

Redescription of *Marstonia comalensis* (Pilsbry & Ferriss, 1906), a poorly known and possibly threatened freshwater gastropod from the Edwards Plateau region (Texas)

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Abstract

Marstonia comalensis, a poorly known nymphophiline gastropod (originally described from Comal Creek, Texas) that has often been confused with *Cincinnatia integra*, is re-described and the generic placement of this species, which was recently allocated to *Marstonia* based on unpublished evidence, is confirmed by anatomical study. *Marstonia comalensis* is a large congener having an ovate-conic, openly umbilicate shell and penis having a short filament and oblique, squarish lobe bearing a narrow gland along its distal edge. It is well differentiated morphologically from congeners having similar shells and penes and is also genetically divergent relative to those congeners that have been sequenced (mtCOI divergence 3.0–8.5%). A Bayesian analysis of a small COI dataset resolved *M. comalensis* in a poorly supported sub-clade together with *M. hershleri*, *M. lustrica* and *M. pachyta*. The predominantly new records presented herein indicate that *M. comalensis* was historically distributed in the upper portions of the Brazos, Colorado, Guadalupe and Nueces River basins, south-central Texas. The species has been live collected at only 12 localities and only two of these have been re-visited since 1993. These data suggest that the conservation status of this snail, which has a critically imperiled (G1) NatureServe ranking and was recently proposed for federal listing, needs to be re-assessed.

Keywords

Marstonia, Hydrobiidae, Gastropoda, United States, Texas, freshwater, taxonomy, conservation

Introduction

The freshwater gastropod genus *Marstonia* (Hydrobiidae: Nymphophilinae) is composed of 15 small (shell height < 5.0 mm), ovate- to elongate-shelled species that are distributed in springs, streams and lakes in eastern North America (Thompson and Hershler 2002, Hershler et al. 2003a, Thompson 2005). Most of these species have extremely narrow geographic ranges and consequently have become a focus of conservation activities; two are federally listed as endangered (USFWS 1994, 2000) and others are variously listed by state wildlife agencies. *Marstonia* differs from the other eight North American nymphophilina genera in that the (female) oviduct and bursal duct join well in front of (instead of behind) the posterior wall of the pallial cavity (Thompson and Hershler 2002); it has also been resolved as a well supported sub-clade within its subfamily based on mtDNA sequences (Hershler et al. 2003a). Although *Marstonia* has been reviewed three times since 1978 (Thompson 1978, Hershler 1994, Thompson and Hershler 2002), three of its congeners have been little studied beyond their original descriptions and their anatomy is unknown. Two of these — *M. olivacea* (Pilsbry), *M. ozarkensis* (Hinkley) — may be extinct (Thompson 1978, NatureServe 2009) and thus will likely remain *incertae sedis*. The third, *M. comalensis* (Pilsbry and Ferriss) (originally *Amnicola comalensis* Pilsbry & Ferriss), which is extant, is the focus of this paper.

Pilsbry and Ferriss (1906) described *A. comalensis* based on six shells from Comal Creek and the Guadalupe River near New Braunfels, south-central Texas. They differentiated this species from *A. limosa* (Say) and two *nomina* (*A. cincinnatiensis* [Anthony], *A. peracuta* Pilsbry & Walker) that are currently recognized as synonyms of *Cincinnatia integra* (Say) (see Hershler and Thompson 1996) by its much smaller size and noted that it further differed from the latter by its less shouldered whorls. The genus *Amnicola* was used at that time as “a catch-all for most American amnicoloid species that could not conveniently be placed elsewhere on the basis of their shells” (Thompson 1968: 150). *Amnicola comalensis* was not further treated taxonomically until Taylor (1975) transferred it to *Cincinnatia* without comment in a bibliographic compilation; this allocation was widely followed in the subsequent literature (e.g., Burch and Tottenham 1980, Turgeon et al. 1998). During the course of a revisionary study of *C. integra*, Hershler and Thompson (1996) examined several alcohol preserved collections of a snail that they identified as *A. comalensis* and noted that it closely resembled species of *Marstonia* (which were then placed in *Pyrgulopsis*); *A. comalensis* was subsequently transferred to *Marstonia* based on this unpublished work (Thompson and Hershler 2002). Hershler et al. (2003a) recently published a molecular phylogenetic analysis of the North American nymphophilines that included a specimen of *M. comalensis* from Old Faithful Spring in Real County, Texas (ca. 180 km from the type locality), which was depicted as nested within the *Marstonia* clade. This is the only published record for *M. comalensis* subsequent to its original description.

We redescribe *M. comalensis* herein based on study of a large series of dry shell and alcohol-preserved material, most of which was collected by malacologists J.J. Landye and D.W. Taylor from 1971–1993, and provide anatomical evidence supporting its current generic allocation. The new records detailed in this paper considerably expand the geographic range of *M. comalensis*, which lives in springs and fluvial habitats spread among four river basins in south-central Texas. We also further analyze previously published molecular data (Hershler et al. 2003a) to evaluate the divergence and phylogenetic relationships of *M. comalensis*, whose geographic range is broadly disjunct relative to other members of the genus. The information presented in this paper may assist efforts to protect this poorly known species, which was included in a recent federal listing petition (Rosmarino and Tutchton 2007) based on its critically imperiled (G1) NatureServe (2009) ranking, but found not to warrant listing owing to insufficient information (USFWS 2009).

Materials and methods

Anatomical study was based on specimens that were relaxed with menthol crystals and fixed in dilute formalin. Types and other material of *M. comalensis* in the collections of the Academy of Natural Sciences of Philadelphia (ANSP); Florida Museum of Natural History (FMNH); National Museum of Natural History, Smithsonian Institution (USNM); and University of Minnesota Bell Museum of Natural History (UMBM-NH) were examined during the course of this study.

Variation in the number of cusps on the radular teeth was assessed using the method of Hershler et al. (2007). Other methods of morphological study and descriptive terminology are those used in recent taxonomic investigations of nymphophiline gastropods (Hershler 1998, Hershler et al. 2003b). Shell data were compiled using Systat for Windows 11.00.01 (SSI 2004).

The molecular phylogenetic analysis included single mtCOI sequences from *M. comalensis*, six other species of *Marstonia* and representatives of six other North American nymphophiline genera. *Hydrobia acuta* (Draparnaud) was used as the root. Sample information, GenBank accession numbers and publication references for the sequences are in Table 1. Sequence divergences (uncorrected p distance) were calculated using MEGA4 (Tamura et al. 2007). Phylogenetic relationships were inferred using Bayesian inference in MrBayes 3.12 (Ronquist and Huelsenbeck 2003). MrModeltest (Nylander 2004) selected the Hasegawa-Kishino-Yano model with some sites assumed to be invariable and with variable sites assumed to follow a discrete gamma distribution (HKY + I + G), which best fit the data under the Akaike Information Criterion. In the initial Bayesian analysis the burn-in was set at 10% (10,000 generations) of the chain length (100,000 generations). Three runs were conducted in MrBayes using the HKY + I + G model and the default random tree option to determine when the log-likelihood sum reached a stable value (by plotting the log-likelihood scores of sample

Table 1. Species (specimen codes), locality details, GenBank accession numbers and publication references for mtCOI sequences.

Species (code)	Locality	GenBank accession number	Reference
<i>Marstonia agarhecta</i> Thompson	Bluff Creek, Pulaski Co., GA	AF520934	Hershler et al. 2003a
<i>Marstonia castor</i> Thompson	Mercer Mill Creek, Worth Co., GA	AF520938	Hershler et al. 2003a
<i>Marstonia comalensis</i> (Pilsbry & Ferriss)	Old Faithful Spring, Real Co., TX	AF520933	Hershler et al. 2003a
<i>Marstonia halcyon</i> Thompson	Ogeechee River, Screven Co., GA	AF520935	Hershler et al. 2003a
<i>Marstonia hershleri</i> (Thompson)	Coosa River, Elmore Co., AL	AF520946	Hershler et al. 2003a
<i>Marstonia lustrica</i> (Pilsbry)	Stockbridge Bowl, Berkshire Co., MA	AF520945	Hershler et al. 2003a
<i>Marstonia pachyta</i> Thompson	Limestone Creek, Limestone Co., AL	AF520939	Hershler et al. 2003a
<i>Cincinnatia integra</i> (Say)	Stream north of Fredericksburg, Gillespie Co., TX	AF520948	Hershler et al. 2003a
<i>Notogillia wetherby</i> (Dall) (WW)	Weeki Wachee River, Hernando Co., FL	AF367630	Wilke et al. 2001
<i>Notogillia wetherbyi</i> (Dall) (RS)	Rainbow Springs, Marion Co., FL	AF520918	Hershler et al. 2003a
<i>Pyrgulopsis bruneauensis</i> Hershler	Bruneau Hot Springs, Owyhee Co., ID	AF520941	Hershler et al. 2003a
<i>Rhaphinema dacryon</i> Thompson	Chipola River, Jackson Co., FL	AF520932	Hershler et al. 2003a
<i>Spilochlamys gravis</i> Thompson	Alexander Springs, Lake Co., FL	AF520919	Hershler et al. 2003a
<i>Stiobia nana</i> Thompson	Coldwater Spring, Calhoun Co., AL	AF520921	Hershler et al. 2003a
<i>Hydrobia acuta</i> (Draparnaud)	Lagoon 6, Suffolk, East Anglia, United Kingdom	AF354773	Liu et al. 2001

Additional locality details are in Hershler et al. (2003a).

points against generation time). The ln likelihoods started around -4,300 and quickly converged upon a stable value of about -3,050 after 1,000 generations. For the final run, Metropolis-coupled Markov chain Monte Carlo simulations were performed with four chains for 1,000,000 generations and Markov chains were sampled at intervals of 10 generations to obtain 100,000 sample points. The sampled trees with branch lengths were used to generate a 50% majority rule consensus tree with the first 5000 trees (equal to 50,000 generations) removed to ensure that the chain sampled a stationary portion.

Systematic description

Family Hydrobiidae

Subfamily Nymphophilinae

Genus *Marstonia* Baker, 1926

Marstonia comalensis (Pilsbry & Ferriss, 1906)

Figs 1–3

Amnicola comalensis Pilsbry & Ferriss, 1906: 171, fig. 37 (Comal Creek, near New Braunfels, Comal County, Texas; also from the Guadalupe River about four miles [3.2 km] above New Braunfels). Pilsbry 1910: 98 (corrected measurement of figured specimen [lectotype]). Walker 1918: 133. Baker 1964: 172 (lectotype selection). Hershler & Thompson 1996: 51.

Cincinnatia comalensis Taylor 1975: 61 (transfer to *Cincinnatia*, summary of literature citations). Burch & Tottenham 1980: 110, fig. 190 (from Pilsbry & Ferriss 1906). Turgeon et al. 1998: 72.

Marstonia comalensis Thompson & Hershler 2002: 270 (transfer to *Marstonia*). Hershler et al. 2003a: 366, figs. 2, 3 (new record, phylogenetic analysis).

Types: Figured lectotype, ANSP 91323 (Fig. 1A); paralectotypes (from same lot), ANSP 420575.

Referred material: TEXAS. USNM 123757, USNM 134007, Guadalupe River. ANSP 134247, Nueces River. *Bell County*: UMBMNH uncat., Salado Creek, Salado, old US 81 (30.944°N, 97.539°W), 14.IV.1972. *Comal County*: ANSP 90562, drift of Guadalupe River, 3.2 km above New Braunfels (29.756°N, 98.138°W). UMBMNH uncat., Spring Branch, west of Spring Branch (29.891°N, 98.435°W), 28.III.1963. USNM 473488, New Braunfels (29.702°N, 98.124°W). *Kerr County*: USNM 874910, South Fork Guadalupe River, ca. 56.4 km northwest of Leakey (29.957°N, 99.456°W), 30.XII.1979. USNM 874932, spring run adjacent to South Fork of Guadalupe River, ca. 11.2 km southwest of Hunt (30.005°N, 99.409°W), 30.XII.1979. USNM 883412, North Fork Guadalupe River (30.054°N, 99.486°W), 26.IV.1993. USNM 874923, North Fork of Guadalupe River at Riverbend Ranch crossing at FM 1340 (30.065°N, 99.373°W), 29.XII.1979. USNM 251887, Japonica (30.064°N, 99.344°W). *Kimble County*: UMBMNH uncat., Llano River at FM 385, 25.6 km northeast of Junction (30.589°N, 99.598°W), 12–13.IV.1972. *Kinney County*: UMBMNH uncat., Nueces River, Tularosa Road, A.G. “Tony” Rose Ranch (29.518°N, 100.271°W), 9.VI.1971. USNM 883413, West Nueces River above crossing on Tularosa Road near Spring Ranch, just below Silver Lake (29.523°N, 100.251°W), 25.IV.1993. *Real County*: UMBMNH uncat., USNM 874926, Old Faithful Spring outflow, Hwy 55, 0.8 km north of Camp Wood (29.680°N, 100.015°W), 8.VI.1971, 31.XII.1979. FMNH 283564, FMNH 283565, FMNH 283573, FMNH 287574, Old Faithful Spring,

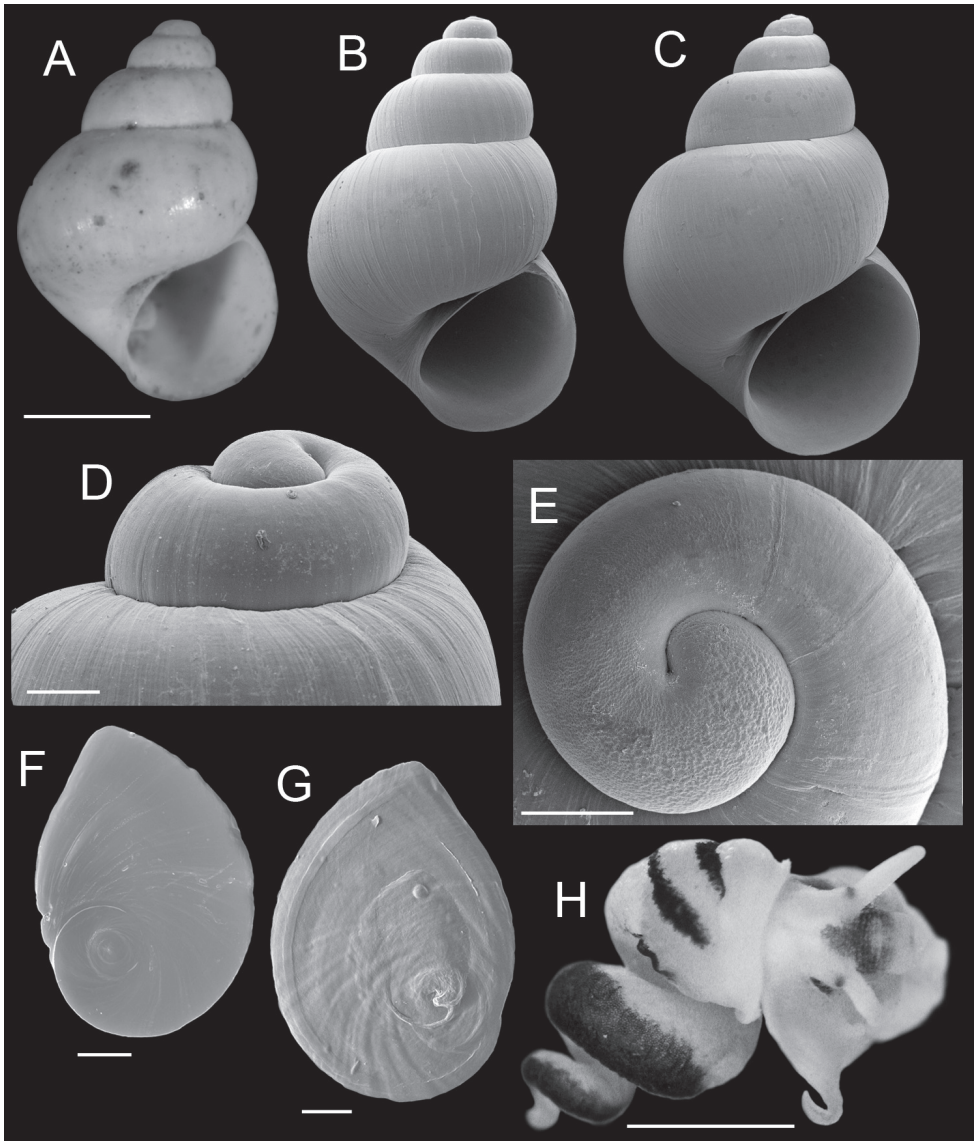


Figure 1. Shells, opercula and animal, *M. comalensis*. **A** Lectotype, ANSP 91323 **B, C** Shells, USNM 874932, USNM 874926 **D** Lateral view of shell apex, USNM 874932 **E** Protoconch, USNM 874926 **F, G** Opercula (outer, inner sides), USNM 874926 **H** Relaxed, alcohol-preserved preserved male (dorsal view), showing distinctive pigment bands on the pallial roof, USNM 874926. Scale bars A–C, H, 1.0 mm; D, E, 100 µm; F, G, 200 µm.

1.0 km north of Camp Wood (29.680°N, 100.015°W), 27.I.2001. USNM 883414, Leakey Springs run at Hwy 337 crossing, ca. 0.48 km east of Leakey (29.723°N, 99.757°W), 25.IV.1993. FMNH 283561, Leakey Springs creek, 0.64 km east of Leakey (29.723°N, 99.757°W), 26.I.2001. *Uvalde County*: UMBMNH uncat., Nueces River,

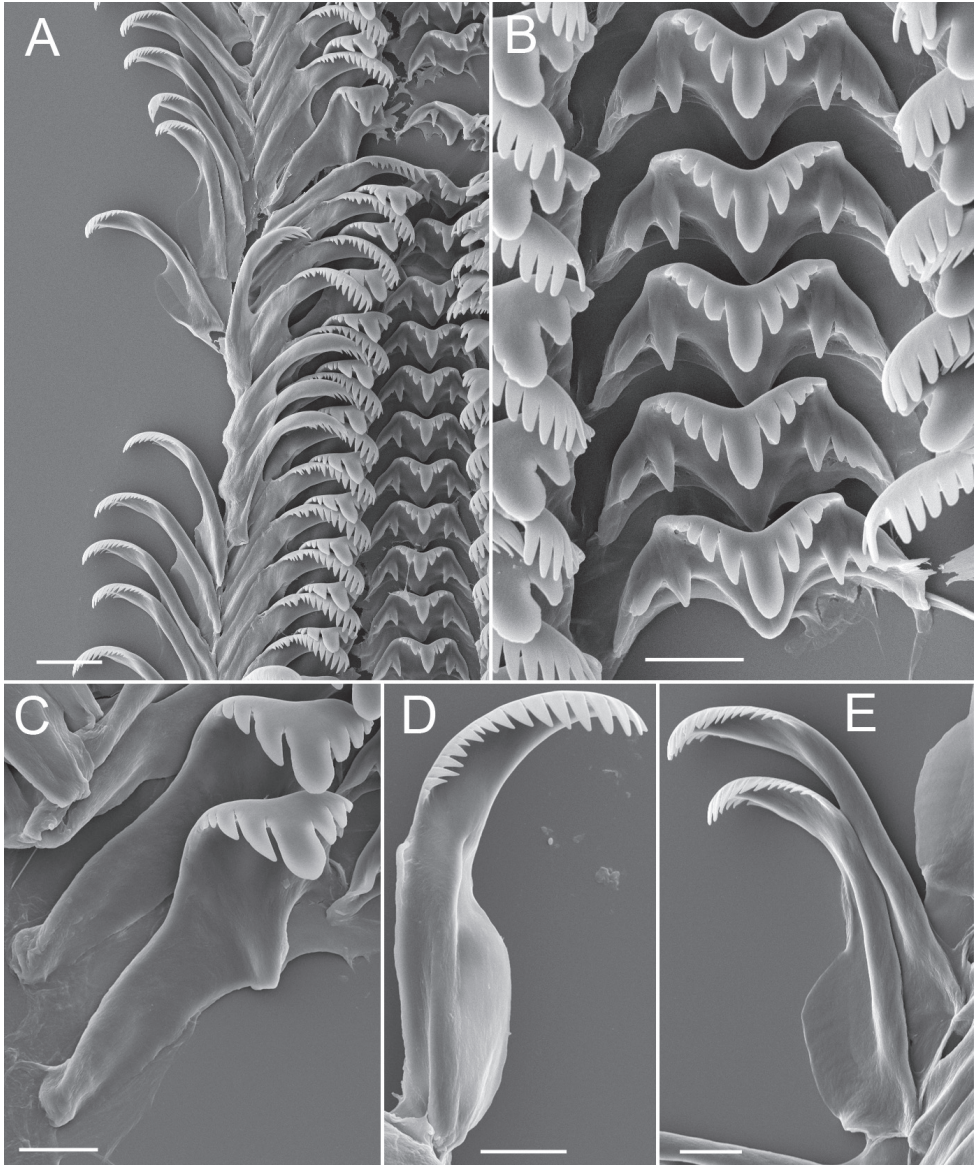


Figure 2. Radula, *M. comalensis*, USNM 874926. **A** Portion of radular ribbon **B** Central teeth **C** Lateral teeth **D** Inner marginal tooth **E** Outer marginal teeth. Scale bars A, 20 µm; B-E, 10 µm.

Chalk Bluff, 24 km northwest of Uvalde (29.359°N, 99.984°W), 27.V.1971. USNM 883477, spring at Camp Chalk Bluff, tributary to East Nueces River (29.362°N, 99.984°W), 23.IV.1993. USNM 883666, USNM 883421, East Nueces River at 19 Mile Crossing, 1.6–3.2 km south of Hwy 55 and FM 334 (29.398°N, 100.00°W), 31.XII.1979, 29.IV.1993. UMBMNH uncat., USNM 883420, East Nueces River, Hwy 55, Lake Nueces County Park (29.619°N, 100.01°W), 1-VI-1971, 29.IV.1993.

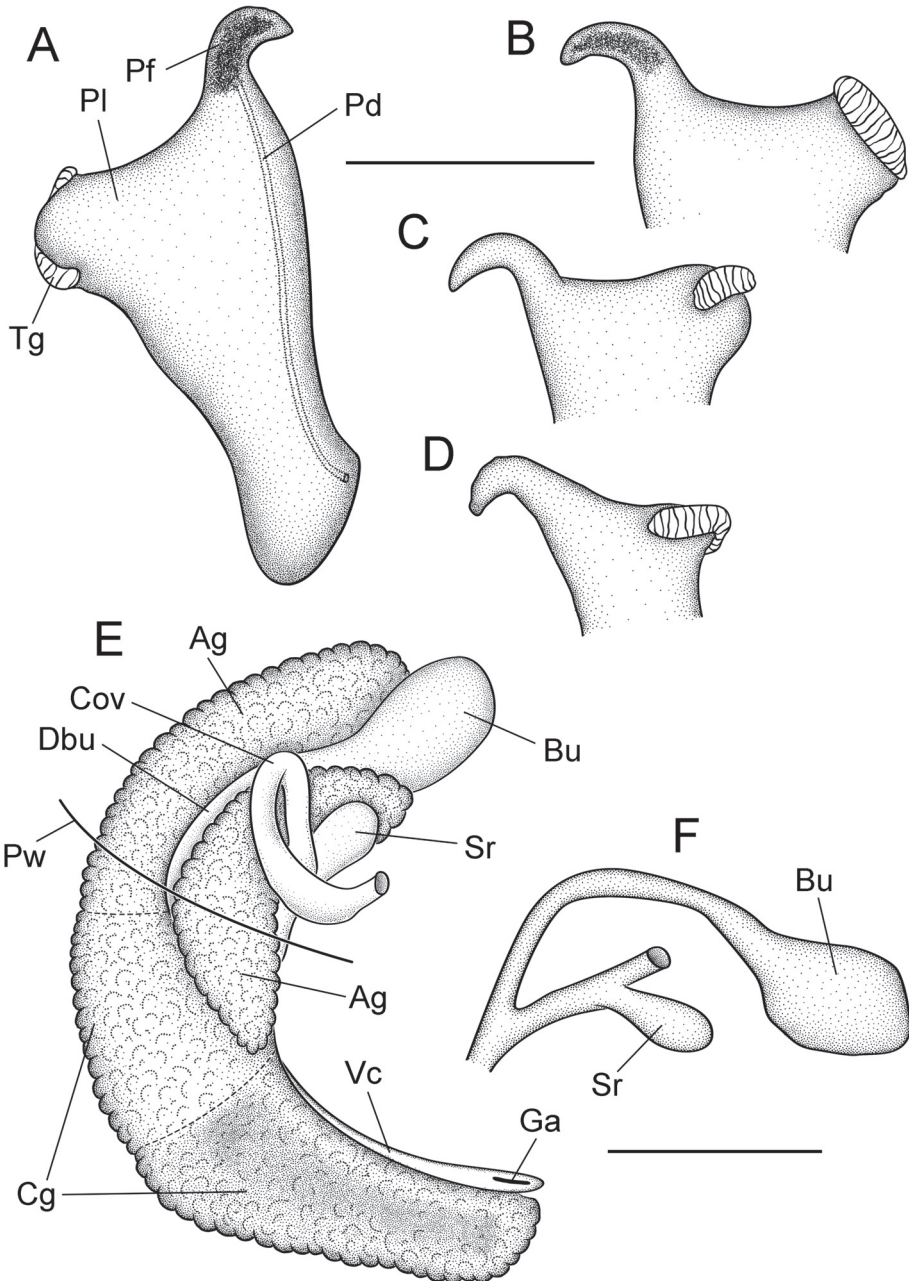


Figure 3. Reproductive anatomy, *M. comalensis*, USNM 874926. **A** Penis, dorsal surface **B–D** Distal portion of penis showing terminal gland variation **E** Female glandular oviduct and associated structures (viewed from left side) **F** Bursa copulatrix and seminal receptacle and their ducts. Scale bars = 500 μ m. **Ag** albumen gland **Bu** bursa copulatrix **Cg** capsule gland **Cov** coiled oviduct **Dbu** bursal duct **Ga** genital aperture **Pf** penial filament **Pl** penial lobe **Pw** posterior wall of pallial cavity **Sr** seminal receptacle **Vc** ventral channel of capsule gland.

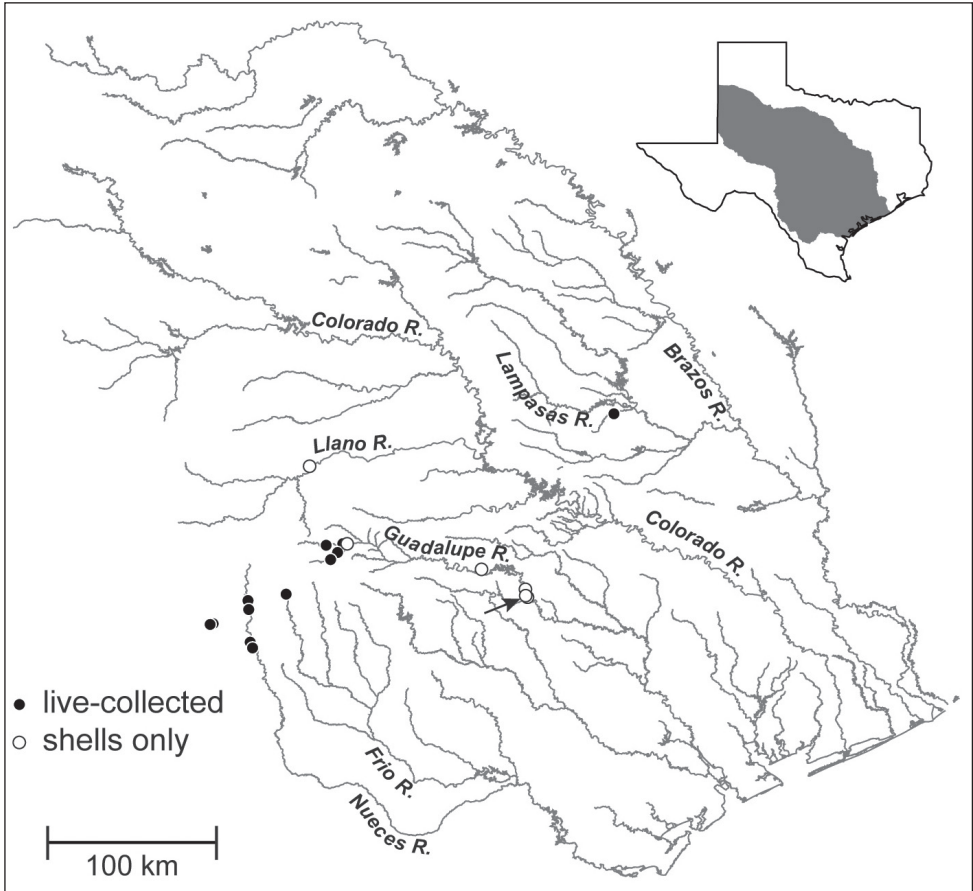


Figure 4. Map showing the distribution of *M. comalensis* in the Brazos, Colorado, Guadalupe and Nueces River basins, south-central Texas. The arrow indicates the type locality (Comal Creek).

Revised diagnosis: Shell large for genus (maximum height, 4.6 mm), ovate-conic, openly umbilicate; penis with short filament and oblique, squarish lobe bearing a single terminal gland along its distal edge. Distinguished from congeners having closely similar shells and penes as follows: from *M. gaddisorum* Thompson by its less convex shell whorls, distinctive pallial roof pigmentation, larger number of cusps on the inner side of the lateral teeth and on the outer marginal teeth, larger penial lobe, narrower terminal gland, and smaller overlap of the bursa copulatrix by the albumen gland; from *M. lustrica* by its smaller prostate gland, smaller penial lobe, narrower penial filament, straight anterior vas deferens, partly imbedded (in albumen gland) bursal duct, and larger seminal receptacle; and from *M. ogmorhapha* Thompson by its smaller size, broader shell, smaller prostate gland, straight anterior vas deferens, and smaller bursa copulatrix.

Description: Shell ovate-conic, (Fig. 1A–C); height about 2.6–4.6 mm; whorls 4.5–5.5. Protoconch near planispiral, slightly tilted (Fig. 1D), initial 0.75–1.0 whorl strongly wrinkled (Fig. 1E). Teleoconch whorls weakly convex, often narrowly shoul-

dered, rarely having subsutural angulation; sculpture of strong collabral growth lines, later whorls having numerous weak spiral striae. Aperture pyriform or ovate. Inner lip complete across parietal wall in larger specimens, usually narrowly adnate, rarely slightly disjunct; usually thin, sometimes slightly thickened apically; columellar shelf absent or very narrow; outer lip thin or slightly thickened, orthocline or prosocline. Umbilicus open but small. Measurements of the lectotype and a live-collected series of shells from the Nueces River basin are in Table 2.

Operculum thin, amber, narrowly ovate, multispiral with eccentric nucleus (Fig. 1F); last 0.25 whorl sometimes frilled on outer side; inner side having well developed rim near outer edge (Fig. 1G); attachment scar border sometimes weakly thickened near nucleus. Radula (Fig. 2A), having about 36 well-formed rows of teeth. Central teeth about 38 μm wide, cutting edge convex (Fig. 2B); lateral cusps 3–8; central cusp pointed or hoe-shaped, parallel-sided proximally or tapering throughout; basal cusps 1–3, small; basal tongue U- or V-shaped, about as long as lateral margins. Lateral tooth face rectangular; central cusp pointed or hoe-shaped (Fig. 2C); lateral cusps 2–5 (inner), 3–7 (outer); outer wing broad, flexed, about 140% length of cutting edge; basal tongue weakly developed. Inner (Fig. 2D) and outer (Fig 2E) marginal teeth both having 14–21 cusps and basally positioned rectangular wing. Radular count data were from USNM 874926.

Cephalic tentacles pale except for black eyespots. Snout brown; distal lips pale; foot pale. Pallial roof having black pigment bands along edges of ctenidium and dorsal edge of genital duct (Fig. 1H); visceral coil pale except for black pigment on testis. Ctenidium positioned a little in front of pericardium; ctenidial filaments 24–25 ($n=5$), broadly triangular, lateral surfaces ridged. Osphradium narrow, positioned slightly posterior to middle of ctenidium. Hypobranchial gland large, overlapping rectum and part of genital duct, thickened alongside kidney. Style sac longer than remaining portion of stomach, posterior stomach having small caecal appendix. Testis large (1.75 whorls), composed of compound lobes, broadly overlapping stomach anteriorly. Seminal vesicle opening near anterior edge of testis, composed of a few thickened coils, positioned along ventral side of anterior 33% of testis. Prostate gland small, pea-shaped, with about 50% of length in pallial roof. Anterior vas def-

Table 2. Shell parameters for *M. comalensis*.

	WH	SH	SW	HBW	WBW	AH	AW	SW/SH	HBW/SH	AH/SH
Lectotype, ANSP 91323										
	4.5	3.00	2.08	2.12	1.81	1.36	1.14	0.69	0.71	0.45
USNM 874926 (n=30)										
Mean	4.79	3.49	2.39	2.58	2.08	1.66	1.35	0.69	0.74	0.48
S.D.	0.18	0.17	0.09	0.11	0.08	0.09	0.05	0.03	0.02	0.02
Range	4.5– 5.0	3.20– 3.87	2.22– 2.55	2.38– 2.84	1.93– 2.25	1.50– 1.84	1.26– 1.45	0.63–0.74	0.70–0.77	0.43–0.51

Abbreviations: **WH** total shell whorls; **SH** shell height; **SW** shell width; **HBW** height of body whorl; **WBW** width of body whorl; **AH** aperture height; **AW** aperture width.

erens opening from antero-ventral edge of prostate gland, section of duct on columellar muscle straight. Penis large, base rectangular, inner edge without folds; filament short, narrow, tapering, oblique; lobe rather medium-sized, squarish, oblique (Fig. 3A). Terminal gland (Fig. 3A–D) narrow, usually transversely positioned along outer edge of lobe (58/86 specimens examined from three samples), less frequently horizontal (28/86), sometimes borne on short stalk. Penial duct narrow, near outer edge, almost straight. Penial filament having black internal pigment core along most of length. Ovary small (0.75 whorl), composed of simple, stalked lobes; slightly overlapping stomach anteriorly. Female glandular oviduct and associated structures shown in Figure 3E–F. Coiled oviduct narrow, vertical. Bursa copulatrix small, ovate, horizontal, about 50% overlapped by albumen gland. Bursal duct longer than bursa, narrow, opening from distal edge, partly embedded in albumen gland proximally, entirely embedded distally, junction with common duct well in front of posterior wall of pallial cavity. Seminal receptacle small, pouch-like, positioned near ventral edge of albumen gland slightly anterior to bursa copulatrix. Albumen gland largely visceral. Capsule gland composed of two distinct tissue sections. Genital aperture a terminal slit.

Distribution and habitat: *Marstonia comalensis* is distributed in the upper portions of the Brazos, Colorado, Guadalupe and Nueces River basins, south-central Texas (Fig. 4); almost all of these localities are on the Edwards Plateau. We were unable to confirm a previous report of this species from a drainage canal near Galveston Bay (Cable and Isserhoff 1969). *Marstonia comalensis* lives in cold water springs near their sources and slack water riverine habitats; it has been most commonly found on mud, aquatic vegetation and dead leaves.

Remarks: The material referred to *M. comalensis* herein, which includes specimens from the Guadalupe River above the Comal Creek confluence, closely conforms to the types of this species both in size and shell shape (Fig. 1A–C). This snail clearly belongs to *Marstonia* based on its strongly wrinkled shell protoconch, distally bifurcate penis ornamented with a gland along the edge of the lobe (terminal gland), and connection between the oviduct and bursal duct well in front of the posterior pallial wall (Thompson and Hershler 2002). As noted above, this generic placement is also supported by molecular phylogenetic evidence (Hershler et al. 2003a).

The original collections of *M. comalensis* are worn shells having the appearance of drift material (Fig. 1A). We have not seen any live-collected specimens of this species in the numerous samples that we have examined from the type locality (Comal Springs) and other waters near New Braunfels. The various reports of living *M. comalensis* from this portion of the Guadalupe River basin (e.g., EHA 1975; Arsuffi 1994; Tolley-Jordan and Owen 2008) are probably of misidentified *C. integra*, as evidenced by the illustrations of shells in several of these documents (Lindholm 1979, fig. 4; Cauble 1998, fig. 7). It is possible that *M. comalensis* became extinct at Comal Springs when this water body temporarily dried in 1964 (USFWS 1996); it is also possible that the shells of this species which have been found at this site were washed downflow from extant populations in the headwaters of the Guadalupe River.

Taylor's (1975) allocation of *A. comalensis* to *Cincinnatia* appears to have been the result of a misidentification as all of the material in his collection that he referred to this species (per the original labels), including several lots from the type locality, is *C. integra* (RH unpublished). Some of these records were detailed in an unpublished manuscript, "Freshwater molluscs from the Nueces River drainage, Texas" that Taylor circulated in the mid-1970's. *Cincinnatia integra*, which is widely distributed in Texas (Hershler and Thompson 1996), has been frequently confused with *M. comalensis* in museum collections despite the obvious differences between their shells that were noted in the original description of the latter (Pilsbry and Ferriss 1906). These two species also well differentiated anatomically (see Hershler and Thompson 1996 for details of the former).

Discussion

Thompson (1978) speculated that *Marstonia* is composed of two species lineages that are differentiated by the size and shape of the penial lobe and filament. *Marstonia comalensis*, which is distributed almost 800 km distant from its most proximal congener, conforms to the putative lineage characterized by a large, squarish lobe and small, slender filament. This group includes widely ranging *M. lustrica* and species distributed in the Tennessee (*M. arga* Thompson, *M. ogmorhaphae*, *M. pachyta*), Alabama (*M. hershleri*; see Thompson 1995) and Altamaha (*M. gaddisorum*; see Thompson 2005) River basins. The molecular phylogenetic relationships of *M. comalensis* were previously delineated by Hershler et al. (2003a), who analyzed a mtCOI dataset using maximum parsimony and maximum likelihood methods. We re-analyzed the relevant portion of these data using a Bayesian algorithm. The resulting topology (Fig. 5) is closely similar to those illustrated by Hershler et al. (2003a: figs. 2, 3) and has slightly better resolution. *Marstonia* is resolved as a well supported (100% posterior probability) clade. Three congeners living in Georgia coastal drainage, which Thompson (1978) recognized as a distinct lineage based on their elongate penial lobe and robust filament, formed a well supported (95%) subclade. The other four congeners included in the analysis, which conform to the second putative lineage discussed above, formed a weakly supported subunit, within which *M. comalensis* was positioned as sister to a subclade containing *M. lustrica* and *M. pachyta*. The single sequenced specimen of *M. comalensis* differs from those of the six other congeners that have been similarly analyzed by 3.0–8.5%; it is most similar to *M. pachyta*.

Marstonia comalensis is ranked as critically imperiled (G1) by NatureServe (2009), but has a minimal conservation profile otherwise. Following the negative finding per its proposed listing (USFWS 2009) it was categorized by the USFWS (2010) as "status undefined." It was misidentified as a "mussel" in a ecological sustainability report for the Cibola National Forest Grasslands plan revision (USDAFS 2008) and is not mentioned on the Texas Parks and Wildlife's website (<http://www.tpwd.state.tx.us/>) or in the State Wildlife Action Plan (Texas Parks and Wildlife 2010). Given that *M. comalensis* has been live-collected at only 12 localities (Fig. 4) and only two of these sites (Leakey Springs, Old Faithful Spring) have been re-visited since 1993, it would

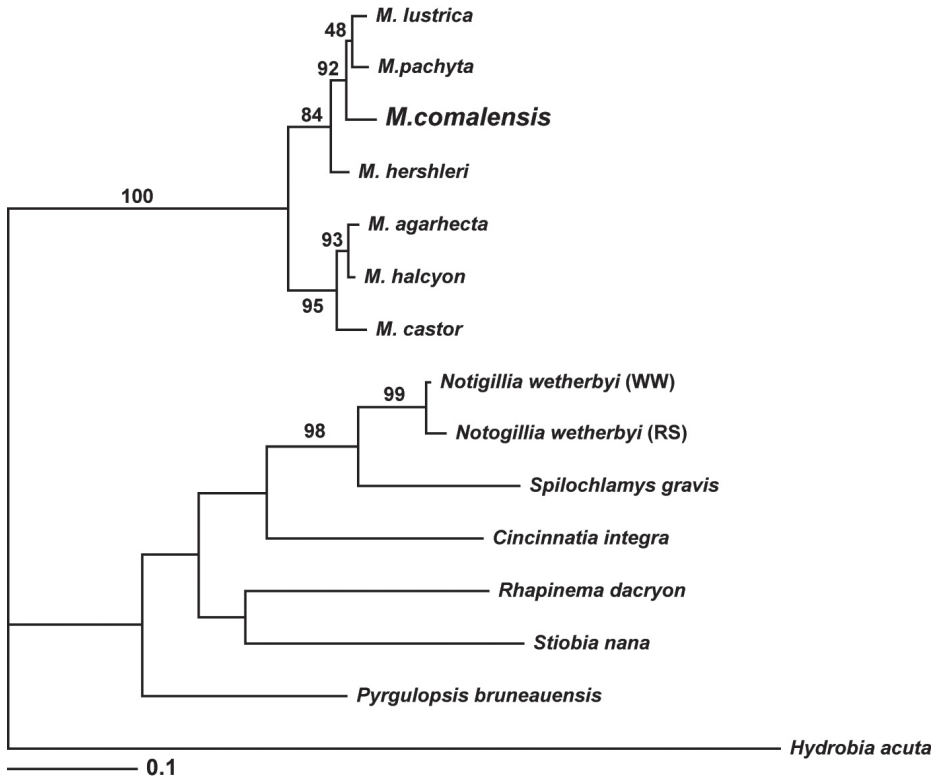


Figure 5. Bayesian tree based on the COI dataset. Posterior probabilities for each node within the *Marstonia* clade are shown for the reader’s interest; only those >95% are considered significant.

seem prudent to add this species to the list of aquatic biota of the Edwards Plateau region meriting protection (Bowles and Arsuffi 1993) and assess its current conservation status. Depending on the extent of its possible decline since 1993, *M. comalensis* may merit addition to the IUCN Red List (e.g., if it consists of 10 or fewer extant populations; IUCN 2001) and other conservation watch lists.

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On the placement of the Cretaceous orthopteran *Brauckmannia groeningae* from Brazil, with notes on the relationships of Schizodactylidae (Orthoptera, Ensifera)

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Abstract

The fossil orthopteran *Brauckmannia groeningae* Martins-Neto (Orthoptera, Ensifera) from the Early Cretaceous Crato Formation of Brazil, currently misplaced at both the genus and family level, is transferred to the family Schizodactylidae and assigned to the extant genus *Schizodactylus* Brullé; ergo, *Brauckmannia* enters synonymy under *Schizodactylus* and Brauckmanniidae enters synonymy under Schizodactylidae. *Schizodactylus groeningae* (Martins-Neto), **comb. n.** agrees in size and general habitus with extant members of the genus, but can be readily separated by the robust, subovoid form of the metatibiae and the distinctive morphology of the lateral metabasitarsal processes. This species represents the first fossil occurrence of Schizodactylidae and the only New World record of this ancient lineage. Phylogenetic relationships of the schizodactylids are reviewed and a sister-group relationship with Grylloidea advocated based on a reappraisal of morphological and molecular evidence.

Keywords

Orthoptera, Ensifera, Grylloidea, Schizodactylidae, Brauckmanniidae, *Brauckmannia*, *Schizodactylus*, phylogeny, Crato Formation, Early Cretaceous, Brazil

Introduction

The Lower Cretaceous Crato Formation of northeastern Brazil is famous for the truly exquisite preservation of its remarkable fossil assemblage (e.g. Grimaldi and Engel 2005; Heads et al. 2005, 2008; Martill et al. 2007 and contributions therein). Of the many animal and plant taxa hitherto reported from the Crato palaeobiota, insects are without doubt the most diverse and account for more than 75 percent of the total number of species described from the formation to date. Insect fossils occur in superabundance within the laminated limestones of the Nova Olinda Member, where they are frequently preserved as complete, fully articulated individuals with wings, setae, soft tissues and even original colour patterns (Grimaldi 1990; Martill and Frey 1995; Heads et al. 2005; Martill et al. 2007). More than 300 species representing over 20 insect orders have been described from the Crato Formation to date (Martill et al. 2007; Heads et al. 2008) and given that the most diverse groups (notably Coleoptera, Hymenoptera, Diptera and Hemiptera) remain almost entirely unstudied, the total number of species is certain to be much higher. Indeed, this remarkable deposit is perhaps the most important source of fossil insects yet encountered in the Cretaceous of Gondwana (Heads et al. 2008), with the potential to shed light on the evolution and biogeography of the insects during what is arguably one of the most dynamic periods in their history.

Orthoptera (crickets, katydids, grasshoppers and their kin) are well-represented in the Crato Formation (Heads and Martins-Neto 2007) and constitute the most frequently encountered insect fossils in the Nova Olinda laminites. Both orthopteran suborders are present, including a diverse assemblage of Ensifera comprising the superfamilies Grylloidea, “Hagloidea” and Stenopelmatoidea *sensu lato* (Martins-Neto 1991, 2007; Heads and Martins-Neto 2007). Caelifera are represented by primitive Tridactyloidea, Eumastacoidea and stem-acridomorphs of the paraphyletic ‘locustopoid’ complex (Martins-Neto 2003; Heads 2008). Crickets (Grylloidea) are perhaps the most diverse component of this assemblage, though the Elcanidae are by far the most abundant (Heads and Martins-Neto 2007). Fossil Orthoptera are rare in most Mesozoic deposits, though in the Crato Formation they represent as many as 30 per cent of all fossil insect specimens (Bechly 1998; Martill et al. 2007; Heads et al. 2008). This remarkable diversity and abundance highlight the importance of the assemblage and yet, despite over 20 years of research, a comprehensive treatment of the Orthoptera is still unavailable. Nevertheless, a detailed taxonomic revision is now underway (Heads in prep.) and will undoubtedly shed much-needed light not only on the evolution and biogeography of Cretaceous Orthoptera, but also on the origins of the modern fauna.

The unusual orthopteran *Brauckmannia groeningae* was described by Martins-Neto (2007: 3–4, fig. 1) based on a single specimen from a large quarry complex

to the northeast of Mina Pedra Branca, 4–5 km west of Nova Olinda on the northern flanks of the Chapada do Araripe (see Martill et al. 2007 for locality details). Martins-Neto (2007) assigned the genus to its own family, Brauckmanniidae, which he assigned to the superfamily Stenopelmatoidea *sensu lato*; a group comprising the Anostomatidae (king crickets and wetas), Cooloolidae (Cooloola monsters), Gryllacrididae (leaf-rolling or raspy crickets) and Stenopelmatidae (Jerusalem crickets). However, Martins-Neto's original description (2007) is cursory at best and suffers from numerous errors in the identification and interpretation of morphological structures critical to the proper placement of the fossil. Here, we present a detailed redescription of *B. groeningae* based on a new and near-complete specimen, allowing us to establish its true identity as a species of the extant genus *Schizodactylus* Brullé, 1835 and thus, the first fossil representative of the Schizodactylidae, or splay-footed crickets.

Material and methods

The holotype of *Brauckmannia groeningae* is in the private collection of Rafael Gioia Martins-Neto, referred to in his publications as the 'Coleção de Sociedad Brasileira de Paleoartropodologia' with the number RGMN 500. This collection was apparently stored at his home in Ribeirão Preto, São Paulo, though since his death in August 2010 its whereabouts are unknown. As a result, any discussion of the holotype presented herein is based entirely on the illustrations in the original description (Martins-Neto 2007). However, we were recently able to examine a second, more completely preserved specimen in the Museum für Naturkunde, Berlin, Germany (MfNB). This new specimen is evidently conspecific with the holotype and allows us to redescribe the species and more accurately determine its systematic placement.

The MfNB specimen was studied using a Zeiss Stemi SV11 zoom stereomicroscope and drawings produced with the aid of a camera lucida. Macro photographs were taken using a Nikon D700 digital SLR with a 60 mm macro objective. In addition, the following extant material was also examined: *Schizodactylus brevinotus* Ingrisch, 2002; *S. inexpectatus* (Werner, 1901); *S. burmanus* Uvarov, 1935; *S. monstrosus* (Drury, 1773); *S. hesperus* Bei-Bienko, 1967; *Comicus arenarius* Ramme, 1931; *C. calcaris* Irish, 1986; *C. campestris* Irish, 1986; and *C. capensis* Brunner von Wattenwyl, 1888. Terminology used follows that normally employed for Orthoptera, with the following distinctions concerning tibial armature: 'spine' refers to elongate, distally pointed, unsocketed processes; and 'spur' refers to all socketed processes of variable form (e.g. spine-like, blade-like, lobate, etc.). The geology, stratigraphy, environment and palaeobiota of the Crato Formation were most recently reviewed by Martill et al. (2007) and contributions therein.

Systematics

Family Schizodactylidae Blanchard, 1845

Schizodactylites Blanchard 1845: 249.

Schizodactylinae Ramme 1931: 163.

Schizodactylidae Ander 1939: 622.

Brauckmanniidae Martins-Neto 2007: 3, syn. n.

Comments. The Schizodactylidae, or splay-footed crickets, are a relict group of primitive Ensifera notable for their uniquely modified tarsi, which bear distinctive lobe-like lateral processes that serve to support the insects as they walk around their sandy habitats. The family is traditionally subdivided into two monotypic subfamilies: Schizodactylinae Blanchard, 1845 containing the type genus *Schizodactylus* Brullé, 1835 found primarily in India, Pakistan, Afghanistan and parts of Southeast Asia; and Comicinae Ander, 1939 containing the apparently pedomorphic genus *Comicus* Brunner von Wattenwyl, 1888 found only in southern parts of Africa. Schizodactylids are primarily nocturnal and are thought to be active predators (Fletcher 1914). Indeed, species of *Schizodactylus* have an intimidating habitus and clear predatory adaptations including raptorial prothoracic legs and powerful, enlarged mouthparts. Sub-social behaviour and cannibalism have been observed in populations of *S. monstrosus* (Drury, 1773) (Choudhuri and Bagh 1974) and *S. inexpectatus* (Werner, 1901) was recently the subject of a detailed biological and ecological study by Aydin and Khomutov (2008).

Genus *Schizodactylus* Brullé, 1835

Schizodactylus Brullé 1835: 161. Type species: *Gryllus monstrosus* Drury, 1773.

Schizocephalus Brunner von Wattenwyl 1888: 313, lapsus calami.

Dactylocomicus Karny 1931: 102. Type species: *Comicus inexpectatus* Werner, 1901.

Brauckmannia Martins-Neto 2007: 4. Type species: *Brauckmannia groeningae* Martins-Neto, 2007, syn. n.

Diagnosis. The genus *Schizodactylus* as presently defined comprises all large and robust schizodactylids with wings developed and, with the exception of *S. inexpectatus* in which the wings are reduced, extending beyond the apex of the abdomen where they terminate in a conspicuous coil. *Schizodactylus* species are further characterised by greatly enlarged mouthparts, a broad diamond-shaped labrum, and strong laterally compressed pro- and mesothoracic legs. The genus is readily separated from *Comicus*, the only other genus in the family, which is characterised by a markedly smaller and more gracile body (usually less than 25 mm in length), long, slender legs, and complete reduction of the wings.

Comments. Given the presence of distinctively coiled wings and well-developed lateral processes on the tarsi, there can be no doubt as to the placement of *B. groeningae* in Schizodactylidae. In addition, there are no characters preserved in either the holotype (so far as can be seen from Martins-Neto's illustrations) or the new material described below to exclude the species from the genus *Schizodactylus*. Both fossil specimens match closely the general habitus, tarsal morphology and metatibial armature of extant *Schizodactylus* species, and there are no convincing apomorphies to support separate generic placement.

***Schizodactylus groeningae* (Martins-Neto, 2007), comb. n.**

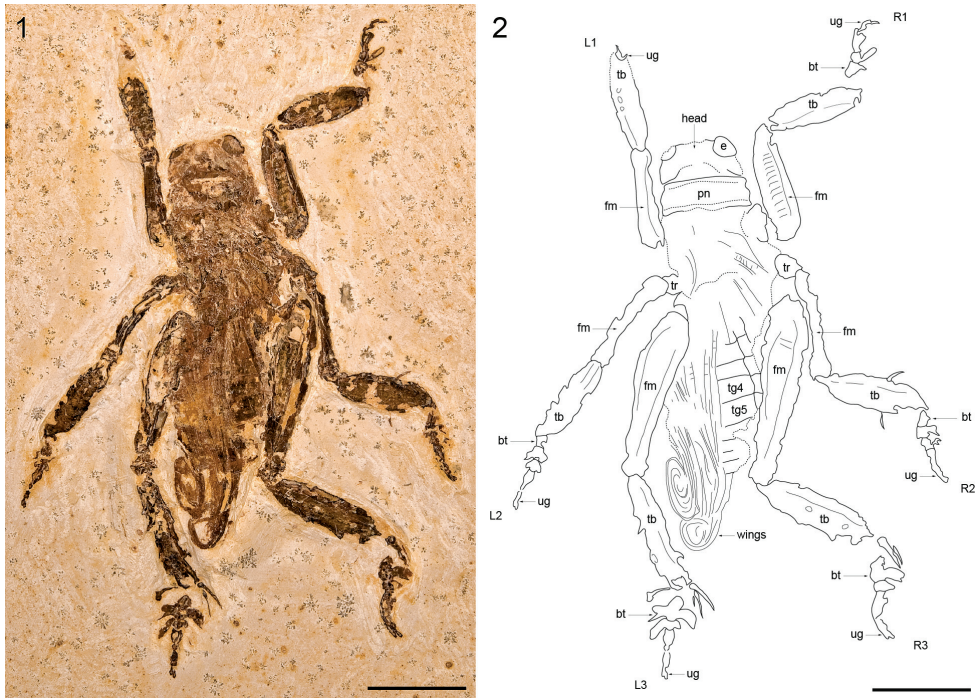
Figs 1–2

Brauckmannia groeningae Martins-Neto 2007: 4, fig 1.

Material examined. Near-complete adult (sex indet.), MfNB-I.2079. Brazil, Ceará, Chapada do Araripe; Crato Formation, Nova Olinda Member, Lower Cretaceous.

Diagnosis. *Schizodactylus groeningae* is distinguished from all congeners by the following characters: [1] robust and acutely subovoid metatibiae (in all extant species the metatibiae are of equal width along their entire length); and [2] distinctive blade- or paddle-like lateral processes arising in the distal half of the metabasitarsus (in all extant species these processes are triangular with a broad base and acute, posteriorly directed apex, and arise within the proximal half of the metabasitarsus).

Description of MfNB-I.2079. Large, near-complete specimen preserved in slightly oblique, dorsal aspect (Figs 1–2). Head capsule robust, 8.46 mm wide at genae; vertex short, c. 2.43 mm from occipital margin as preserved; occipital foramen large, broad; interocular distance 3.98 mm; compound eyes large, c. 2.61 mm wide dorsally. Pronotum markedly wider than long with distinctive marginal sulci; medial length 3.41 mm; width 9.36 mm. Pterothorax poorly preserved, c. 9.20 mm long. Wings incompletely preserved basally, extending posteriorly beyond abdominal apex, tightly folded in a distinctive apical coil. Abdomen somewhat crushed dorsolaterally, c. 16.12 mm long as preserved (apical part missing); first tergite (tg1) largely indistinct, at least 1.45 mm long; tg2 1.96 mm long; tg3 1.83 mm long; tg4 2.17 mm long; tg5 2.35 mm long; remaining tergites incompletely preserved but shorter than previous tergites; right lateral parts of abdominal sternites 1 through 5 visible next to corresponding tergal sclerites; pleural margin distinct. Total body length measured from fastigium verticis to abdominal apex 34.91 mm. Profemora robust and laterally compressed, 12.33 mm long; left profemur preserved in dorsal aspect, with distinct longitudinal dorsal carina; right profemur preserved in lateral aspect, with prominent transverse dorsolateral striae and distinct longitudinal inferior carina. Protibiae robust and lateral compressed, markedly inflated and acutely subovoid in form, 10.24 mm long; left protibia incompletely preserved in oblique dorsal aspect, bearing at least three spur sockets on outer lateral margin, spurs themselves not preserved; right protibia preserved in lateral aspect and somewhat crushed. Left prothoracic leg (L1 in Fig. 2) with distal part missing, only apical part of unguis preserved. Right pro-



Figures 1–2. *Schizodactylus groeningae* (Martins-Neto, 2007), comb. n. from the Lower Cretaceous Crato Formation of Brazil. **1** Photograph of MfNB-I.2079 **2** Camera lucida drawing of MfNB-I.2079. Abbreviations: **R1** – right prothoracic leg; **L1** – left prothoracic leg; **R2** – right mesothoracic leg; **L2** – left mesothoracic leg; **R3** – right metathoracic leg; **L3** – left metathoracic leg; **bt** – basitarsus; **fm** – femur; **pn** – pronotum; **tb** – tibia; **tr** – trochanter; **ug** – ungues. Scale bars represent 10 mm.

thoracic leg (R1 in Fig. 2) with tarsus incompletely preserved, at least 6.52 mm in total length; basitarsus subcylindrical in form, inflated apically, at least 1.75 mm long; second tarsomere short, c. 1.21 mm long, with prominent blade-like lateral process, 2.35 mm long; third tarsomere 2.10 mm long, with stout lateral process, 0.95 mm long; fourth tarsomere indistinctly preserved; ungues incompletely preserved, strongly curved, 1.44 mm long. Mesotrochantora small, c. 2.40 mm long and c. 2.20 mm wide. Mesofemora very slender, somewhat curved, inflated slightly at both the base and geniculae, 11.26 mm long and 1.46 mm wide at midlength. Mesotibiae similar in form to protibiae but somewhat larger and more acutely subovoid in lateral aspect, 10.75 mm long; left mesotibia incompletely preserved in dorsal aspect; right mesotibia preserved in lateral aspect, 3.36 mm wide at midlength, with two short subapical spurs preserved. Left mesothoracic leg (L2 in Fig. 2) with tarsus preserved in dorsal aspect, 8.17 mm long; basitarsus small, 1.15 mm long; second tarsomere 1.25 mm long with broad, incomplete lateral processes at least 1.49 mm long; third tarsomere 1.28 mm long with stout lateral processes at least 0.62 mm long; fourth tarsomere basally inflated, apically slender, 2.18 mm long; ungues at least 2.08 mm long. Right mesothoracic leg (R2 in Fig. 2) with tarsus preserved in lateral aspect, c. 8.10 mm long; basitarsus small, 1.55 mm long; second tarsomere

1.15 mm long with broad, apically incomplete lateral process at least 1.58 mm long; third tarsomere 1.23 mm long with incompletely preserved lateral process at least 0.95 mm long; margin between fourth tarsomere and unguis indistinct, combined length c. 3.91 mm. Metafemora large, robust, 19.78 mm long. Metatibiae markedly shorter than metafemora, 12.58 mm long; acutely subovoid in form, though more elongate than pro- and mesotibiae. Left metatibia preserved in dorsal aspect, somewhat crushed, with poorly preserved spines along dorsolateral margins; first apical spur 3.62 mm long; second apical spur 3.07 mm long; third apical spur incompletely preserved and visible only as a thin, 0.86 mm long fragment immediately adjacent and inferior to the second apical spur; sixth apical spur partially preserved in lateral aspect, 2.88 mm long and 0.96 mm wide apically. Right metatibia preserved in lateral aspect, 3.29 mm wide at midlength, with bases of poorly preserved spines visible along the dorsal margin; first apical spur blade-like, 3.80 mm long; second apical spur incompletely preserved immediately adjacent and inferior to the first apical spur, 2.06 mm long. Left metathoracic leg (L3 in Fig. 2) with tarsus preserved in dorsal aspect, at least 8.76 mm long; basitarsus well-developed, at least 2.80 mm long, with large, broadly paddle-like lateral processes at least 2.41 mm long and 1.78 mm wide; second tarsomere short, 0.98 mm long, with large, blade or paddle-like lateral processes at least 2.28 mm long and 0.94 mm wide; third tarsomere incomplete, at least 1.98 mm long; combined length of fourth tarsomere and unguis c. 2.98 mm. Right metathoracic leg (R3 in Fig. 2) with tarsus preserved in lateral aspect, at least 9.50 mm long; basitarsus well-developed, at least 2.66 mm long, with large, paddle-like lateral process at least 2.37 mm long; second tarsomere short, 1.04 mm long, incompletely preserved; third tarsomere indistinct, with basal part of small lateral process visible; fourth tarsomere and unguis poorly preserved, combined length 3.97 mm.

Comments. The photograph of the holotype provided by Martins-Neto (2007: fig. 1A) is of rather poor quality, though it is obvious that the specimen is not as well preserved as MfNB-I.2079. Moreover, the accompanying drawing (fig. 1B) is not only incomplete (for reasons that are unclear, the drawing only depicts part of the specimen) but does not correspond entirely with features clearly visible in the photograph. Nevertheless, the photograph shows sufficient details for the identification of the holotype as a schizodactylid; namely the presence of distinctive paddle-like lateral processes on the tarsi (clearly visible on both metatarsi though misidentified as ‘well-developed pulvilli’ by Martins-Neto), and apically coiled wings (not mentioned in the original description). Moreover, the holotype is clearly conspecific with MfNB-I.2079, agreeing with it not only in the relative proportions of the legs and overall size and habitus, but also in the distal origin of the metabasitarsal processes.

Schizodactylus groeningae represents the only fossil record of Schizodactylidae and confirms the antiquity of an extant lineage hitherto unknown from the fossil record. Especially significant is that the species belongs to an extant, albeit relict genus, suggesting that the initial radiation of the Schizodactylidae occurred at least during the Jurassic if not earlier. Moreover, the presence of *S. groeningae* represents the only record of Schizodactylidae from the New World, confirming presence of the family in the Atlantic rift zone of South America prior to its complete separation from Africa. An arid or semi-arid

local environment for the Crato hinterland was first suggested by Martill (1993) and later supported by the discovery of solifuges (Selden and Shear 1996) and diplurid spiders (Selden et al. 2006). The development of thick and laterally extensive sandstones within the Crato Formation (Heimhofer and Martill 2007) provides direct evidence for the existence of large local sand bodies and the preserved root balls of fossil plants often consist largely of sand-rich palaeosols (Mohr et al. 2007). Evidence for seasonal flash flooding is also well attested (see Martill et al. 2007 and contributions therein) and might explain how the terrestrial elements of the biota were transported into the Crato lagoon. The presence of *Schizodactylus* in sandy, xeric monsoonal environments today is therefore, entirely consistent with the hypothesised palaeoenvironment and would suggest that the habitat preferences of schizodactylids have changed little in over 100 million years.

Discussion

The relationships of the splay-footed crickets have proven somewhat controversial (see Fig. 3), with the group generally regarded as a subfamily within Gryllacrididae (Ramme 1931; Karny 1937; Zeuner 1939; Gorochov 1995a, b) or as a subfamily close to Gryllacridinae but within Stenopelmatidae (Gorochov 2001). Sharov (1968: 71) considered the group a ‘*reliktovyi oskolok*’ or ‘relictual fragment’ of Hagloidea, closest to Prophalangopsidae amongst the extant Ensifera. In contrast, Ragge (1955) and Gwynne (1995) considered the Schizodactylidae as occupying a basal position within Gryllidea as sister-group to the Grylloidea. Ander (1939) included the family in his ‘Tettigoniioidea’ (= Tettigoniidae), basal to a lineage giving rise to the Gryllacrididae, Stenopelmatidae *sensu lato*, Prophalangopsidae and Tettigoniidae. This view was upheld at least in part by Desutter-Grandcolas (2003) who, in her landmark cladistic study of ensiferan relationships, recovered Schizodactylidae as sister-group to a clade comprising Cooloolidae, Stenopelmatidae, Anostostomatidae, Prophalangopsidae and Tettigoniidae (Fig. 3g). However, recent molecular analyses (Jost 2002; Jost and Shaw 2006; Legendre et al. 2010) have consistently failed to support such a relationship, instead recovering Schizodactylidae (represented in all three studies only by *Comicus*) as sister-group to the Grylloidea as proposed by Ragge (1955) and Gwynne (1995).

Morphological support for a schizodactylid–grylloid relationship comes primarily from the morphology and venation of the wings, namely: [1] marked reduction or loss of costal veins; [2] development in the tegmina of a longitudinal fold; [3] concurrent development of a distal medial fan in the tegmina; [4] development of fan-like folding in the cubital and medial systems of the hind wings; and [5] hind wing CuA two-branched. In addition, Gwynne (1995; following Ander 1939) noted the fusion of abdominal ganglion 7 with the posterior ganglionic mass (comprising fused abdominal ganglia 8 through 10) in both Schizodactylidae and Grylloidea as a potential autapomorphy of Gryllidea *sensu* Ragge (1955). Such an arrangement is also known in certain Rhabdophoridae (e.g. *Dolichopoda*, *Hadenoecus* and all Rhabdophorini) though in other members of the family the 7th ganglion is free (e.g. *Ceuthophilus*, *Neonetus* and *Pristoceuthophilus*).

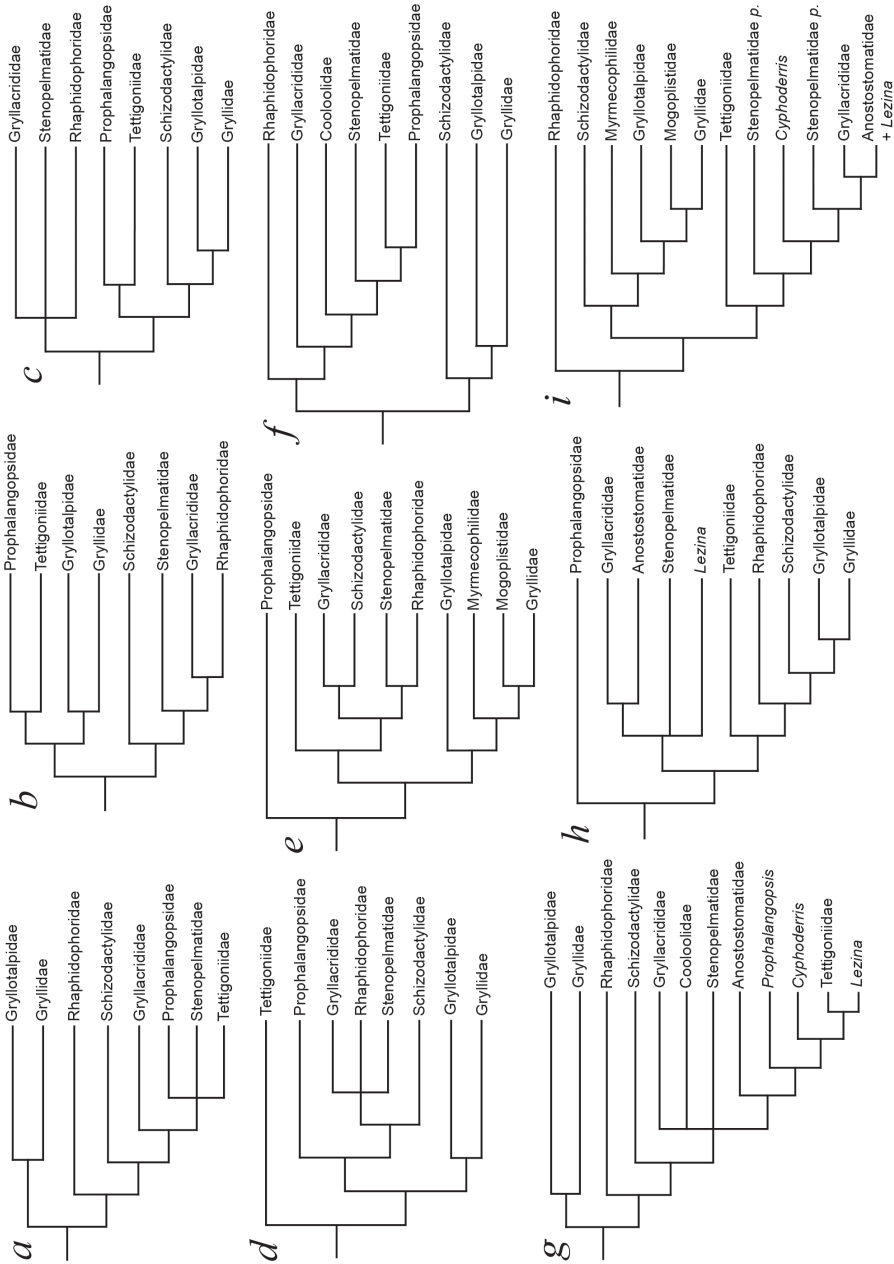


Figure 3. Competing hypotheses of ensiferan relationships, after: **a** – Ander (1939); **b** – Zeuner (1939); **c** – Ragge (1955); **d** – Sharov (1968); **e** – Gorochov (1995a, b); **f** – Gwynne (1995); **g** – Desutter-Grandcolas (2003); **h** – Jost and Shaw (2006); **i** – Legendre et al. (2010).

Indeed, the Rhaphidophoridae have traditionally been considered transitional between Grylloidea and the other Ensifera (e.g. Snodgrass 1937; Ander 1939; see also Desutter-Grandcolas 2003). The optimal tree recovered by Legendre et al. (2010) in their reanalysis of the Jost and Shaw (2006) molecular data set, placed the raphidophorids as sister-group to the rest of Ensifera (Fig. 3i). However, both Desutter-Grandcolas (2003) and Legendre et al. (2010) noted that none of the existing morphological or molecular datasets are adequate to test raphidophorid monophyly and the group could be paraphyletic with respect to Grylloidea (Schizodactylidae + Grylloidea), Tettigoniidea (the so-called ‘katydid clade’ comprising Tettigoniidae and the various ‘stenopelmatoid’ families), or both (*contra* Béthoux and Nel 2002). Clearly, comprehensive and integrated morphological-molecular and neontological-palaeontological analyses are necessary and will undoubtedly shed much-needed light on ensiferan phylogeny.

Figure 4 shows a tentative reconstruction of relationships among major ensiferan groups based on a review of hypotheses presented in the various studies summarized in Fig. 3. The phylogenetic relationships of the gryllidean taxa are based primarily on the molecular phylogeny of Legendre et al. (2010; refer to Fig. 3i herein) with minor modification regarding the uncertain position of the obscure and highly derived Myrmecophilidae. We mapped phylogenetically informative morphological characters onto this topology and lists of character transformations are provided for each node in the figure caption. As discussed above, there appears to be considerable congruence between morphological and molecular data. Moreover, our attempt to place fossil Grylloidea (Protogryllidae and Baissogryllidae) on this phylogeny did not radically alter the topology. Indeed, whilst the monophyly of these taxa is questionable, their relationships are clearly delimited in the current hypothesis. In particular, the Protogryllidae almost certainly represent a paraphyletic grade of basal crickets that gave rise to all other Grylloidea sometime between the Late Triassic and Late Jurassic. The oldest protogryllids are known from the mid-Triassic (Carnian, *c.* 225 Ma) Molteno Formation of South Africa (Gorochov and Rasnitsyn 2002) which would suggest that the schizodactylid lineage is at least mid-Triassic in age. Such an extensive ‘ghost lineage’ is not uncommon among orthopterans, which are often frustratingly rare as fossils.

Whilst it is clear that major group relationships within Ensifera remain largely unresolved (see Legendre et al. 2010), the morphological and molecular support for a Schizodactylidae–Grylloidea sister-group relationship is compelling. Moreover, evidence for a close relationship between Schizodactylidae and Gryllacrididae or any of the other ‘stenopelmatoid’ families (Zeuner 1939; Sharov 1968; Gorochov 1995a, b, 2001) is based either on misinterpretation of non-homologous structures as homologous autapomorphies (e.g. gryllacridid pulvilli and the lateral processes of schizodactylid tarsi) or characters known to be plesiomorphic in Ensifera (e.g. four-segmented tarsi, ventral subapical spurs on the metatibiae etc.). A sister-group relationship between Grylloidea and the Triassic Gryllavidae as proposed by Gorochov (1995a, b) is difficult to demonstrate given that the latter family are known only from fossil wings. However, the tegminal venation of Gryllavidae is similar to that of Cyrtophyllitinae and it is likely that *Gryllavus* and related genera are closer to the paraphyletic “hagloid” assemblage than to the Grylloidea. With

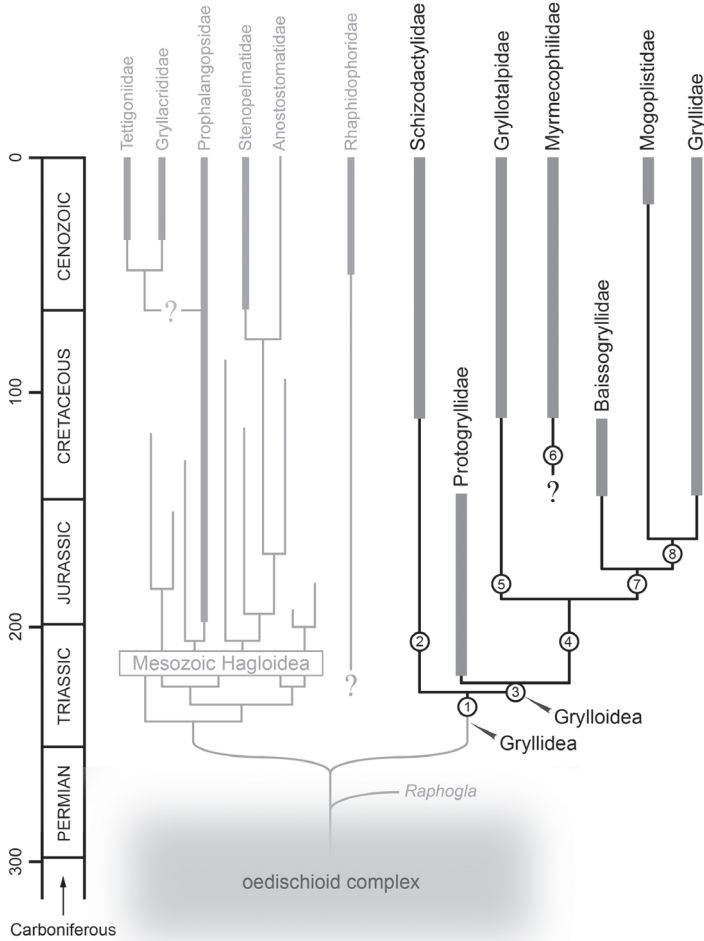


Figure 4. Possible relationships among major ensiferan groups (both fossil and extant), with an emphasis on the infraorder Gryllidea. Thick lines indicate known geological ranges whilst thinner lines project likely ranges based on sister-group relationships. Arabic numerals at nodes indicate autapomorphic character transformations as follows: **1** (i) reduction or loss of cubitus; (ii) development of longitudinal radio-medial fold in tegmina; (iii) development of a distal medial fan in tegmina; (iv) development of fan-like folding in cubital and medial systems of hind wings; (v) hind wing CuA two-branched; (vi) fusion of abdominal ganglion 7 with posterior ganglionic mass **2** (i) hind wings, when developed, tightly folded at rest and apically coiled in a distinctive ring; (ii) well-developed, blade or paddle-like lateral processes present on the 2nd and 3rd tarsomeres of the pro- and mesotarsi and also on the metabasitarsus; (iii) predatory **3** (i) tarsi reduced to three tarsomeres; (ii) loss of the fastigium verticis; (iii) development of stridulatory file on ventral surface of tegminal CuP; (iv) presence of a dividing vein and harp between CuA₂ and CuP **4** (i) tegminal medial fan expanded, forming a subapical medial lobe **5** (i) prothoracic legs fossorial; (ii) ovipositor vestigial **6** (i) compound eyes markedly reduced; (ii) all coxae large and closely approximated; (iii) pseudosegmented cerci; (iv) reduced ovipositor; (v) obligate inquilines of ants **7** (i) development of a tegminal mirror **8** (i) migration of dividing veins in the mirror to a position perpendicular with respect to long axis of tegmen.

this in mind, and given the lack of convincing morphological or molecular autapomorphies for Stenopelmatoidea *sensu* Gorochov (2001), it seems reasonable to accept a schizodactylid–grylloid clade as shown in Fig. 4 until evidence is presented to the contrary.

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Review of the European *Greenomyia* Brunetti (Diptera, Mycetophilidae) with new descriptions of females

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Abstract

The females of the four continental *Greenomyia* Brunetti species in Europe are associated with the males, diagnosed and keyed, providing the first association and description of the females of *G. baikalica* Zaitzev, 1994 and *G. stackelbergi* Zaitzev, 1982. Colour photographs of their habitus and line drawings of their female terminalia are provided. *Greenomyia mongolica* Laštovka & Matile, 1974 is found to be a senior synonym of *Greenomyia theresae* Matile, 2002. **syn. n.** The diagnostic characters used to distinguish between *Greenomyia* and *Neoclastobasis* Ostroverkhova in keys did not hold up to a closer scrutiny and leave the status of *Neoclastobasis* as separate genus questionable.

Keywords

Mycetophilidae, *Greenomyia*, *Neoclastobasis*, fungus gnats, systematics, identification key, synonymy, Europe

Introduction

The genus *Greenomyia* Brunetti was erected to distinguish a single oriental species, *Greenomyia nigricoxa* Brunetti, 1912. Since then several species (mainly Holarctic) have been described and new combinations proposed. Laštovka and Matile (1974) and Chandler and Ribeiro (1995) characterised the genus and Matile (2002) provided a key to all 11 world species of *Greenomyia*. Species of *Greenomyia* are mostly dark coloured medium-sized fungus gnats with a typical wing venation similar to that of *Leia*

Meigen, 1818 and allied genera where R_1 is notably shorter than the long and nearly horizontally aligned crossvein *rm*. Further diagnostic characters include the lateral ocelli being well separated from the eye margins and all veins reaching the wing margin (cf. Söli et al. 2000). Edwards (1925) introduced the tribe Leiini for *Leia*, *Greenomyia* and a number of other genera with an intermediate position between the subfamilies Sciophilinae and Mycetophilinae. Later the tribe has sometimes been given subfamily status (see review by Gammelmo 2004), but recent morphological and molecular studies have questioned its monophyly (e.g. Amorim and Rindal 2007; Rindal et al. 2009). *Greenomyia* appears most closely related to the genus *Neoclastobasis* Ostroverkhova, 1970, a genus that includes two eastern Palaearctic (*N. sibirica* Ostroverkhova, 1970 and *N. kamijoi* Sasakawa, 1964) and one European species (*N. draskovitsae* Matile, 1978). The genus *Neoclastobasis* is diagnosed by a prolonged apical palpal segment, the veins M_2 and CuA_1 terminating before the wing margin, and distinctive terminalia (Ostroverkhova 1970; Matile 1978; Zaitzev 1994; Söli et al. 2000).

Species of *Greenomyia* are not frequently encountered in Europe and apart from the widespread *G. mongolica* Laštovka & Matile, 1974 (e.g. Bechev 1989; Ševčík and Martinovský 1999; Plassmann 1996; Caspers 1996; Kurina 1997; Chandler 2010), they are generally thought of as quite rare. A revitalized focus on fungus gnats the last two decades, however, has yielded a number of new records and five species are now reported from Europe: viz. *G. baikalica* Zaitzev, 1994, *G. borealis* (Winnertz, 1863), *G. lucida* (Becker, 1908), *G. mongolica* (= *G. theresae* Matile, 2002, syn. n.), and *G. stackelbergi* Zaitzev, 1982 (see Fig. 29 for published records, except *G. lucida*, which is endemic to the Canary Islands).

While the males of most *Greenomyia* species are adequately illustrated and keyed (Zaitzev 1982, 1994; Laštovka and Matile 1974; Chandler and Ribeiro 1995; Matile 2002) the females of several species remain to be properly diagnosed and described. The current communication was initiated by the finding of three *Greenomyia* species from two localities 1 km apart in Vuollerim, Lule Lappmark in northern Sweden (Kjærandsen et al. 2007). The material gave us the opportunity to associate and describe females of two species for the first time. The shifted focus to females further revealed that the generic characters separating *Neoclastobasis* from *Greenomyia* do not hold, and highlights a need to re-evaluate their status as separate genera.

Material and methods

Material and collections from a wide range of Palaearctic sources were studied. The collecting methods, if known, are referred to in case by each specimen in the studied material section below. The following codens obtained from Evenhuis (2009) are used for depositories:

Coll. Hedmark Private collection of Kjell Hedmark, Orsa, Sweden.

Coll. Selin Private collection of Allan Selin, Tallinn, Estonia.

EIHU Hokkaido University Museum, Sapporo, Japan.

- IZBE** Institute of Agricultural and Environmental Sciences, Estonian University of Life Sciences (former Institute of Zoology and Botany), Tartu, Estonia.
MNHN Muséum National d'Histoire Naturelle, Paris, France.
MZLU Museum of Zoology, Lund University, Lund, Sweden.
ZIN Zoological Institute of Russian Academy of Sciences, St. Petersburg, Russia.
ZMHB Museum für Naturkunde Humbolt-Universität zu Berlin, Germany.
ZSM Zoologische Staatssammlung in München, Germany

Three of four species were photographed and figured based on material collected in Vuollerim (Sweden), while illustrations of *G. mongolica* were based on Greek material. The terminalia were detached and cleared in a solution of KOH, followed by neutralization in acetic acid and washing in distilled water or in alcohol. The remaining chitinous parts were inserted into glycerine for detailed study, including illustration, and thereafter preserved as glycerine preparations in polyethylene micro vials. Habitus and wing photos were taken of specimens in alcohol, using a Canon 7D camera fitted with a Canon MP-E65 (F2.8 1–5 ×) lens. Illustrations of the terminalia were prepared using a U-DA drawing tube attached to a Olympus CX31 compound microscope. Terminalia are figured in three different positions: laterally, dorsally and ventrally. Sternite VIII was detached and figured separately to better expose the shape of hypoproct and gonapophysis IX. The preservation method of the studied specimens is indicated in the material section for each species. We used a 70–80 % solution of ethanol for alcohol preservation and the chemical method described by Vockeroth (1966) for dry-mounting from alcohol. Slide mounting in Euparal followed the method described by Kurina (2008b). Morphological terminology follows Söli (1997).

Systematics

Key to females of European *Greenomyia* species

Compiled from Zaitzev (1982, 1994), Chandler and Ribeiro (1995), Matile (2002) and original data.

- | | |
|---|---|
| 1 | Wing hyaline (Fig. 12). Coxae yellow, femora and tibiae yellow, only hind femur brown in apical fourth. Mesonotum yellow with three fused longitudinal brown stripes. Cercus one segmented. Sternite VIII with three apical incisions (Fig. 28) <i>G. stackelbergi</i> Zaitzev, 1982 |
| – | Wing with apical or preapical dark band. Mesonotum dark brown to black. Coxae yellow or blackish. Cercus one- or two-segmented. Sternite VIII with single central incision apically (Figs 25–27) 2 |
| 2 | Wing tip darkened on about apical third (Fig. 11) 3 |
| – | Wing with preapical dark band leaving tip hyaline (Figs 9–10) 4 |

- 3 Mid and hind coxae brown to black (Fig. 3). Cercus clearly two-segmented...
 *G. mongolica* Laštovka & Matile, 1974
- All coxae yellow or slightly darkened basally
 *G. lucida* (Becker, 1908) [Endemic to the Canary Islands, not seen]
- 4 Last palpal segment elongated (Fig. 6). C terminating distinctly before apex
 of wing, making R_5 straight to slightly sinuate (Fig. 10). Cercus two-segment-
 ed but segments partly fused (Figs 14, 18)
 *Greenomyia borealis* (Winnertz, 1863)
- Last palpal segment not elongated (Fig. 5). C terminating almost at apex of
 wing, making R_5 distinctly arched (Fig. 9). Cercus one-segmented (Figs 13,
 17) *Greenomyia baikalica* Zaitzev, 1994

The species

Greenomyia baikalica Zaitzev, 1994

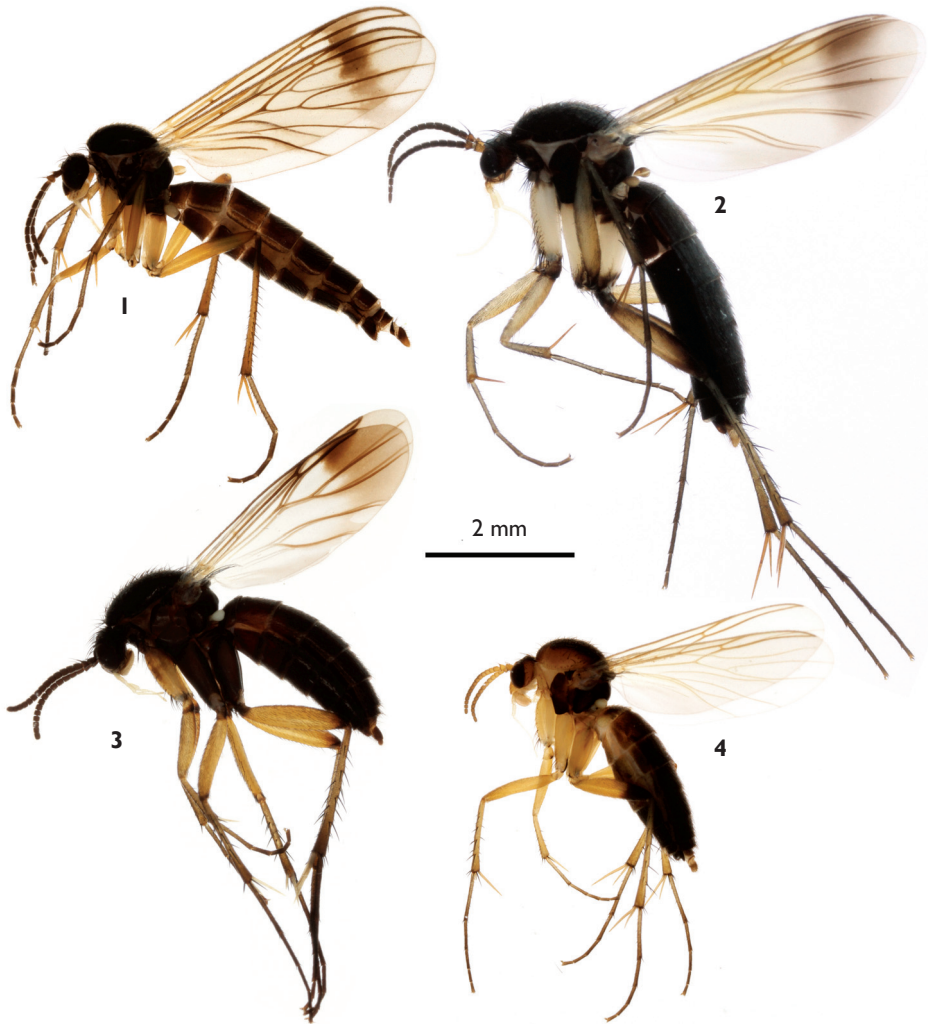
Figures 1, 5, 9, 13, 17, 21, 25

Material studied: SWEDEN. 1♀, Lu. Jokkmokk, Vuollerim, Bomyrberget, in forest 135 m.a.s.l., Malaise trap, 16.–18.VIII.2006 (K. Hedmark leg.) [IZBE, mounted from alcohol]; 1♀, Lu. Jokkmokk, Vuollerim, Bomyrberget, 135 m.a.s.l., Malaise trap, 18.–24.VIII.2007 (K. Hedmark leg.) [MZLU, in alcohol]. FINLAND. 1♂, Kn. Sotkamo, Urpovaara, window trap N2, 26.VIII.–11.IX.1997 (M. Kuussaari leg.) [IZBE, on pin].

Diagnostic characters. Female. Thorax blackish, abdomen brown. Legs yellow, cx_3 with small dark markings basally. All trochanters yellow, with small black apicoventral spots. Tibiae with dense brown setae. Scape and pedicel dark yellow, first flagellomere basally yellowish, rest of flagellum brown. Mouthparts pale yellow. Apical palpal segment 1.4–1.6 ($n=2$) times as long as penultimate segment. Wing with narrow preapical brownish band, gradually tapering towards hind margin. C terminating almost at apex of wing, R_5 distinctly arched (Fig. 9). Medial and cubital veins both reach wing margin, CuA_1 basally obsolete, brownish shade along posterior margin of CuA_2 . Terminalia brown, cercus one-segmented, yellow apically. Tergite IX larger than tergite VIII. Gonapophysis IX visible in lateral view, with wide pear-shaped medial incision apically. Sternite VIII deeply incised apicomediaally and moderately emarginated basally.

Male. Coloration and other non-terminal characters including palpi similar to female. Apical palpal segment is 1.4 ($n=1$) times as long as penultimate segment.

Remarks. Zaitzev (1994) described this species from Siberian material (Buryat Republic). Subsequently only a few specimens have been recorded from Norway, Sweden, Finland and Russian Karelia (cf. Kjærandsen et al. 2007; Fig. 29). Zaitzev (1994) figured the male terminalia whereas the female terminalia have not been figured earlier. Using the key by Zaitzev (1994) the studied females run to *G. baikalica* and they are also morphologically conspecific with material of both sexes collected simultaneously



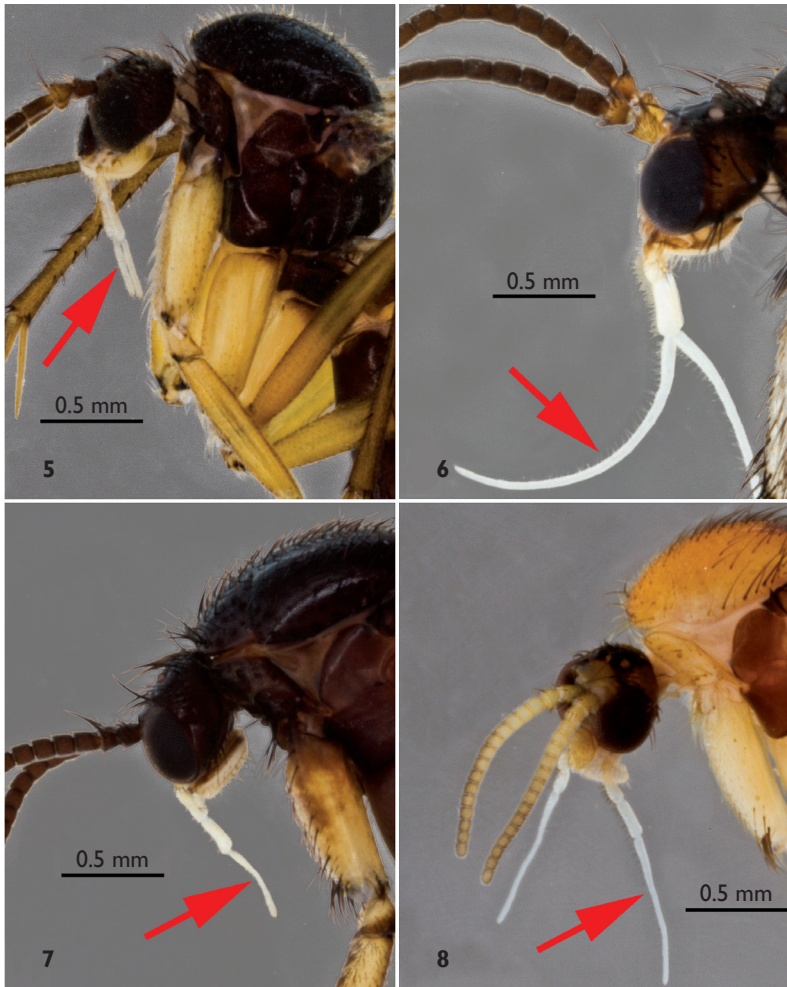
Figures 1–4. Habitus photos of European *Greenomyia* females. **1** *G. baikalica* **2** *G. borealis* **3** *G. mongolica* **4** *G. stackelbergi*.

in Russian Karelia (A. Polevoi, pers. comm.). The studied female specimens were collected in a boggy forest stand within a small (9 ha) protected remnant of semi-natural, mixed forest.

***Greenomyia borealis* (Winnertz, 1863)**

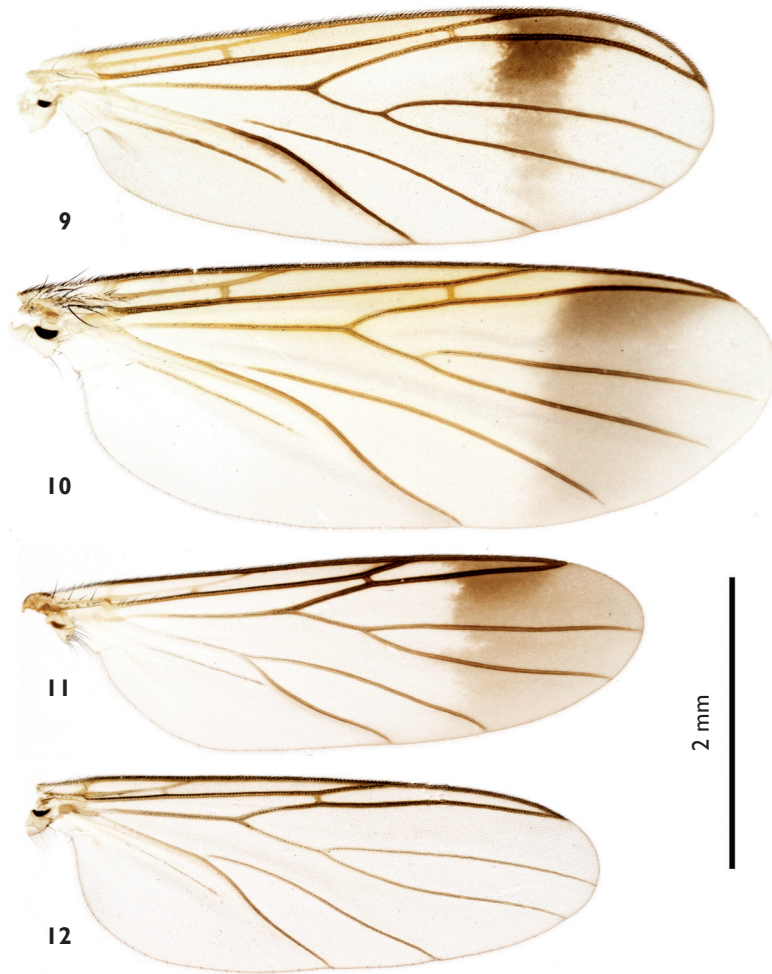
Figures 2, 6, 10, 14, 18, 22, 26

Material studied: SWEDEN. 2♂♂, SK, Lund and Lund, Abusa, undated (J. W. Zetterstedt leg.) [MZLU, on pins]; 1♀, ÖG, Valdemarsvik, Snäckevarp (Snäckehvarps



Figures 5–8. Head and palpi of European *Greenomyia* females, lateral view. **5** *G. baikalica* **6** *G. borealis* **7** *G. mongolica* **8** *G. stackelbergi*. Last palpal segment is indicated by a red arrow.

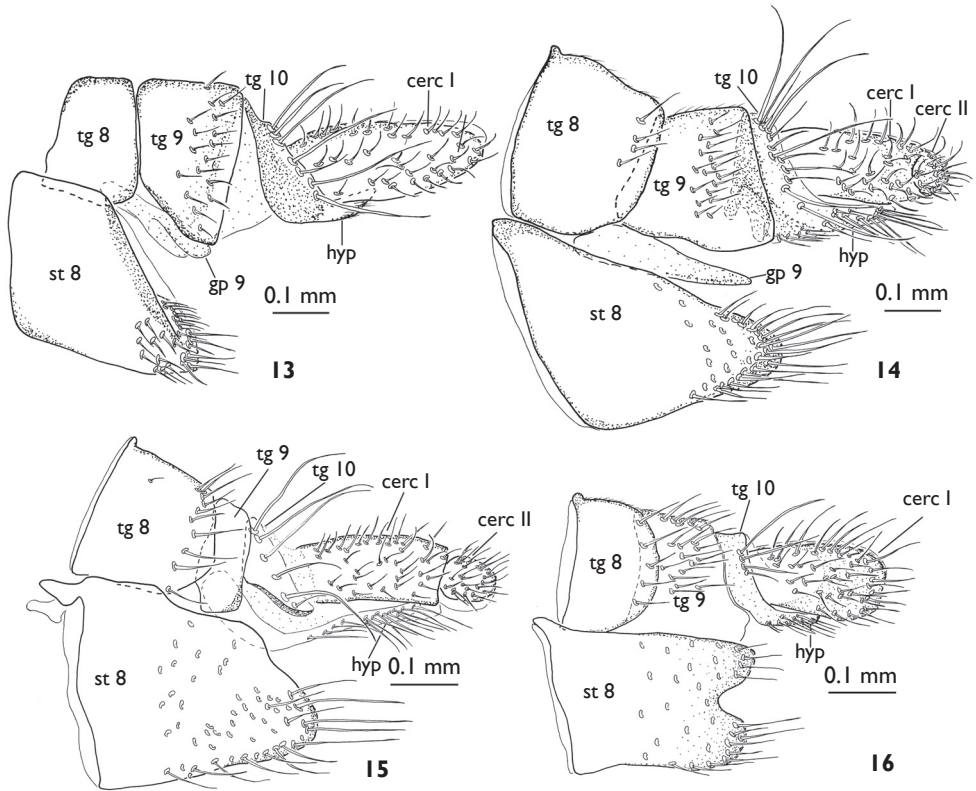
gästgifvaregård 1 km NE Gryt), 11 Aug 1825 (C. Stenhammar leg.) [MZLU, on pin]; 1♀, Lu. Jokkmokk, Vuollerim, in a garden, 105 m.a.s.l., Malaise trap, 8.–15.VIII.2008 (K. Hedmark and M. Karström leg.) [IZBE, mounted from alcohol]; **ESTONIA.** 1♂, Nigula NR, Haavapeaksi, sweeping, 12.VII.1998 (O. Kurina leg.) [IZBE, on pin]; 1♀, Tartu Marja 14, on window 21.VIII.2008 (O. Kurina leg.) [IZBE, on pin]. **GREECE.** 1♂ 2♀♀, Central Macedonia, Kerkini lakes area, village Vironia, Ramna site, 41°17'42.5"N, 023°11'33.1"E, 750 m.a.s.l., Malaise trap, 7.–13.VII.2008 (G. Ramel leg.) [IZBE, mounted from alcohol]; 1♂, Central Macedonia, Kerkini lakes area, village Vironia, Beabies site, 41°19'15.4"N, 023°13'39.6"E, 1150 m.a.s.l., Malaise trap, 21.–27.VII.2008 (G. Ramel leg.) [IZBE, mounted from alcohol]; 1♂ Central Macedonia, Kerkini lakes area, village Neo Petritsi, Midway site, 41°18'49.8"N,



Figures 9–12. Wings of European *Greenomyia* females. **9** *G. baikalica* **10** *G. borealis* **11** *G. mongolica* **12** *G. stackelbergi*.

023°16'35.6"E, 750 m.a.s.l., Malaise trap, 23.–29.VI.2008 (G. Ramel leg.) [IZBE, mounted from alcohol]. **KAZAKHSTAN.** 1♀, Alma-Ata, 13.–16.VI. 1824 (Kuzin leg.) [ZIN, on pin].

Diagnostic characters. Female. Thorax brown to blackish. Abdomen entirely brown or first two segments slightly lighter. Legs pale to yellow, except cx_2 and cx_3 with dark markings basally and apically, all trochanters brown and f_3 brown, with lateral parts lighter to yellow. Tibiae with dense brown setae. Scape and pedicel dark yellow, flagellomeres brown. Mouthparts yellow. Apical palpal segment 5.0–5.4 ($n=4$) times as long as penultimate segment. Wing with broad preapical brownish band, reaching hind margin but gradually paler. C terminating distinctly before apex of wing, R_5 straight to slightly sinuate (Fig 10). M_2 and CuA_1



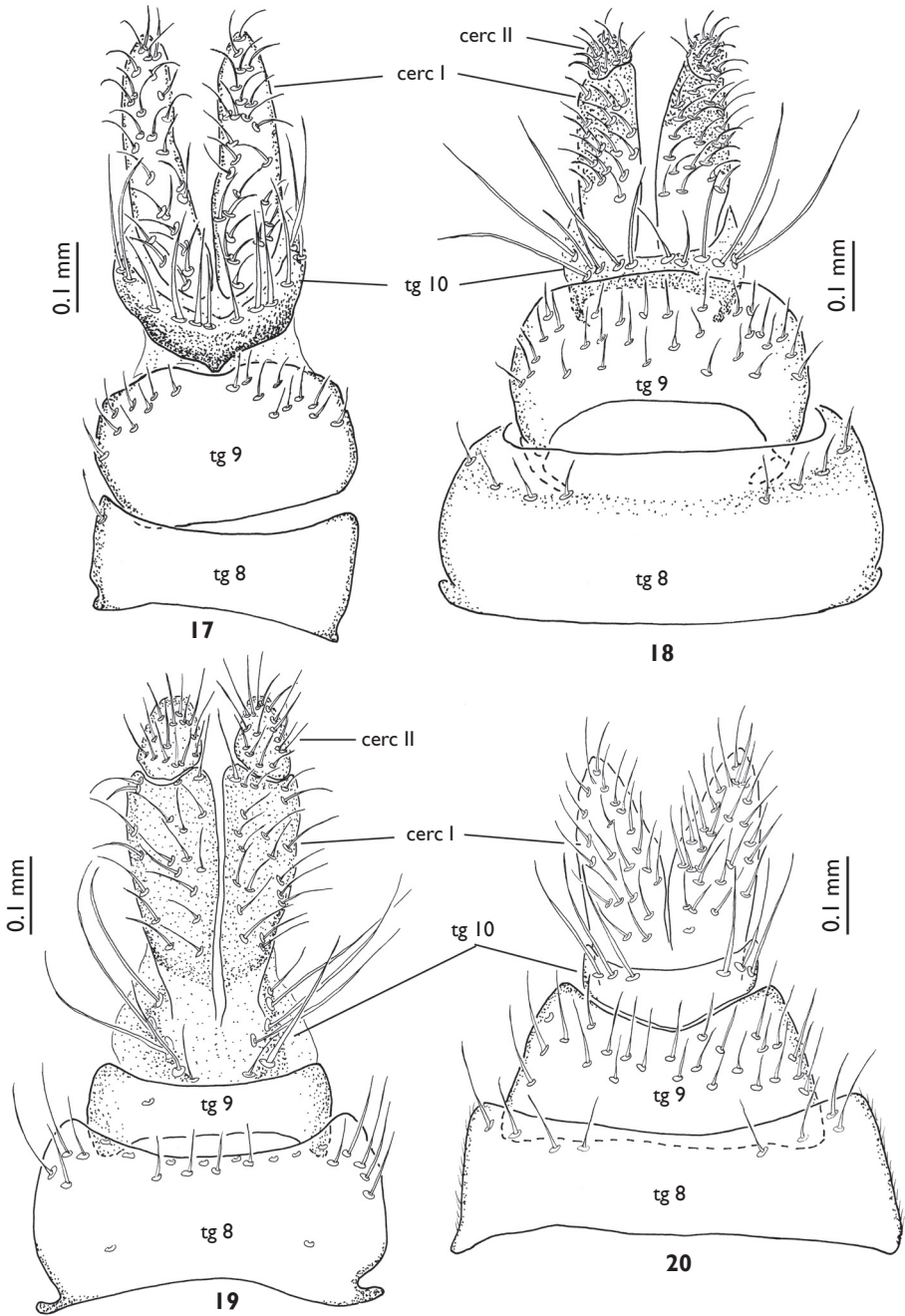
Figures 13–16. Female terminalia of European *Greenomyia* species, lateral view. **13** *G. baikalica* **14** *G. borealis* **15** *G. mongolica* **16** *G. stackelbergi*.

cerc = cercus; gp = gonapophysis; hyp = hypoproct; st = sternite; tg = tergite.

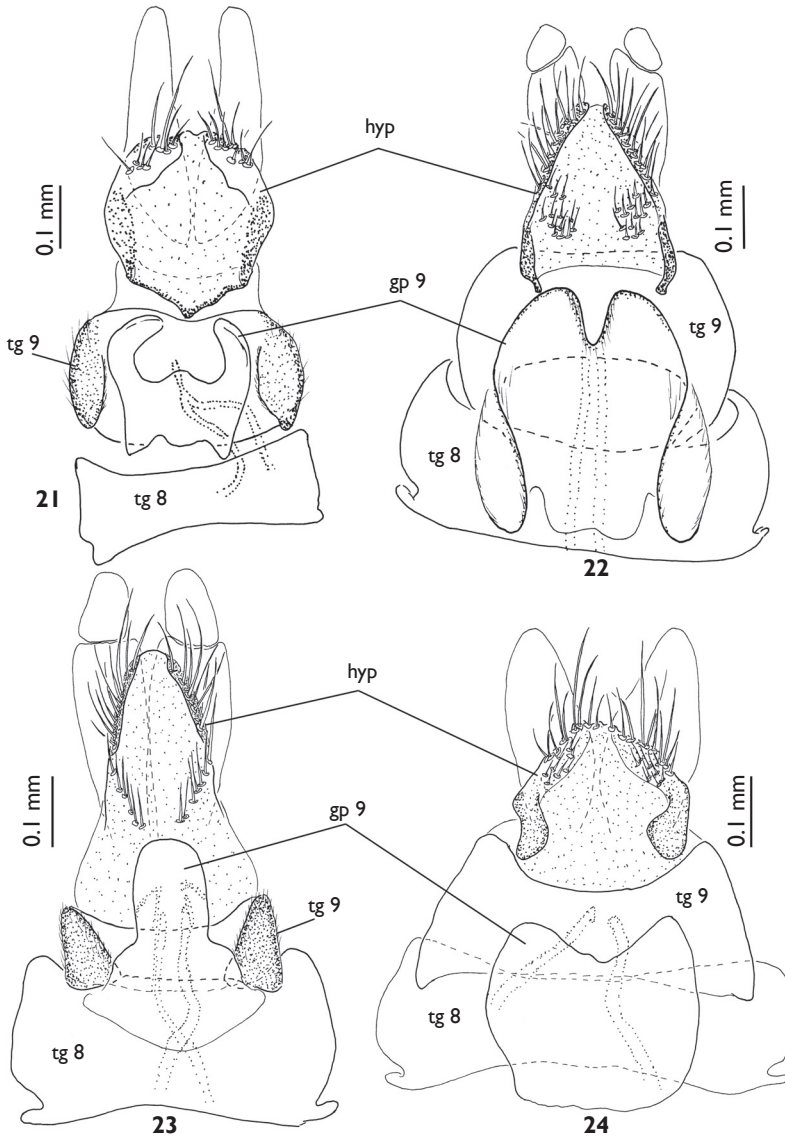
not reaching wing margin, CuA_1 basally obsolete or very weak. Terminalia brown; cercus yellow, two-segmented, apical segment small and partly fused with basal segment. Gonapophysis IX well sclerotized apically, visible in lateral view and with well developed narrow apical incision. Tergite VIII equal in size but slightly wider than tergite IX. Sternite VIII with medial incision apically and well emarginated basally.

Male. Coloration and other non-terminal characters including palpi similar to female. Apical palpal segment is 4.7–5.7 ($n=4$) times as long as penultimate segment.

Remarks. While studying the Swedish specimen from Vuollerim, it ran by the first attempt using the key by Zaitzev (1994) to *Neoclastobasis* because of the extra long last palpal segment and M_2 and CuA_1 not reaching the wing margin. The colouration of the studied specimen is, however, different and female terminalia lack strong spines on sternite VIII, being typical to all of the described *Neoclastobasis* species (Zaitzev 1982; JK and OK *pers. obs.* of *N. kamijoi*: 5♂♂ 2♀♀, South Korea, Sanan, I-li-Keumsan, [MNHN], 1♂ 3♀♀, Japan, Hokkaido, Sapporo [EIHU, MZLU]; *N. draskovicae*: paratypes, 1♂ 1♀ in MNHN, see Matile 1978). The dis-

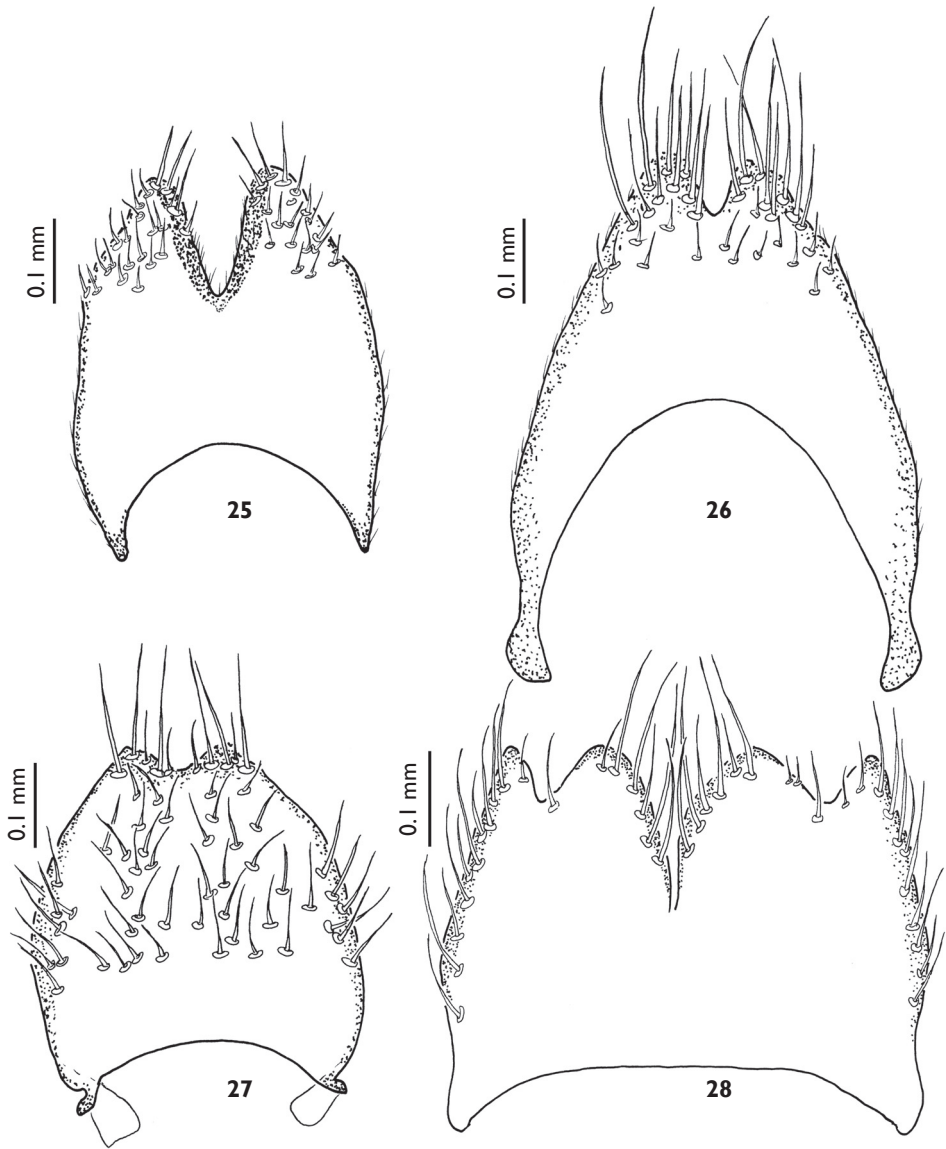


Figures 17–20. Female terminalia of European *Greenomyia* species, dorsal view. **17** *G. baikalica* **18** *G. borealis* **19** *G. mongolica* **20** *G. stackelbergi*.



Figures 21–24. Female terminalia of European *Greenomyia* species, ventral view, sternite VIII detached. **21** *G. baikalica* **22** *G. borealis* **23** *G. mongolica* **24** *G. stackelbergi*.

covery of a *Greenomyia* female, with similar size and coloration as the male of *G. borealis* in the same Malaise trap sample from northern Greece (Kerkin Lake area) allowed a safe association of the sexes. The females from Sweden, Estonia and Kazakhstan were further found to be conspecific with the Greek material of both sexes. According to Chandler et al. (2006), a male specimen from Greek mainland (Vikos Aaos National Park) has mainly yellow coxae, while other European specimens of



Figures 25–28. Female terminalia of European *Greenomyia* species, ventral view of sternite VIII. **25** *G. baikalica* **26** *G. borealis* **27** *G. mongolica* **28** *G. stackelbergi*.

G. borealis have mainly dark coxae. This may represent an intraspecific variation, however, all specimens studied during the current investigation have coxae whitish yellow. The above-mentioned Estonian specimen represents the first record of *G. borealis* from the country. The female specimen from Vuollerim was collected in the same garden as *G. stackelbergi*. *G. borealis* was previously known only with two 19th century findings from southern Sweden.

***Greenomyia mongolica* Laštovka et Matile, 1974**

Figures 3, 7, 11, 15, 19, 23, 27

= *Greenomyia theresae* Matile, 2002, syn. n.

G. theresae Kurina 2008a: 255, 270.

Type material studied: Paratype ♂ of *G. mongolica*: **MONGOLIA**. Central aimak, Tosgoni oovo, 5–10 km N von Ulan-Baator, 1500–1700 m a.s.l., Exp. Dr. Z. Kaszab 1967 nr. 926, 19–24 Jul 1967 (Z. Kaszab leg.) [MNHN, JKJ-SPM-011843, on pin]

Holotype ♂ of *G. theresae*: **ITALY**. Aosta, Champlong, Dessus, 1000 m a.s.l., “courant sur Feuille de Frêne - 2m -”, 26 Aug 1997 (L. Matile leg.) [MNHN, JKJ-SPM-011844, on pin].

Other material studied: **SWEDEN**. 1♂, SÖ, Stockholm, Skarpnäck, Skarpa by, 13.VII.–4.X.2003 (B. Viklund leg.) [MZLU, in alcohol]. **GERMANY**. 1♂, D. Oberpfals, NM Main-Donau-Kanal (Proj. Warncke), 12.IX.–5.X.1988 (S. Blank leg.) [No. 30132 in ZSM, in alcohol]. **RUSSIA**. 2♂♂ 3♀♀, Nikolsk-Ussur, 29.VII.1926 (Kuznetsov leg.) [ZIN, on pins]. **ESTONIA**. 1♀, Kääriku, 5.X.1985 (H. Remm leg.) [IZBE, on pin]; 1♀, Luunja, 20.X.1996, on the house wall (O. Kurina leg.) [IZBE, on pin]; 6♂♂ 3♀♀, Karilatsi near Tartu, bait traps, 19.–28.VIII.2005 and 04.–25.IX.2005 (T. Tammaru leg.) [IZBE, on pins]. **HUNGARY**. 38♂♂ 3♀♀, 10 km S Eger, 47°49'11"N, 020°21'37"E, 20 Aug 1989 (R. Danielsson leg.) [MZLU, on pins]. **ITALY**. 1♂, Aosta valley, Verrayes, Promellian, 1200 m.a.s.l., sweeping, 17.VI.2007 (V. Soon leg.) [IZBE, on pin]; 1♀, Siena, 6.V.2007 (A. Selin leg.) [Coll. Selin, on pin]; 3♂♂, Trentino-Alto Adige, Prov. Bolzano, Parco Nazionale dello Stelvia, Sulden Valley near Schmelz southwest of Prad, 46°36'42.1"N, 010°34'35.6"E, 940 m.a.s.l., 5.IX.–14.X.2005 (J. Ziegler and C. Lange leg.) [1♂ in ZMHB, 2♂♂ in IZBE, mounted from alcohol]. **GREECE**. 1♂ 2♀♀, Central Macedonia, Kerkini lakes area, village Vironia, Beabies site, 41°19'15.4"N, 023°13'39.6"E, 1150 m.a.s.l., Malaise trap, 30.VI.–6.VII.2008 (G. Ramel leg.) [IZBE, mounted from alcohol]; 6♀♀, Central Macedonia, Kerkini lakes area, village Vironia, Ramna site, 41°17'42.5"N, 023°11'33.1"E, 750 m.a.s.l., Malaise trap, 23.–29.VI.2008 (G. Ramel leg.) [IZBE, mounted from alcohol].

Diagnostic characters. Female. Thorax dark brown to blackish. Abdomen entirely blackish brown or first three segments slightly paler laterally. cx_1 entirely yellow or darkened in basal half, cx_2 and cx_3 entirely dark brown to black. Fore trochanter yellow basally, brown apically. Mid and hind trochanters brown. f_1 and f_2 yellow, f_3 yellow with brown apical fifth. Tibiae yellow, apically slightly darkened, with dense brown setae. Scape, pedicel and flagellomeres brown. Mouthparts pale yellow. Apical palpal segment 1.8–2.2 (n=5) times as long as penultimate segment. Wing tip shaded on about apical third, with darkened area along fore margin. All veins reach wing margin, M_2 sometimes basally obsolete or very weak, A_1 ending close to, sometimes fused into base of CuA_2 . Terminalia brown. Cercus distinctly two-segmented, apical segment small, ovate. Gonapophysis IX membranous, widely protruding apically, not visible

in lateral view. Tergite VIII larger than tergite IX. Sternite VIII apically with shallow medial incision, moderately emarginated basally.

Male. Coloration and other non-terminal characters including palpi similar to female. Apical palpal segment is 1.7–2.1 (n=5) times as long as penultimate segment.

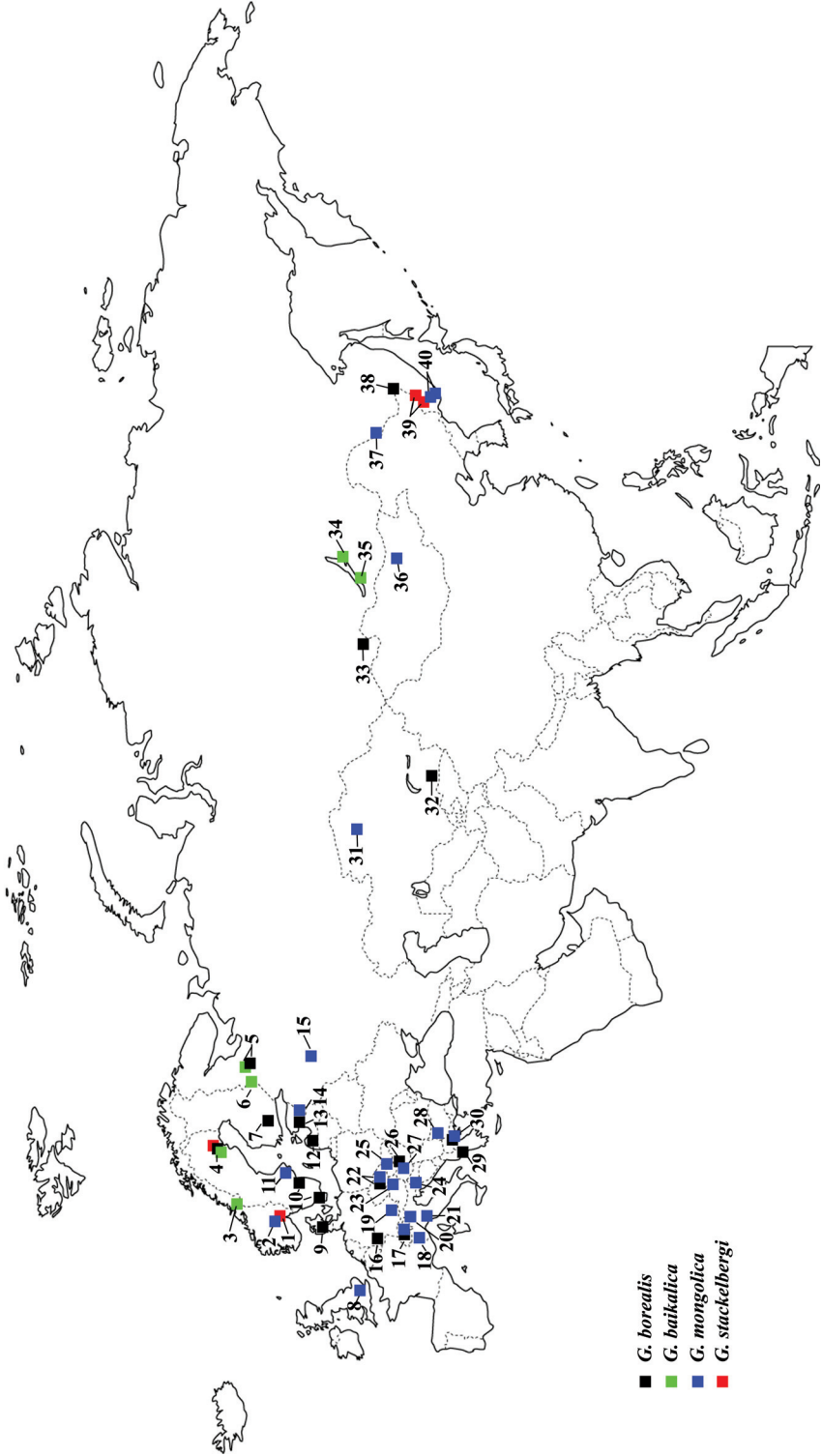
Remarks. This species was originally described by Laštovka and Matile (1974) based on Mongolian material and subsequently widely recorded in Europe. Chandler (2005) did not include *G. mongolica* in the European list and assigned all records to *G. theresae*, a species described from northern Italy by Matile (2002). Careful comparisons of type material of both species at MNHN in Paris (independently undertaken by two of the authors, OK and JK; the holotype of *G. mongolica* deposited in the Hungarian Natural History Museum was not available for the study) did not indicate any substantial differences in their male terminalia. The minor diagnostic characters as indicated in the original description and illustrations by Matile (2002) are liable to different angles of views only. Consequently we have come to the conclusion that *G. theresae* at present state of knowledge must be treated as a junior synonym of *G. mongolica* and that all published records in Europe should rather be associated with the latter. In addition to the studied type material, we also compared the terminalia of female specimens from the Russian Far East, Estonia and northern Greece without finding any reliable differences. Moreover, Papp (2000) confirmed conspecificity when he compared central European material from Hungary with the Mongolian type material. Male terminalia are figured by Laštovka and Matile (1974) and subsequently by Matile (2002), while female terminalia have previously been figured by Zaitzev (1982) and Kurina (1997). Our association of males and females are based on multiple simultaneous findings in trap samples (see above) that agrees with previous descriptions of the female. In the Pre-Balkan mountain range in Bulgaria, the species has been collected in xerothermic oak forest (Bechev 2000). The species was quite common in samples taken in a bait trap, operated on the basis of a mixture of fermenting sugar and red wine, in southern Estonia (see also Kurina 2006). The above-mentioned specimens from Greece are the first records from the country.

***Greenomyia stackelbergi* Zaitzev, 1982**

Figures 4, 8, 12, 16, 20, 24, 28

Type material studied: Holotype ♂, **RUSSIA**. Primorskiy Terr., Santaheza, 07.VII.1927 (A. Stackelberg leg.) [ZIN, on pin].

Other material studied: **SWEDEN**. 4 ♀♀, Lu. Jokkmokk, Vuollerim, in garden, 105 m.a.s.l., Malaise trap, 11.VIII.–19.IX.2003 (K. Hedmark and M. Karström leg.); 1♂, the same locality, Malaise trap 11.–19.VIII.2004; 25♂♂ 15♀♀, the same locality, Malaise trap 11.VIII.–7.X.2005; 11♂♂ 4♀♀, the same locality, Malaise trap 11.VIII.–22.IX.2006; 18♂♂ 14♀♀, the same locality, yellow pan-trap VII–08.X.2006; 17♂♂ 7♀♀, the same locality, yellow pan-trap 16.VI.–20.VII.2007; 14♂♂ 4♀♀, the same



locality, Malaise trap 12.VIII.–28.IX.2007; 9♂♂ 3♀♀, the same locality, window trap VI–11.IX.2007; 4♂♂ 1♀, the same locality, Malaise trap 13.–27.VI.2008; 1♀, the same locality, yellow pan-trap 19.VI.2008; 1♂, the same locality, window trap 1.VI.–1.VII.2008. In total 153 specimens: 100♂♂ 53♀♀, [most in Coll. Hedmark, some in IZBE and MZLU, most of the material preserved in alcohol, while some specimens are mounted from alcohol to pins or slide mounted].

Diagnostic characters. Female. Thorax bi-coloured; mesonotum yellow with variably developed black thoracic stripes; pronotum and propleuron yellow, other pleural parts brown to blackish. Abdominal sternites I–IV entirely yellow or slightly brownish; tergites of first four segments bi-coloured: basally yellow, apically brown (in a few occasions first four tergites entirely brown). Legs all yellow except dark brown band on apical fourth of hind femur. Tibiae densely covered with brown setulae. Scape, pedicel, and 3–5 flagellomeres yellow, rest of flagellum light brown. Mouthparts yellow. Apical palpal segment 4.1–4.4 (n=5) times as long as penultimate segment. Wing hyaline with slight yellowish tinge, all veins reach wing margin, M_1 and CuA_2 basally obsolete or very weak. Terminalia brown, cercus one-segmented, apically yellow. Gonapophysis IX membranous, subsquare with shallow incision apically, not visible in lateral view. Tergite VIII wider than tergite IX. Sternite VIII medially with deep and narrow incision, lateral incisions more shallow.

Male. Coloration and other non-terminal characters similar to female. The apical palpal segment is 4–5 (n=5) times as long as penultimate segment.

Remarks. Besides its peculiar distribution (see Fig. 29), *G. stackelbergi* is unique among the four studied species in having vivid yellowish colouration and hyaline wings. It was described from South Primorje in the Russian Far East (Zaitzev 1982) and has subsequently been recorded only from two semi-urban localities in the Nordic region: the single locality in Swedish Lapland (present material, Kjærandsen et al. 2007) and from one locality in the capital of Norway, Oslo (Søli and Kjærandsen 2008). Eight years of collecting (2002–2009) with Malaise traps, yellow pan-traps and window traps near a compost in the garden of one of the authors (MK) yielded 153

Figure 29. Known records of European *Greenomyia* species.

G. borealis (black squares): **4** original data **5** Polevoi 2000 (marked with a question mark) **7** Chandler 2005 **9** Chandler 2005 **10** Kjærandsen et al. 2007, original data **12** Lackschewitz 1937 **13** original data from two localities **16** Winnertz 1863 **17** Chandler 1998, 2005 (doubtful) **22** Ševčík and Košel 2009 **26** Ševčík and Papp 2001 **29** Chandler et al. 2006 **30** original data **32** Zaitzev 1982, 1994 **33** Zaitzev 1982, 1994 **38** Zaitzev 1982, 1994.

G. baikalica (green squares): **3** Gammelmo and Søli 2006 **4** Kjærandsen et al. 2007 **5** Polevoi 2000 (three different localities) **6** Polevoi 2001 **34** Zaitzev 1994 **35** Zaitzev 1994.

G. mongolica (blue squares): **2** Søli et al. 2009 **8** Chandler 2010 (seven different localities) **11** Kjærandsen et al. 2007 **14** Kurina 1997 **15** Zaitzev 1994 **17** Matile 2002 (as *G. theresae*) **18** Matile 2002 (as *G. theresae*) **19** Caspers 1996 **20** Kurina 2008a (as *G. theresae*) **21** original data **22** Martinovský and Ševčík 1998, Martinovský and Barták 2000 **23** Plassmann 1996 **24** Matile 2002 (as *G. theresae*) **25** Ševčík and Martinovský 1999 **27** Papp 2000 (several different localities), original data **28** Bechev 1989 **30** original data **36** Laštovka and Matile 1974 **37** Zaitzev 1982, 1994 **40** Zaitzev 1982, 1994.

G. stackelbergi (red squares): **1** Søli and Kjærandsen 2008 **4** Kjærandsen et al. 2007 **39** Zaitzev 1982, 1994.

specimens, indicating rise and decline of a small population. None was collected in the first and the last year, while four in 2003, one in 2004, 40 in 2005, 47 in 2006, 54 in 2007 and seven in 2008. The flight activity lasted almost the whole vegetation season, from the middle of June (in 2007) to the beginning of October (in 2004). A garden compost is the supposed microhabitat for this population of *G. stackelbergi* and its origin should be somewhere in the surroundings. A close potential natural habitat could be the Vuollerim ravine a few hundred meters away. Waste from picked forest fungi might be another possibility.

Discussion

Species descriptions of fungus gnats are largely based and depending on characters in the male terminalia. Females are often ignored in taxonomic reviews and only a few generic reviews cover all or the majority of associated females (e.g. Søli 1997; Martinsen and Søli 2000; Kjærandsen 2006, 2009). Still, females usually have distinctive yet less pronounced characters in their terminalia. In the case of the few European *Greenomyia* species we found it fairly easy to safely associate the females based on body characters such as colouration patterns, wing shape and venation details shared between the sexes, and the associations were further strengthened by co-occurrence in multiple trap samples.

Our study of *Greenomyia* revealed that the diagnostic characters used to distinguish *Greenomyia* and *Neoclastobasis* in keys (e.g. Søli et al. 2000) does not hold up to a closer scrutiny, especially when both sexes are considered. Both sexes of *G. borealis* have wings where M_2 and CuA_1 end slightly before the wing margin, and both sexes of *G. borealis* and *G. stackelbergi* have prolonged apical segment of their palps. These characters are akin to those used to diagnose *Neoclastobasis*. Yet, although the three known species of *Neoclastobasis* are very similar to *Greenomyia* in general appearance they show distinctive features in their terminalia that separate them from *Greenomyia*. In *Greenomyia* the dorsal branch of the male gonostylus always has two distinct combs of blunt spines on an otherwise bare inner surface. In *Neoclastobasis* the entire inner surface is covered with short blunt setae and a single row of larger spines is situated basally. Females of *Neoclastobasis* have a few short and strong spines along the apical margin of sternite VIII, which are never found in *Greenomyia*. We think *Greenomyia* and *Neoclastobasis* may prove to be monophyletic sistertaxa, but pending genetic studies and a better definition of the entire Leini clade we leave the question whether they deserve to retain their status as separate genera or could be joined into one. In the meantime separating the two genera must rest entirely on differences in their terminalia as described above.

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Review of the genus *Isodemis* Diakonoff (Lepidoptera, Tortricidae) from China, with description of three new species

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Abstract

The genus *Isodemis* Diakonoff, 1952 in China is reviewed, with seven species recognized. Three new species are described: *I. quadrata* **sp. n.**, *I. guangxiensis* **sp. n.** and *I. hainanensis* **sp. n.** The female of *I. stenotera* Diakonoff, 1983 is described for the first time. Variation within *I. illiberalis* (Meyrick, 1918) and *I. stenotera* is briefly discussed. Images of the adults and genitalia are provided, along with a key to the described species.

Keywords

Lepidoptera, Tortricidae, *Isodemis*, new species, China

Introduction

The genus *Isodemis* was erected by Diakonoff (1952) for the type species *Batodes serpentinana* Walker, 1863. It belongs to the tribe Archipini in the subfamily Tortricinae. Diakonoff (1976, 1983) transferred *Tortrix illiberalis* Meyrick, 1918 to *Isodemis* and described *I. stenotera* from Sumatra. Razowski (2000, 2009a, 2009b) described

I. proxima Razowski, 2000 from Chinese Taiwan, and *I. brevicera* Razowski, 2009, *I. longicera* Razowski, 2009 and *I. ngoclinha* Razowski, 2009 from Vietnam. Currently, *Isodemis* consists of seven species, mainly distributed in Southeast Asia.

Prior to the present study, four species were recorded in China: *I. serpentinana* (Walker, 1863), *I. illiberalis* (Meyrick, 1918), *I. stenotera* Diakonoff, 1983 and *I. proxima* Razowski, 2000. The aim of the present paper is to review the genus *Isodemis* in China and to describe three new species. A key is provided on a worldwide basis based on the forewing patterns and the male genitalia except *I. ngoclinha* Razowski, 2009 whose male remains unknown. A map is provided to show the distribution of *Isodemis* species in China (Map 1).

Material and methods

Examined specimens were collected by light traps. Terminology follows Diakonoff (1948) and Razowski (2009a, b) in descriptions of forewing pattern and genitalia. Genitalia dissection and slide mounting methods follow Li (2002). The examined specimens, including the types of the new species, are deposited in the Insect Collection, College of Life Sciences, Nankai University, Tianjin, China.

Taxonomic accounts

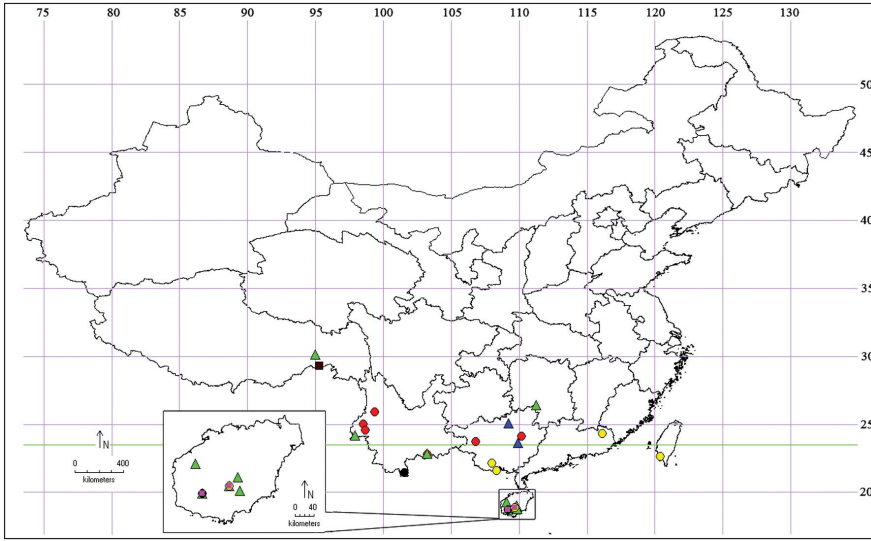
Isodemis Diakonoff, 1952

Isodemis Diakonoff 1952: 147. Type species: *Batodes serpentinana* Walker 1863 (original designation).

Diagnosis. *Isodemis* is characterized by the labial palpus obliquely uprising almost as high as upper edge of eye; the forewing dominantly yellowish brown or ochreous brown; the median fascia interrupted or indistinct near costal margin; male genitalia with gnathos hooked, valva with a C-shaped plica, with numerous fine wrinkles between plica and costa, and the sacculus with terminal process; female genitalia with the ductus bursae usually with cestum, and the single dentate signum with a conspicuous globular process placed posteriorly in the corpus bursae.

Distribution. China, Vietnam, Thailand, Indonesia, Nepal, India and Sri Lanka.

Discussion. Most species of this genus show a strong sexual dimorphism, which makes species identification difficult. Of the seven previously described species, *I. longicera* Razowski, 2009 and *I. brevicera* Razowski, 2009 were described from the males, while *I. ngoclinha* Razowski, 2009 was described from females. Currently, no additional knowledge has been added to these three species. Therefore, we have excluded *I. ngoclinha* from the key based on forewing patterns and male genitalia.



Map I. The distribution of *Isodemis* Diakonoff in China. ● *I. illiberalis* (Meyrick) ▲ *I. stenotera* Diakonoff ● *I. proxima* Razowski ● *I. serpentinana* (Walker) ■ *I. quadrata* sp. n. ▲ *I. guangxiensis* sp. n. ■ *I. hainanensis* sp. n.

Key to the known species of *Isodemis*

- 1 Forewing with a semicircular pattern above dorsum.....2
- Forewing without such a pattern above dorsum4
- 2 Subapical blotch extending from costal margin to tornus.....
..... *I. illiberalis* (Meyrick, 1918)
- Subapical blotch not reaching tornus.....3
- 3 Uncus broad rectangular, phallus with one cornutus in male genitalia.....
..... *I. quadrata* sp. n.
- Uncus broadened slightly from basal 1/4 to apex, phallus with two cornuti in male genitalia..... *I. guangxiensis* sp. n.
- 4 Forewing with an annular pattern at middle5
- Forewing without such a pattern at middle.....7
- 5 Terminal process of sacculus long, reaching plica in male genitalia.....
..... *I. longicera* Razowski, 2009
- Terminal process of sacculus short, not reaching plica in male genitalia6
- 6 Uncus with basal portion narrower than distal portion
..... *I. brevicera* Razowski, 2009
- Uncus nearly rectangular, slightly narrowed in distal 2/5*I. hainaniensis* sp. n.
- 7 Phallus with one cornutus in male genitalia *I. proxima* Razowski, 2000
- Phallus with two cornuti in male genitalia8
- 8 Cornuti equal in length, not undulate*I. stenotera* Diakonoff, 1983
- Cornuti unequal in length, longer one undulate
..... *I. serpentinana* (Walker, 1863)

***Isodemis illiberalis* (Meyrick, 1918)**

Figs 1, 11–12

Tortrix illiberalis Meyrick 1918: 168. Type locality: India.*Cacoecia interjecta* Meyrick 1922: 496. Type locality: India.*Syndemis montivola* Diakonoff 1941: 40. Type locality: India.*Isodemis illiberalis* (Meyrick 1918): Diakonoff 1976: 113.

Material examined. 1 ♂, **China, Guangxi Zhuang Autonomous Region:** Milv Village, Nanping Town, Shangsi County (22°09'N, 107°58'E), 770 m, 3.IV.2002, coll. Shulian Hao and Huaijun Xue; 1 ♂, Mt. Pinglong, Shangsi County (22°09'N, 107°58'E), 510 m, 6.IV.2002, coll. Shulian Hao and Huaijun Xue; 1 ♂, Mt. Villa Huawang, Jinxiu Yao Autonomous County (24°08'N, 110°11'E), 550 m, 14.IV.2002, coll. Shulian Hao and Huaijun Xue; 8 ♂♂, Grand Canyon Laohutiao, Napo County (23°44'N, 106°48'E), 30.VII.2008, coll. Liusheng Chen and Guoyi Wu; 1 ♂, **China, Yunnan Province:** Tengchong County (25°01'N, 98°30'E), 1950 m, 28.IX.2002, coll. Huaijun Xue; 2 ♂♂, Xiaoheishan Nature Reserves (24°35'N, 98°41'E), 2300 m, 10.VIII.2005, coll. Yingdang Ren.

Diagnosis. Adult (Fig. 1) with wingspan 16.0–19.5 mm. This species is characterized by the male genitalia with the uncus broadening from basal 1/3 to blunt apex, and the phallus having eight to twenty-three deciduous cornuti and a single non-deciduous cornutus (Figs 11–12); in the female genitalia by the sterigma deeply V-shaped, the ductus bursae about 1.5 times the corpus bursae, and the globular process almost 1/2 length of the signum (Diakonoff 1941: 40, fig. 5). It can be easily distinguished from its congeners by the median fascia extending from below distal half of the costal fold to the dorsum and the subapical blotch reaching the tornus.

Distribution. China (Guangdong, Guangxi, Yunnan), Vietnam, Thailand, India, Nepal.

Variation. The uncus broadens from basal 1/3 to apex and the phallus has sixteen to twenty-three deciduous cornuti and a single non-deciduous cornutus in the specimens collected in Guangxi (Fig. 11); while the uncus is parallel sided and the phallus bears eight deciduous cornuti and a single non-deciduous cornutus in the specimens collected in Yunnan (Fig. 12).

***Isodemis stenotera* Diakonoff, 1983**

Figs 2–4, 13, 18

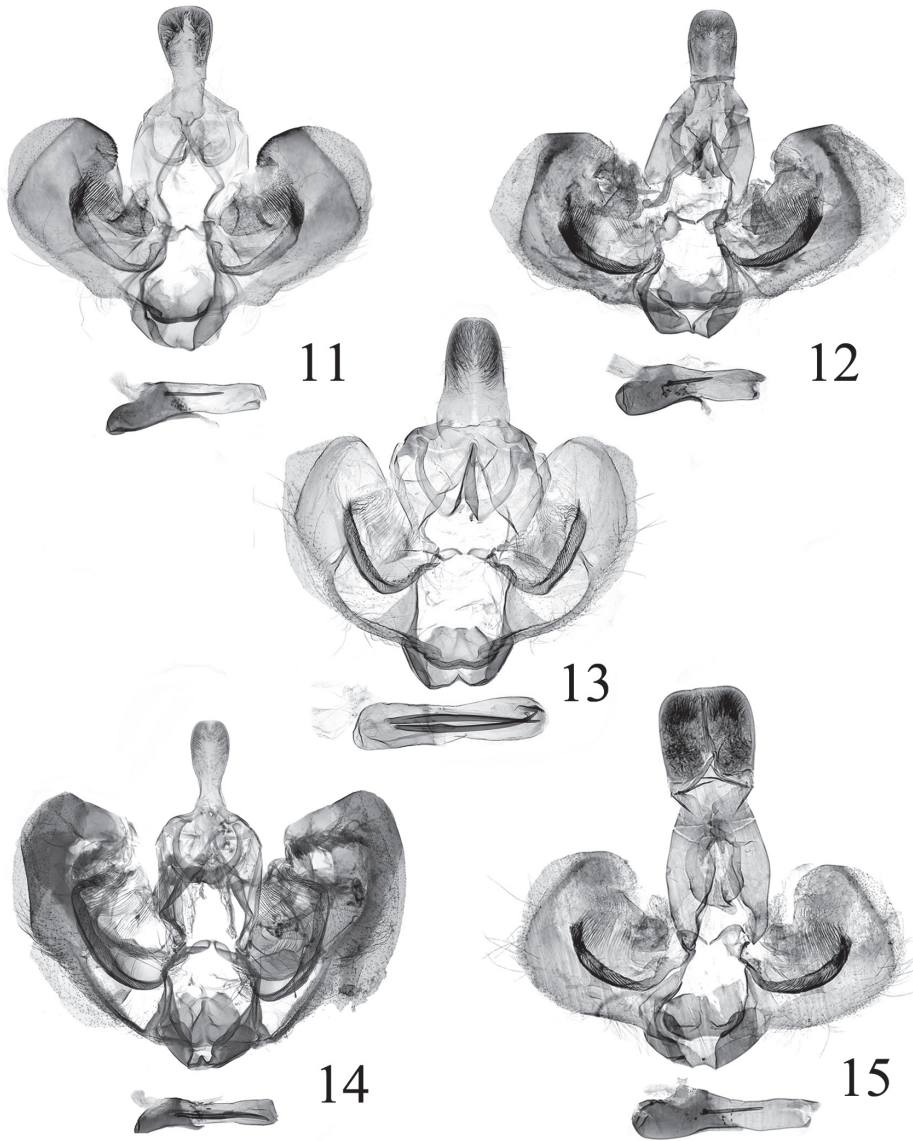
Isodemis stenotera Diakonoff 1983: 92. Type locality: Indonesia.

Material examined. 1 ♂, 1 ♀, **China, Hainan Province:** 12–15.V.2005, coll. Min Wang and Liusheng Chen; 6 ♂♂, 2 ♀♀, Jianfengling (18°44'N, 109°10'E), V.2004, coll. Min Wang *et al.*; 1 ♂, 1 ♀, (21.V.2004) and 6 ♂♂, Jianfengling (18°44'N, 109°10'E), 940 m, 4–7.VI.2007, coll. Zhiwei Zhang and Weichun Li; 4 ♂♂, 1 ♀,



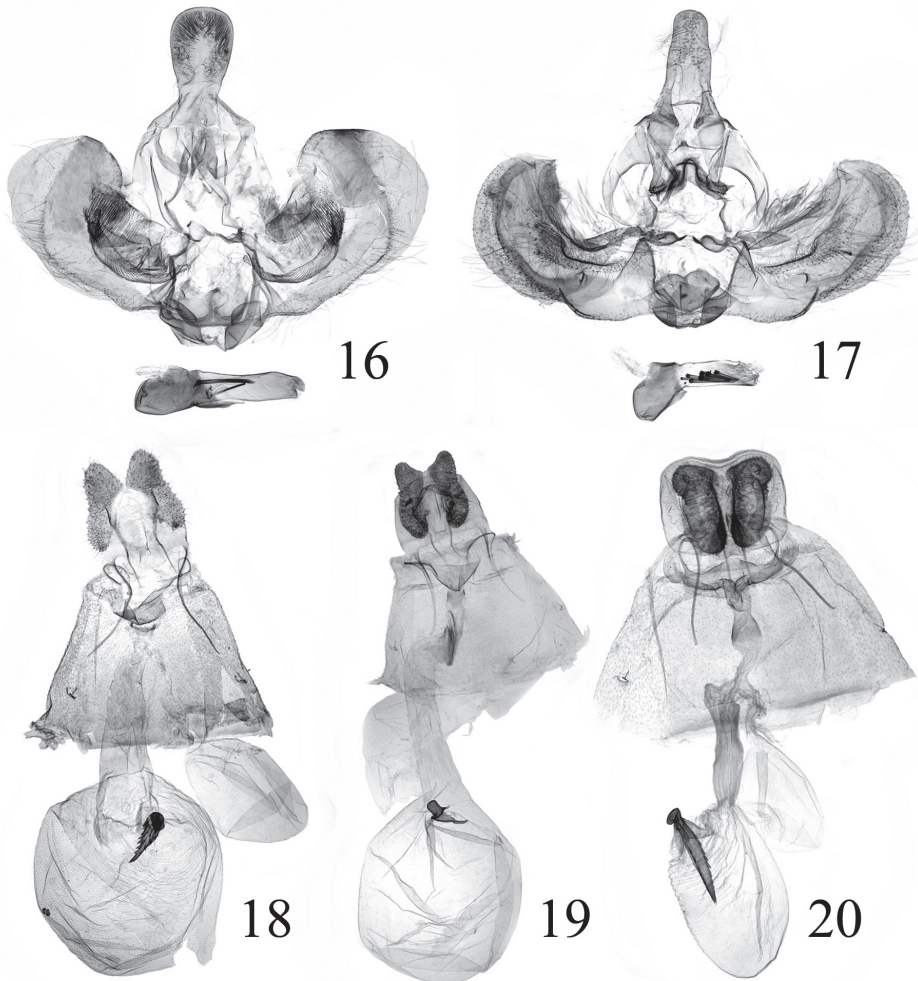
Figures 1–10. Adults of *Isodemis* spp. 1 *I. illiberalis* (Meyrick), ♂ 2–3 *I. stenotera* Diakonoff, ♂ (showing variation of markings) 4 *I. stenotera* Diakonoff, ♀ 5 *I. proxima* Razowski, ♂ 6 *I. quadrata* sp. n., holotype, ♂ 7 *I. quadrata* sp. n., paratype, ♀ 8 *I. guangxiensis* sp. n. (male) 9 *I. hainanensis* sp. n., holotype, ♂ 10 *I. hainanensis* sp. n., paratype, ♀.

Tianchi, Jianfengling, 790–810 m, 30.III-1.IV.2008, coll. Bingbing Hu and Haiyan Bai; 3 ♂♂, 20.IV.-12.VI.2010, coll. Bingbing Hu and Jing Zhang; 2 ♂♂, Yingge-ling (19°02'N, 109°50'E), 28.VIII-3.IX.2005, coll. Min Wang and Liusheng Chen;



Figures 11–15. Male genitalia of *Isodemis* spp. **11–12** *I. illiberalis* (Meyrick): **11** slide no. SYH10014 **12** slide no. SYH10002 (showing variation of genitalia) **13** *I. stenotera* Diakonoff, slide no. SYH09017 **14** *I. proxima* Razowski, slide no. SYH10015 **15** *I. quadrata* sp. n., holotype, slide no. WXP03332.

1 ♂, Yinggeling, 620 m, 28.IV.2010, coll. Bingbing Hu and Jing Zhang; 3 ♂♂, 1 ♀, Mt. Wuzhi (18°52'N, 109°40'E), 700 m, 18–19.V.2007, coll. Zhiwei Zhang and Weichun Li; 7 ♂♂, 740 m, 14–15.IV.2009, coll. Qing Jin and Bingbing Hu; 2 ♂♂, Shuiman Town, Mt. Wuzhi (18°52'N, 109°40'E), 630 m, 16.IV.2009, coll. Qing



Figures 16–20. Genitalia of *Isodemis* spp. 16–17. ♂: **16** *I. guangxiensis* sp. n., paratype, slide no. SYH10010 **17** *I. hainanensis* sp. n., holotype, slide no. SYH09042 18–20. ♀: **18** *I. stenotera* Diakonoff, slide no. SYH10005 **19** *I. quadrata* sp. n., paratype, slide no. SYH10003 **20** *I. hainanensis* sp. n. paratype, slide no. SYH09043.

Jin and Bingbing Hu; 1 ♀, Mt. Diaoluo (18°47'N, 109°52'E), 940 m, 2.VI.2007, coll. Zhiwei Zhang and Weichun Li; 1 ♂, 1 ♀, River Nancha, Bawangling (19°16'N, 109°03'E), 600 m, 9.VI.2007, coll. Zhiwei Zhang and Weichun Li; 9 ♂♂, 4 ♀♀ (4–9.IV.2008, coll. Bingbing Hu and Haiyan Bai); 3 ♂♂, 2 ♀♀ (23.IV.2009, coll. Bingbing Hu and Qing Jin), Dong'er Workstation, Bawangling (19°16'N, 109°03'E), 1000 m; 3 ♂♂, Dongyi Protection Station, Bawangling (19°16'N, 109°03'E), 650 m, 7.IV.2008, coll. Bingbing Hu and Haiyan Bai; **China, Hunan Province:** 3 ♂♂, Mt. Shunhuang, Dong'an County (26°24'N, 111°17'E), 20–22.V.2007, coll. Min Wang

and Liusheng Chen; **China, Yunnan Province:** 1 ♂, Rare Botanic Garden, Ruili City (24°00'N, 97°50'E), 1000 m, 6.VIII.2005, coll. Yingdang Ren.

Diagnosis. This species is very similar to the type species *I. serpentinana* both in appearance and in the genitalia, but can be distinguished by the male genitalia having two nearly straight cornuti that are equal in length, and the female genitalia having the ductus bursae about the same length as the corpus bursae and broadening slightly from the inception of the ductus seminalis to the corpus bursae. In *I. serpentinana*, the male genitalia have a phallus bearing two cornuti that are unequal in length with the longer one undulate, and the female genitalia have a ductus bursae about 1.5 times the length of the corpus bursae and slightly broader from middle of the ductus seminalis to corpus bursae (Diakonoff 1948: 511, fig. 37).

Description. Adult: Male (Figs 2–3) wingspan 17.5–22.0 mm. Female (Fig. 4) wingspan 19.0–27.0 mm. Head, antenna and labial palpus yellow, scattered with ochreous. Thorax and tegula ochreous brown tinged with yellow. Forewing broad, nearly rectangular, apex slightly protruding anteriorly; ground color yellow, with scattered pale ochreous scales medially, densely covered with ochreous brown scales along dorsal area; markings ochreous brown with sparse brownish black scales: costal margin with two dots near base, with a triangular spot at basal 1/5; median fascia interrupted or indistinct medially, extending to distal 1/3 of dorsum, then along tornus obliquely reaching anteriorly to middle of termen; faint pale ochreous yellow stripe from below costal portion of median fascia to termen below apex, gradually narrowing; subapical blotch from middle of costal margin to before apex, narrowly stripe-shaped, with brownish black and yellow dots along costal margin; cilia ochreous mixed with brownish black, yellow at apex. Hindwing pale grayish brown, distally with a large yellow patch tinged with sparse pale ochreous brown scales; cilia pale grayish brown. Legs pale yellow, mixed with brownish black on ventral side of foreleg; outer side of mid- and hindlegs yellow, tinged with brownish black. Abdomen grayish brown.

Female genitalia (Fig. 18). Papilla analis long and narrow, distal 2/5 slightly expanded. Apophysis anterioris about 1.3 times length of apophysis posterioris. Sterigma nearly band-shaped, protrudent backward posterolaterally. Antrum short, with inner sclerite anteriorly; ductus seminalis from posterior 1/5 of ductus bursae; ductus bursae about same length as corpus bursae, broadened slightly from inception of ductus seminalis to corpus bursae; cestum absent. Corpus bursae rounded; signum horn-shaped, with tiny spines on ventral surface, dentate marginally, its globular process about 1/4 length of signum.

Distribution. China (Hunan, Guangxi, Hainan, Tibet, Yunnan), Indonesia (Sumatra).

Variation. In some male individuals, the median fascia has a small brownish yellow spot placed near the posterior 1/4 of termen, connected with the yellow stripe above it (Fig. 3); the vinculum has a tiny spine at middle on the anterior margin in the male genitalia.

Notes. The female of this species is described for the first time.

***Isodemis proxima* Razowski, 2000**

Figs 5, 14

Isodemis proxima Razowski, 2000: 325. Type locality: Taiwan.

Material examined. 1 ♂, **China, Guangxi Province:** Mt. Pinglong, Shangsi County (22°09'N, 107°58'E), 250 m, 7.IV.2002, coll. Shulian Hao and Huaijun Xue; 1 ♂, Dongzhong Woodfarm, Fangchenggang City (21°37'N, 108°20'E), 370 m, 9.IV.2002, coll. Shulian Hao and Huaijun Xue; 3 ♂♂, **China, Hainan Province:** Shuiman Town, Mt. Wuzhi (18°52'N, 109°40'E), 650 m, 15–17.V.2007, coll. Zhiwei Zhang and Weichun Li; 4 ♂♂, Shuiman Town, Mt. Wuzhi (18°52'N, 109°40'E), 630–740 m, 13–17.IV.2009, coll. Qing Jin and Bingbing Hu.

Diagnosis. Adult (Fig. 5) with wingspan 16.0–21.0 mm. This species is very similar to *I. stenotera* both in appearance and in the genitalia, but can be distinguished by the forewing dominantly dark ochreous brown; the uncus narrowed basally and the phallus with single cornutus in male genitalia (Fig. 14); and the ductus bursae about 1.5 times length of the corpus bursae in female genitalia (Razowski, 2000: 325, fig. 14). In *I. stenotera*, the forewing is mainly ochreous brown; the uncus is broadened basally and the phallus bears two cornuti; and the ductus bursae is about the same length as the corpus bursae.

Distribution. China (Guangdong, Guangxi, Hainan, Taiwan).

***Isodemis serpentanana* (Walker, 1863)**

Batodes serpentanana Walker 1863: 317. Type locality: Indonesia.

(*Tortrix?*) *sulana* Walker 1866: 1784. Type locality: New Guinea.

Cacoecia serpentanana (Walker 1863): Meyrick 1912: 18.

Tortrix serpentanana (Walker 1863): Meyrick 1921: 149.

Syndemis serpentanana (Walker 1863): Diakonoff 1941: 41.

Isodemis serpentanana (Walker 1863): Diakonoff 1952: 147.

Distribution. China (Hainan, Yunnan, Taiwan); India, Indonesia (Borneo, Java, Sumatra), New Guinea, Philippine, Sri Lanka, Thailand.

Notes. Based on the description of *I. serpentanana* and the illustration of its male genitalia provided by Diakonoff (1941), this species is distinguished by the phallus bearing two unequal cornuti with the longer one undulate in the male genitalia. When Diakonoff (1983) described *I. stenotera*, he pointed out that *I. stenotera* was very similar to *I. serpentanana* superficially, but could be separated by the male genitalia having two cornuti equal in length. By checking the holotype deposited in the Natural History Museum, London, we also found that the subapical blotch in *I. serpentanana* is subtriangular, while it is narrowly semioval in *I. stenotera*. More differences of the two species are stated under *I. stenotera*.

***Isodemis quadrata* sp. n.**

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Figs 6–7, 15, 19

Type material. Holotype ♂ – **China, Xizang (Tibet) Autonomous Region:** Hanmi, Medog County (29°13'N, 95°18'E), 2380 m, 9.VIII.2003, coll. Xinpu Wang and Huaijun Xue, genitalia slide no. WXP03332. Paratypes: 1 ♂, 2 ♀♀, same data as for holotype.

Diagnosis. The male is similar to *I. illiberalis* superficially, but can be separated by the median fascia extending from the costal margin to the dorsum, the subapical blotch reaching across 1/3 width of wing and the quadrate uncus. In *I. illiberalis*, the median fascia extends from the lower edge of costal fold to the dorsum, the subapical blotch reaches the tornus, and the uncus broadens from the basal 1/3 to the apex. The female genitalia are close to those of *I. stenotera*, but can be distinguished by the ductus bursae being longer than the corpus bursae and the signum without tiny spines on its ventral surface; in *I. stenotera*, the ductus bursae is about the same length as the corpus bursae and the signum consists of tiny spines on its ventral surface. In addition, the female can be easily separated from *I. stenotera* by the ground color being yellowish brown mixed with ochreous, the median fascia extending from the costal margin to distal 1/3 of the dorsum, and the subapical blotch nearly inverted triangular; in *I. stenotera*, the ground color is yellow with scattered pale ochreous scales, the median fascia reaches the middle of termen and is interrupted or indistinct medially, and the subapical blotch is narrowly stripe-shaped.

Description. Adult: Male (Fig. 6) wingspan 19.5–20.0 mm. Head, antenna and labial palpus yellowish brown, with scattered ochreous brown. Thorax and tegula ochreous brown mixed with yellowish brown. Forewing yellowish brown with sparse ochreous scales; costal fold tinged with brownish black, about 3/5 length of costal margin; markings brownish black mottled with ochreous: median fascia extending from costal margin to distal 1/3 of dorsum, slightly interrupted near costal fold, with a large rounded gray patch present on its outer side posteriorly; short stripe from basal 1/3 of dorsum extending anteriorly and joining inner side of median fascia at anterior 1/3, forming an irregular semicircular pattern above dorsum, leaving a rounded subtriangular patch of groundcolour at middle of dorsum; subapical blotch inverted triangular, extending from distal 1/3 of costal margin to before apex, reaching across 1/3 width of wing; cilia yellowish brown. Hindwing dark gray, distally with a pale grayish brown patch tinged with yellowish brown; cilia dark gray. Legs dark yellow, tinged with brownish black on ventral side of foreleg and on outer side of mid- and hindlegs. Abdomen grayish brown.

Female (Fig. 7) wingspan 21.0–22.5 mm. Head and labial palpus dark grayish brown. Antenna brownish black tinged with yellowish brown. Forewing broader than in male, nearly rectangular, apex slightly protruding anteriorly; costal margin tinged with brownish black; posterior 4/5 of median fascia ochreous brown with sparse brownish black scales; lower edge of subapical blotch slightly rounded; with small diffused

patch placed near middle of termen. Hindwing gray, anterodistally with a yellowish brown patch mottled with brownish black.

Male genitalia (Fig. 15). Tegumen developed. Uncus nearly quadrate, straight on posterior margin. Gnathos arm slender and long; terminal plate nearly triangular, about 1/3 length of arm. Valva with length about 1.5 times width, rounded terminally; transtilla spine-shaped, disconnected medially. Sacculus weakly sclerotized; terminal process nearly thumblike, reaching plica. Vinculum somewhat concave at middle on anterior margin, with two small spines near middle of anterior margin. Juxta approximately oval, slightly concave at middle anteriorly. Phallus slightly longer than length of valva, straight, dilated basally, with ten deciduous cornuti and a single non-deciduous cornutus that is about 1/3 length of phallus.

Female genitalia (Fig. 19). Papilla analis narrow and long. Apophysis anterioris slightly longer than apophysis posterioris. Sterigma inverted subtriangular. Antrum short, with inner sclerite anteriorly; ductus seminalis coming from anterior margin of antrum; ductus bursae longer than corpus bursae, curved perpendicularly at posterior 1/3; cestum placed between posterior 1/3 of ductus bursae and anterior margin of antrum. Corpus bursae rounded; signum horn-shaped, dentate marginally, its globular process about 1/3 length of signum.

Distribution. China (Tibet).

Etymology. The specific name is from the Latin *quadratus* (= square), referring to the rectangular uncus in the male genitalia.

***Isodemis guangxiensis* sp. n.**

urn:lsid:zoobank.org:act:F2E5B790-7F5B-46F6-813D-F1CC182AD4E6

Figs 8, 16

Type material. Holotype ♂ – **China, Guangxi Zhuang Autonomous Reging:** Rongshui Miao Autonomous County (25°04'N, 109°13'E), 31.VII.2003, genitalia slide no. SYH09041. Paratype: 1 ♂, Huaping Nature Reserves (23°39'N, 109°55'E), 1300 m, 1.VIII.2006, coll. Weichun Li.

Diagnosis. This species is similar to *I. illiberalis* both in appearance and in male genitalia, but can be separated by the median fascia extending from the costal margin to the dorsum, the subapical blotch reaching across 1/3 width of wing and the phallus having eight deciduous cornuti and two non-deciduous cornuti. In *I. illiberalis*, the median fascia extends from below the costal fold to the dorsum, the subapical blotch reaches the tornus and the phallus has eight to twenty-three deciduous cornuti and a single non-deciduous cornutus. *Isodemis guangxiensis* is superficially also similar to *I. quadrata*, the differences between them are as follows: in *I. guangxiensis*, the uncus broadens from the basal 1/4 to the apex and the phallus bears eight deciduous cornuti and two non-deciduous cornuti, whereas in *I. quadrata*, the uncus is quadrate and the phallus has ten deciduous cornuti and a single non-deciduous cornutus.

Description. Adult: Male (Fig. 8) wingspan 18.0–18.5 mm. Head yellowish brown. Antenna and labial palpus ochreous brown, with scattered yellowish brown scales. Thorax and tegula dark grayish brown, sparsely mixed with yellowish brown. Forewing yellowish brown tinged with ochreous scales; costal fold densely suffused with brownish black scales, about $3/5$ length of costal margin; markings brownish black mottled with ochreous: median fascia extending from costal margin to distal $2/5$ of dorsum, interrupted near costal margin, with nearly oval gray patch present on its outer side posteriorly; short stripe from basal $1/4$ of dorsum extending anteriorly and touching inner side of median fascia at anterior $1/3$, forming an irregularly semicircular pattern above dorsum, leaving a rounded subtriangular patch of groundcolour near middle of dorsum; subapical blotch inverted triangular, from distal $1/3$ of costal margin to before apex, reaching across $1/3$ width of wing; with small diffusion near middle of termen; cilia yellowish brown mixed with brownish black. Hindwing and cilia grayish brown. Legs dark yellow, mottled brownish black on ventral side of foreleg and on outer side of mid- and hindlegs. Abdomen grayish brown.

Male genitalia (Fig. 16). Uncus nearly rectangular in basal $1/4$, then broadened slightly to rounded apex, densely setose in distal half. Gnathos arm slender and long; terminal plate triangular, about $2/3$ length of arm. Valva slightly widened distally, length about 2 times of width, rounded terminally; transtilla irregularly round, with pointed apical process. Sacculus weakly sclerotized, protruding ventrally at middle; terminal process nearly triangular, rounded at apex, reaching plica. Vinculum somewhat concave at middle on anterior margin. Juxta large and broad, straight on anterior margin; posterior margin concave and arched, protruding posterolaterally. Phallus slightly shorter than length of valva, slightly curved and dilated in basal $2/5$, with eight deciduous cornuti and two non-deciduous unequal cornuti that are about $1/3$ length of phallus.

Female. Unknown.

Distribution. China (Guangxi).

Etymology. The name is derived from the type locality.

***Isodemis hainanensis* sp. n.**

urn:lsid:zoobank.org:act:0BDC5A29-95B3-43AC-A8B3-77C9BDC4DA8F

Figs 9–10, 17, 20

Type material. Holotype ♂ – **China, Hainan Province:** Mt. Wuzhi Nature Reserves (18°52'N, 109°40'E), 740 m, 15.IV.2009, coll. Qing Jin and Bingbing Hu, genitalia slide no. SYH09042. Paratype: 1 ♀, Jianfengling (18°44'N, 109°10'E), 800–900 m, 6.XII.2009, coll. Zhaohui Du.

Diagnosis. This species is superficially very similar to *I. longicera* and *I. brevicera*, but it can be separated by the uncus being slightly narrowed in the distal $2/5$ and rounded apically, the spine-shaped terminal process of the sacculus not reaching plica and the phallus bearing eight cornuti. In *I. longicera*, the uncus is slightly concave at middle on posterior margin, the terminal process of the sacculus reaches the plica and the phallus bears twelve cornuti; in *I. brevicera*, the uncus broadens from base to apex, the termi-

nal process of the sacculus is nearly triangular, and the phallus has ten cornuti. Female genitalia resemble those of *I. ngoclinha*, but can be distinguished by the anterior portion of the papilla analis not being inflated and the sterigma extending posteriorly uniformly in width to both sides; whereas in *I. ngoclinha*, the basal 2/3 of papilla analis is inflated, and the sterigma widens from the inception of ductus bursae to the lateral side.

Description. Adult: Male (Fig. 9) wingspan 17.5 mm. Head, antenna and labial palpus grayish brown, mixed with brownish black scales. Thorax and tegula brownish black, with sparse grayish brown scales. Forewing dark yellowish brown, tinged with ochreous scales in distal half; costal fold narrow, about 1/2 length of costal margin, brownish black, with short black stripes along costal margin; markings brownish black mottled ochreous: median fascia interrupted near costal margin, reaching above tornus, then extending obliquely anteriorly to lower corner of cell; longitudinal broad median stripe from apical margin of median fascia to end of cell, forming an annular pattern with indentation; subapical blotch from distal 2/5 of costal margin to apex, reaching across 1/4 width of wing; pale brownish black terminal lines between veins; dorsal area densely suffused with grayish brown scales, forming a broad band along dorsum; cilia grayish brown mixed with brownish black. Hindwing and cilia grayish brown. Legs dark yellowish brown, mottled brownish black on ventral side of foreleg and on outer side of mid- and hindlegs. Abdomen dark grayish brown.

Female (Fig. 10) wingspan 22.0 mm. As in male except with small, brownish black basal fascia near base; costal margin more arched basally than in male; subapical blotch from middle of costal margin to apex, narrow, reaching across 1/5 width of wing; stripe along anal vein to beyond mid-length of wing.

Male genitalia (Fig. 17). Tegumen with a small triangular process at posterior 1/4 medially. Uncus nearly rectangular, slightly narrowed in distal 2/5, sparsely setose in distal half, rounded at apex. Gnathos arm tapering to distal end, with distinct lateral prominence that bears many tiny spines; terminal plate short, about 1/2 length of arm. Valva length about two times width, rounded terminally; plica extremely thin, straight; small sclerotized projection at basal 1/3 between plica and ventral margin. Transtilla irregularly oval, with pointed and curved apical process. Sacculus sclerotized; terminal process a long spine, not reaching plica. Vinculum sclerotized anteriorly. Juxta approximately semioval, slightly concave at middle on posterior margin. Phallus about 2/3 length of valva, pistol-shaped, basal 1/3 dilated; cornuti composed of one deciduous cornutus and seven non-deciduous cornuti, each about 1/4 length of phallus.

Female genitalia (Fig. 20). Papilla analis broad. Apophysis anterioris about 1.3 times length of apophysis posterioris. Sterigma narrow and long transversely, weakly notched at middle posteriorly. Antrum long, about 1/4 length of ductus bursae, anterior 1/3 sclerotized; ductus bursae slightly longer than corpus bursae, wrinkled; ductus seminalis from middle of ductus bursae; cestum absent. Corpus bursae oval, posterior half wrinkled; signum large spine-shaped, dentate marginally, its globular process about 1/6 length of signum.

Distribution. China (Hainan).

Etymology. The name is from the type locality.

Acknowledgments

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Review of the genus *Merulempista* Roesler, 1967 (Lepidoptera, Pyralidae) from China, with description of two new species

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Abstract

The genus *Merulempista* Roesler, 1967 is reviewed for China. Of the four species treated in this paper, *Merulempista rubriptera* Li & Ren, **sp. n.** and *M. digitata* Li & Ren, **sp. n.** are described as new; *M. cyclogramma* (Hampson, 1896) is newly recorded for China, and its taxonomic position is briefly discussed. Photographs of the adults and genitalia are provided, along with a key to the known Chinese species.

Keywords

Lepidoptera, Pyralidae, Phycitinae, *Merulempista*, new species, China

Introduction

Merulempista Roesler, 1967 is a small genus of ten described species and subspecies, distributed in the Palearctic Region except *M. cyclogramma* (Hampson, 1896) occurring in the Oriental Region and *M. oppositalis* (Walker, 1863) ranging from Oriental to Australian regions (Roesler 1984; Asselbergs 1997; Leraut 2001, 2002). The genus is characterized by the male gnathos distally hooked, the sclerotized costa often produced

to a distal process, and the female antrum deeply concave at middle and greatly extending backward posterolaterally.

Prior to this study, only *Merulempista cingillella* (Zeller, 1846) was known from China. The aim of the present paper is to review the Chinese *Merulempista* based on the specimens collected in Gansu, Guangxi, Hebei, Inner Mongolia, Ningxia, Tianjin and Xinjiang, describe two species new for science and record one species new for the Chinese fauna. All the specimens, including the types of the new species, are deposited in the Insect Collection, College of Life Sciences, Nankai University, Tianjin, P. R. China.

Taxonomic accounts

Merulempista Roesler, 1967

Merulempista Roesler, 1967: 274. Type species: *Pempelia cingillella* Zeller, 1846, by original designation.

Diagnosis. *Merulempista* is similar to *Meroptera* Grote, 1882 by the forewing with M_1 and M_2 separated (Fig. 1), the third segment of the labial palpus rounded apically; the short robust gnathos hooked distally, the sclerotized costa of valva often with a distal process, and the narrow sacculus without spine. In *Meroptera*, M_1 and M_2 are shortly stalked on the forewing, the third segment of the labial palpus tapered distally, the gnathos is long and slender, the costa of valva lacks the distal process, and the sacculus has a spine (according to Roesler 1967).

Hostplants. Tamaricaceae: *Myricaria* spp., *Tamarix* spp. (Huertas-Dionisio 2010).

Distribution. China (Fig. 2: Gansu, Guangxi, Hebei, Inner Mongolia, Ningxia, Tianjin, Xinjiang), Europe, North Africa and Australia.

Key to *Merulempista* species in China based on male genitalia

- 1 Costa sclerotized inconspicuously, without distal process; vinculum with a small papillate process anteromedially *M. cyclogramma*
- Costa sclerotized conspicuously, with developed distal process; vinculum without papillate process anteromedially 2
- 2 Distal process of costa short triangular, without apical spine; phallus with three cornuti placed medially *M. rubriptera*
- Distal process of costa somewhat fingerlike, bearing an apical spine; phallus with one cornutus placed medially, two placed distally 3
- 3 Distal process of costa almost straightly bending upward, forming a right angle with valva at outside *M. cingillella*
- Distal process of costa obliquely bending upward, forming an acute angle with valva at outside *M. digitata*

***Merulempista rubripectera* Li & Ren, sp. n.**

urn:lsid:zoobank.org:act:DB61FC4B-ECD2-4F98-BE6D-D53BF581933D

Figs 3, 7, 11

Type material. Holotype ♂ – **China, Inner Mongolia Autonomous Region:** Erdaoqiao, Eji'naqi (41.56°N, 101.04°E), 927 m, 18.VII.2006, coll. Xinpu Wang and Xiangfeng Shi, genitalia slide no. LSR09083. Paratypes: 2 ♂♂, 2 ♀♀, same data as for holotype except dated 17–18.VII.2006.

Diagnosis. This species is characterized by the rosy-colored forewing with a longitudinal greyish black stripe at base below costa. It can be distinguished from its congeners by the costa with a triangular distal process arising from 2/3 length of valva, the stout phallus with three thornlike cornuti located at middle in the male genitalia; and the antrum angularly protruding backward posterolaterally in the female genitalia.

Description. Adult (Fig. 3). Wingspan 23.5–24.5 mm. Head khaki in male, pale yellowish brown in female. Antenna with scape reddish brown dorsally, yellow ventrally; flagellum yellowish brown ringed with brown; male sinus with shining deep greyish brown mixed with rosy scales, somewhat shelllike, pale yellow on ventral surface. Labial palpus pale yellowish white, densely covered with rosy scales ventrally, in female third segment tinged with black ventrodistally, far exceeding vertex; second

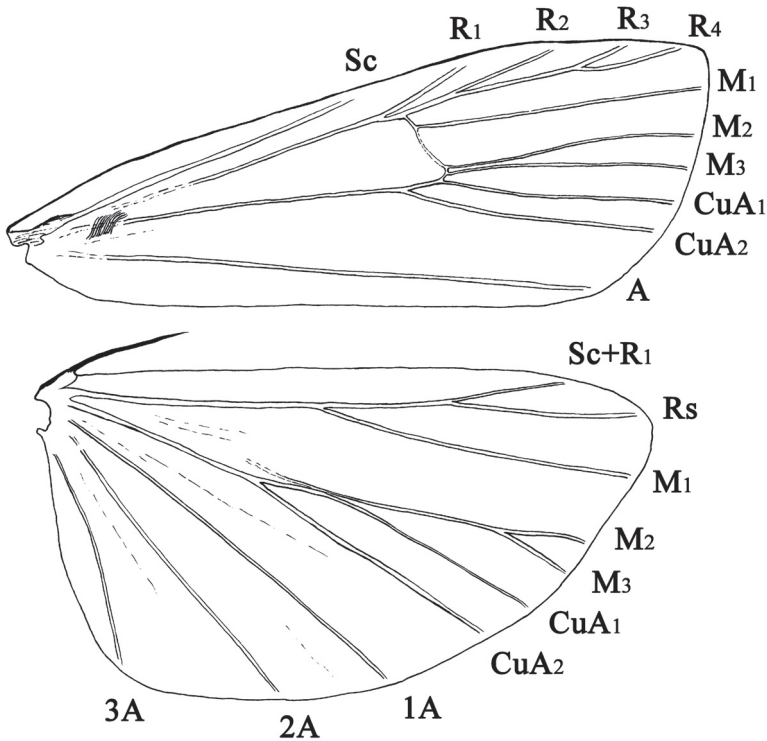


Figure 1. Wing venation. *Merulempista digitata* sp. n., paratype, slide No. LSR09042W.

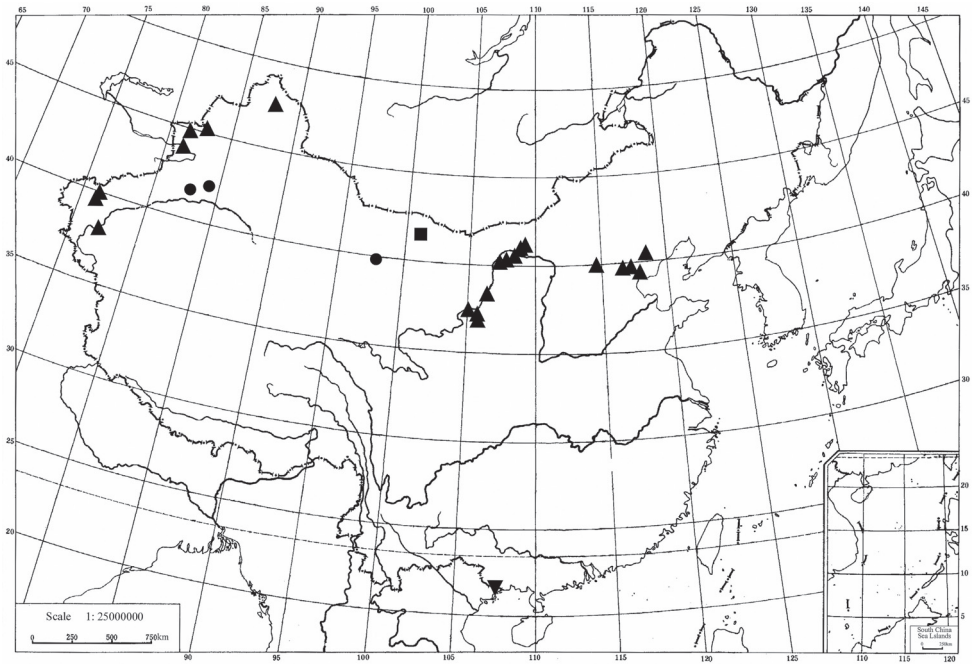


Figure 2. Distribution of Chinese *Merulempista* species. ■ *M. rubriptera*, ● *M. digitata*, ▲ *M. cingillella*, ▼ *M. cyclogramma*.

segment shorter than diameter of eye, about 4 times length of third; third segment rather blunt apically. Patagium in male whitish yellowish tinged with pale yellowish brown, in female densely covered with greyish white-tipped rosy scales. Thorax and tegula in male rosy, in female greyish-brown tinged with rosy. Forewing rosy, with scattered greyish white and black scales in distal half, with a longitudinal greyish black stripe at base just below costa; posterior margin yellowish white at base; antemedian line yellowish white, straight, situated beyond basal 1/3, its posterior half tinged with black on inside, ochreous yellow on outside; postmedian and subterminal lines greyish white, slightly sinuate, nearly parallel; cilia rosy mixed with greyish brown, with a fine yellowish white basal line. Hindwing pale brown; cilia with basal 1/3 greyish brown, distal 2/3 greyish white. Legs rosy on outside, yellowish white on inside; tarsi brownish black, ringed with whitish yellow at apex of each segment, lined with short black spines on inside.

Male genitalia (Fig. 7). Uncus somewhat trapezoid, with sparse setae laterally, blunt posteriorly. Gnathos slightly shorter than 1/2 length of uncus, heavily sclerotized, wide basally, tapering to hooked apex. Costa with distal process triangular, uprising obliquely outward from about 2/3 length of valva. Valva narrow basally, widened and arciform beyond middle ventrally, slightly narrowed toward bluntly rounded apex distally, densely setose; sacculus narrow, about 1/3 length of valva; clasper thumb-shaped. Vinculum large U-shaped, longer than valva, arciform anteriorly. Juxta slightly elliptical, concave deeply at middle on posterior margin. Phallus stout, about same length

as valva; three thornlike cornuti located at middle of phallus, median one longest and curved basally. Eighth sternite and culcita shown in figure 7a.

Female genitalia (Fig. 11). Papillae anales triangular, narrowed to bluntly rounded posterior margin. Eighth abdominal segment longer than wide, anterior margin roundly protruding, posterior margin straight. Apophyses anteriores about as long as apophyses posteriores, slightly dilated at base. Antrum weakly sclerotized, deeply concave at middle on posterior margin, angularly protruding backward posterolaterally. Ductus bursae membranous, with longitudinal rumples. Corpus bursae membranous, elongate ovate; large, more or less rectangular accessory sac arising from left side of corpus bursae posteriorly, densely covered with granules, ductus seminalis from its apex; signa comprised of two clusters of short spines, placed posteriorly.

Distribution. China (Inner Mongolia).

Etymology. The specific epithet is derived from the Latin *ruber* (= red) and the suffix *-pteron* (= wing), in reference to the color of forewing.

***Merulempista digitata* Li & Ren, sp. n.**

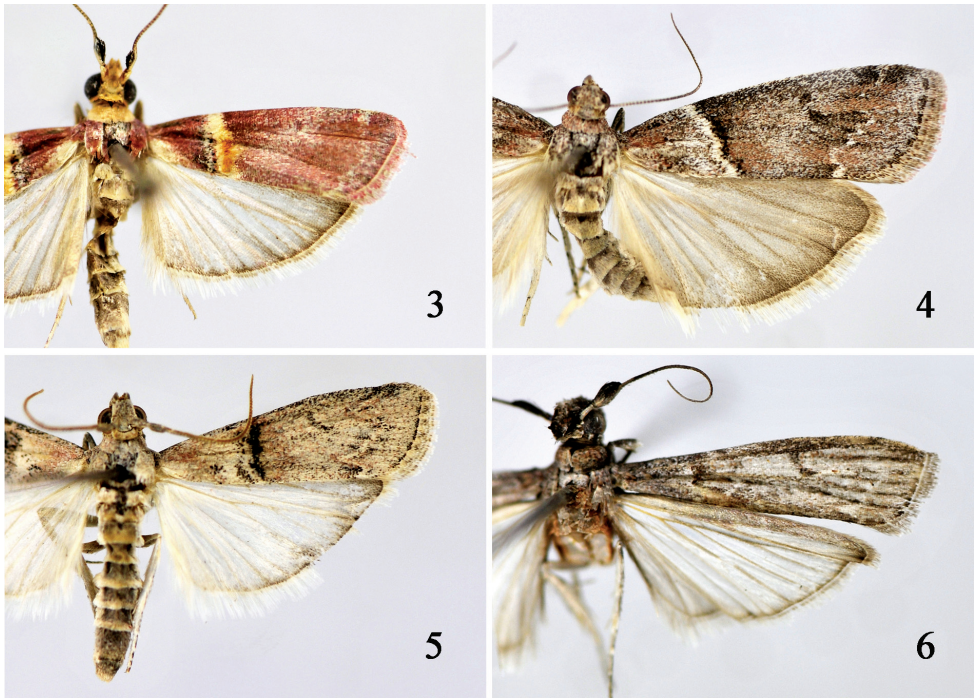
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Figs 1, 4, 8, 12

Type material. Holotype ♂ – **China, Xinjiang Uygur Autonomous Region:** Xinyuan (43.19°N, 84.01°E), 1562 m, 7.VIII.2007, coll. Xinpu Wang, genitalia slide no. LSR09078. Paratypes: 22 ♂♂, 33 ♀♀, same data as for holotype except dated 6–7.VIII.2007; 1 ♂, Mohe, Gongliu (43.13°N, 82.45°E), 1500 m, 29.VII.1994, coll. Houhun Li and Hongyan Qin; 4 ♂♂, 5 ♀♀, Kuerdening, Gongliu (43.13°N, 82.50°E), 1500 m, 27.VII.1994, coll. Houhun Li and Hongyan Qin; **China, Gansu Province:** 2 ♀♀, Sunan (39.42°N, 98.29°E), 2251 m, 16.VIII.2007, coll. Feng Yang and Hanguang Gao.

Diagnosis. This species is similar to *Merulempista cingillella*, but differs in the clearly separated discocellular stigmata on the forewing; in the male genitalia the costa with distal process arising from 5/6 of the valva and in the female genitalia the antrum being triangular posterolaterally. In *M. cingillella*, the discocellular stigma on the forewing is kidney-shaped, the distal process of the costa arises from 3/4 of the valva, and the antrum is elongately leaf-shaped posterolaterally.

Description. Adult (Fig. 4). Wingspan 22.0–27.0 mm. Head greyish brown to dark brown. Antenna with scape greyish brown to dark brown, twice longer than wide; flagellum greyish yellow ringed with brown on dorsal surface, yellowish brown on ventral surface; male sinus with brush of brownish black scales. Labial palpus in male stronger than in female; first segment greyish white, in male mixed with pale ochreous; second and third segments brown, mixed with pale ochreous except greyish white dorsally. Maxillary palpus columniform; in male golden yellow, about equal length to second segment of labial palpus; in female greyish white, slightly longer than third segment of labial palpus. Patagium pale reddish brown. Thorax and tegula brown tinged



Figures 3–6. Adults of *Merulempista* species. **3** *M. rubripecta* sp. n., paratype male **4** *M. digitata* sp. n., paratype female **5** *M. cingillella* male **6** *M. cyclogramma* male.

with greyish white except tegula pale reddish brown at base. Forewing three times longer than wide, apex rounded, termen bluntly oblique; ground coloration greyish brown to brownish black, mixed with reddish brown and greyish white; antemedian line white, extending from 1/4 of costal margin to 1/3 of posterior margin, edged with erect black scales along outside; discocellular stigmata brownish black, clearly separated, forming two distinct spots; postmedian line white, dentate, parallel with termen; termen pale brown to brownish black, discontinuous, sometimes forming small dark spots; cilia grey mottled brown. Hindwing pale grey; cilia yellowish white.

Male genitalia (Fig. 8). Uncus wide at base, narrowed toward bluntly rounded apex, length as long as basal width. Gnathos dilated basally, slender and pointed distally, hooked apically, about 2/5 length of uncus. Costa wider than sacculus; distal process fingerlike, arising from about 4/5 length of valva, forming an acute angle with valva at outside, bearing a needlelike apical prong slightly exceeding end of valva. Valva about four times longer than wide, basal half slightly narrower, widened and arciform ventrally from middle to 5/6; distal 1/6 triangularly shaped, densely covered with long setae, narrowly rounded at apex; clasper finger-shaped, blunt apically; sacculus about half length of valva, basal half slightly wider than distal half. Vinculum broad, U-shaped; anterior margin slightly concave inward at middle. Juxta V-shaped; lateral lobe narrowed distally, curved inward. Phallus about same length as valva, thick at base; with three needle-like cornuti, longest one about 3/5 length

of phallus, located medially, other two placed distally. Eighth sternite and culcita shown in figure 8a.

Female genitalia (Fig. 12). Papillae anales triangular, finely haired. Apophyses anteriores shorter than apophyses posteriores, slightly expanded at base. Antrum large, with a longitudinal crevice centrally, triangularly protruding backward posterolaterally. Ductus bursae slightly shorter than corpus bursae; posterior 1/3 membranous, smooth; anterior 2/3 sclerotized, with small pieces of sclerites. Corpus bursae ovate, membranous; large elongate accessory sac from left side of corpus bursae posteriorly, ductus seminalis from its distal part; signum deeply sunken, with numerous coniform spines, placed posteriorly.

Distribution. China (Gansu, Xinjiang).

Etymology. The specific epithet is derived from the Latin *digitatus* (= digitate), in reference to the distal process of costa.

Merulempista cingillella (Zeller, 1846)

Figs 5, 9, 13

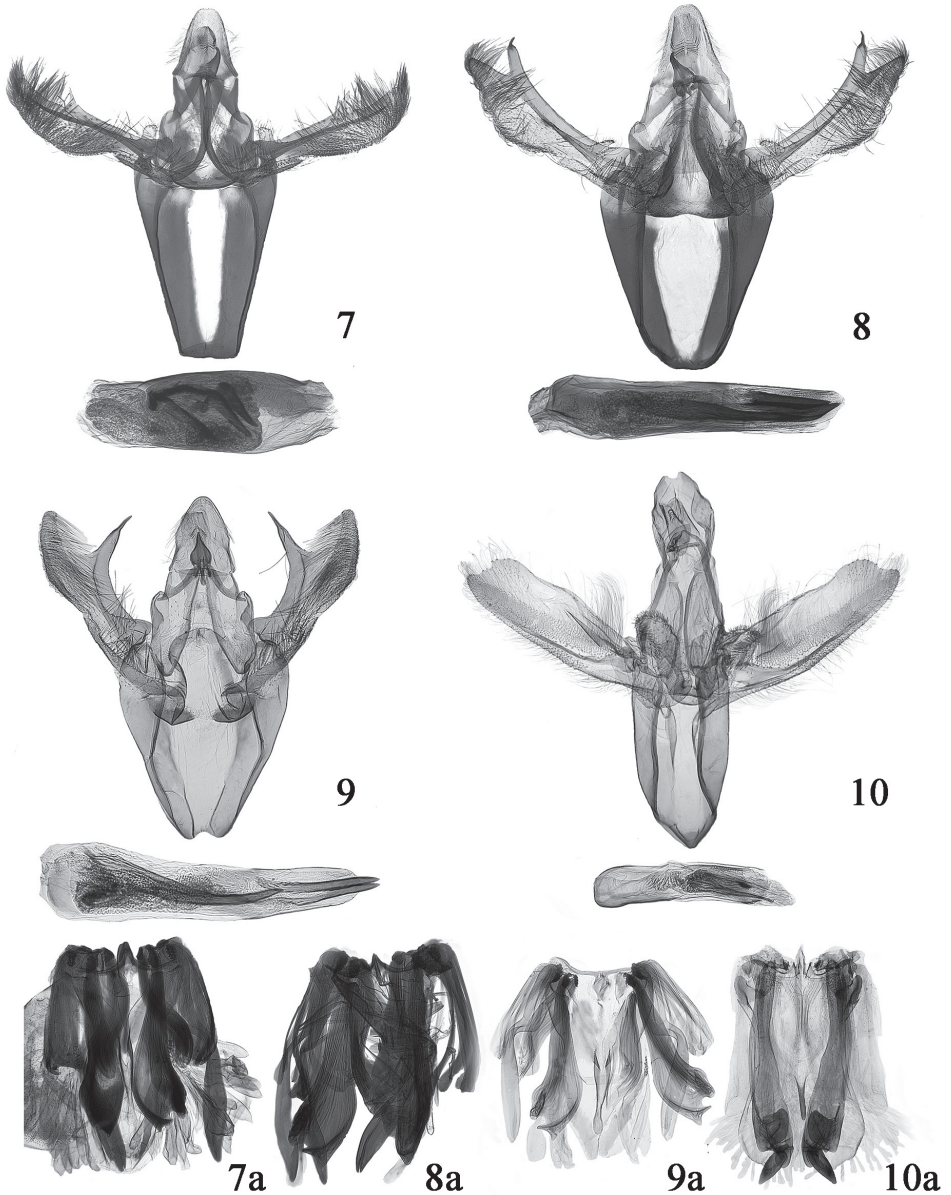
Pempelia cingillella Zeller, 1846: 779. Syntypes, Type locality: Hungary.

Salebria cingillella: Rebel in Spuler 1910: 211.

Meroptera cingillella: Hannemann 1964: 164.

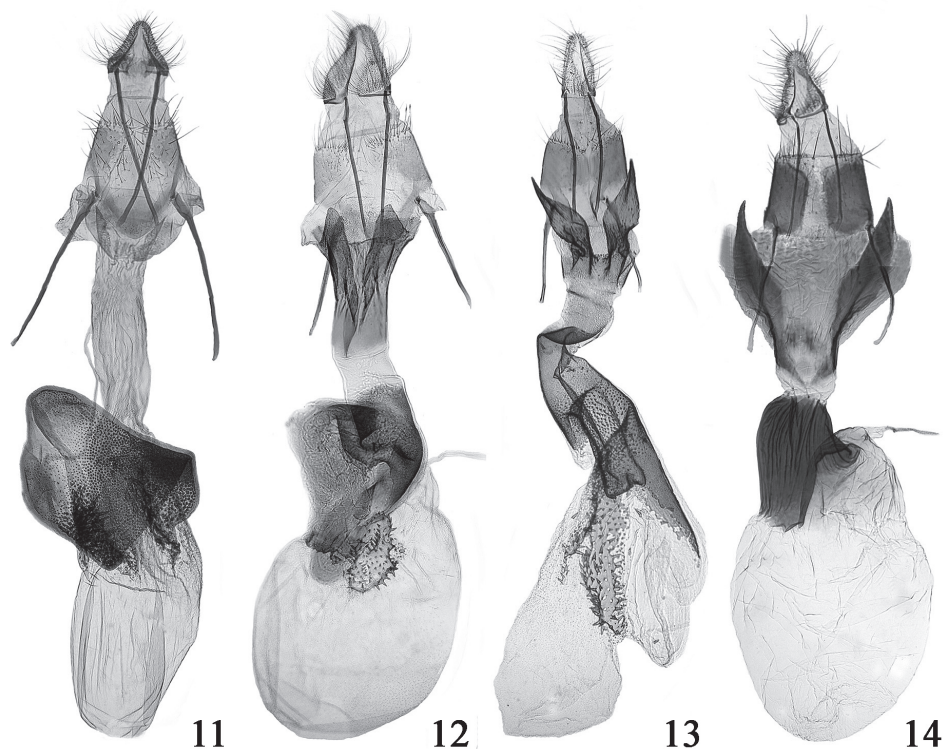
Merulempista cingillella: Ivinskis 1984: 65.

Material examined. China, Tianjin: 5 ♀♀, Dahuangpu (39.26°N, 117.16°E), Wuqing, 15 m, 20–21.VII.2005, coll. Houhun Li; 1 ♀, Beidagang (38.43°N, 117.21°E), 25.VIII.2004, coll. Jiasheng Xu and Jialiang Zhang; 1 ♀, Yadian (38.56°N, 117.14°E), 24.VIII.2004, coll. Jiasheng Xu and Jialiang Zhang; **China, Hebei Province:** 1 ♂, 1 ♀, Xiaowutaishan (39.59°N, 114.48°E), Weixian, 1200 m, 24, 28.VII.2000, coll. Yanli Du and Zhendong Li; 1 ♂, Wulingshan (40.38°N, 117.27°E), 900 m, 31.VII.2001, coll. Yanli Du and Zhendong Li; **China, Inner Mongolia Autonomous Region:** 1 ♂, 1 ♀, Chengguanzhen, Dengkou County (40.18°N, 107.00°E), 1000 m, 18.VIII.2002, coll. Zhiqiang Li and Dandan Zhang; 4 ♂♂, 11 ♀♀, Chengguanzhen, Dalateqi (40.24°N, 110.01°E), 960 m, 13.VIII.2002, coll. Zhiqiang Li and Dandan Zhang; 3 ♂♂, 5 ♀♀, Dongfeng (40.53°N, 107.09°E), Hangjihouqi, 1000 m, 20–21.VIII.2002, coll. Zhiqiang Li and Dandan Zhang; 2 ♂♂, 1 ♀, Baliqiao (41.04°N, 108.13°E), Wuyuan County, 960 m, 17.VIII.2002, coll. Zhiqiang Li and Dandan Zhang; 3 ♀♀, Fuxingzhen (40.56°N, 107.56°E), Wuyuan County, 960 m, 16.VIII.2002, coll. Zhiqiang Li and Dandan Zhang; 4 ♂♂, 8 ♀♀, Qianqi (40.75°N, 108.65°E), Bameng, 1075 m, 12.VIII.2006, coll. Zhiwei Zhang; **China, Ningxia Hui Autonomous Region:** 2 ♂♂, Shapotou (37.30°N, 105.11°E), Zhongwei, 1200 m, 10.VIII.2000, coll. Houhun Li and Shuxia Wang; 3 ♀♀, Yuanyichang (37.27°N, 105.42°E), Zhongning, 1170 m, 16–17.VII.1993, coll. Houhun Li; 1 ♂, 1 ♀, Xinpü (37.09°N, 105.43°E), Zhongning County, 1170 m, 26.VII.1993, coll. Houhun



Figures 7–10. Male genitalia of *Merulempista* species. **7** *M. rubripecta* sp. n., holotype, slide No. LSR09083 **8** *M. digitata* sp. n., holotype, slide No. LSR09078 **9** *M. cingillella*, slide No. DYL00263 **10** *M. cyclogramma*, slide No. LJY10100 **7a–10a** 8th sternite and culcita.

Li; 3 ♂♂, 3 ♀♀, Luhuatai (38.37°N, 106.12°E), Yinchuan, 24, 31.VII.1982, coll. unknown; 1 ♂, Yinchuan (38.29°N, 106.13°E), 20.V.1963, coll. unknown; **China, Xinjiang Uygur Autonomous Region:** 4 ♂♂, 2 ♀♀, Jinghe County (44.35°N,



Figures 11–14. Female genitalia of *Merulempista* species. **11** *M. rubripetra* sp. n., paratype, slide No. LSR09084 **12** *M. digitata* sp. n., paratype, slide No. LSR09079 **13** *M. cingillella*, slide No. DYL00279 **14** *M. cyclogramma*, slide No. RYD04575.

82.53°E), 22.VIII.1994, coll. Duoliken Bashanbayi; 2 ♂♂, 4 ♀♀, Beitun (47.21°N, 87.49°E), 530 m, 20, 22.vii.1994, coll. Houhun Li and Hongyan Qin; 4 ♂♂, 10 ♀♀, Mohe (43.13°N, 82.45°E), Gongliu, 1100–1500 m, 6, 29.VI-7.VII.1994, coll. Xincheng An, Houhun Li and Hongyan Qin; 4 ♂♂, 2 ♀♀, Zepu (38.11°N, 77.16°E) 29.VI-7.VII.1994, coll. Aisihaer Maimaiti; 2 ♂♂, 1 ♀, Ganjiahu (44.54°N, 83.23°E), 27.VI.1984; 1 ♂, 2 ♀♀, Jiashi County (39.29°N, 76.23°E), 1240 m, 17-18.IX.1987, coll. Houhun Li; 1 ♀, Yengisar County (38.55°N, 76.10°E), 1320 m, 15.IX.1987, coll. Houhun Li.

Diagnosis. This species is characterized by the discocellular spots being fused to a kidney-shaped stigma, in the male genitalia by the costa of valva having a distal process straightly bending backward, forming a right angle with the valva, and in the female genitalia by the corpus bursae having a large elongate spined sclerite extending from the posterior end to middle or to near anterior margin.

Hostplants. *Myricaria germanica* (Linn.), *Tamarix gracilis* Willd., *Tamarix* sp.

Distribution. China (Hebei, Inner Mongolia, Qinghai, Ningxia, Tianjin, Xinjiang); Europe: Albania, Austria, Bosnia and Herzegovina, Croatia, France, Germany,

Hungary, Italy, Russia, Slovakia, Spain, Switzerland, Turkey, Ukraine (Zeller 1846; Nuss et al. 2010); North Africa: Morocco.

***Merulempista cyclogramma* (Hampson, 1896)**

Figs 6, 10, 14

Phycita (*Dioryctria*) *cyclogramma* Hampson 1896: 91. Type locality: Sri Lanka.

[*Gyrtona cyclogramma*: Roesler and Küppers 1979: 78. Misidentification.]

Merulempista cyclogramma: Roesler 1984: 39.

Material examined. China, Guangxi Zhuang Autonomous Region: 4 ♂♂, 5 ♀♀, Nanping and Pinglongshan, Shangsi County (22.09°N, 107.59°E), 510–770 m, 3–6. IV.2002, coll. Shulian Hao and Huaijun Xue.

Diagnosis. This species is conspicuously different from its congeners by the costa of valva weakly sclerotized and lacking the distal process, the juxta with gradually broadened, posteriorly rounded and spinulate lateral lobe, and the vinculum with a small papillate anteromedian process in the male genitalia; and by the antrum deeply and widely concave at middle, elongate featherlike posterolaterally in the female genitalia.

Distribution. China (Guangxi); Indonesia (Sumatra), India, Sri Lanka.

Remarks. Of the four species described in this paper, *M. cyclogramma* is the only one that is distributed in the southern part of China, while the other three occur in the northern and northwestern parts of China (Fig. 2). Taking the genital structures into consideration, the taxonomic position of this species needs further study with additional material.

This species is recorded as new for China.

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