5% to 20% benzocaine, preserved using 10% formalin and then transferred to 70% ethanol (American and Veterinary Medical Association 2013, CEBEA/CFMV 2013).

We also reviewed the literature and compiled records of amphibians for Santa Teresa. In addition, we examined specimens deposited in the following institutions:



Figure 1. Location of the municipality of Santa Teresa, southeastern Brazil. Forest remnants from SOS Mata Atlântica (2014).

Coleção de Anfíbios Célio F. B. Haddad (CFBH), Universidade Estadual Paulista (UN-ESP); Museu de Biologia Mello Leitão (MBML), Instituto Nacional da Mata Atlântica (INMA); Universidade Federal de Minas Gerais (UFMG); Museu Nacional, Universidade Federal do Rio de Janeiro (MNRJ); Museu de Zoologia Prof. Adão José Cardoso (ZUEC), Universidade Estadual de Campinas (UNICAMP); Museu de Zoologia, Universidade de São Paulo (MZUSP); and Smithsonian National Museum of Natural History (USNM) (see Appendix I). We followed Frost (2019) for taxonomic arrangements.

Results

We recorded 108 amphibian species for Santa Teresa, of which 106 (98%) belong to Anura (16 families and 41 genera) and two (2%) to Gymnophiona (one family and one genus) (Table 1; Figure 2, 3, 4, 5, 6, 7). The most represented families were Hylidae

Table 1. Amphibian species of Santa Teresa municipality, Espírito Santo state, Southeastern Brazil. Anasterisk * indicates a taxonomic change.

Species by Family	Туре	Our	Almeida	Rödder
· · ·	locality	study	et al. 2011	et al. 2007
AROMOBATIDAE				
Allobates capixaba (Lutz, 1925)		Х	Х	X*
BRACHYCEPHALIDAE				
Brachycephalus alipioi Pombal & Gasparini, 2006		Х	Х	-
Brachycephalus aff. didactylus		Х	-	-
Ischnocnema abdita Canedo & Pimenta, 2010	Х	Х	Х	_
Ischnocnema colibri Taucce, Canedo, Parreiras, Drummond, Nogueira-	Х	Х	-	-
Costa & Haddad, 2018				
Ischnocnema epipeda (Heyer, 1984)	Х	Х	Х	Х
Ischnocnema aff. guentheri		Х	X*	X*
Ischnocnema cf. nasuta (Lutz, 1925)		Х	X*	X*
Ischnocnema oea (Heyer, 1984)	Х	Х	Х	Х
Ischnocnema aff. parva sp. 1		Х	X*	X*
Ischnocnema aff. parva sp. 2		Х	_	_
Ischnocnema verrucosa Reinhardt & Lütken, 1862		Х	Х	Х
BUFONIDAE				
Dendrophryniscus carvalhoi Izecksohn, 1994	Х	Х	Х	Х
Rhinella crucifer (Wied-Neuwied, 1821)		Х	Х	Х
Rhinella granulosa (Spix, 1824)		Х	Х	Х
Rhinella diptycha (Cope, 1862)		Х	Х	Х
CENTROLENIDAE				
Vitreorana aff. eurygnatha		Х	X*	X*
Vitreorana uranoscopa (Müller, 1924)		Х	Х	Х
CERATOPHRYIDAE				
Ceratophrys aurita (Raddi, 1823)		Х	Х	X*
CRAUGASTORIDAE				
Euparkerella tridactyla Izecksohn, 1988	Х	Х	Х	Х
Haddadus binotatus (Spix, 1824)		Х	Х	Х
CYCLORAMPHIDAE				
Cycloramphus fuliginosus Tschudi, 1838		Х	Х	Х
Thoropa aff. lutzi		Х	X*	-
Thoropa miliaris (Spix, 1824)		Х	Х	Х
Thoropa petropolitana (Wandolleck, 1907)		Х	Х	_
Zachaenus carvalhoi Izecksohn, 1983	Х	Х	Х	Х
ELEUTHERODACTYLIDAE				
Adelophryne glandulata Lourenço-de-Moraes, Ferreira, Fouquet & Bastos,	Х	Х	X*	-
2014				
HEMIPHRACTIDAE				
Fritziana aff. fissilis		Х	X*	X*
Fritziana tonimi Walker, Gasparini, Haddad, 2016	Х	Х	X*	X*
Gastrotheca albolineata (Lutz & Lutz, 1939)		Х	Х	_
Gastrotheca ernestoi Miranda-Ribeiro, 1920		Х	-	_
Gastrotheca megacephala Izecksohn, Carvalho-e-Silva & Peixoto, 2009		Х	_	_

Species by Family	Туре	Our	Almeida	Rödder
	locality	study	et al. 2011	et al. 2007
HYLIDAE				
Aparasphenodon brunoi Miranda-Ribeiro, 1920		Х	-	Х
Aplastodiscus cavicola (Cruz & Peixoto, 1985)	Х	Х	Х	Х
Aplastodiscus aff. eugenioi		Х	_	_
Aplastodiscus weygoldti (Cruz & Peixoto, 1987)	Х	Х	Х	Х
Boana albomarginata (Spix, 1824)		Х	Х	Х
Boana albopunctata (Spix, 1824)		Х	Х	Х
Boana crepitans (Wied-Neuwied, 1824)		Х	Х	Х
Boana faber (Wied-Neuwied, 1821)		Х	Х	Х
Boana pardalis (Spix, 1824)		Х	Х	Х
Boana polytaenia (Cope. 1870)		Х	Х	_
Boana semilineata (Spix, 1824)		X	X	Х
Bokermannohula caramaschii (Napoli 2005)	x	x	X	X
Dendrotsophus berthalutzae (Bokermann 1962)	71	x	x	x
Dendropsophus berunatatus (Spix 1824)		v	X V	X V
Dendropsophies orpunctures (Spix, 1824)		л V	л v	л v
Denaropsoprus oranneri (Cochran, 1948)	v	A V	Λ	Λ
Denaropsophus bromeuaceus Ferreira, Faivovich, Beard & Pombai, 2013	А	A	V	V
Dendropsophus decipiens (Lutz, 1925)		X	X	X
Dendropsophus elegans (Wied-Neuwied, 1824)		X	X	X
Dendropsophus giesleri (Mertens, 1950)		Х	Х	Х
Dendropsophus haddadi (Bastos & Pombal, 1996)		Х	Х	Х
Dendropsophus microps (Peters, 1872)		Х	Х	Х
Dendropsophus minutus (Peters, 1872)		Х	Х	Х
Dendropsophus ruschii (Weygoldt & Peixoto, 1987)		Х	Х	Х
Dendropsophus seniculus (Cope, 1868)		Х	Х	Х
Itapotihyla langsdorffii (Duméril & Bibron, 1841)		Х	Х	Х
Ololygon arduous (Peixoto, 2002)	Х	Х	Х	Х
Ololygon argyreornata (Miranda-Ribeiro, 1926)		Х	Х	Х
Ololygon cf. flavoguttata (Lutz & Lutz, 1939)		Х	-	_
Ololygon aff. heyeri		Х	_	_
Ololygon heyeri Peixoto & Weygoldt, 1986	Х	Х	Х	Х
Ololygon kautskyi Carvalho-e-Silva & Peixoto, 1991		Х	Х	Х
Phasmahyla exilis (Cruz, 1980)	Х	Х	Х	Х
Phrynomedusa marginata (Izecksohn & Cruz, 1976)	Х	Х	Х	Х
Phyllodytes kautskyi Peixoto & Cruz, 1988		х	_	_
Phyllodytes luteolus (Wied-Neuwied, 1824)		X	х	х
Phyllodytes aff luteolus		x	_	_
Phyllomeduse hurmeisteri Boulenger 1882		x	x	x
Dithecapus off rahdai		v	X*	X*
Soin an alter (Luta 1973)		v	X V	X V
Science sustidates (Lutz, 1975)		v	v	v
Scinax cuspitatus (Lutz, 1923)		л v	A V	A V*
Scinux euryauce (Dokermann, 1908)		A V	A V	A [*] V
Scinax juscovarius (Lutz, 1925)		X	X	Å V*
Scinax hayii (Barbour, 1909)		X	Х	Х*
Scinax att. perereca		Х	-	-
Scinax ct. x-signatus (Spix, 1824)		Х	Х	Х
Species by Family	Туре	Our	Almeida	Rödder
---	----------	-------	-------------	-------------
	locality	study	et al. 2011	et al. 2007
Trachycephalus mesophaeus (Hensel, 1867)		Х	Х	Х
Trachycephalus nigromaculatus Tschudi, 1838		Х	Х	Х
HYLODIDAE				
Crossodactylus aff. gaudichaudii		Х	Х	X*
Crossodactylus timbuhy Pimenta, Cruz & Caramaschi, 2014	Х	Х	X*	X*
Hylodes cf. babax Heyer, 1982		Х	X*	X*
Hylodes lateristrigatus (Baumann, 1912)		Х	Х	Х
Megaelosia apuana Pombal, Prado & Canedo, 2003		Х	Х	X*
LEPTODACTYLIDAE				
Crossodactylodes bokermanni Peixoto, 1983	Х	Х	Х	Х
Crossodactylodes izecksohni Peixoto, 1983	Х	Х	Х	Х
Leptodactylus cupreus Caramaschi, Feio & São Pedro, 2008		Х	Х	-
Leptodactylus fuscus (Schneider, 1799)		Х	Х	Х
Leptodactylus aff. latrans (Steffen, 1815)		Х	X*	X*
Leptodactylus aff. spixi		Х	X*	X*
Physalaemus crombiei Heyer & Wolf, 1989	Х	Х	Х	Х
Physalaemus cuvieri Fitzinger, 1826		Х	Х	Х
Physalaemus maculiventris (Lutz, 1925)		Х	Х	-
Physalaemus cf. olfersii (Lichtenstein & Martens, 1856)		Х	X*	X*
MICROHYLIDAE				
Chiasmocleis capixaba Cruz, Caramaschi & Izecksohn, 1997		Х	-	-
Chiasmocleis schubarti Bokermann, 1952		Х	-	Х
Myersiella microps (Duméril & Bibron, 1841)		Х	Х	Х
ODONTOPHRYNIDAE				
Macrogenioglottus alipioi Carvalho, 1946		Х	Х	Х
Proceratophrys boiei (Wied-Neuwied, 1824)		Х	Х	Х
Proceratophrys laticeps Izecksohn & Peixoto, 1981		Х	Х	Х
Proceratophrys moehringi Weygoldt & Peixoto, 1985	Х	Х	Х	Х
Proceratophrys paviotii Cruz, Prado & Izecksohn, 2005	Х	Х	Х	Х
Proceratophrys phyllostomus Izecksohn, Cruz & Peixoto, 1999		Х	Х	Х
Proceratophrys schirchi (Miranda-Ribeiro, 1937)		Х	Х	Х
PIPIDAE				
Pipa aff. carvalhoi		Х	X*	X*
RANIDAE				
Lithobates catesbeianus (Shaw, 1802)		Х	-	-
SIPHONOPIDAE				
Siphonops annulatus (Mikan, 1822)		Х	_	_
Siphonops hardyi Boulenger, 1888		Х	-	-

with 47 species (43%), Brachycephalidae with 11 species (10%), and Leptodactylidae with 10 species (9%). Santa Teresa is currently the type locality for 23 species (20%) (Table 1). So far, four species (3%) are only found in Santa Teresa such as *Crossodactylodes izecksohni*, *Crossodactylus timbuhy*, *Ischnocnema colibri* and *Ischnocnema epipeda*. The species density of Santa Teresa is 0.16 species per km² (i.e., 108 species/683 km²).



Figure 2. Amphibians from Santa Teresa: A Allobates capixaba B Brachycephalus alipioi C Ischnocnema abdita D Ischnocnema colibri E Ischnocnema cf. nasuta F Ischnocnema aff. guentheri G Ischnocnema oea H Ischnocnema gr. parva sp. new 1 I Ischnocnema gr. parva sp. new 2 J Ischnocnema verrucosa K Dendrophryniscus carvalhoi L Rhinella crucifer M Rhinella granulosa N Rhinella diptycha O Vitreorana aff. eurygnatha. Photographs by JFR Tonini (A), CN Fraga (B), RB Ferreira (C, D, H, I, K), AT Mônico (E, G, J, K, L, M, N, O), T Silva-Soares (F).



Figure 3. Amphibians from Santa Teresa: A Vitreorana uranoscopa B Euparkerella tridactyla C Haddadus binotatus D Thoropa miliaris E Zachaenus carvalhoi F Adelophryne glandulata G Fritziana aff. fissilis H Fritziana tonimi I Gastrotheca megacephala J Aparasphenodon brunoi K Aplastodiscus cavicola L Aplastodiscus aff. eugenioi M Aplastodiscus weygoldti N Boana albomarginata O Boana albopunctata. Photographs by AT Mônico (A, C, D, G, H, K, L, O), RB Ferreira (B, E, F, I, N), C Zocca (J), T Silva-Soares (M).



Figure 4. Amphibians from Santa Teresa: A Boana crepitans B Boana faber C Boana pardalis D Boana polytaenia E Boana semilineata F Bokermannohyla caramaschii G Dendropsophus berthalutzae H Dendropsophus bipunctatus I Dendropsophus branneri J Dendropsophus bromeliaceus K Dendropsophus decipiens L Dendropsophus elegans M Dendropsophus giesleri N Dendropsophus haddadi O Dendropsophus microps.
Photographs by AT Mônico (A, C, D, E, F, H, L, M, N, O), RB Ferreira (B, G, I, J), ET Silva (K).



Figure 5. Amphibians from Santa Teresa: A Dendropsophus minutus B Dendropsophus ruschii C Dendropsophus seniculus D Itapotihyla langsdorffii E Ololygon arduous F Ololygon argyreornata G Ololygon heyeri
H Ololygon kautskyi I Pithecopus aff. rohdei J Phasmahyla exilis K Phyllomedusa burmeisteri L Phyllodytes kautskyi M Phyllodytes luteolus N Phyllodytes aff. luteolus O Scinax alter. Photographs by RB Ferreira (A, D, J), AT Mônico (B, C, E, F, G, I, K, N, O), T Silva-Soares (H), CZ Zocca (L, M).



Figure 6. Amphibians from Santa Teresa: A Scinax cuspidatus B Scinax eurydice C Scinax fuscovarius D Scinax hayii E Scinax aff. perereca F Scinax cf. x-signatus G Trachycephalus mesophaeus H Trachycephalus nigromaculatus I Crossodactylus aff. gaudichaudii J Crossodactylus timbuhy K Hylodes lateristrigatus L Crossodactylodes bokermanni M Crossodactylodes izecksohni N Leptodactylus cupreus O Leptodactylus fuscus. Photographs by ET Silva (A, E, F), CZ Zocca (B, O), T Silva-Soares (C), AT Mônico (D, I, K, L), RB Ferreira (G, H, J, M), JFR Tonini (N).



Figure 7. Amphibians from Santa Teresa: A Leptodactylus aff. latrans B Leptodactylus aff. spixi C Physalaemus crombiei D Physalaemus cuvieri E Physalaemus maculiventris F Chiasmocleis capixaba G Chiasmocleis schubarti H Myersiella microps I Proceratophrys boiei J Proceratophrys laticeps K Proceratophrys paviotii L Proceratophrys schirchi M Pipa aff. carvalhoi N Siphonops annulatus O Siphonops hardyi. Photographs by T Silva-Soares (A, B, L, M, N), AT Mônico (C, D, E, G, H, J, K), RB Ferreira (F, I, O).

Compared to previous anuran lists for Santa Teresa, we added 14 species, removed 17 previously reported species, and re-determined 14 species based on recent taxonomic rearrangements. Out of the 14 added species, 11 (79%) were first recorded during our fieldwork and specimen examination, two (14%) records were from the literature, and one (7%) new record was from pers. comm. (*Gastrotheca ernestoi*; MT Rodrigues, field number MTR 34695).

Fourteen species classified to morphotypes are new species, such as *Aplastodiscus* aff. *eugenioi* (M Mongin, pers. comm.), *Brachycephalus* aff. *didactylus* (TSS, in. prep.), *Crossodactylus* aff. *gaudichaudii* (R Montesinos, in. prep.), *Fritziana* aff. *fissilis* (RBF, pers. obs.), *Ischnocnema* aff. *parva* sp. 1 (CAG Cruz, in. prep.), *Ischnocnema* aff. *parva* sp. 2 (TSS, in. prep.), *Leptodactylus* aff. *spixi* (L Nascimento, in. prep.), *Ololygon* aff. *heyeri* (J Lacerda, pers. comm.), *Phyllodytes* aff. *luteolus* (ATM, in. prep.), *Pipa* aff. *carvalhoi* (PV Scherrer, in. prep.), *Pithecopus* aff. *lutzi* (CL Assis, pers. comm.), and *Vitreorana* aff. *eurygnatha* (R Pontes, in. prep.).

Discussion

The current number of 106 anuran species for Santa Teresa is remarkable, and represents 78% of the 136 species listed for Espírito Santo state (Almeida et al. 2011, Rossa-Feres et al. 2017), 10% of the 1,080 species listed for Brazil (Segalla et al. 2016), and 1.5% of the 7,068 species listed worldwide (AmphibiaWeb 2019). To date, the species density (i.e., 0.16 species per km²) is one of the highest in the world at regional scale. For instance, Yasuní National Park in Ecuador has 0.015 species per km² (i.e., 150 species/9,820 km²; Bass et al. 2010); Tambopata in southern Peru has 0.06 species per km² (i.e., 99 species/1,600 km²; Doan and Arriaga 2002); Iquitos region of northern Loreto in Peru has 0.012 species per km² (i.e., 141 species/11,310 km²; IUCN 2008, Rodríguez and Duellman 1994); and Leticia in Colombia has 0.13 species per km² (i.e., 123 species/927 km²; Lynch 2005). Several other localities across the Atlantic Forest also have remarkable amphibian richness at local scales. For example, Reserva Biológica de Paranapiacaba in Sao Paulo state has 20.5 species per km² (69 species/3.36 km²; Verdade et al. 2009); Fazenda Vista Bela in Bahia state has 7.3 species per km² (34 species/4.65 km²; Silvano and Pimenta 2003); and Reserva Particular do Patrimônio Natural Serra Bonita has 4 species per km² (80 species/20 km²; Dias et al. 2014). We acknowledge that amphibian richness per area represents just a first approximation for practical spatial comparisons and that the lack of adequate surveys in more unexplored diverse regions (e.g., Indonesia, New Guinea, and the Congo Basin) may reveal remarkable amphibian richness. So far, Brazil's Atlantic Forest and the northwest Amazon are considered the world's greatest amphibian diversity on a landscape scale (Young et al. 2004, Bass et al. 2010).

The two species of Gymnophiona (*Siphonops annulatus* and *S. hardyi*) were found during our fieldwork but have been reported previously for Santa Teresa (Caramaschi

et al. 2004, Maciel et al. 2009). The former has a wide distribution in South America from Colombia to Argentina (Frost 2018). The latter has a more restricted distribution in southeastern of Brazil (Maciel et al. 2009, Frost 2018). Caecilians are difficult to sample due to the subterranean or aquatic habits (Oommen et al. 2000, Maciel and Hoogmoed 2011). Although amphibians are dramatically declining (Stuart et al. 2004), the conservation status of caecilians is largely unknown due to the lack of information on their biology, ecology and natural history (Wilkinson and Nussbaum 1999, Oommen et al. 2000, Gower and Wilkinson 2005). It is likely more species of caecilians will be recorded in Santa Teresa if the use of sampling methods specific for these taxa is applied in the field.

Our fieldwork since 2005 in Santa Teresa has made notable contributions toward the knowledge of local amphibians. It has resulted in the description of three new species for the municipality (i.e., *Adelophryne glandulata* in Lourenço-de-Moraes, Ferreira, Fouquet, Bastos 2014, *Dendropsophus bromeliaceus* in Ferreira, Faivovich, Beard, Pombal 2015, and *Ischnocnema colibri* in Taucce, Canedo, Parreiras, Drummond, Nogueira-Costa, Haddad 2018). Furthermore, our fieldwork found individuals of 13 morphospecies that are currently under formal description (i.e., *Aplastodiscus* aff. *eugenioi, Brachycephalus* aff. *didactylus, Crossodactylus* aff. *gaudichaudii, Fritziana* aff. *fissilis, Ischnocnema* aff. *parva* sp. 1, *Ischnocnema* aff. *parva* sp. 2, *Leptodactylus* aff. *spixi, Ololygon* aff. *heyeri, Phyllodytes* aff. *luteolus, Pipa* aff. *carvalhoi, Pithecopus* aff. *rohdei, Scinax* aff. *perereca*, and *Vitreorana* aff. *eurygnatha*). The discovery of new species, morphospecies, and new records for Santa Teresa may be due to our sampling in remote forested areas and rocky outcrops through both visual bromeliad surveys and active leaf-litter searches (Ferreira et al. 2016).

Our species list resolved some differences between the previous species lists of Santa Teresa, which had disagreements on 11 species (e.g., Rödder et al. 2007, Almeida et al. 2011). We confirmed that Chiasmocleis schubarti occurs in Santa Teresa based on several individuals sampled in the Reserva Biológica Augusto Ruschi, whereas Almeida et al. (2011) challenged previous records of this species listed in Cruz et al. (1997) and Rödder et al. (2007). We also confirmed the presence of Aparasphenodon brunoi and Trachycephalus nigromaculatus reported in Santa Teresa at the buffer zone of the Parque Municipal do Goiapaba-Açu (Ramos and Gasparini 2004). Almeida et al. (2011) challenged the record of Rhinella hoogmoedi referring to the species as Rhinella gr. margaritifer, because the former species was not mentioned in Rödder et al. (2007). We agree with Almeida et al. (2011) regarding the exclusion of several species from Rödder et al. (2007), such as Bokermannohyla aff. nanuzae (MBML 4528 corresponds to B. caramaschii), Dendrophryniscus sp. (MBML 3841 corresponds to D. carvalhoi), Ischnocnema cf. juipoca (MBML 5737 corresponds to I. abdita), I. lactea (MBML 1143 corresponds to I. abdita), Physalaemus aguirrei (MBML 2803-04 correspond to P. cf. olfersii), and Proceratophrys appendiculata (MBML 1154 corresponds to P. schirchii). Rödder et al. (2007) and Almeida et al. (2011) listed Leptodactylus natalensis for Santa Teresa but the voucher specimens (MBML 3909-10) were misidentified and actually refer to individuals of L. aff. spixi. Rödder et al. (2007) listed Allobates cf. olfersioides

following Verdade and Rodrigues (2007) who placed *A. capixaba* as synonym of *A. olfersioides*. Studies on *Allobates* indicate *A. capixaba* is a valid taxon (e.g., Bokermann 1967; Forti et al. 2017), which agrees with Almeida et al. (2011). Fieldwork should be conducted in the vicinities of Santa Teresa to confirm the presence of *Brachycephalus alipioi*. This species has not been found in Santa Teresa since 1952 when the municipality was larger than it is today (Pombal and Gasparini 2006).

The wide elevational range of Santa Teresa (~120–1099 m a.s.l.) partially explains the high richness of amphibian species. Species typical of both Atlantic Forest lowlands (e.g., Allobates capixaba, Chiasmocleis schubarti, C. capixaba, Dendropsophus bipunctatus, Ololygon argyreornata) and highlands (e.g., Aplastodiscus cavicola, Bokermannohyla caramaschii, Dendropsophus ruschii) occur in Santa Teresa, which suggest that the elevational gradient influences species composition. The high amphibian diversity also may be related to edaphic and topographic heterogeneity, which is known to cause speciation in many Atlantic Forest species occurring in mountainous areas (Carnaval et al. 2014). The high altitude and proximity to the Atlantic Ocean favors frequent orographic rain, which contribute to the meeting the reproductive requirements of amphibians. It is worth highlighting that Santa Teresa is one of the most sampled regions for amphibians in the Atlantic Forest (Rödder et al. 2007, Almeida et al. 2011, Zocca et al. 2014, Ferreira et al. 2016). About 3,800 anuran specimens collected in Santa Teresa were found housed in Brazilian collections (ET Silva, pers. obs.). This high sampling effort, which is comparable to only a few localities in the Atlantic Forest, may also account for such high species richness.

Conservation remarks

Amphibians from Santa Teresa have faced several anthropogenic disturbances over the last couple of decades. The first report on amphibian declines for Santa Teresa was in 1989 (see Weygoldt 1989). During long-term sporadic samplings (i.e., 1975 and 1988), Weygoldt (1989) reported the decline and possible disappearances of eight species (updated taxonomy: Allobates capixaba, Crossodactylus aff. gaudichaudii, C. timbuhy, Cycloramphus fuliginosus, Hylodes lateristrigatus, H. cf. babax, Phasmahyla exilis, and Vitreorana aff. eurygnatha). To our knowledge, Cycloramphus fuliginosus and Hylodes cf. babax have not been recorded after Weygoldt (1989). Additionally, Thoropa petropolitana, a frog not mentioned by Weygoldt (1989) has disappeared with no recent records along its entire range (Haddad et al. 2016). Several potential causes of these declines were mentioned by Weygoldt (1989), such as pollution (acid rain and pesticides), long-term climatic changes, and epidemic diseases. Weygoldt (1986) mentioned that Crossodactylus cf. dispar (currently C. timbuhy) was rare in Santa Teresa and later reported its decline. However, during our surveys we easily found this species on creeks across Santa Teresa. We cannot assess whether species declines are actually happening in Santa Teresa because only long-term and species-specific studies can precisely understand population trends.

Over the decades, we have noted population disappearances of anurans in Santa Teresa. The construction of condominiums and vacation ranches has intensified over the last decade and consequently increased deforestation of primary forest. We have also observed the expansion of the non-native *Eucalyptus* spp. plantations near primary and secondary forests and the replacement of coffee plantations. Another unmeasured concern is the increasing record of morphological anuran deformities, which is likely a result of pesticides used on crops (e.g., Mônico et al. 2016), including inside the buffer zone of the largest forest reserve (i.e., Reserva Biológica Augusto Ruschi; pers. obs.). The report of the invasive frog, *Lithobates catesbeianus*, in Santa Teresa (see Ferreira and Lima 2012) should be further evaluated to monitor its establishment, and possible spread and impacts. We emphasize the need to sample the surroundings of the nearby breeding farms of *L. catesbeianus*. Studies have shown that non-native *L. catesbeianus* can be voracious predators of native anurans and vectors of diseases (Schloegel et al. 2010, Silva et al. 2011, Boelter et al. 2012).

The landscape configuration of Santa Teresa does not safeguard the maintenance of amphibian reproduction outside protected reserves because forests on private properties are mostly restricted to hilltops and non-natural matrix habitats occupy most valleys. Because water-body breeding species migrate toward reproductive habitats in the valleys, these species face severe threats, such as the risk of predation and desiccation (Becker et al. 2007, Ferreira et al. 2016). In addition, pollution of creeks and streams further strengthen conservation concern of lotic body breeders. We reinforce the need of studies focused on the threats amphibians are facing in the region to provide knowledge for conservationists and reserves managers to safeguard the local diversity.

Santa Teresa is an important hotspot for amphibian conservation due to its high richness and number of endemic species. The discovery of several new species further emphasizes the importance of this mountainous region for amphibian conservation. Even though Santa Teresa and its surrounding areas in southeastern Brazil are one of the most sampled regions in the Atlantic Forest, the region still harbors numerous remote areas that have not yet been sampled for frogs (e.g., Almeida et al. 2011). Forests on private properties are also important for preserving amphibian diversity in the area (Ferreira et al. 2016). In addition, private properties may function as forest corridors for dispersing and migrating species. We suggest that a program to stimulate the creation of private-owner reserves and ecotourism activities should be implemented in this region. Finally, we have been developing outreach activities (e.g., Bromeligenous Project) with the local farmers, aiming to minimize the anthropogenic effects on anurans. Nevertheless, there is a strong need for a long-term outreach program in the local schools and in the farmlands to protect these forest areas in the future.

Acknowledgements

We dedicated this manuscript to Rogério L Teixeira who was born and raised in Santa Teresa and dedicated decades sampling frogs and mentoring herpetologists. We thank

Bromeligenous Project for field support; landowners for allowing access to their properties; Instituto Nacional da Mata Atlântica for logistic support. We are grateful to Cecilia Waichert, Francys Lacchine, Gustavo Milanezi, Jandyra Zocca Zandomenico, Juliano Saich, Lamara P Barbosa, Namany Lourpen, Paulo R Jesus, Randerson LB Ferreira for field sampling. We especially thank Carlos A Cruz, Clarissa Canedo, Clodoaldo L Assis, Délio Baeta, Gustavo Prado, João V Lacerda, Juliana Kirchmeyer, Juliana Peres, Leo Malagoli, Marcele Mongin, Marco A Peixoto, Miguel Trefault Rodrigues, Paulo V Scherrer, Pedro Taucce, Rafael Pontes, Raquel Montesinos, and Victor Dill for discussions on species identification. Sampling permits were issued by Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio, permits 28607, 50402, and 63575) and Institutional Animal Care and Use Committee (IACUC-USU, permit 2002). RBF (0823/FCLF (001/1774502), and CZZ (001/1700071) thank Coordenação de Aperfeiçoamento Pessoal de Nível Superior - Brasil (CAPES) for scholarships. RBF, ATM, ETS and TSS thank Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq: 430195/2018, 304374/2016-4, 141569/2014-0, and 454789/2015-7) for scholarships. JFRT thanks CAPES/Science without Borders and David Rockefeller Center for Latin Studies/Harvard University for scholarships. This research was supported by the Utah Agricultural Experiment Station, Utah State University, and approved as journal paper number 9217 and by Harvard Open Access Equity Fund (HOPE).

References

- Almeida AP, Gasparini JL, Peloso PLV (2011) Frogs of the state of Espírito Santo, southeastern Brazil – The need for looking at the coldspots. CheckList 7(4): 542–560. https://doi. org/10.15560/7.4.542
- Alvares CA, Stape JL, Sentelhas PC, Gonçalves JLM, Sparoveck G (2013) Koppen's climate classification map for Brazil. Meteorologische Zeitschrift 22: 711–728. https://doi. org/10.1127/0941-2948/2013/0507
- American and Veterinary Medical Association (2013) Guidelines for the euthanasia of animals. AVMA, Schaumberg, IL.
- AmphibiaWeb (2019) University of California, Berkeley, CA. http://amphibiaweb.org [Accessed on 20 May 2019]
- Bass MS, Finer M, Jenkins CN, Kreft H, Cisneros-Heredia DF, McCracken SF, Pitman NCA, English PH, Swing K, Villa G, Fiore AD, Voigt CC, Kunz TH (2010) Global Conservation Significance of Ecuador's Yasuní National Park. PloS ONE 5: e8767. https://doi. org/10.1371/journal.pone.0008767
- Becker CG, Fonseca CR, Haddad CFB, Batista RF, Prado PI (2007) Habitat split and the global decline of amphibians. Science 318: 1775–1777. https://doi.org/10.1126/science.1149374
- Boelter RA, Kaefer IL, Both C, Cechin S (2012) Invasive bullfrogs as predators in a Neotropical assemblage: What frog species do they eat? Animal Biology 62: 397–408. https://doi. org/10.1163/157075612X634111

- Bokermann WCA (1967) Novas espécies de *Phyllobates* do leste e sudeste brasileiro (Anura, Dendrobatidae). Revista Brasileira de Biologia 27: 349–353.
- Brasil (1983) Departamento Nacional de Produção Mineral. Projeto RADAM. V32. Folhas SF23/24 Rio de Janeiro/Vitória, Rio de Janeiro.
- Brown KS Jr, Freitas AVL (2000) Atlantic Forest butterflies: indicators for landscape conservation. Biotropica 32: 934–956. https://doi.org/10.1111/j.1744-7429.2000.tb00631.x
- Campos FS, Lourenço-de-Moraes R, Llorente GA, Solé M (2017) Cost-effective conservation of amphibian ecology and evolution. Science Advances 3(6): e1602929. https://doi. org/10.1126/sciadv.1602929
- Campos FS, Lourenço-de-Moraes R (2017) Amphibians from the mountains of the Serra do Mar Coastal Forest, Brazil. Herpetology Notes 10: 547–560.
- Caramaschi U, Rodrigues MT, Carvalho-e-Silva SP, Cruz CAG (2004) *Siphonops hardyi*. IUCN Red List of Threatened Species. http://www.iucnredlist.org [Acessed on 17 April 2009]
- Carnaval AC, Waltari E, Rodrigues MT, Rosauer D, VanDerWal J, Damasceno R, Prates I, Strangas M, Spanos Z, Rivera D, Pie MR, Firkowski CR, Bornschein MR, Ribeiro LF, Moritz C (2014) Prediction of phylogeographic endemism in an environmentally complex biome. Proceedings of the Royal Society B. Biological Science 281: 20141461. https://doi. org/10.1098/rspb.2014.1461
- Carvalho T, Becker CG, Toledo LF (2017) Historical amphibian declines and extinctions in Brazil linked to chytridiomycosis. Proceedings of the Royal Society Biological Sciences 284: 20162254. https://doi.org/10.1098/rspb.2016.2254
- CEBEA/CFMV CdÉBeB-EA (2013) Guia brasileiro de boas práticas para eutanásia de animais. Conselho Federal de Medicina Veterinária do Brasil, Brasília, 62 pp.
- Cruz CAG, Caramaschi U, Izecksohn E (1997) The genus *Chiasmocleis* Méhely 1904 (Anura, Microhylidae) in the Atlantic Rain Forest of Brazil, with description of three new species. Alytes 15: 49–71.
- Dias I, Medeiros T, Vila Nova M, Solé M (2014) Amphibians of Serra Bonita, southern Bahia: a new hotpoint within Brazil's Atlantic Forest hotspot. ZooKeys 449: 105-130. https://doi. org/10.3897/zookeys.449.7494
- Doan TM, Arriaga WA (2002) Microgeographic variation in species composition of the herpetofaunal communities of Tambopata Region, Peru. Biotropica 34: 101–117. https://doi. org/10.1111/j.1744-7429.2002.tb00246.x
- Dodd Jr CK (2010) Diversity and similarity. In: Dodd Jr CK (Ed.) Amphibian Ecology and Conservation. A Handbook of Techniques, Oxford University Press, Oxford, 321–337.
- Ferreira RB, Faivovich J, Beard KH, Pombal JP (2015) The first bromeligenous species of *Den-dropsophus* (Anura, Hylidae) from Brazil's Atlantic Forest. PloS ONE 10: 1–21. https://doi.org/10.1371/journal.pone.0142893
- Ferreira RB, Lima C (2012) Anuran hotspot at Brazilian Atlantic rainforest invaded by the non-native *Lithobates catesbeianus* Shaw 1802 (Anura, Ranidae). North-Western Journal of Zoology 8: 386–389.
- Ferreira RB, Beard KH, Crump ML (2016) Breeding guild determines frog distributions in response to edge effects and habitat conversion in the Brazil's Atlantic Forest. PloS ONE 11: e0156781. https://doi.org/10.1371/journal.pone.0156781

- Forti LR, da Silva TRA, Toledo LF (2017) The acoustic repertoire of the Atlantic Forest Rocket Frog and its consequences for taxonomy and conservation (*Allobates*, Aromobatidae). ZooKeys 692: 141–153. https://doi.org/10.3897/zookeys.692.12187
- Frost DR (2018) Amphibian Species of the World: an Online Reference. Version 6.0. American Museum of Natural History, New York. http://research.amnh.org/herpetology/amphibia/ index.html [accessed on 15 August 2017]
- Gower DJ, Wilkinson M (2005) The conservation biology of caecilians. Conservation Biology 19: 45–55. https://doi.org/10.1111/j.1523-1739.2005.00589.x
- Haddad CFB, Segalla MV, Bataus YSL, Caramaschi U (2016) Avaliação do Risco de Extinção de *Thoropa petropolitana* (Wandolleck 1907). http://www.icmbio.gov.br/portal/faunabrasileira/ estado-de-conservacao/7521-anfibios-thoropa-petropolitana [Accessed on 17 April 2017]
- Heyer WR, Rand AS, Cruz CAG, Peixoto OL (1988) Decimations, extinctions, and colonizations of frog populations in Southeast Brazil and their evolutionary implications. Biotropica 20: 230–235. https://doi.org/10.2307/2388238
- IUCN (2008) Guidelines for using the IUCN red list categories and criteria. Version 11. Prepared by the Standards and Petitions Subcommittee. www.iucnredlist.org [accessed on 15 August 2017]
- Lourenço-de-Moraes R, Ferreira RB, Fouquet A, Bastos R (2014) A new diminutive frog of the genus *Adelophryne* Hoogmoed and Lescure 1984 (Amphibia, Anura, Eleutherodactylidae) from the Atlantic forest of Espírito Santo, Brazil. Zootaxa 3846: 348–360. https://doi.org/10.11646/zootaxa.3846.3.2
- Lourenço-de-Moraes R, Campos FS, Ferreira RB, Beard K, Solé M, Bastos RP (2019) Back to the future: the role of climatic refuges in amphibians hotspot Atlantic Forest. Biodiversity and Conservation 28(5):1049–1073. https://doi.org/10.1007/s10531-019-01706-x
- Lynch JD (2005) Discovery of the richest frog fauna in the world. An exploration of the forests to the North of Leticia. Revista de la Academia Colombiana de Ciencias Exactas, Físicas y Naturales 29: 581–588.
- Maciel AO, Santana DJ, da Silva ET, Feio RN (2009) Amphibia, Gymnophiona, Caeciliidae, Siphonops hardyi Boulenger 1888: Distribution extension, new state record and notes on meristic data. Check List 5: 919–921. https://doi.org/10.15560/5.4.919
- Maciel AO, Hoogmoed MS (2011) Taxonomy and distribution of caecilian amphibians (Gymnophiona) Of Brazilian Amazonia, with a key to their identification. Zootaxa 2984: 1–53. https://doi.org/10.11646/zootaxa.2984.1.1
- Marciano-Jr E, Lantyer-Silva ASF, Solé M (2017) A new species of *Phyllodytes* Wagler 1830 (Anura, Hylidae) from the Atlantic Forest of southern Bahia, Brazil. Zootaxa 4238: 135– 142. https://doi.org/10.11646/zootaxa.4238.1.11
- Mendes SL, Padovan MP (2000) A Estação Biológica de Santa Lúcia, Santa Teresa, Espírito Santo. Boletim Museu Biologia Mello Leitão 11/12: 7–34.
- Mônico AT, Ferreira RB, Lauvers WD, Mattos RO, Clemente Carvalho RBG (2016) *Itapoti-hyla langsdorffii* (Perereca castanhola; Ocellated Treefrog). Head Abnormality. Herpetological Review 47: 278–279.
- Olson DM, Dinerstein E, Wikramanayake ED, Burgess ND, Powell GVN, Underwood EC, D'amico JA, Itoua I, Strand HE, Morrison JC, Loucks CJ, Allnutt TF, Ricketts TH, Kura

Y, Lamoreux JF, Wettengel WW, Hedao P, Kassem KR (2001) Terrestrial ecoregions of the world: a new map of life on Earth. BioScience 51: 933–938. https://doi.org/10.1641/0006-3568(2001)051[0933:TEOTWA]2.0.CO;2

- Oommen VO, Measey GJ, Gower DJ, Wilkinson M (2000) Distribution and abundance of the caecilian *Gegeneophis ramaswamii* (Amphibia, Gymnophiona) in southern Kerala. Current Science 79: 1386–1389.
- Passamani M, Mendes SL, Chiarello AG (2000) Non-volant mammals of the Estação Biológica de Santa Lúcia and adjacents areas of Santa Teresa, Espírito Santo, Brazil. Boletim do Museu de Biologia Mello Leitão 11/12: 201–214.
- Pimenta BVS, Cruz CAG, Caramaschi U (2014) Taxonomic review of the species complex of *Crossodactylus dispar* Lutz 1925 (Anura, Hylodidae). Arquivos de Zoologia 45: 1–33. https://doi.org/10.11606/issn.2176-7793.v45i1p1-33
- Pombal Jr JP, Gasparini JL (2006) A new *Brachycephalus* (Anura, Brachycephalidae) from the Atlantic Rainforest of Espírito Santo, southeastern Brazil. South American Journal Herpetology 1: 87–93. https://doi.org/10.2994/1808-9798(2006)1[87:ANBABF]2.0.CO;2
- Ramos AD, Gasparini JL (2004) Anfíbios do Goiapaba-Açu. Gráfica Santo Antônio, Fundão, Brazil, 75 pp.
- Ribeiro MC, Metzger JP, Martensen AC, Ponzoni FJ, Hirota MM (2009) The Brazilian Atlantic forest: how much is left, and how is the remaining forest distributed? Implications for conservation. Biological Conservation 142: 1141–1153. https://doi.org/10.1016/j.biocon.2009.02.021
- Rizzini CT (1979) Tratado de Fitogeografia do Brasil: aspectos sociológicos e florísticos. Editora Hucitec Ltda & Ed. Universidade de São Paulo, São Paulo, 374 pp.
- Rödder D, Teixeira RL, Ferreira RB, Dantas RB, Pertel W, Guarniere GJ (2007) Anuran hotspots: the municipality of Santa Teresa, Espírito Santo, southeastern Brazil. Salamandra 43: 91–110.
- Rodríguez LO, Duellman WE (1994) Guide to the frogs of the Iquitos region, Amazonian Peru. University of Kansas Natural History Museum Special Publication 22: 1–80.
- Rossa-Feres D, Garey MV, Caramaschi U, Napoli MF, Nomura FA, Bispo A, Brasileiro CA, Thomé MT, Sawaya RJ, Conte CE, Cruz CAG, Nascimento LB, Gasparini JL, Almeida AP, Haddad CFB (2017) Anfíbios da Mata Atlântica: Lista de espécies, histórico dos estudos, biologia e conservação. In: Monteiro Filho EML, Conte CE (Eds) Revisões em Zoologia: Mata Atlântica, Curitiba: Editora UFPR, 237–314.
- Scaramuzza CAM, Simões LL, Rodrigues ST, Accacio GM, Hercowitz M, Rosa MR, Goulart W, Pinagé ER, Soares MS (2011) Visão da Biodiversidade da Ecorregião Serra do Mar: domínio biogeográfico Mata Atlântica. Brasília, WWF-Brasil, 167 pp.
- Schloegel LM, Ferreira CM, James TY, Hipolito M, Longcore JE, Hyatt AD, Yabsley M, Martins AMCRPF, Mazzoni R, Davies AJ, Daszak P (2010) The North American bullfrog as a reservoir for the spread of *Batrachochytrium dendrobatidis* in Brazil. Animal Conservation 13: 53–61. https://doi.org/10.1111/j.1469-1795.2009.00307.x
- Segalla MV, Caramaschi U, Cruz CAG, Grant T, Haddad CFB, Garcia PCA, Berneck BVM, Langone JA (2016) Brazilian Amphibians: list of species. Herpetologia Brasileira 5: 34–46.

- Silva ET, Ribeiro-Filho OP, Feio RN (2011) Predation of native anurans by invasive bullfrogs in southeastern Brazil: spatial variation and effect of microhabitat use by prey. South American Journal of Herpetology 6: 1–10. https://doi.org/10.2994/057.006.0101
- Silva ET, Peixoto MAA, Leite FSF, Feio RN, Garcia PCA (2018) Anuran distribution in a highly diverse region of the Atlantic Forest: the Mantiqueira mountain range in southeastern Brazil. Herpetologica 74: 294–305. https://doi.org/10.1655/Herpetologica-D-17-00025.1
- Simon JE (2000) Composição da avifauna da Estação Biológica de Santa Lúcia, Santa Teresa -ES. Boletim do Museu de Biologia Mello Leitão 11/12: 149–170.
- Simon JE, Peres J (2012) Revisão da distribuição geográfica de *Phyllodytes kautskyi* Peixoto, Cruz 1988 (Amphibia, Anura, Hylidae). Boletim do Museu de Biologia Mello Leitão 29: 17–30.
- SOS Mata Atlântica, Fundação INPE Instituto Nacional De Pesquisas Espaciais (2013) Atlas dos Remanescentes Florestais da Mata Atlântica. Período 2013–2014. http://www.sosma. org.br/ [accessed on 11 February 2017]
- Silvano DL, Pimenta BVS (2003) Diversidade de anfíbios na Mata Atlântica do Sul da Bahia. In: Prado PI, Landau EC, Moura RT, Pinto LPS, Fonseca GAB, Alger K (Eds) Corredor de Biodiversidade na Mata Atlântica do Sul da Bahia. IESB, CI, CABS, UFMG, UNICAMP, Ilhéus, CD-ROM.
- Stuart S, Chanson J, Cox N, Young B, Rodrigues A, Fischman D, Waller R (2004) Status and trends of amphibian declines and extinctions worldwide. Science 306: 1783–1786. https:// doi.org/10.1126/science.1103538
- Tabarelli M, Aguiar AV, Ribeiro MC, Metzger JP, Peres CA (2010) Prospects for biodiversity conservation in the Atlantic forest: lessons for aging human-modified landscapes. Biological Conservation 143: 2328–2340. https://doi.org/10.1016/j.biocon.2010.02.005
- Thomaz LD, Monteiro R (1997) Composição florística da Mata Atlântica de encosta da Estação Biológica de Santa Lúcia, município de Santa Teresa, Espírito Santo. Boletim Museu Biologia Mello Leitão 7: 3–48.
- Verdade VK, Rodrigues MT (2007) Taxonomic review of *Allobates* (Anura, Aromobatidae) from the Atlantic Forest, Brazil. Journal of Herpetology 41: 566–580. https://doi. org/10.1670/06-094.1
- Verdade VK, Rodrigues MT, Pavan D (2009) Anfíbios anuros da Reserva Biológica de Paranapiacaba e entorno, pp. 579–604. In: Lopes IMS, Kirizawa M, Melo MRF (Eds) Patrimônio da Reserva Biológica do Alto da Serra de Paranapiacaba. A antiga Estação Biológica do Alto da Serra, Instituto de Botânica, São Paulo, 720 pp.
- Verdade VK, Valdujo PH, Carnaval ACOQL, Schiesari C, Toledo LF, Mott T, Andrade G, Eterovick PC, Menin M, Pimenta BVS, Lisboa CS, Paula DC, Silvano D (2012) A leap further: the Brazilian Amphibian Conservation Action Plan. Alytes International Journal of Batrachology 29: 28–43.
- Walker M, Gasparini JL, Haddad CFB (2016) A new polymorphic species of egg-brooding frog of the genus *Fritziana* from southeastern Brazil (Anura, Hemiphractidae). Salamandra 52: 221–229.
- Weygoldt P (1986) Beobachtungen Zur Ökologie und biologie von fröschen an einem neotropischen bergbach. Zoologische Jahrbücher (Systematik) 113: 429–454.

- Weygoldt P (1989) Changes in the composition of mountain stream frog communities in the Atlantic mountains of Brazil: frogs as indicators of environmental deterioration? Studies on Neotropical Fauna and Environment 243: 249–255. https://doi. org/10.1080/01650528909360795
- Wilkinson M, Nussbaum RA (1999) Evolutionary relationships of the lungless caecilian Atretochoana eiselti (Amphibia, Gymnophiona, Typhlonectidae). Zoological Journal of the Linnean Society 126: 191–223. https://doi.org/10.1111/j.1096-3642.1999.tb00153.x
- Young BE, Stuart SN, Chanson JS, Cox NA, Boucher TM (2004) Disappearing jewels: The status of new world amphibians. Nature Serve, Arlington, VA, 53 pp.
- Zocca CZ, Tonini JFR, Ferreira RB (2014) Uso do espaço por anuros em ambiente urbano de Santa Teresa, Espírito Santo. Boletim do Museu de Biologia Mello Leitão 35: 105–117.

Appendix I

Vouchers of examined specimens

Adelophryne glandulata (MBML 9560), Allobates capixaba (MZUSP 53559), Aplastodiscus cavicola (MBML 9620), Aplastodiscus aff. eugenioi (MBML 7901), Aplastodiscus weygoldti (MBML 9540), Boana albomarginata (MBML 9610), Boana albopunctata (MBML 9673), Boana crepitans (MBML 9624), Boana faber (MBML 9576), Boana pardalis (MBML 9577), Boana semilineata (MBML 9554), Bokermannohyla caramaschii (MBML 9552), Brachycephalus alipioi (MNRJ 25405), Ceratophrys aurita (MBML 591), Chiasmocleis capixaba (MBML 2644), Chiasmocleis schubarti (MBML 9599), Crossodactylodes bokermanni (MBML 3984), Crossodactylodes izecksohni (MBML 768), Crossodactylus aff.gaudichaudii (MBML 15), Crossodactylus timbuhy (MBML 13), Cycloramphus fuliginosus (USNM 200441), Dendrophryniscus carvalhoi (MBML 8722), Dendropsophus berthalutzae (MBML 8589), Dendropsophus bipunctatus (MBML 2446), Dendropsophus branneri (MBML 9611), Dendropsophus bromeliaceus (MBML 7712), Dendropsophus decipiens (MBML 9590), Dendropsophus elegans (MBML 9543), Dendropsophus giesleri (MBML 8795), Dendropsophus haddadi (MBML 8775), Dendropsophus microps (MNRJ 30445), Dendropsophus minutus (MBML 9593), Dendropsophus ruschii (CFBH 37010), Dendropsophus seniculus (MBML 9591), Euparkerella tridactyla (MBML 7585), Fritziana aff. fissilis (MBML 46), Fritziana tonimi (MBML 8604), Gastrotheca albolineata (MBML 47), Gastrotheca megacephala (MBML 9672), Haddadus binotatus (MBML 9621), Hylodes cf. babax (USNM 222553), Hylodes lateristrigatus (MBML 9595), Ischnocnema abdita (MBML 1143), Ischnocnema colibri (MBML 10568-10572), Ischnocnema aff. guentheri (MBML 4534), Ischnocnema cf. nasuta (MBML 4667), Ischnocnema oea (MBML 8705), Ischnocnema aff. parva sp. 1 (MBML 9550), Ischnocnema verrucosa (MBML 9569), Itapotihyla langsdorffii (MBML 8585), Leptodactylus cupreus (MBML 6845), Leptodactylus fuscus (MBML 6003), Leptodactylus aff. latrans (MBML 2077), Leptodactylus aff. spixi (MBML 2439), Macrogenioglottus alipioi (MBML 93), Myersiella microps (MBML 9561), Ololygon arduous (MBML

9657), Ololygon argyreornata (MBML 2828), Ololygon cf. flavoguttata (MBML 9649), Ololygon heyeri (MBML 8581), Ololygon kautskyi (MBML 9594), Phasmahyla exilis (MNRJ 4120), Phrynomedusa marginata (MNRJ 46881), Phyllodytes luteolus (MBML 6785), Phyllodytes aff. luteolus (MBML 9658), Phyllomedusa burmeisteri (MBML 9581), Physalaemus crombiei (MBML 9542), Physalaemus cuvieri (MBML 9579), Physalaemus maculiventris (MBML 9567), Physalaemus cf. olfersii (MBML 2803), Pipa aff. carvalhoi (MBML 4519), Pithecopus aff. rohdei (MBML 9580), Proceratophrys boiei (MBML 142), Proceratophrys laticeps (MBML 3905), Proceratophrys moehringi (MBML 6409), Proceratophrys paviotii (MBML 9585), Proceratophrys phyllostomus (MBML 325), Proceratophrys schirchi (MBML 9677), Rhinella crucifer (MBML 9575), Rhinella granulosa (MBML 2573), Rhinella diptycha (MBML 687), Scinax alter (MBML 9612), Scinax cuspidatus (MBML 3594), Scinax eurydice (MBML 1128), Scinax fuscovarius (MBML 7820), Scinax hayii (MBML 4707), Scinax aff. perereca (MBML 508), Scinax cf. x-signatus (MBML 4542), Siphonops annulatus (MBML 8586), Siphonops hardyi (MBML 8909), Thoropa aff. lutzi (MNRJ 1373), Thoropa miliaris (MBML 9571), Thoropa petropolitana (MZUSP 27725), Trachycephalus mesophaeus (MBML 8793), Trachycephalus nigromaculatus (MBML 9213), Vitreorana aff. eurygnatha (MBML 9678), Vitreorana uranoscopa (MBML 3725), Zachaenus carvalhoi (MNRJ 84116).