ZooKeys 724: 1–20 (2017)
doi: 10.3897/zookeys.724.20680
http://zookeys.pensoft.net

RESEARCH ARTICLE

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

Two new *Dolichothele* Mello-Leitão, 1923 species from Brazil and Bolivia (Araneae, Theraphosidae)

Irene Soliz Revollo[1,2], Pedro Ismael da Silva Júnior[3], Rogério Bertani[2]

1 *UNESP, Universidade Estadual Paulista Júlio de Mesquita Filho, Instituto de Biociências, Letras e Ciências Exatas, Rua Cristóvão Colombo, 2265, 15054-000, São José do Rio Preto, São Paulo, Brazil* **2** *Instituto Butantan, Laboratório de Ecologia e Evolução, Av. Vital Brazil, 1500, 05503-900, São Paulo, São Paulo, Brazil* **3** *Instituto Butantan, Laboratório Especial de Toxinologia Aplicada, Av. Vital Brazil, 1500, 05503-900, São Paulo, São Paulo, Brazil*

Corresponding author: *Rogério Bertani* (rogerio.bertani@butantan.gov.br)

Academic editor: *C. Hamilton* | Received 29 August 2017 | Accepted 24 October 2017 | Published 21 December 2017

http://zoobank.org/FF4ED4A9-50CC-4704-8A7E-0D9C342D6B6F

Citation: Revollo IS, Silva Júnior PI, Bertani R (2017) Two new *Dolichothele* Mello-Leitão, 1923 species from Brazil and Bolivia (Araneae, Theraphosidae). ZooKeys 724: 1–20. https://doi.org/10.3897/zookeys.724.20680

Abstract

Two new species of *Dolichothele* Mello-Leitão, 1923 are described from Brazil and Bolivia, *D. mottai* **sp. n.** from Distrito Federal and the state of Goiás, Brazil, and *D. camargorum* **sp. n.** from the state of Rondônia, Brazil, and the La Paz region, Bolivia. Males of the two new species resemble *Dolichothele bolivianum* (Vol, 2001) in having a small subapical keel on the distal embolus and females in particular by the short spermatheca. *Dolichothele bolivianum* is redescribed, and its geographical distribution is herein restricted to Bolivia and the state of Mato Grosso in Brazil.

Keywords

Bolivia, cerrado, Ischnocolinae, tarantula, taxonomy

Introduction

The genus *Dolichothele* Mello-Leitão, 1923 was described based on a single species, *Dolichothele exilis* Mello-Leitão, 1923, from the state of Paraíba, Brazil, and included in Barychelidae. Later, Bücherl et al. (1971) examined the female holotype and transferred it to Theraphosidae, Ischnocolinae. Raven (1985), in his mygalomorph revision, considered the genera *Dolichothele* and *Goniodontium* Mello-Leitão, 1923 junior synonyms of *Hapalotremus* Simon, 1903 (Theraphosidae, Theraphosinae), but he was not followed by Schmidt (2002), who restored the genus *Dolichothele* and considered it *incertae sedis*. Recently, Lucas and Indicatti (2015) examined the holotype of the type species, *D. exilis*, synonymized *Oligoxystre caatinga* Guadanucci, 2007 and *Goniodontium muticum* Mello-Leitão, 1923 with *D. exilis* Mello-Leitão, 1923 and considered *Dolichothele* a senior synonym of *Goniodontium* and *Oligoxystre* Vellard, 1924, making several new combinations: *D. auratum* (Vellard, 1924), *D. bolivianum* (Vol, 2001), *D. diamantinensis* (Bertani, Santos & Righi, 2009), *D. dominguense* (Guadanucci, 2007), *D. mineirum* (Guadanucci, 2011), *D. rufoniger* (Guadanucci, 2007), and *D. tucuruiense* (Guadanucci, 2007).

Most of the species presently considered in *Dolichothele* were described in the genus *Oligoxystre,* which was revised by Guadanucci (2007, 2011). This author recognized eight species distributed in Brazil and Bolivia, one of which, *D. bolivianum*, as having “a very wide distribution, from central Brazil to eastern Bolivia” (Guadanucci 2007: 10). Guadanucci (2007) observed variations in color between populations of *D. bolivianum* but considered that the examined specimens had the same genitalia morphology and, therefore, belonged to the same species. Morphologically re-analyzing part of the specimens studied by Guadanucci (2007) and with additional material, two new species closely related to *D. bolivianum* were found, which are herein described.

Materials and methods

Specimens of the following institutions were examined: **DZUB**, Departamento de Zoologia da Universidade de Brasília, Brasília; **IBSP**, Instituto Butantan, São Paulo; **MHNNKM**, Museo de Historia Natural Noël Kempff Mercado, Santa Cruz de la Sierra; **MNRJ**, Museu Nacional da Universidade Federal do Rio de Janeiro, Rio de Janeiro; **MZUSP**, Museu de Zoologia da Universidade de São Paulo, São Paulo; **UFMG**, Coleções Taxonômicas da Universidade Federal de Minas Gerais, Belo Horizonte.

All measurements are in millimeters and were obtained from the right appendages, unless they were missing or regenerated. For measuring larger structures, such as carapace, abdomen and appendages, a Mitutoyo digital caliper was used with an error of 0.005 mm, rounded up to two significant decimals. Appendages were measured from the dorsal aspect. Image captures of the structures were made with a Leica M205C dissecting microscope, with a Leica LAS montage and a LAS 3D module with which small structures such as eyes were measured.

The position of spines on legs and palp followed the terminology of Petrunkevitch (1925) with the modifications of Bertani (2001). Abbreviations used were as follows:

ALE	anterior lateral eye,	**d**	dorsal,
AME	anterior median eye,	**ITC**	inferior tarsal claw,
ap	apical,	**PLE**	posterior lateral eye,

PLS	posterior lateral spinneret,	**r**	retrolateral,
PME	posterior median eye,	**STC**	superior tarsal claw,
PMS	posterior median spinneret,	**v**	ventral.
p	prolateral,		

Maps of species distributions were made with the program ArcGIS 10. Geographical coordinates were obtained from the labels when available (primary source, indicated by parentheses) or using Google Earth (secondary source, indicated by brackets).

Taxonomy

Dolichothele Mello-Leitão, 1923

Dolichothele Mello-Leitão, 1923: 119 (Type species by original designation *D. exilis* Mello-Leitão, 1923, type in MNRJ, not examined); Lucas and Indicatti 2015: 205.
Oligoxystre Vellard, 1924: 151, pl. 10, f. 38 (Type species by original designation *O. auratum* Vellard, 1924, should be deposited at Instituto Vital Brazil, Niterói, lost); first synonymized by Lucas and Indicatti 2015: 205.
Pseudoligoxystre Vol, 2001: 4–6, f. 7 (type species *Pseudoligoxystre bolivianum* Vol, 2001, deposited at MHNNKM, examined); first synonymized by Guadanucci 2007.
Goniodontium Mello-Leitão, 1923: 126 (type species by original designation *Goniodontium muticum* Mello-Leitão, 1923, type in MNRJ, not examined); first synonymized by Lucas and Indicatti 2015: 205.

Diagnosis (from Guadanucci 2011). Differs from other ischnocoline and resembles genus *Catumiri* Guadanucci, 2004 by the labium much wider than long, bearing a reduced number of cuspules (fewer than 10). It differs from *Catumiri* Guadanucci, 2004 by the undivided tarsal scopula on legs I–III and scopula on tarsi IV undivided but with a longitudinal band of setae, the metatarsus I having scopula ventrally for all its length, the well-developed retrolateral branch of the male tibial apophysis, the tarsal claws of males without teeth, and by the spermathecae with numerous lobules.

Dolichothele bolivianum (Vol, 2001)

Figs 1–8, 25, 28–29, 36

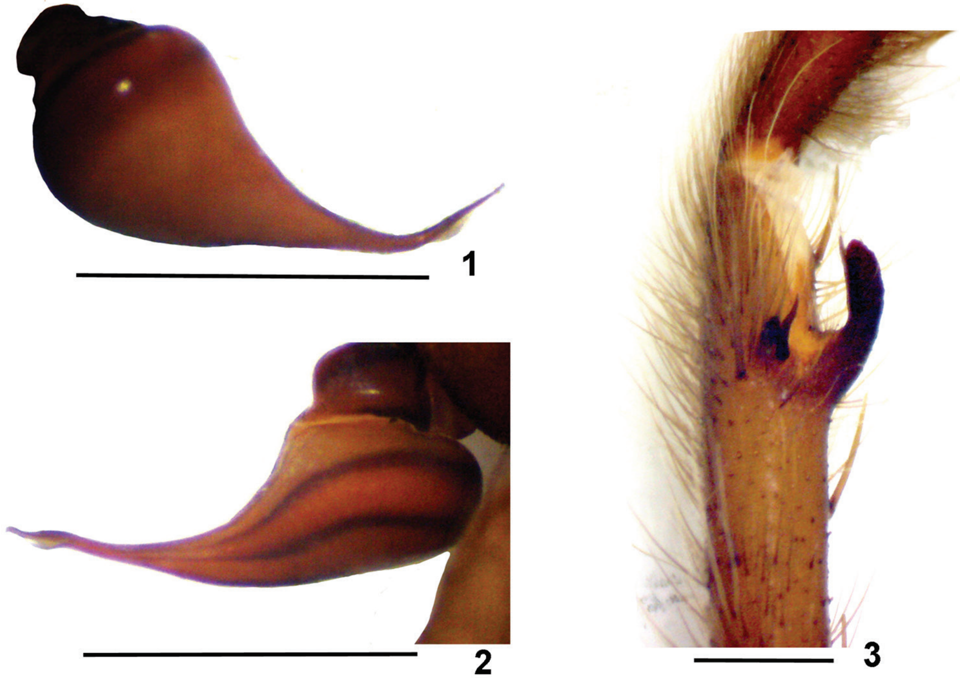
Pseudoligoxystre bolivianus Vol, 2001: 3, f. 1–7.
Oligoxystre bolivianum; Guadanucci 2007: 4, f. 1–12 (only f. 9).
Dolichothele bolivianum; Lucas and Indicatti 2015: 207; World Spider Catalog 2017.

Type material. Holotype male, BOLIVIA: *Santa Cruz*: Samaipata [18°7'S; 63°53'W], September 2000, J. M. Verdez & H. Simoens coll. (MHNNKM 003).

Other material. BOLIVIA: *Santa Cruz*: Samaipata [18°10'S; 63°50'W], 1 male, 06 October 2004, D. Weinmann & A. Stirm coll. (MZUSP 26083); 1 male, 07 October 2004, D. Weinmann & A. Stirm coll. (MUZSP 26082); 1 female, 28 December 2015, I. S. Revollo & R. B. Huanto coll. (MHNNKM unnumbered); BRAZIL: *Mato Grosso*: Chapada dos Guimarães [15°27'S; 55°44'W], 1 male, 19 March 1992, D. Pinz coll. (IBSP 109495); 1 male, February 1991, S. M. Lucas coll. (IBSP 109494); 1 female, 2000, equipe de resgate de fauna coll. (IBSP 109040); Cuiabá [15°36'S; 56°05'W], 1 male, January 1991, D. M. de Paula coll. (IBSP109496); Poconé [16°16'S; 56°37'W], 1 female (IBSP 109502).

Differential diagnosis. Males of *D. bolivianum* resemble those of *D. dominguense* , *D. camargorum* sp. n., and *D. mottai* sp. n. by the presence of a small subapical keel on male palpal bulb embolus (Figs 1–2, 4–5, 25). They differ from *D. dominguense* (Guadanucci 2007, f. 26–28) by the short embolus; from *D. mottai* sp. n. (Figs 9–10, 24) by the less curved and longer embolus; and from *D. camargorum* sp. n. (Figs 14–15, 19–20, 26–27) by stouter embolus, mainly on its more basal portion. Females of *D. bolivianum* (Fig. 8) resemble those of *D. camargorum* sp. n. (Fig. 18, 23) and *D. mottai* sp. n. (Fig. 13) by the short spermathecae. They differ from *D. camargorum* sp. n. by the shorter and somewhat triangular shape; from *D. mottai* sp. n. they differ by slender spermathecae and cephalothorax covered by brown setae.

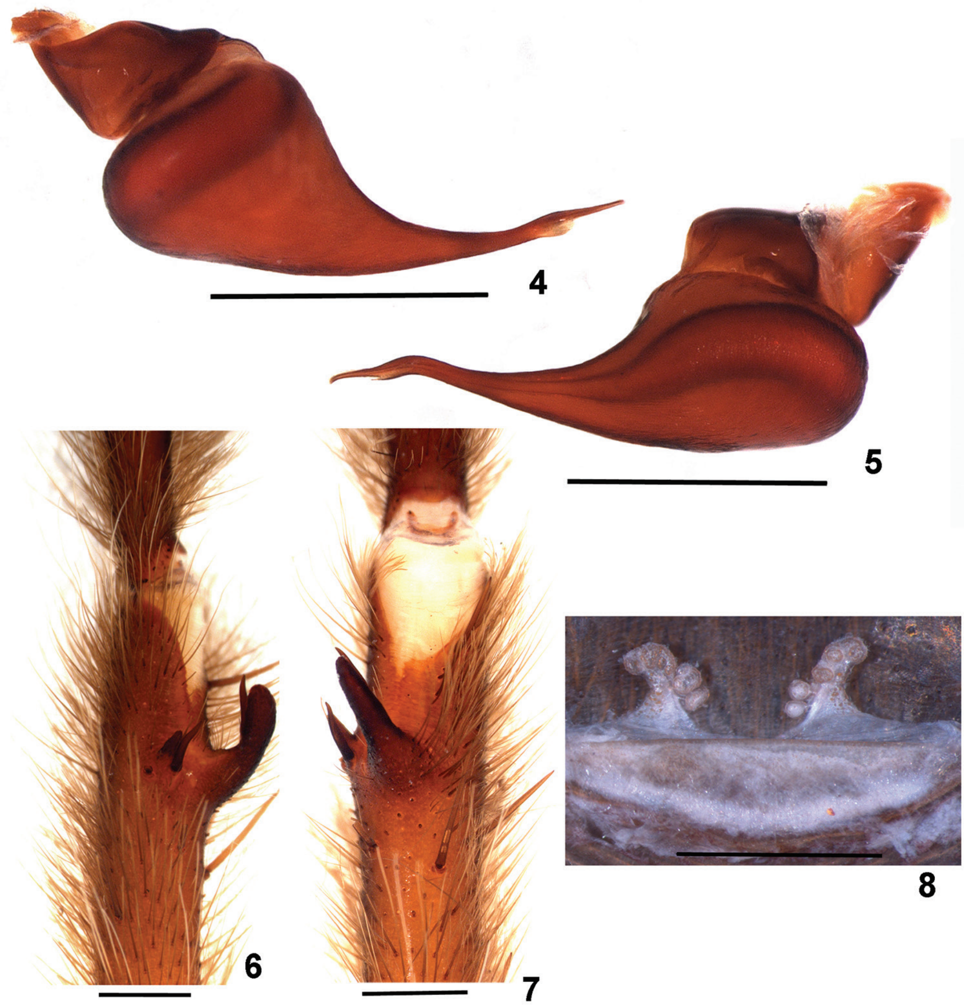
Redescription. Holotype (Figs 1–3). Carapace 7.3 long, 5.4 wide, chelicerae 2.6. Legs (femur, patella, tibia, metatarsus, tarsus, total): I: 7.2, 3.9, 5.3, 5.1, 3.6, 25.1. II: 6.5, 3.2, 4.5, 4.2, 3.1, 21.5. III: 5.2, 2.4, 3.6, 4.5, 3.0, 18.7. IV: 7.1, 3.0, 5.6, 6.3, 3.6, 25.7**.** Palp: 3.9, 2.6, 3.5, – , 1.5, 11.5. Mid-widths: femora I–IV = 1.6, 1.3, 1.6, 1.2, palp = 1.0; patellae I–IV = 1.2, 1.4, 1.0, 1.2, palp = 1.2; tibiae I–IV = 1.1, 1.0, 1.3, 0.9, palp = 1.0; metatarsi I–IV = 1.3, 0.9, 0.7, 0.7; tarsi I–IV = 0.7, 0.7, 0.7, 0.9, palp = 0.9. Abdomen 7.7 long, 3.9 wide. Spinnerets: PMS, 0.7 long, 0.4 wide, 0.3 apart; PLS, 1.4 basal, 1.1 middle, 1.4 distal; mid-widths 0.8, 0.7, 0.6, respectively. Carapace. Length to width 1.35. Fovea: straight, deep, 0.8 wide. Eyes and eye tubercle. Tubercle 0.8 long, 1.1 wide. Clypeus 0.3 wide. Anterior eye row slightly procurved, posterior slightly recurved. Sizes and inter-distances: AME 0.5, ALE 1.1, PME 0.6, PLE 1.0, AME–AME 0.1, AME–ALE 0.1, AME–PME 0.1, ALE–ALE 0.4, ALE–PME 0.2, PME–PME 0.6, PME–PLE 0.1, PLE–PLE 0.7, ALE–PLE 0.2, AME–PLE 0.2. Maxillae: 1.7 long, 1.5 wide, with 20 cuspules spread over ventral inner heel. Labium: 0.3 long, 1.0 wide, with 3 cuspules. Labio-sternal groove shallow, narrow, with two sigilla. Chelicerae: rastelum absent, basal segment with 8 teeth decreasing in size from distal to basal portion. Sternum: 3.7 long, 2.8 wide. Sigilla: three pairs ovals, hardly visible, less than one diameter from margin. Legs: leg formula: IV I II III. Clavate trichobothria: on distal half of tarsi I–IV. Scopula: tarsi I–IV fully scopulate; IV with two rows of setae, not separating the scopula. Metatarsi I–II fully scopulate; III 2/3, IV 1/3 distal scopulate, with two rows of setae, not separating the scopula. Spination: palp: femur p0-0-1, patella v0-2-1, tibia v0-1-1; leg I: femur 0, patella 0, tibia v2-2-2, r2-2-1, metatarsus v0-1-0, p1-1-0, r1-0-0; leg II: femur p0-0-1, patella 0, tibia v1-2-1, p1-1-0; metatarsus v0-1-0; leg III: femur d0-1-0, patella 0, tibia v2-4-1, p1-1-0, r1-1-0,



Figures 1–3. *Dolichothele bolivianum*. Holotype male. **1–2** right male palpal bulb **1** retrolateral view **2** prolateral view **3** left leg I tibial apophysis, prolateral view. Scale bar: 1 mm.

metatarsus v0-2-1ap, p1-1-0, r0-1-2(1ap), d0-0-1ap; IV: femur d0-2-0, patella 0, tibia v2-3-2, p1-1-1, r1-1-0, metatarsus v0-1-1ap, p0-1-1ap, r1-2-1ap. Claws: ITC absent from all legs; STC without teeth. Palpal bulb (Figs 1–2, compare 4–5, and 25 from MZUSP 26083): pyriform, embolus broad at its base, tapering and curved 45° to the retrolateral side on its distal third, with a small keel just after the curvature. Embolus the same or a little longer than tegulum. Male tibial apophysis (Fig. 3, compare Figs 6–7) with two branches originating from a common low base, positioned distant from metatarsus. Retrolateral branch longer than prolateral, not dilated on distal portion, with a spine on its mid-length. Prolateral branch shorter than contiguous spine. Both branches inclined ca. 45° to the prolateral side. Metatarsus I slightly curved. Color pattern. Carapace, chelicerae and legs dorsally brown, covered with light brown setae. Distal metatarsi and tarsi darker. Carapace with long light brown setae. Sternum, labium, maxillae and coxae light brown. Other leg articles ventrally brown. Abdomen dark brown covered with short golden setae and long light brown setae. Distal femora, patellae, tibiae and metatarsi with narrow whitish rings. Longitudinal stripes on leg articles not evident.

Female MHNNKM unnumbered. Carapace 7.8 long, 6.1 wide, chelicerae 3.1. Legs (femur, patella, tibia, metatarsus, tarsus, total): I: 5.3, 3.3, 3.5, 3.1, 2.3, 19.8. II: 4.9, 3.3, 3.1, 3.0, 2.2, 16.5. III: 4.2, 2.8, 2.6, 3.0, 2.1, 14.7. IV: 5.6, 3.6, 4.5, 4.6, 2.5, 20.8. Palp: 4.2, 2.5, 2.3, – , 2.4, 11.4. Mid-widths: femora I–IV = 1.4, 1.5, 1.5,



Figures 4–8. *Dolichothele bolivianum*. **4–7** male (MZUSP 26083) **4–5** right male palpal bulb **4** retrolateral view **5** prolateral view **6–7** right leg I tibial apophysis (mirrored) **6** prolateral view **7** ventral view **8** female (MHNNKM unnumbered), spermathecae, dorsal view. Scale bar: 1 mm.

1.2, palp = 1.2; patellae I–IV = 1.2, 1.3, 1.4, 1.3, palp = 1.2; tibiae I–IV = 1.3, 1.3, 1.1, 1.3, palp = 1.3; metatarsi I–IV = 1.0, 1.0, 1.1, 0.8; tarsi I–IV = 1.3, 1.2, 1.1, 1.1, palp = 1.3. Abdomen 10.1 long, 6.4 wide. Spinnerets: PMS 0.92 long, 0.42 wide, 0.33 apart; PLS 1.42 basal, 1.02 middle, 1.85 distal; mid-widths 0.98, 0.84, 0.70, respectively. Carapace: length to width 1.27. Fovea: straight, deep, 0.66 wide. Eyes and eye tubercle. Tubercle 0.97 long, 1.36 wide. Clypeus 0.10 wide. Anterior eye row slightly procurved, posterior eye row slightly recurved. Sizes and inter-distances: AME 0.42, ALE 0.41, PME 0.22, PLE 0.28, AME–AME 0.07, AME–ALE 0.08, AME–PME 0.06, ALE–ALE 0.75, ALE–PME 0.30, PME–PME 0.66, PME–PLE 0.09, PLE–PLE

1.05, ALE–PLE 0.16, AME–PLE 0.30. Eye group 1.36 wide, 0.72 long. Maxillae: 2.22 long, 1.35 wide, with 18 cuspules spread over ventral inner heel. Lyra absent. Labium: 0.61 long, 1.20 wide, with 4 cuspules. Labio-sternal groove shallow, narrow, with two sigilla. Chelicerae: rastellum absent, basal segment with 8 teeth decreasing in size from distal to basal portion, with small teeth on basal area. Sternum: 3.64 long, 3.12 wide. Posterior angle rounded, not separating coxae IV. Sigilla: three pairs, all small, rounded, hardly visible, less than one diameter from margin. Legs: leg formula: IV I II III. Clavate trichobothria: on distal 2/3 of tarsi I–IV. Scopula: tarsi I–IV fully scopulate, IV with two rows of setae, not separating the scopula. Metatarsi I–II fully scopulate; III–IV 2/3 distal scopulate, IV with two rows of setae, not separating the scopula. Spination: palp: femur 0, patella 0, tibia v0-0-1ap; leg I: femur 0, patella 0**,** tibia v0-0-1ap, metatarsus v1-0-0; leg II: femur p0-0-1, patella 0, tibia 0; metatarsus v1-0-0; leg III: femur 0, patella 0, tibia v0-0-2ap, p0-1-0, r1-1-0**,** metatarsus v2-0-2ap, p1-2-2(1ap), r0-1-1; IV: femur r0-0-1, patella 0, tibia v0-1-2ap, r1-0-1, metatarsus v2-0-1ap, p0-1-2(1ap), r1-0-3(2ap). Claws: STC lacking teeth. Genitalia (Fig. 8): Spermathecae short, triangular, with 5–6 lobes on internal side, from tip to base. Color pattern (Fig. 31): as in male.

Immatures (Fig. 29) have black carapace and abdomen and reddish brown legs, except for the black tarsi.

Distribution. Bolivia, department of Santa Cruz; and Brazil, state of Mato Grosso (Fig. 36).

Remarks. Guadanucci (2007) examined only males from the type locality of *D. bolivianum*, even though a photo of a female (Guadanucci 2007, f. 9) is shown in his paper. The female of *D. bolivianum* was originally described based on a casting skin by Vol (2001), and the specimen, a paratype, was not located in the MHNNKM where it should be deposited. Thus, herein, the topotypical female is described and illustrated for first time.

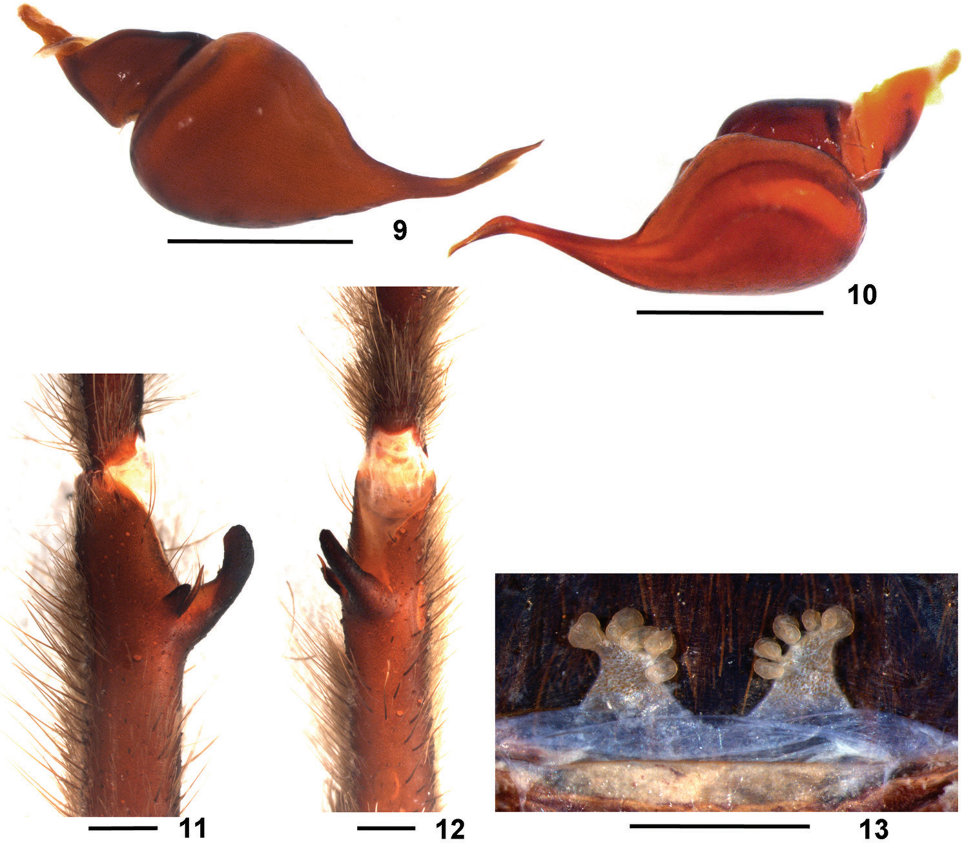
Ecology. The species is found in Bosque montañoso (Bolivian Montaine Dry Forests) in Bolivia and Cerrado (a type of savannah vegetation) in Brazil. One of the authors (ISR) collected females and immatures under rocks on the way to mountains on Samaipata (Figs 28–29), Santa Cruz, Bolivia, during the day and afternoon (December 2015).

Dolichothele mottai sp. n.

http://zoobank.org/2D8F4B25-9226-44FD-BEA8-B1CADF52BD27
Figs 9–13, 24, 30–31, 36

Oligoxystre bolivianum; Guadanucci 2007: 4, f. 1–12 (in part, only f. 1–8).
Dolichothele bolivianum; Lucas and Indicatti 2015: 207 (in part).

Type material. Holotype female, BRAZIL: *Distrito Federal*, Brasília, Reserva Ecológica do IBGE [16°56'S; 47°53'W], 10 July 2007, R. Bertani, P. Motta, C. S. Fukushima, R. H. Nagahama, J. Crisóstomo coll. (DZUB 8246); paratype male, BRAZIL: *Distrito Federal*, Brasília [15°47'S; 47°52'W], without additional data (DZUB 8248).



Figures 9–13. *Dolichothele mottai* sp. n. **9–12** paratype male (DZUB 8248) **9–10**) right male palpal bulb **9** retrolateral view **10** prolateral view **11–12** left leg I tibial apophysis **11** prolateral view **12** ventral view **13** holotype female, spermathecae, dorsal view. Scale bar: 1 mm.

Other material. BRAZIL: *Distrito Federal*, Brasilia, 1 male, without additional data (DZUB 131); SHIS – QI 26 Chac. 17 [15°49'S; 47°48'W], 1 female, 29 September 2002, S. S. Salles coll. (DZUB 343); Reserva Ecológica do IBGE [16°56'S; 47°53'W], cerrado, termite mound, 1 male, 02 September 2002, J. R. R. Pinto coll. (DZUB 1129); IBGE, cerrado, 43JC, 1 male, 02 October 2003, M. Milhomem coll. (DZUB 870); IBGE, termite mound, 1 female, 02 October 2014, R. Japiassu coll. (DZUB 6741); Centro de Instrução e Adestramento de Brasília-CIAB-Marinha (16°00’6.73”S; 47°57’5.82”W), termite mound, 1 female, 11 July 2007, R. Bertani, P. C. Motta, C. S. Fukushima, R. H. Nagahama, J. Crisóstomo coll. (DZUB 8247); Sobradinho [15°39'S; 47°47'W], Cond. Fraternidade, DF425, casa, 1 male, 06 September 2006, P. C. Motta coll. (DZUB 1824); same data, 1 female, 06 November 2006 (DZUB 1992); same data, 1 female, 11 January 2007, P. C. Motta coll. (DZUB 2099); Córrego do Urubú, 1 male, 06 October 2009, I. Wagas coll. (DZUB 3951), 1 male, 29 October 2007, J. Marinho coll. (DZUB 2752); *Goiás*: Aragarças [16°05'S; 52°14'W], 1 male, 15 July 1976, L. Edmundo coll. (MNRJ 03850); Caldas Novas [17°44'S; 48°37'W], P. E. Pescan, Cerrado s. s., coleta ativa diurna, 1 male, 01 November 2014, P. C. Motta *et al.* coll. (DZUB 7592); Catalão [18°09'S; 47°56'W] (Fazenda Alvorada), 1 male, January 2004, J. P. L. Guadanucci & A. Monteiro coll. (MZUSP 26076), 1 female, February 2003, J. P. L. Guadanucci coll. (MZUSP 23224); Cocalzinho de Goiás [15°46'S; 48°46'W], 1 male, 07 October 2011, I. R. Pereira Silva coll. (DZUB 4788); Mineiros, Parque Nacional das Emas [18°08'S; 52°55'W], 1 male, 5 September 1997, C. Nogueira & P. Valdujo coll. (IBSP 109493).

Differential diagnosis. Males of *D. mottai* sp. n. resemble those of *D. dominguense* (Guadanucci 2007, f. 26–28), *D. camargorum* sp. n. (Figs 14–15, 19–20, 26–27) and *D. bolivianum* (Figs 1–2, 4–5, 25) by the presence of a small subapical keel on male palpal bulb embolus. They differ from all these species by the very short and strongly curved embolus (Figs 9–10, 24). Females of *D. mottai* sp. n. (Fig. 13) resemble those of *D. camargorum* sp. n. (Fig. 18, 23) and *D. bolivianum* (Fig. 8) by the short spermathecae. They differ from *D. camargorum* sp. n. by the shorter and somewhat triangular spermathecae shape; from *D. bolivianum* sp. n. they differ by broader spermathecae. Additionally, males and females differ from all *Dolichothele* species by the carapace covered with iridescent red setae (Figs 28–29).

Description. Female holotype (DZUB 8246). Carapace 9.4 long, 8.3 wide, chelicerae 4.3. Legs (femur, patella, tibia, metatarsus, tarsus, total): I: 7.1, 4.7, 4.4, 4.5, 2.9, 23.6. II: 6.6, 4.4, 4.3, 4.2, 2.5, 22.0. III: 6.0, 3.5, 3.7, 4.4, 2.7, 20.3. IV: 7.1, 4.2, 5.4, 6.1, 2.9, 25.7. Palp: 5.4, 3.6, 3.2, –, 2.9, 15.1. Mid-widths: femora I–IV = 1.5, 1.5, 1.6, 1.7, palp = 1.3; patella I–IV = 1.1, 1.2, 1.2, 1.4, palp = 1.3; tibiae I–IV = 1.5, 1.3, 1.2, 1.2, palp = 1.3; metatarsi I–IV = 1.2, 1.3, 1.2, 0.9; tarsi I–IV = 1.3, 1.3, 1.1, 1.0, palp = 1.5. Abdomen 10.8 long, 5.3 wide. Spinnerets: PMS, 1.36 long, 0.63 wide, 0.41 apart; PLS, 2.27 basal, 1.24 middle, 1.48 distal; mid-widths: 1.11, 1.08, 0.81, respectively. Carapace: length to width 1.13. Fovea: straight, deep, 1.30 wide. Eyes and eye tubercle. Tubercle 1.07 long, 1.39 wide. Clypeus 0.20 wide. Anterior row slightly procurved, posterior row slightly recurved. Sizes and inter-distances: AME 0.37, ALE 0.35, PME 0.28, PLE 0.30, AME–AME 0.36, AME–ALE 0.15, AME–PME 0.08, ALE-ALE 1.00, ALE–PME 0.30, PME–PME 0.86, PME–PLE 0.08, PLE–PLE 1.22, ALE–PLE 0.22, AME–PLE 0.30. Eye group 1.39 wide, 0.75 long. Maxillae: 3.08 long, 1.41 wide, with 22 cuspules spread over ventral inner heel. Lyra absent. Labium: 0.62 long, 1.38 wide, with 4 cuspules. Labio-sternal groove shallow, narrow, with two sigilla. Chelicerae: rastellum absent, basal segment with 8 teeth decreasing in size from distal to basal portion; and small teeth on basal area. Sternum: 4.53 long, 4.26 wide. Posterior angle rounded, not separating coxae IV. Sigilla: three pairs, all small, rounded, less than one diameter from margin. Legs: leg formula: IV I II III. Clavate trichobothria: on distal 2/3 of tarsi I–IV. Scopula: Tarsi I–IV fully scopulate, IV with two rows of setae, not separating the scopula. Metatarsi I–III fully scopulate; IV 2/3 scopulate, with two rows of setae, not separating the scopula. Spination: palp: femur p0-0-2, patella 0, tibia v0-2-2(1ap), metatarsus 0; leg I: femur p0-0-1, patella 0, tibia v0-1-1ap, p0-0-1, metatarsus v1-0-0; leg II: femur p0-0-1, patella 0, tibia v0-1-1ap, p1-0-1, metatarsus v1-0-0; leg III: femur 0, patella 0, tibia v0-2-2ap, p1-0-1, r0-0-1; metatarsus v1-1-2ap, p1-0-1ap, r0-1-0; IV: femur r0-0-1, patella 0, tibia v1-2-3(2ap), p0-0-1, r0-0-1, metatarsus v2-0-2ap, p1-1-1, r0-1-1. Claws: ITC absent from all legs; STC lacking teeth. Genitalia (Fig. 13). Spermathecae short, triangular, with ca. 6 lobes on internal side, from tip to base. Color pattern (Fig. 28). Carapace brown covered with long metallic reddish setae. Chelicerae and legs ventrally and dorsally dark, except for black femora. Sternum, labium, maxillae, and coxae brown. Abdomen ventrally brown, dorsally black. Distal femora, patellae, tibiae and metatarsi rings not evident. Longitudinal stripes on leg articles not evident.

Male paratype (DZUB 8248). Carapace 8.1 long, 7.3 wide, chelicerae 3.5. Legs (femur, patella, tibia, metatarsus, tarsus, total): I: 8.3, 4.6, 5.6, 5.5, 3.6, 27.6. II: 7.2, 4.4, 4.0, 5.1, 3.2, 23.9. III: 6.2, 3.3, 4.1, 5.2, 3.3, 22.1. IV: 8.2, 4.0, 6.4, 7.3, 3.7, 29.6. Palp: 4.9, 3.3, 3.7, – , 1.6, 13.5. Mid-widths: femur I–IV = 1.9, 1.8, 1.7, 1.7, palp = 1.5; patella I–IV = 1.5, 1.6, 1.6, 1.5, palp = 1.4; tibiae I–IV = 1.2, 1.3, 1.2, 1.2, palp = 1.3; metatarsi I–IV = 0.9, 0.9, 0.9, 0.8; tarsi I–IV = 1.1, 1.0, 1.0, 1.0, palp = 1.2. Abdomen 8.8 long, 5.0 wide. Spinnerets: PMS, 0.76 long, 0.45 wide, 0.25 apart; PLS, 1.13 basal, 1.06 middle, 1.60 distal; mid-widths: 0.51, 0.53, 0.39, respectively. Carapace. Length to width 1.10. Fovea: straight, deep, 1.37 wide. Eyes and eye tubercle. Tubercle 1.12 long, 1.51 wide. Clypeus 0.09 wide. Anterior eye row slightly procurved, posterior eye row slightly recurved. Sizes and inter-distances: AME 0.41, ALE 0.38, PME 0.26, PLE 0.38, AME–AME 0.08, AME–ALE 0.10, AME–PME 0.02, ALE–ALE 0.85, ALE–PME 0.29, PME–PME 0.74, PME–PLE 0.08, PLE–PLE 1.17, ALE–PLE 0.18, AME–PLE 0.31. Eye group 1.51 wide, 0.79 long. Maxillae: 2.52 long, 1.35 wide, with 8 cuspules spread over ventral inner heel. Lyra absent. Labium: 0.48 long, 1.32 wide, with 2 cuspules. Labio-sternal groove shallow, narrow, with two sigilla. Chelicerae: rastellum absent, basal segment with 8 teeth decreasing in size from distal to basal portion, with very small denticles on base. Sternum: 4.41 long, 2.70 wide. Posterior angle rounded, not separating coxae IV. Sigilla: three pairs, all small, rounded, less than one diameter from margin. Legs: leg formula: IV I II III. Clavate trichobothria: on distal 2/3 of tarsi I–IV. Scopula: tarsi I–IV fully scopulate, IV with two rows of setae, not separating the scopula. Metatarsi I–II fully scopulate; III–IV 2/3 scopulate. IV with two rows of setae, not separating the scopula. Spination: palp: femur p0-0-2, patella 0, tibia 0; leg I: femur p0-0-1, patella 0, tibia v0-1-0, p0-1-0, metatarsus 0; leg II: femur p0-0-1; patella 0, tibia v0-2-1ap, p1-0-1, metatarsus v1-0-0; leg III: femur 0, patella 0, tibia v0-2-2ap, p1-1-0, r1-0-1, metatarsus v1-0-0, r0-1-1; leg IV: femur r0-0-1, patella 0, tibia v0-1-0, p1-0-0, r2-0-1, metatarsus v1-0-1ap, p1-1-1, r0-1-1. Claws: ITC absent from all legs; STC lacking teeth. Palpal bulb (Figs 9–10, 24): pyriform, embolus narrowing abruptly at its base and curved slightly to prolateral and then 45° to the retrolateral side on its distal third (“s” shape, as seen from above), with a small keel just after the curvature. Embolus shorter than tegulum. Male tibial apophysis (Figs 11–12) with two branches originating from a common low base, positioned distant from metatarsus. Retrolateral branch longer than prolateral, not dilated on distal portion, with a spine on its mid-length. Prolateral branch shorter than contiguous spine. Both branches inclined ca. 45° to the prolateral side. Metatarsus I slightly curved. Color pattern (Fig. 29): as in female, except chelicerae and trochanters dorsally reddish and abdomen with long reddish setae.

Etymology. The specific name is a patronym in honor of the arachnologist Dr. Paulo Cesar Motta, for his contributions to the taxonomy and biology of mygalomorphs inhabiting the Brazilian Cerrado region.

Distribution. Brazil, Distrito Federal and state of Goiás (Fig. 36).

Remarks. The specimens used by Guadanucci (2007) to redescribe *D. bolivianum* (MZUSP 26076 and MZUSP 23224) were reanalyzed and belong to *D. mottai* sp. n. The female specimen (IBSP 103094) from Miranda (Agachi), state of Mato Grosso do Sul, Brazil, cited by Lucas and Indicatti (2015) as *D. bolivianum* has long and slender spermathecae with several lobes on apex and laterals. Therefore, it seems related with forms from eastern Brazil (see Guadanucci 2007, 2011), and probably the locality is a label mistake.

Ecology. *Dolichothele mottai* sp. n. occurs on the Cerrado *stricto sensu* from Central-Western Brazil. The female constructs silk tunnels under rocks and logs, and males were found moving between September and November when they leave their shelter to search for females, in Distrito Federal (Motta 2014).

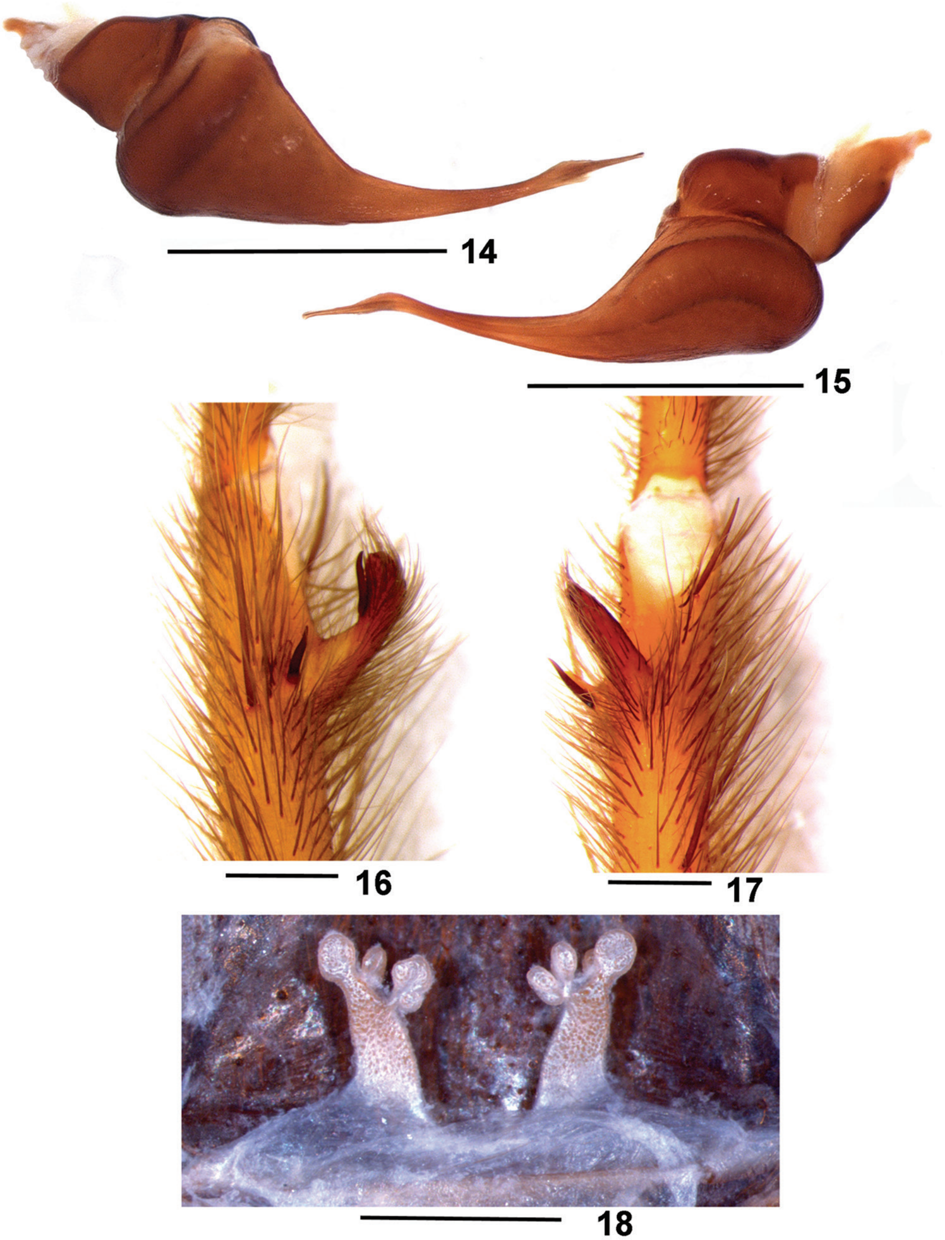
***Dolichothele camargorum* sp. n.**
http://zoobank.org/FB361627-5A32-4722-BB96-92ADB1A8D78D
Figs 14–23, 26–27, 32–36

Oligoxystre bolivianum; Guadanucci 2007: 4, f. 1–12 (in part, f. 10–12).
Dolichothele bolivianum; Lucas and Indicatti 2015: 207 (in part).

Type material. Male holotype (DZUB 8249). BRAZIL: *Rondônia*: Monte Negro [10°15'S; 63°17'W], nighttime hand collecting, 23 July 2007, P. I. Silva Jr., R. Bertani & R. Martins coll. (DZUB 8249); female paratype (DZUB 8250), BRAZIL: *Rondônia*: Monte Negro [10°15'S; 63°17'W] BR421, km 30, 20 December 2013, P. I. Silva Jr coll.

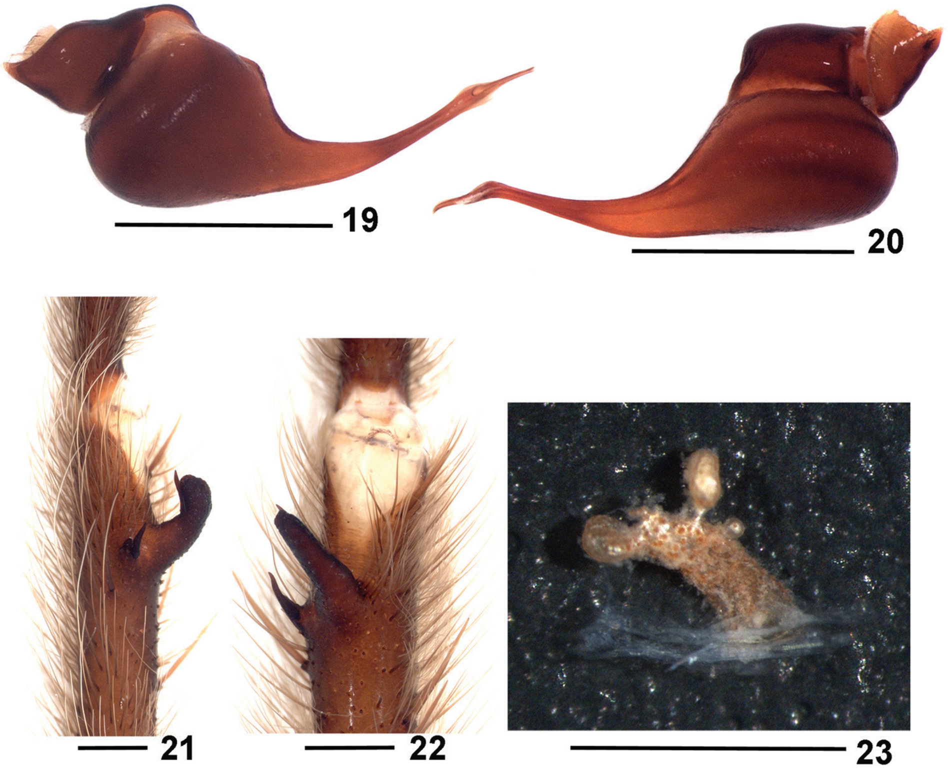
Other material. BRAZIL, *Rondônia*: Monte Negro [10°15'S; 63°17'W], BR421, km 30, daytime hand collecting, 1 female, 18 December 2013, P. I. Silva Jr coll. (DZUB 8251); 1 female, 18 December 2013, P. H. Martins *et al.* coll. (UFMG 17214); Porto Velho, Mutum [8°33'S; 63°42'W], 1 male, 18 April 2012, R. P. Indicatti coll. (MZUSP 51008); BOLÍVIA, *La Paz*: San Buenaventura [14°27'S; 67°35'W], 1 female, 04 October 2004, D. Weinmann & A. Stirm coll. (MZUSP 26084); 1 male, 04 October 2004, D. Weinmann & A. Stirm coll. (MZUSP 26085).

Differential diagnosis. Males of *D. camargorum* sp. n. (Figs 14–15, 19–20, 27) resemble those of *D. dominguense* (Guadanucci 2007, f. 26–28), *D. bolivianum* sp. n. (Figs 1–2, 4–5, 25) and *D. mottai* sp. n. (Figs 9–10, 24) by the presence of a small subapical keel on male palpal bulb embolus. They differ from *D. dominguense* by the



Figures 14–18. *Dolichothele camargorum* sp. n. **14–17** holotype male (DZUB 8249) **14–15** right male palpal bulb **14** retrolateral view **15** prolateral view **16–17** left leg I tibial apophysis **16** prolateral view **17** ventral view **18** paratype female (DZUB 8250), spermathecae, dorsal view. Scale bar: 1 mm.

short embolus; from *D. mottai* sp. n. by the less curved and longer embolus; and from *D. bolivianum* by the slender embolus. Females of *D. camargorum* sp. n. (Figs 18, 23) resemble those of *D. bolivianum* and *D. mottai* sp. n. by the short spermathecae. They



Figures 19–23. *Dolichothele camargorum* sp. n. **19–22** male (MZUSP 26085) **19–20** right male palpal bulb **19** retrolateral view **20** prolateral view **21–22** right leg I tibial apophysis (mirrored) **21** prolateral view **22** ventral view **23** female (MZUSP 26084), spermathecae, dorsal view. Scale bar: 1 mm.

differ from both *D. bolivianum* and *D. mottai* sp. n. by the long and narrow spermathecae shape.

Description. Male holotype (DZUB 8249). Carapace 5.6 long, 5.2 wide, chelicerae 2.5. Legs (femur, patella, tibia, metatarsus, tarsus, total): I: 6.2, 3.4, 5.1, 5.0, 3.6, 23.3 II: 6.5, 3.1, 4.3, 4.7, 3.0, 21.6. III: 5.2, 2.2, 3.6, 4.1, 3.0, 18.1. IV: 6.6, 3.0, 5.1, 6.5, 3.4, 24.6. Palp: 4.2, 2.1, 3.5, – , 1.3, 11.1. Mid-widths: femur I–IV = 1.0, 1.1, 1.2, 0.9, palp = 1.0; patella I–IV = 1.0, 1.1, 1.0, 0.6, palp = 0.9; tibiae I–IV = 1.0, 0.5, 0.7, 0.7 palp = 1.0; metatarsi I–IV = 0.9, 0.7, 0.7, 0.7; tarsi I–IV = 0.8, 0.7, 0.8, 0.6, palp = 0.7. Abdomen 6.8 long, 4.9 wide. Spinnerets: PMS, 0.66 long, 0.27 wide, 0.25 apart; PLS, 1.20 basal, 1.16 middle, 1.98 distal; mid-widths: 0.56, 0.52, 0.39, respectively. Carapace: length to width 1.07. Fovea: slightly procurved, deep, 0.86 wide. Eyes and eye tubercle. Tubercle 0.89 long, 1.23 wide. Clypeus 0.05 wide. Anterior row slightly procurved, posterior row slightly recurved. Sizes and inter-distances: AME 0.38, ALE 0.32, PME 0.23, PLE 0.29, AME–AME 0.11, AME–ALE 0.14, AME–PME 0.43, ALE–ALE 0.71, ALE–PME 0.23, PME–PME 0.64, PME–PLE 0.40, PLE–PLE 0.90, ALE–PLE 0.17, AME–PLE 0.27. Eye group

Figures 24–27. *Dolichothele* spp. Male palpal bulbs, dorsal view. **24** *Dolichothele mottai* sp. n., paratype (DZUB 8248) **25** *Dolichothele bolivianum* (MZUSP 26083) **26** *Dolichothele camargorum* sp. n. (MZUSP 26085) **27** *Dolichothele camargorum* sp. n., holotype (DZUB 8249). Scale bar: 1 mm.

1.23 wide, 0.64 long. Maxillae: 1.96 long, 1.03 wide, with 22 cuspules spread over ventral inner heel. Lyra absent. Labium: 0.41 long, 0.96 wide, with 4 cuspules. Labio-sternal groove shallow, narrow, with two sigilla. Chelicerae: rastellum absent, basal segment with 8 teeth decreasing in size from distal to basal portion, with very small denticles on base. Sternum: 3.07 long, 2.62 wide. Posterior angle rounded, not separating coxae IV. Sigilla: sigilla not evident. Legs: leg formula: IV I II III. Clavate trichobothria: on distal 2/3 of tarsi I–IV. Scopula: tarsi I–IV fully scopulate, IV with sparse setae, not separating the scopula. Metatarsi I fully scopulate; II–IV 2/3 distal scopulate, IV with sparse setae, not separating the scopula. Spination: palp: femur p0-0-1, patella 0, tibia p0-1-0; leg I: femur p0-0-1, patella 0, tibia v0-0-2(1ap), p0-0-2, r2-2-1ap, metatarsus p0-1-0, r1-0-0; leg II: femur p0-1-1, patella 0, tibia v2-2-2(1ap), p1-1-0, metatarsus v1-0-0; leg III: femur p1-1-1, r1-1-1, d1-0-0, patella 0, tibia v2-3-2ap, p1-0-1, r1-0-1, metatarsus v 1-1-1ap, p1-1-2(1ap), r0-1-1; leg IV: femur p0-0-1, r0-0-1, patella 0, tibia v3-2-1ap, p 1-0-1, r 0-1-0, metatarsus v2-0-2ap, p1-1-1, r1-1-1. Claws: ITC absent from all legs; STC lacking teeth. Palpal bulb (Figs 14–15, 27, compare 19–20, and 26 from MZUSP 26085): pyriform, embolus narrowing abruptly at its base and curved 45° to the retrolateral side on its distal third, with a small keel just after the curvature. Embolus longer than tegulum. Male tibial apophysis (Figs 16–17, compare 21–22) with two branches originating from a common low base, positioned distant from metatarsus. Retrolateral branch longer than prolateral, not dilated on distal portion, with a spine on its mid-length. Prolateral branch shorter than contiguous spine. Both branches inclined ca. 45° to the prolateral side. Metatarsus I slightly curved. Color pattern (Fig. 32). Carapace black

Figures 28–35. *Dolichothele* species. **28–29** *Dolichothele bolivianum* **28** female **29** immature. Both from Bolivia, Santa Cruz, Samaipata **30–31** *Dolichothele mottai* sp. n. **30** female **31** male. Both from Brazil, Distrito Federal, Brasília **32–35** *Dolichothele camargorum* sp. n. from Brazil, Rondônia, Monte Negro **32** male **33** immature **34** female (DZUB 8250) **35** female (DZUB 8250), detail of lateral abdomen showing stripes. Photographs IS Revollo and RB Huanto (**28–29**). PC Motta (**31**),R Bertani (**30, 32–35**).

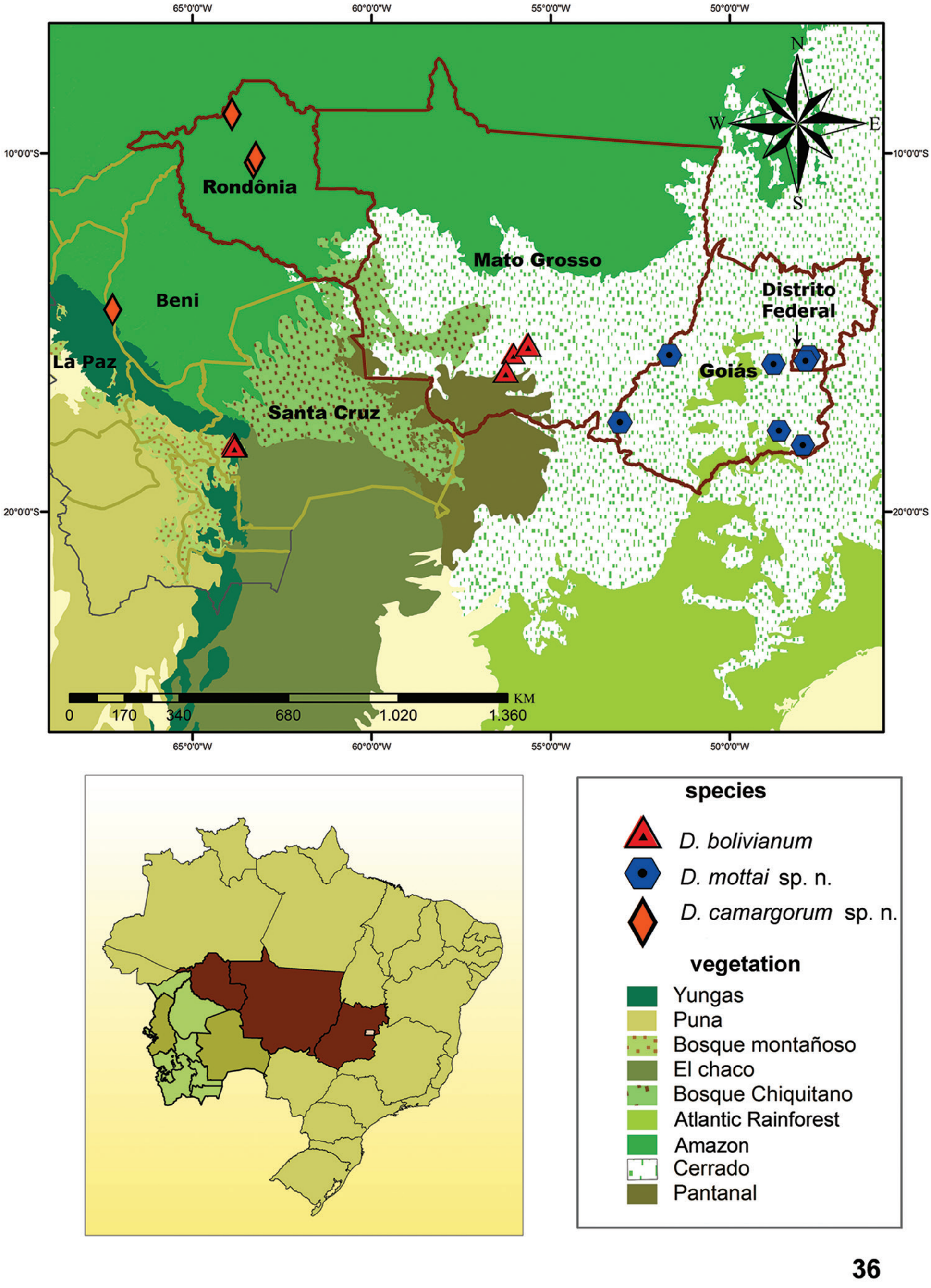


Figure 36. Map showing records of *D. bolivianum*, *D. mottai* sp. n., and *D. camargorum* sp. n.

bordered by light brown long setae. Chelicerae and legs dorsally and ventrally black. Sternum, labium, maxillae, and coxae brown. Abdomen ventrally brown, dorsally black. Distal femora, patellae, tibiae and metatarsi rings not evident. Longitudinal stripes on leg articles not evident.

Female paratype (DZUB 8250). Carapace 10.9 long, 8.2 wide, chelicerae 5.5. Legs (femur, patella, tibia, metatarsus, tarsus, total): I: 8.0, 5.3, 5.7, 4.9, 3.3, 27.2. II: 7.4, 5.0, 4.9, 5.1, 3.8, 26.5. III: 7.2, 3.9, 4.7, 5.5, 3.7, 25. IV: 9.0, 4.7, 7.0, 7.7, 3.8, 32.2. Palp: 6.0, 3.8, 3.9, – , 4.7, 18.4. Mid-widths: femora I–IV =2.1, 1.7, 1.5, 1.7, palp = 1.6; patella I–IV = 1.9, 1.8, 1.7, 1.5, palp = 1.6; tibiae I–IV = 1.7, 1.2, 1.4, 1.5, palp = 1.5; metatarsi I–IV = 1.5, 1.3, 1.2, 1.1; tarsi I–IV = 1.2, 1.1, 1.2, 1.3, palp = 1.6. Abdomen 12.2 long, 7.6 wide. Spinnerets: PMS, 1.17 long, 0.62 wide, 0.30 apart; PLS, 2.33 basal, 1.81 middle, 2.70 distal; mid-widths: 1.27, 1.22, 0.93, respectively. Carapace: length to width 1.32. Fovea: slightly procurved, deep, 1.24 wide. Eyes and eye tubercle. Tubercle 1.30 long, 1.83 wide. Clypeus 0.10 wide. Anterior row slightly procurved, posterior row slightly recurved. Sizes and inter-distances: AME 0.46, ALE 0.49, PME 0.29, PLE 0.42, AME–AME 0.12, AME–ALE 0.15, AME–PME 0.07, ALE–ALE 1.05, ALE–PME 0.26, PME–PME 1.02, PME–PLE 0.12, PLE–PLE 1.37, ALE–PLE 0.22, AME–PLE 0.38. Eye group 1.83 wide, 0.96 long. Maxillae: 3.67 long, 1.86 wide, with 16 cuspules spread over ventral inner heel. Lyra absent. Labium: 0.71 long, 1.68 wide, with 2 cuspules. Labiosternal groove shallow, narrow, with two sigilla. Chelicerae: rastellum absent, basal segment with 9 teeth decreasing in size from distal to basal portion, and small teeth on basal area. Sternum: 5.21 long, 4.17 wide. Posterior angle rounded, not separating coxae IV**.** Sigilla: three pairs, all small, rounded, less than one diameter from margin. Legs: leg formula: IV I II III. Clavate trichobothria: on distal 2/3 of tarsi I-IV. Scopula: tarsi I–IV fully scopulate, IV with two rows of setae, not separating the scopula. Metatarsi I–II fully scopulate; III–IV 3/4 distal scopulate with two rows of setae, not separating the scopula. Spination: palp: femur p0-0-1, patella 0, tibia v0-2-3(2ap), p0-1-0; leg I: femur 0, patella 0, tibia v0-1-1ap, p0-0-1, metatarsus v1-0-0; leg II: femur p0-0-1, patella 0, tibia v0-1-1ap, p0-0-1; metatarsus v1-0-0; leg III: femur p0-1-1, r0-1-1, patella 0, tibia v1-2-2ap, p0-1-1, r 0-1-1, metatarsus v2-0-3ap, p1-1-1, r0-1-1; IV: femur r0-0-1, patella 0, tibia v1-2-2, p0-1-0, r1-0-1, metatarsus v2-0-3ap, p0-1-1, r1-0-1. Claws: ITC absent from all legs; STC lacking teeth. Genitalia: Spermathecae (Fig. 18, compare 23) short, longer than wide, rectangular, with 4 lobes on its tip. Color pattern (Figs 34–35). Carapace brown covered with long light brown setae. Chelicerae dark brown. Legs dorsally brown, covered with dark brown setae. Sternum, labium, maxillae, and coxae light brown. Other leg articles ventrally brown. Abdomen ventrally brown, dorsally dark brown extending laterally and forming four wide marks (Fig. 35). Distal femora, patellae, tibiae and metatarsi with narrow whitish rings. Longitudinal stripes on leg articles not evident.

Immatures (Fig. 33) have black carapace and abdomen and the legs are dorsally greyish to brownish with black tarsi. The abdomen dorsum shows broad black marks on the laterals and a narrow posterior black stripe (Fig. 33). Adult females have only four broad black marks extending laterally.

Etymology. The specific name is a patronym in honor of Dr. Erney F. Plessmann de Camargo and Dr. Luis Marcelo Aranha Camargo for their efforts to develop medical and biological research in the state of Rondônia, Brazil. They encouraged the field work on which the specimens of this new species were collected.

Remarks. Guadanucci (2007) examined a single specimen of this new species from Brazil, a female from State of Rondônia, Porto Velho, U. H. Samuel (IBSP 9506). This specimen was not examined here, as it was destroyed by a fire in the Instituto Butantan collection buildings in 2010. Other specimens examined from nearby localities show the female has very distinct spermathecae, slender and with lobes only on their tips (Figs 18, 23). The male has a more slender embolus, mainly on its base (Figs 14–15, 27). Males, females and immatures have distinct color patterns from those of *D. bolivianum* and *D. mottai* sp. n. Male and female from Rurrenabaque, Beni, Bolivia shown in Guadanucci (2007) f. 11–12 have a distinct color pattern. As only two males and a female were examined from Bolivia, it is not possible to conclude whether it is morphological variation or another undescribed species. For this reason, figures of male palpal bulb and spermathecae were included to show the morphological variation in the specimens from the two distant localities (Figs 19–21, 26).

Distribution. Brazil, state of Rondônia; and Bolivia, department of La Paz (Fig. 36).

Ecology. *Dolichothele camargorum* sp. n. occurs in the Amazon region, probably in Cerrado remnants.

Discussion. Guadanucci (2007, 2011) recognized eight species in *Oligoxystre* Vellard, 1924 (now *Dolichothele*). One of these species, *D. bolivianum*, was considered to have a wide distribution from Central-Western Brazil to Bolivia, close to the Andes (Guadanucci 2007). Guadanucci (2007) found variation in color pattern throughout the distribution of this species but considered them as local population variation. Examining the available material of Guadanucci (2007) together with additional specimens recently collected, it is possible to recognize two more species, which are herein described. *Dolichothele mottai* sp. n. males clearly have a shorter embolus with a strong “S”-shaped curvature (Figs 9–10, 24), distinct from the longer and straighter embolus of *D. bolivianum* (Figs 1–2, 4–5, 25). *Dolichothele mottai* sp. n. females have a broader spermathecae than those of *D. bolivianum* (Fig. 13) and, as the male, have the carapace with a distinct color pattern of iridescent reddish setae covering it (Figs 30–31). Another new species also closely related with *D. bolivianum* was recognized from the state of Rondônia, Brazil and department La Paz, Bolivia. Males of the new species *D. camargorum* sp. n. have a slender embolus (Figs 14–15, 19–20, 27), when comparing with *D. bolivianum*, and the females have narrow spermathecae with lobes restricted to their apex (Fig. 18). The color pattern is also distinct, males have a dark carapace with orange setae on its borders and the females have dark marks on the lateral abdomen (Figs 33, 35), character unknown in other species of *Dolichothele*.

Acknowledgements

We are grateful to the curators Drs. Adalberto Santos (UFMG), Adriano Kury (MNRJ), Paulo Motta (DZUB), Antonio Brescovit (IBSP), Ricardo Pinto da Rocha (MZUSP), and Patricia Herrera (MHNNKM) for the loan of specimens. We thank Julieta Ledezma, Kathia Rivero and Yanina Inturias Almanza (MHNNKM) for laboratory facilities. Flavio Terassini, Saymon Albuquerque and Dr. Luis Marcelo Camargo are thanked for their kindness and help with expeditions in Rondônia. Robert Blanco Huanto (MHNNKM) is thanked for help in a field trip in Bolivia. We appreciate IBGE and Marinha do Brasil for allowing the collection of specimens in areas under their care. ICMBio is thanked for collection permits, and Paulo Motta and Robert Blanco Huanto for photos. Luis Acosta helped with the map. Denis Pedroso and Paulo Motta are thanked for commenting on a previous version of the manuscript. Finally, we thank Caroline Fukushima, Roberto H. Nagahama, Rosana Martins for help with field work in Rondônia and Brasilia. Support: Fapesp 2015/19976-3 for RB.

References

Bertani R (2001) Revision, cladistic analysis, and zoogeography of *Vitalius*, *Nhandu*, and *Proshapalopus*; with notes on other Theraphosinae genera (Araneae, Theraphosidae). Arquivos de Zoologia 36: 265–356. http://www.revistas.usp.br/azmz/article/view/12020/13797

Bertani R, Santos T, Righi AF (2009) A new species of *Oligoxystre* Vellard 1924 (Araneae, Theraphosidae) from Brazil. ZooKeys 5: 41–51. https://doi.org/10.3897/zookeys.5.83

Bücherl W, Costa AT, Lucas S (1971) Revisão de alguns tipos de aranhas caranguejeiras (Orthognatha) estabelecidos por Cândido de Mello-Leitão e depositados no Museu Nacional do Rio de Janeiro. Memórias do Instituto Butantan 35: 117–138.

Guadanucci JPL (2007) A revision of the Neotropical spider genus *Oligoxystre* Vellard, 1924 (Theraphosidae, Ischnocolinae). Zootaxa 1555: 1–20. http://www.mapress.com/zootaxa/2007f/z01555p020f.pdf

Guadanucci JPL (2011) Cladistic analysis and biogeography of the genus *Oligoxystre* Vellard 1924 (Araneae: Mygalomorphae: Theraphosidae). Journal of Arachnology 39: 320–326. https://doi.org/10.1636/CA10-81.1

Lucas SM, Indicatti RP (2015) Revalidation of *Dolichothele* Mello-Leitão and notes on *Hapalotremus* Simon (Araneae, Mygalomorphae, Theraphosidae). Studies on Neotropical Fauna and Environment 50(3): 204–212. https://doi.org/10.1080/01650521.2015.1103553

Mello-Leitão CF (1923) Theraphosoideas do Brasil. Revista do Museu Paulista 13: 1–438.

Motta PC (2014) Aracnídeos do Cerrado (1st edn). Technical Books, Rio de Janeiro, 209 pp.

Petrunkevitch A (1925) Arachnida from Panama. Transactions of the Connecticut Academy of Arts and Sciences 27: 51–248.

Raven RJ (1985) The spider infraorder Mygalomorphae (Araneae): cladistics and systematics. Bulletin of the American Museum of Natural History 182: 1–180. http://digitallibrary.amnh.org/handle/2246/955

Schmidt G (2002) *Dolichothele* ist kein Synonym von *Hapalotremus* (Araneae: Theraphosidae: Theraphosinae). Tarantulas of the World 68: 14–16.

Simon E (1903) Histoire naturelle des araignées. Tome 2, Paris, 1080 pp. https://doi.org/10.5962/bhl.title.51973

Vellard J (1924) Études de zoologie. Archivos do Instituto Vital Brazil 2: 121–170.

Vol F (2001) Description de *Pseudoligoxystre bolivianus* sp. et gen. n. (Araneae: Theraphosidae: Ischnocolinae), de Bolivie. Arachnides 50: 3–10.

World Spider Catalog (2017) World Spider Catalog. Natural History Museum Bern. http://wsc.nmbe.ch, version 18.5 [August, 11 2017]

ZooKeys 724: 21–29 (2017)
doi: 10.3897/zookeys.724.14742
http://zookeys.pensoft.net

RESEARCH ARTICLE

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

Magadhaideus, a new genus of the tribe Plectoderini with the description of a new species from China (Hemiptera, Fulgoromorpha, Achilidae)

Jian-Kun Long[1,2], Zhi-Min Chang[1,2], Lin Yang[2], Xiang-Sheng Chen[1,2]

1 *College of Animal Sciences, Guizhou University, Guiyang, Guizhou, 550025, P. R. China* **2** *Institute of Entomology, Special Key Laboratory for Development and Utilization of Insect Resources of Guizhou, Guizhou University, Guiyang, Guizhou, 550025, P. R. China*

Corresponding author: *Xiang-Sheng Chen* (chenxs3218@163.com)

Academic editor: *M. Wilson* | Received 28 June 2017 | Accepted 10 November 2017 | Published 21 December 2017

http://zoobank.org/AA433F7F-0C78-4FA9-81AF-67CD4B98EB61

Citation: Long J-K, Chang Z-M, Yang L, Chen X-S (2017) *Magadhaideus*, a new genus of the tribe Plectoderini with the description of a new species from China (Hemiptera, Fulgoromorpha, Achilidae). ZooKeys 724: 21–29. https://doi.org/10.3897/zookeys.724.14742

Abstract

A new planthopper genus and species from China, *Magadhaideus xiphos* Long & Chen, **gen. et sp. n.** (Hemiptera: Fulgoromorpha: Achilidae: Plectoderini), is described and illustrated. A new combination, *Magadhaideus cervina* (Fennah, 1956), **comb. n.** transferred from *Magadha* Distant and a key to species of the new genus are also given.

Keywords

Achilid, distribution, Fulgoroidea, new taxa, planthopper

Introduction

The planthopper tribe Plectoderini (Hemiptera: Achilidae) established by Fennah (Fennah, 1950), containing about 98 genera 335 species to date (Bourgoin 2017), is the largest tribe of Achilidae (Hemiptera: Fulgoromorpha). It is also the most widely dispersed in the world.

Approximately four tribes, 20 genera, and 99 species of Achilidae are known in China. Plectoderini consists of 15 genera and 79 species. Almost all members of the tribe in China are distributed in the Oriental region, especially in southern China. Here, a new genus and species of the tribe from South China are described and illustrated. A new combination and a key to the species of the new genus are also provided.

Materials and methods

The morphological terminology and measurements used in this study mainly follow Chen et al. (1989) and Yang and Chang (2000). The standard terminology for hind and forewing venation follow Bourgoin et al. (2015). The methods follow Long et al. (2014). The genital segments of the examined specimens were macerated in 10% KOH and drawn from preparations in glycerine jelly using an Leica M125 stereomicroscope. The type material is deposited in the Institute of Entomology, Guizhou University, Guiyang, China (GUGC).

Taxonomy

Genus *Magadhaideus* Long & Chen, gen. n.
http://zoobank.org/C6B86A2A-6A05-4022-B8F4-FC21356E323F
Figs 1–15

Type species. *Magadhaideus xiphos* Long & Chen, sp. n., here designated.

Differential diagnosis. The new genus and *Magadha* are readily distinguished from other known genera in the tribe Plectoderini by mesonotum with a transverse callus on anterior third of disc (Fig. 5). The new genus differs from *Magadha* in: pygofer (Fig. 11) in lateral view with dorsal margin distinctly shorter than ventral margin (dorsal margin at least as long as ventral margin in *Magadha*); medioventral process (Fig. 12) broad and short, with a small sharp process lateroapically (relatively slender and without small sharp process lateroapically in *Magadha*); genital style (Fig. 13) without a finger-like process from near base of dorsal margin (with a finger-like process from near base of dorsal margin in *Magadha*); phallobase (Figs 14–15) with apical half branched into much more and longer processes (apical half, in *Magadha*, at most branched into one dorsal, one ventral and two lateral lobes, all of them short).

Description. Width of head with eyes 0.8 times wider than width of pronotum. Vertex (Figs 1, 3, 5) with disc distinctly depressed, width at base wider than length in midline, median carina obsolete, anterior margin carinate, angularly convex, lateral margins slightly foliate, diverging basally, posterior margin subangularly concave. Triangular areolets (Fig. 5) at lateroapical angles of head distinct. Frons (Fig. 6) slightly convex in lateral view, with length in midline distinctly longer than maximum width, median carina complete , lateral margins slightly foliate, straight diverging to below level of antennae then gradually incurved to suture. Clypeus (Fig. 6) with median and lateral carinae distinct, length in midline shorter than frons. Rostrum reaching base of hind femurs, with length of subapical segment shorter than apical segment. Antenna (Figs 2, 4, 6–7) subglobose, not sunk in a depression. Ocelli (Figs 2, 4, 7) separated from eyes. Eyes (Figs 2, 4, 7) almost not excavate beneath. Pronotum (Figs 1, 3, 5) with length in midline as long as length behind eyes, with anterior margin roundly convex, posterior margin subangularly excavate about 130 degrees; median carina distinct, lateral carinae straight, posteriorly diverging and reaching hind margin, with length 1.5 times to length of median carina; lateral lobe slightly inclined antero-ventrally. Mesonotum (Figs 1, 3, 5) with three carinae distinctly, length in midline longer than vertex and pronotum combined, area between lateral carinae with one transverse callus at anterior third. Forewing (Figs 1–4, 8) with costal margin slightly convex; apical margin roundly convex; posterior margin angularly excavate (160 degrees) at apex of clavus; vein Cu_1 forking slightly basally of ScP+R fork, equal to level of veins Pcu and A1 fork, vein MP forking nearly level of nodal line, clavus terminating slightly distally of middle. Hindwing (Fig. 9) Cu with two branches, partly fused with M3+4, CuP and Pcu single, A1 two branched, A2 not reaching wing margin and enlarged apically. Post-tibiae with one lateral spine basalto middle.

Male genitalia. Each side of anal segment (Figs 10–11) with a strong spinous process, directed ventrally. Pygofer (Fig. 11) in lateral view with dorsal margin distinctly shorter than ventral margin, medioventral process (Fig. 12) broad and short, lateroapical margin produced in a small sharp process. Genital style (Fig. 13) without a finger-like process from near the base of dorsal margin, only a larger process rising from near middle of dorsal margin. Aedeagus with phallobase (Figs 14–15) sheath-shaped, asymmetrical, apical half branched into several long processes which narrowing apically and with apexes sharp. Aedeagal appendages (Figs 14–15) relatively straight, clearly exceeding the apical margin of phallobase.

Etymology. The genus name, which is masculine, is a combination of "*Magadha*" (name of the related genus) and "*-ideus*" (similar to), which indicates the new genus is similar to the genus *Magadha*.

Host plant. Unknown.

Distribution. Oriental region (South China).

Key to species of *Magadhaideus* Long & Chen, gen. n.

1 Forewing with a dark brown stripe from base to apex of clavus (Figs 1–4, 8); medioventral process of pygofer with two small lateroapical processes, directed outward, apical margin truncate (Fig. 12); genital style with dorsal process large and broad, almost not branched into lobes (Fig. 13) .... ***M. xiphos* sp. n.**

– Forewing without stripe from base to apex of clavus (Fennah 1956); medioventral process of pygofer with two lateroapical processes, directed inward, apical margin not truncate (Fennah 1956: fig. 15: B); genital style with dorsal process distinctly branched into three lobes (Fennah 1956: fig. 15: C).......... .... ***M. cervina* comb. n**.

Magadhaideus cervina (Fennah, 1956), comb. n.

Magadha cervina Fennah, 1956: 488.

Material examined. No specimens of this species were available for this study. But following Fennah, 1956: fig. 15: A–E, the species here is transferred into *Magadhaideus* gen. n.

Host plant. Unknown.

Distribution. China (Sichuan: Emeishan, 29°32'N, 103°19'E).

Magadhaideus xiphos Long & Chen, sp. n.

http://zoobank.org/F5AD67A1-8000-4149-AC31-8C0035C62BBB
Figs 1–20

Type material. Holotype: ♂, CHINA**, Fujian**: Wuyishan National Natural Reserve (26°54'N, 116°42'E), sweeping, 21 August 2013, Y. Liu. Paratypes, **Fujian**: 2 ♂♂, same data as holotype; 2 ♂♂ 2 ♀♀, Wuyishan National Natural Reserve (26°54'N, 116°42'E), sweeping, 21 August 2013, Y.-Y. Liu; 2 ♂♂, Wuyishan National Natural Reserve (26°54'N, 116°42'E), sweeping, 24 August 2013, Y. Liu. **Shanxi**: 1 ♂, Lishan National Natural Reserve (35°25'N, 111°58'E), sweeping, 24 July 2012, P. Zhang. **Jiangxi**: 1 ♂ 2 ♀♀, Jiulianshan National Natural Reserve (24°38'N, 114°33'E), 600–700 m, sweeping, 19–27 July 2009, Z.-H. Meng. **Zhejiang**: 2 ♀♀, Qingliangfeng National Natural Reserve (30°07'N, 118°51'E), sweeping, 25 July 2009, T.-T. He. **Guizhou**: 1 ♀, Maolan National Natural Reserve (25°30'N, 107°98'E), sweeping, 4 August 2006, F.-L. Xu. **Guangdong**: 2 ♀♀, Nankunshan National Natural Reserve (23°38'N, 114°38'E), sweeping, 23 August 2010, Y.-J. Li.

Diagnosis. The salient features of the new species include the following: forewing with a dark brown stripe from base to apex of clavus (Figs 1–4, 8); medioventral process of pygofer with two small lateroapical processes, directed outward, apical margin truncate (Fig. 12); and phallobase of aedeagus with apical 1/2 branched into seven long processes (Figs 14–15).

Description. *Measurements*. Body length (from apex of vertex to tip of forewing): male 4.2–4.6 mm (n = 7), female 4.9–5.1 mm (n = 10); forewing length: male 3.5–3.9 mm (n = 7), female 4.2–4.3 mm (n = 10).

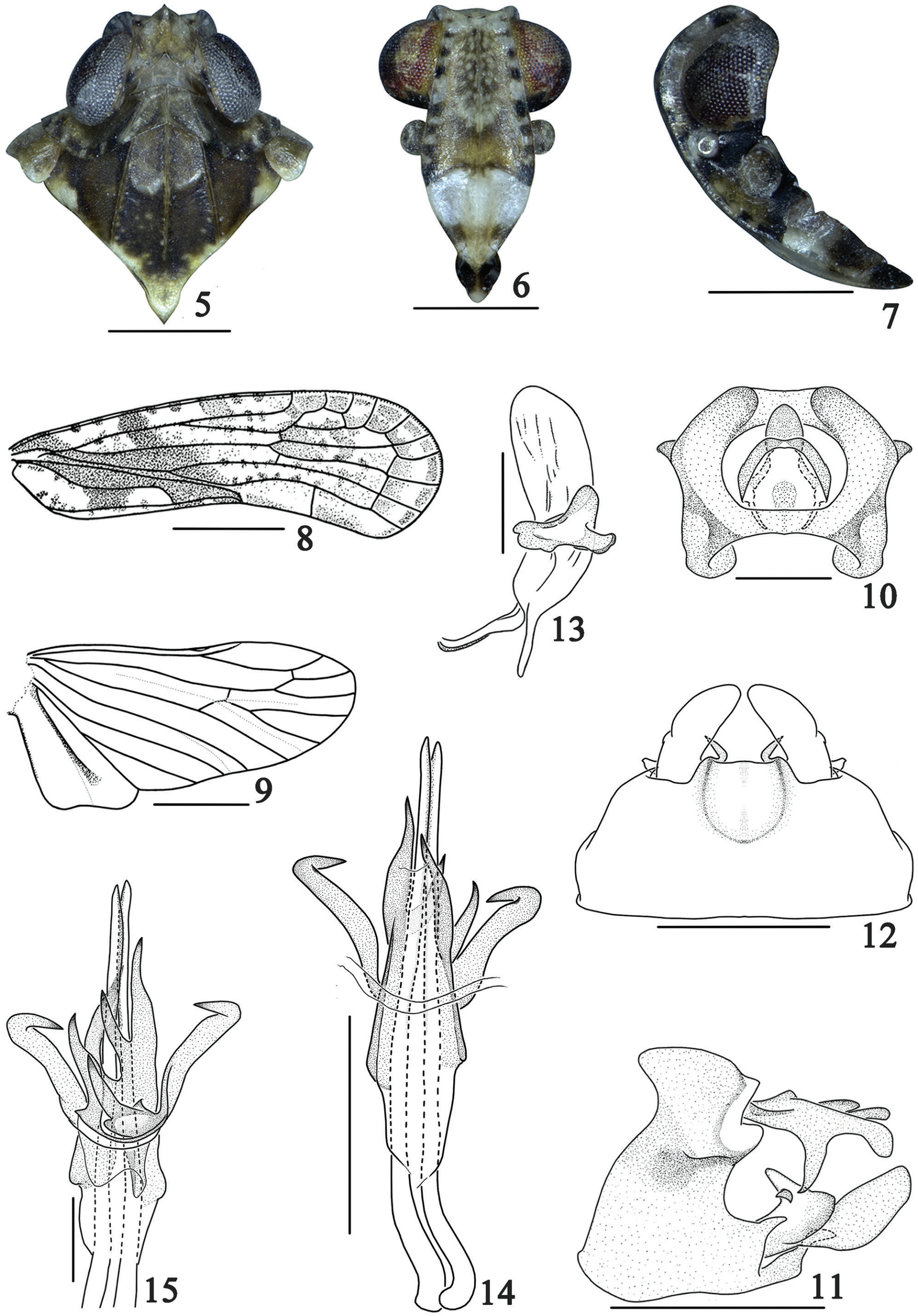
Colouration. Head pale yellowish brown. Vertex (Figs 1, 3, 5) along each lateral margin with one dark brown marking at base and another one brown marking at level of anterior margin of eyes; along midline with two brow to dark brown markings apically. Triangular areolets (Figs 1, 3, 5) at lateroapical angles of head with a dark brown marking. Frons (Fig. 6) with seven dark brown markings along lateral margin, disc in middle scattered ivory-white dots between eyes. Postclypeus ivory-white, with a transverse brown band apically. Frontoclypeus (Fig. 6) dark brown, with the base and apex ivory-white. Rostrum yellowish brown, with apex brown. Genae, as in Fig. 7, with four and two transverse short dark brown stripes, respectively along anterior margin

Figures 1–4. *Magadhaideus xiphos* sp. n. **1–2** Male habitus (dorsal and lateral views) **3–4** Female habitus (dorsal and lateral views).

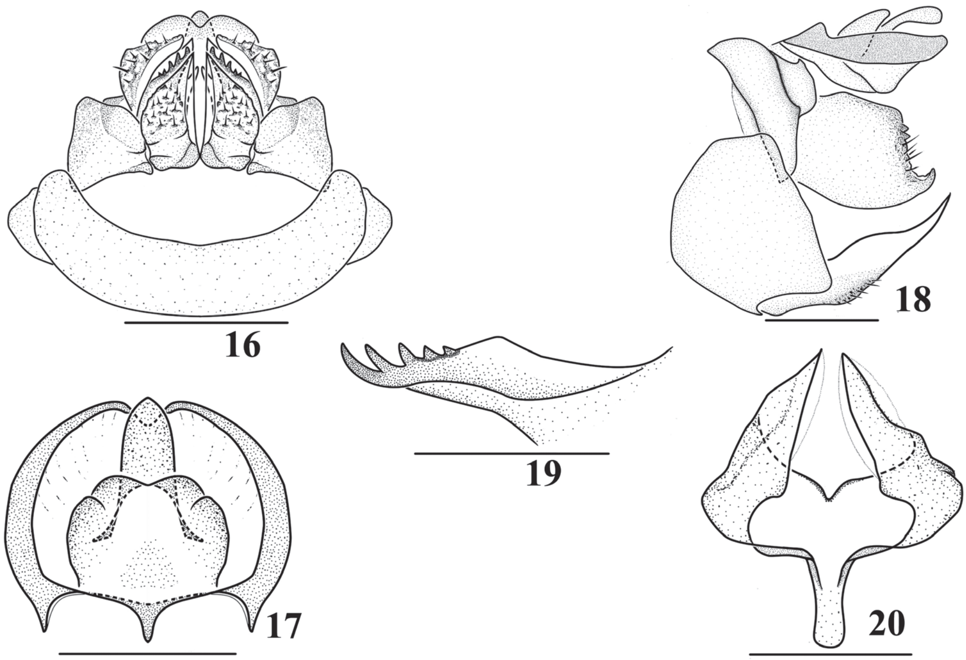
and above eyes; another two large parallel transverse stipes, one above and one beneath antennae. Eyes (Figs 1–7) generally reddish brown; ocellus (Figs 2, 4, 7) yellowish white. Antennae (Figs 2, 4, 6–7) yellowish brown. Pronotum (Figs 1, 3, 5) brown, lateral lobe with five dark brown areas along posterior margin. Mesonotum (Figs 1, 3, 5) dark brown, posterior two-thirds between lateral carinae with few scattered ivory-white dots, apical angle and areas along posterior margin between lateral carinae ivory-white, each lateral angle with a large ivory-white marking along posterior margin. Tegula (Figs 1–5) yellowish brown, along posterior margin paler. Forewing (Figs 1–4, 8) greyish white, with a broad irregular longitudinal dark brown band from base to apex of clavus, small variably sized markings scattered as in Fig. 8. Hindwing pale brown, veins brown. Legs (Figs 2, 4) ivory-white to pale yellowish brown; tibiae yellow basally, the first tarsomeres dark brown; pro- and mesofemora with a dorsal dark brown spot near base, pro- and mesotibiae with a ring dark brown spot respectively near base and in the middle; hind tibia with two ring dark brown spot near base. Abdomen dark brown.

Head and thorax. Ratio width of vertex at posterior margin to its length in midline 1.8 (Fig. 5), anterior third produced before eyes. Ratio length of frons in midline to its maximum width 1.3, ratio maximum of width to width at apex 1.9. Ratio length of postclypeus in midline to length of frons 0.5 (Fig. 6). Rostrum with ratio apical to subapical segment 1.2. Lateral lobes of pronotum with three short longitudinal carinae behind eye, ratio length in midline to length of vertex 0.8 (Fig. 5). Mesonotum (Fig. 5) in midline 5.1 times longer than pronotum, 2.3 times longer than pronotum and vertex combined. Forewing (Fig. 8) with ratio of length to maximum width 2.9, vein R with subapical cell. Hindwing (Fig. 9) with length to maximum width ratio of 2.0. Post-tibiae with a lateral spine in basal two-fifths, spinal formula 7–6–6.

Male genitalia. Anal segment in dorsal view (Fig. 10) with ratio length to maximum width 1.2, basal margin roundly convex in middle, apical margin slightly convex



Figures 5–15. *Magadhaideus xiphos* sp. n. **5** Head and thorax, dorsal view **6** Face **7** Head, lateral view **8** Forewing **9** Hindwing **10** Anal segment of male, dorsal view **11** Male genitalia, lateral view **12** Male genitalia, ventral view **13** Left genital style, dorsal view **14** Aedeagus, dorsal view **15** Aedeagus, ventral view. Scale bars: 0.3 mm (**10, 13, 15**); 0.5 mm (**5–7, 11–12, 14**); 1 mm (**8–9**).



Figures 16–20. *Magadhaideus xiphos* sp. n. **16** Female genitalia, ventral view **17** Anal segment of female, dorsal view **18** Female genitalia, lateral view **19** First valvula, from inside **20** Second valvula, ventral view. Scale bars: 0.2 mm (**17–20**); 0.5 mm (**16**).

to subtruncate, anal style not exceeding apical margin of anal segment; in lateral view (Fig. 11) apex of anal segment bent ventrally, apical margin roundly convex, lateral margin near middle with a strong spinous process, directed ventrally. Pygofer in lateral view (Fig. 11) with posterior margin strongly sinuate, medioventral process (Fig. 12) short and broad, with two small lateroapical processes, directed outward, apical margin truncate. Genital style (Fig. 13) relatively narrow and long with apical margin roundly convex, a large and broad process, with apical margin sinuate, rising from middle of dorsal margin. Aedeagus (Figs 14–15) asymmetrical, phallobase with apical half branched into seven long processes which narrowing apically, acute at apexes; among them, two lateral processes with apexes bent, directed inwards. Phallic appendages straight, xiphoid, distinctly exceeding apical margin of phallobase.

Female genitalia. Seventh abdominal sternum with anterior and posterior margins parallel, posterior margin truncate or slightly concave (Fig. 16). Anal segment (Figs 17–18) in dorsal view suborbicular, apical margin incised in the middle, basal margin M-shaped approximatively, with finger-like process in the middle; apex of anal stylet reaching or slightly exceeding apex of anal segment. First valvula with five spines (Fig. 19). Second valvula with two lateral lobes incompletely symmetrical, narrowing and sharp apically, directed postero-ventrally (Fig. 20). Third valvula with outer surface shagreen (Figs 16, 18); in lateral view (Fig. 18) apical margin sinuate, with an angulate process ventrally, directed inwards.

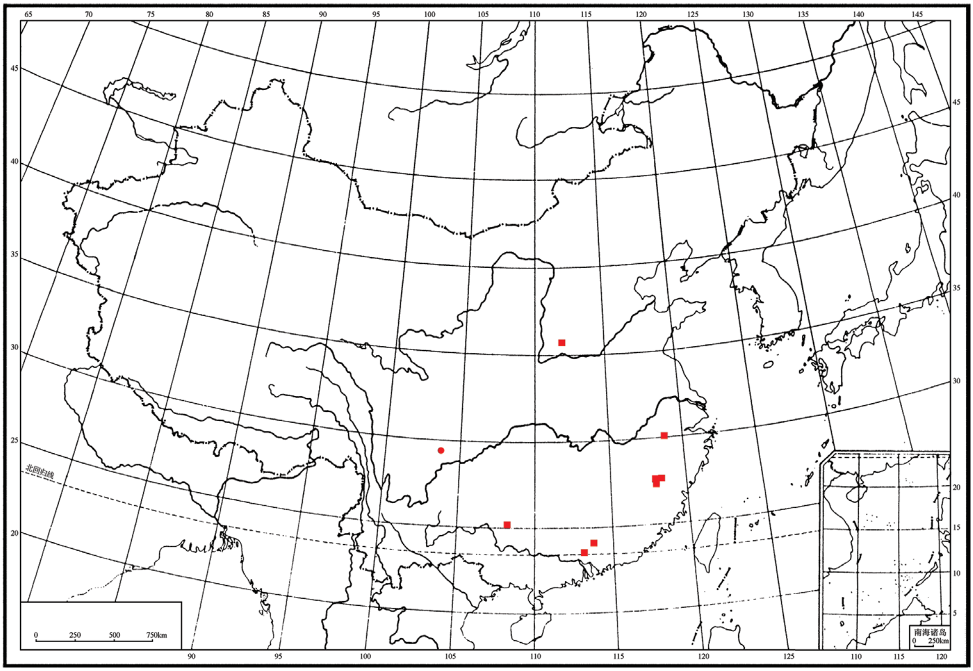


Figure 21. Geographic distribution of *Magadhaideus* species in China. *M. cervina* (Fennah, 1956), comb. n. (●); *M. xiphos* sp. n. (■).

Remarks. This new species differs from *Magadhaideus cervina* (Fennah, 1956) comb. n. by: forewing with a dark brown stripe from base to apex of clavus (without stripe in *cervina*); medioventral process of pygofer with two small lateroapical processes, directed outward (directed inward in *cervina*); genital style with dorsal process almost not branched into lobes (distinctly branched into three lobes in *cervina*).

Etymology. The species name refers to the phallic appendage xiphoid.

Host plant. Unknown.

Distribution. China (Fujian, Shanxi, Jiangxi, Zhejiang, Guizhou and Guangdong).

Discussion

On the basis of the characteristics of the vertex being at least two-thirds as wide as the pronotum and the post-tibiae with one spine characteristically present, *Magadhaideus* gen. n. is attributed to the tribe Plectoderini, following the tribal definition of Emeljanov (1992). On the basis of the peculiar characteristic of the mesonotum with a transverse callus on the anterior third of the disc, *Magadha* is clearly distinguished from other genera of Plectoderini, following the generic definition of Fennah (1950). Although the new genus also has the transverse callus, its male genitalia distinctly differs from that of *Magadha*. According to the descriptions and illustrations of *Magadha cervina* Fennah, 1956 (Fennah 1956: fig. 15: A–E), it is here attributed to the new genus.

The members of Plectoderini are found in seven zoogeographic regions of the world (Bourgoin 2017). Here, the new genus (Fig. 21) is distributed in the Oriental region of southern China. The adults of Plectoderini feed on the sap of trees and shrubs and the nymphs on fungi (O' Brien 1971). However, more precise ecological records for most members of the tribe, including the hosts for *Magadhaideus* gen. n., have not yet been documented.

Acknowledgements

We are grateful to all collectors of specimens and two anonymous reviewers. This work was supported by the National Natural Science Foundation of China (No. 31601886, 31093430), the Program of Science and Technology Innovation Talents Team, Guizhou Province (No. 20144001), the Program of Excellent Innovation Talents, Guizhou Province (No. 20154021), the Provincial Outstanding Graduate Program for Agricultural Entomology and Pest Control (ZYRC-2013) and the International cooperation base for insect evolutionary biology and pest control (No. 20165802).

References

Bourgoin T (2017) FLOW (Fulgoromorpha Lists on The Web): a world knowledge base dedicated to Fulgoromorpha. Version 8, updated 14 June 2017. http://hemiptera-databases.org/flow/ [accessed 26 June 2017]

Bourgoin T, Wang RR, Asche M, Hoch H, Soulier-Perkins A, Stroinski A, Yap S, Szwedo J (2015) From micropterism to hyperpterism: recognition strategy and standardized homology-driven terminology of the fore wing venation patterns in planthoppers (Hemiptera: Fulgoromorpha). Zoomorphology 134(1): 63–77. https://doi.org/10.1007/s00435-014-0243-6

Emeljanov AF (1992) Description of tribes of the subfamily Achilinae (Homoptera, Achilidae) and reconsideration of their volume. Entomologicheskoe Obozrenie 71(3): 574–594.

Fennah RG (1950) A generic revision of the Achilidae (Homoptera, Fulgoroidea). Bulletin of the British Museum (Natural History) Entomology 1(1): 1–170.

Fennah RG (1956) Fulgoroidea from southern China. Proceedings of the California Academy of Science 28(4): 441–527.

Long J-K, Yang L, Chen X-S (2014) A review of the genus *Magadha* Distant, 1906 (Hemiptera: Fulgoromorpha: Achilidae). Zootaxa 3872(3): 235–256. https://doi.org/10.11646/zootaxa.3872.3.2

O'Brien LB (1971) The systematics of the tribe Plectoderini in America, north of Mexico (Homoptera: Fulgoroidea: Achilidae). University of California Publications in Entomology 64: 1–79.

Yang C-T, Chang T-Y (2000) The external male genitalia of Hemiptera (Homoptera-Heteroptera). Shih Way Publishers, Taichung, China, 746 pp.

ZooKeys 724: 31–42 (2017)
doi: 10.3897/zookeys.724.20667
http://zookeys.pensoft.net

RESEARCH ARTICLE

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

Hind wing variation in *Leptura annularis* complex among European and Asiatic populations (Coleoptera, Cerambycidae)

Robert Rossa[1], Jakub Goczał[1], Bartosz Pawliczek[1], Nobuo Ohbayashi[2]

1 *Institute of Forest Ecosystem Protection, Faculty of Forestry, University of Agriculture in Krakow, 29 Listopada 46, 31-425 Krakow, Poland* **2** *Kamimiyada 1334-444, Miura City, Kanagawa, 238-0101 Japan*

Corresponding author: *Jakub Goczał* (j.goczal@wp.pl)

Academic editor: *F. Vitali* | Received 28 August 2017 | Accepted 27 November 2017 | Published 21 December 2017

http://zoobank.org/69615E6B-F155-4AFC-8D7E-C509C404EA22

Citation: Rossa R, Goczał J, Pawliczek B, Ohbayashi N (2017) Hind wing variation in *Leptura annularis* complex among European and Asiatic populations (Coleoptera, Cerambycidae). ZooKeys 724: 31–42. https://doi.org/10.3897/zookeys.724.20667

Abstract

The ability to quantify morphological variation is essential for understanding the processes of species diversification. The geometric morphometrics approach allows reliable description of variation in animals, including insects. Here, this method was used to quantify the morphological variation among European and Asiatic populations of *Leptura annularis* Fabricius, 1801 and its closely related species *L. mimica* Bates, 1884, endemic for Japan and Sakhalin islands. Since the taxonomic status of these two taxa is differently interpreted by taxonomists, they are collectively called "*Leptura annularis* complex" in this paper. The analysis was based on the measurements of hind wings of 269 specimens from six populations from Europe and Asia. The level of morphological divergence between most of continental European and Asiatic populations was relatively small and proportional to the geographic distance between them. However, distinct morphotype was detected in Sakhalin Is. and Japan. These data confirm the morphological divergence of the endemic *L. mimica* species. Obtained results highlight the potential of the geometric morphometric method in studying morphological variation in beetles.

Keywords

Leptura annularis, longhorn beetles, geometric morphometrics, geographic variation, taxonomy

Introduction

The understanding of large-scale patterns of variation in living organisms is a fundamental challenge for biological science (MacArthur 1972, Gaston and Blackburn 2000). Insects have become widely used models for studying the geographical patterns of morphological variation in body size and body shape (Yom-Tov and Geffen 2006, Stillwell et al. 2007, Abbasi 2009, Sadeghi et al. 2009, Stillwell and Fox 2009). The development of rigorous method of shape analysis, the geometric morphometrics, has provided new opportunities in the morphological study on animals (Adams et al. 2004, Zelditch et al. 2004, Lawing and Polly 2010), including insects (Pezzoli et al. 1997, Haas and Tolley 1998, Hoffmann and Shirriffs 2002).

The Cerambycidae family constitutes a large and diverse group of beetles. Among them, there are species with highly limited distribution or even endemics, as well as widely distributed and common taxa (Löbl and Smetana 2010). Longhorn beetles differ also in terms of habitat specialization: from highly-specialized monophagous species to polyphagous opportunists able to inhabit various habitats. The role of ecological and historical factors on Cerambycidae distribution is relatively well studied (Baselga 2008, Koutroumpa et al. 2013, Vitali and Schmitt 2017). However, there is a lack of papers devoted to quantification of the geographical patterns in morphological variation of longhorn beetles.

Leptura annularis is a widely distributed longhorn beetle which taxonomic status remains unclear. In 1801, the species was described as *L. annularis* by Fabricius, based on the sample from Siberia (Fabricius 1801). In 1884, a new species, *Leptura mimica,* was described by Bates, based on specimens from Hokkaido and Honshu (Bates 1884). Nevertheless, many authors have later synonymized these two taxa (e.g., Panin and Săvulescu 1961, Kaszab 1971, Cherepanov 1988, Sláma 1998, Sama 2002) and indicated that there are no significant differences between populations from Europe, Asia, and Sakhalin Is. or Japan (Sama 2002) or treat these two taxa as subspecies but not distinct species (Danilevsky 2014).

On the other hand, comprehensive studies conducted by Japanese taxonomists have indicated significant differences between continental populations of *L. annularis* and populations of *L. mimica* distributed in Japan and Sakhalin. Such differences can be found in elytra coloration pattern, shape of male genitalia parameres and female spermatheca (Makihara and Saito 1985, Makihara et al. 1991). Moreover, the study on mitochondrial genome suggests that *L. annularis* and *L. mimica* should be considered as separate species (Saito et al. 2002). In this study, these two taxa are collectively called the "*Leptura annularis* complex".

So far, all morphological studies on *L. annularis* complex were based on the traditional, qualitative characters only. Therefore, the main aim of this study was to quantify the morphological variation between European and Asiatic populations of *Leptura annularis* complex by using a geometric morphometric approach. This will allow examination of the hypothesis that the Sakhalin Is. and Japanese populations of the studied species constitute a diffrent morphotype than the continental populations.

Materials and methods

Examined material

The study was based on analysis of 269 images (116 females, 153 males) originating from six populations (Fig. 1): Central Europe (121 specimens), Eastern Europe (28 specimens), Central Asia (13 specimens), Eastern Asia (60 specimens), Sakhalin Is. (10 specimens), and Japan (37). Specimens were obtained from museum collections at the Institute of Forest Ecosystem Protection, Faculty of Forestry, University of Agriculture in Krakow, Poland, from collections of the Nature Museum at the Institute of Systematics and Evolution of Animals of the Polish Academy of Science, Krakow, Poland and from private collection of Nobuo Ohbayashi. Specimens were collected between 1888 and 2015.

Measurements

Both left and right hind wings of each specimen were carefully detached from the body, straightened, and mounted between two microscopic slides (Goczał et al. 2016). Each preparation was digitalized using an Epson V330 Photo scanner with a resolution of 4,800 dpi. Subsequently, 23 homologous landmarks were determined manually on each wing image by using of DrawWing software (Tofilski 2004) (Fig. 2).

Statistical analyses

Measurements of left and right hind wing were averaged. Before the analysis, all coordinates of the landmarks were aligned by using generalized orthogonal least-squares procedures (Rohlf and Slice 1990). These procedures involve scaling, translation and

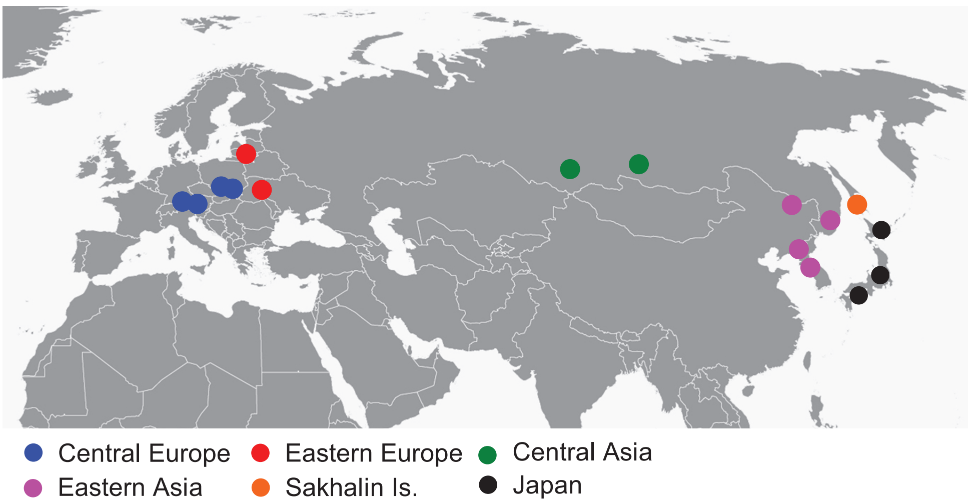


Figure 1. Sampling localities for morphological survey of *Leptura annularis* complex in Europe and Asia.

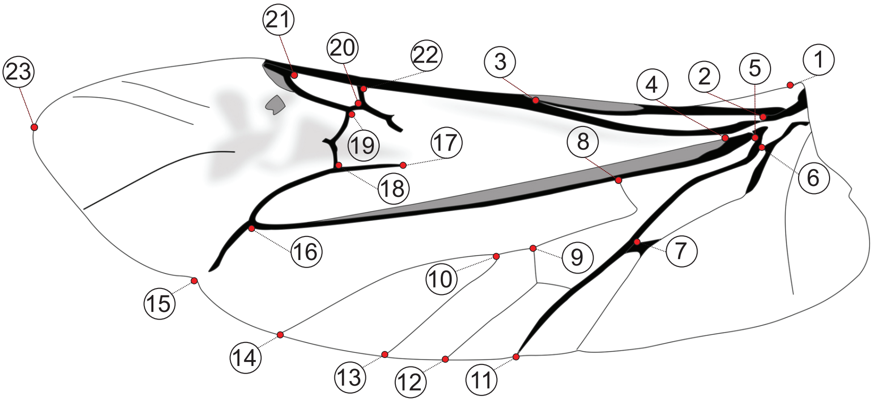


Figure 2. Schematic of landmarks positions on the hind wing of *Leptura annularis* complex.

rotation of the landmarks. After the superposition, coordinates of landmarks can be compared. Wing size was expressed as a centroid size. Wing shape was described by 20 principal components. The ANOVA/MANOVA models were used to analyze the differences in hind wing size and shape between populations and sexes. Mahalanobis distance (MD) was used as a measure of morphological divergence between groups. The distances were also employed to build a similarity tree by using of Unweighted Pair Group Method with Arithmetic Mean (UPGMA) in the Phangorn package (Schliep 2011) in R software(R Core Team 2015).

Results

Size differences

Significant differences in average wing size were detected among populations of *L. annularis* complex (ANOVA: $F_{5, 257} = 22.56$, $P = 0.001$, Fig. 3) and between sexes (ANOVA: $F_{1, 257} = 6.02$, $P = 0.015$, Fig. 3). The interaction between population and sex was not significant (ANOVA: $F_{5, 257} = 0.27$, $P = 0.931$). The post-hoc test revealed that specimens from Central Asia, Eastern Asia and Japan were significantly larger than individuals from Central Europe (Scheffe Test: $P = 0.001$; $P = 0.001$; $P = 0.001$, respectively). Specimens from Eastern Asia were also smaller than individuals from Eastern Europe and Sakhalin Is. (Scheffe Test: $P = 0.001$; $P = 0.009$, respectively). Other populations did not differ significantly in hind wing size.

Shape differences

There were significant differences in hind wing shape among populations of *L. annularis complex* (MANOVA: Wilks' lambda = 0.14, $F_{100, 1165.8} = 5.91$, $P = 0.001$, Fig. 4) and

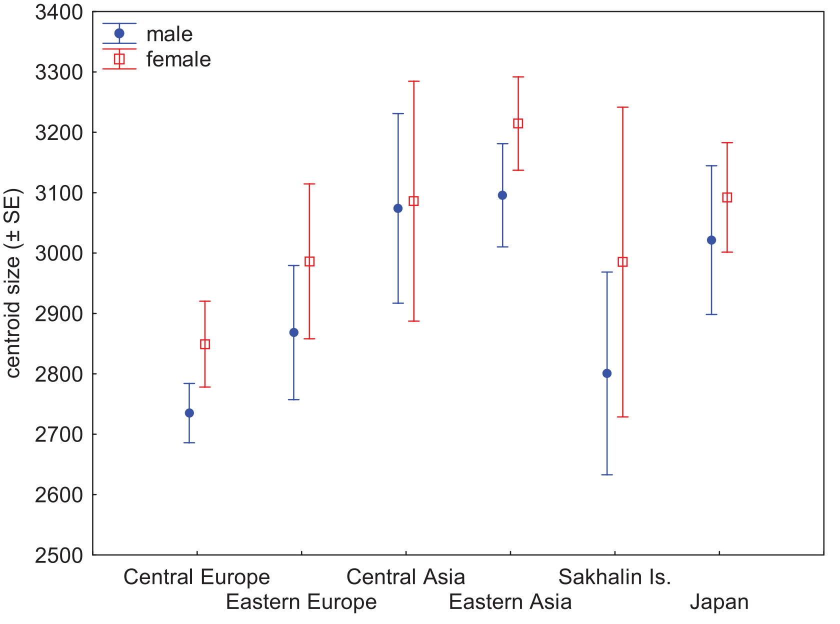


Figure 3. Differences in wing size between six populations of *Leptura annularis* complex.

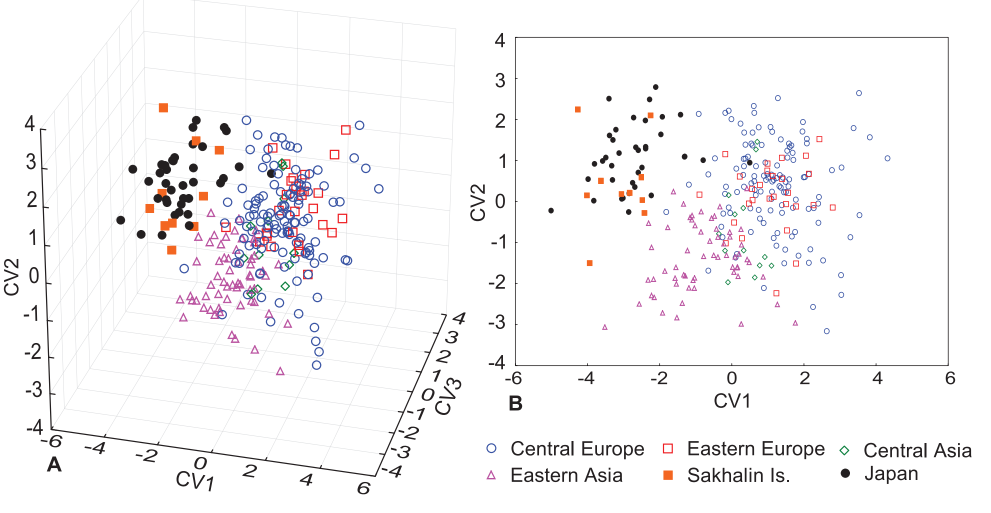


Figure 4. Variation of hind wing shape among European and Asiatic populations of *Leptura annularis* complex: view in three-dimensional (**A**) and two-dimensional (**B**) morphospace.

between sexes (MANOVA: Wilks' lambda = 0.70, $F_{20, 238}$ = 5.07, P = 0.001). The interaction between population and sex was not significant (MANOVA: Wilks' lambda = 0.63, $F_{100, 1165.8}$ = 1.14, P = 0.168). Morphological divergence among populations from Central Europe, Eastern Europe, Central Asia and Eastern Asia have reflected in large degree the geographical distance between them (Figs 4, 5). Accordingly, specimens from Central

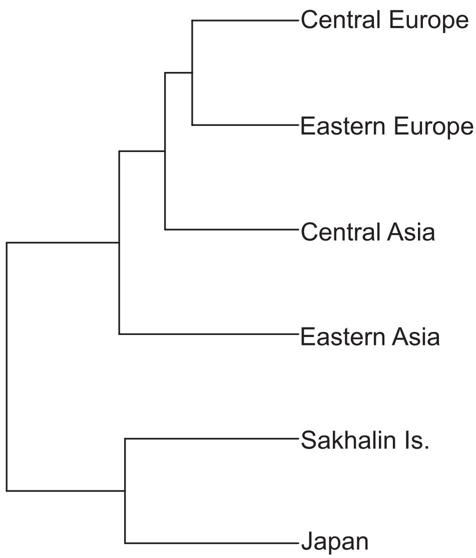


Figure 5. UPGMA similarity tree of hind wing shape of six *Leptura annularis* complex populations based on the Mahalanobis distance.

Europe were most similar to the individuals from Eastern Europe (MD square = 2.1). Individuals from Central Asia were similar to the specimens from Eastern Europe (MD square = 3.1). Specimens from Eastern Asia were similar to the beetles from Central Asia (MD square = 3.8).

Populations from Sakhalin Is. and Japan have shown significant divergence from all continental populations (Figs 4, 5), including the relatively close Eastern Asia population (MD square = 12.5; 9.8, respectively). Furthermore, samples from Sakhalin Is. and Japan were more similar to each other (MD square = 5.7) than to any continental population.

Discriminate analysis allowed to separate samples from Sakhalin Is. and Japan from continental populations based on hind wing shape (P = 0.001). Nevertheless, discrimination accuracy was relatively low and adopted values between 86.5 % (with cross-validation) for identification of continental morphotype, and 87.2 % (with cross-validation) for discrimination of Sakhalin Is. and Japanese morphotype.

The average hind wing of *L. annularis* from Sakhalin Is. and Japan was slightly shorter than the hind wing of specimens from continental populations, and has wider wing tip (Fig. 6). Differences may be also found in the position of some wing veins including cubital and medial veins (Fig. 6). However, these differences were very small and difficult to discern without measurements.

Discussion

Significant differences in size and shape of hind wings were found among European and Asiatic populations of *Leptura annularis* complex. The level of morphological

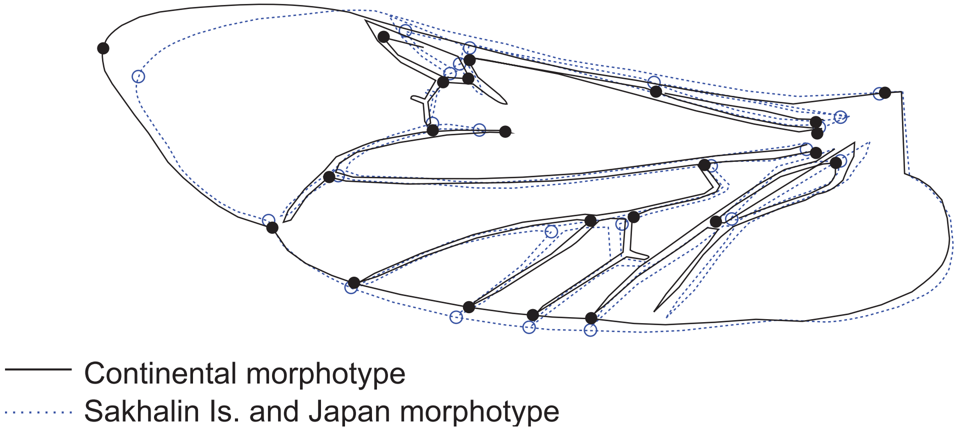


Figure 6. Differences in average hind wing shape between continental *Leptura annularis* complex morphotype (full line) and morphotype from Sakhalin Is. and Japan (dotted line). Differences were exaggerated four times to make them more visible. The position of the lines is a result of interpolation, which is less accurate at greater distances from the landmarks. The presented differences are difficult to discern without measurements.

divergence between most of studied populations was relatively small and proportional to the geographic distance between them. These data suggest that the postglacial colonization of Europe and Asia by *L. annularis* probably originated from single refugium.

The only exception to this pattern was in the case of Japanese and Sakhalin Is. populations. Samples from this region constituted a distinct morphotype, and differences between them and continental populations cannot be explained simply by the geographical distance. These data correspond to the results of other morphological and genetic investigations which have shown clear morphological divergence of Japan and Sakhalin Is. populations (Makihara and Saito 1985; Saito et al. 2002) and confirm the validity of taxonomic status of endemic *L. mimica* species.

The development of the geometric morphometric method is considered to be a milestone in the field of morphological study (Rohlf and Marcus 1993). Replacement of simple linear measurements with the complex informations of shape allows examination of various taxonomic, ecological, and evolutionary hypotheses (Adams et al. 2004, Mitteroecker and Gunz 2009, Lawing and Polly 2010, Fruciano 2016). In the case of insects, flight wings with their relatively flat area and numerous homologous structures constitute a widely used marker in geometric morphometric investigations (e.g. Bai et al. 2012; Chazot et al. 2016; Francoy et al. 2011; Gilchrist et al. 2000; Perrard et al. 2014; Prudhomme et al. 2012; Sadeghi et al. 2009; Tofilski 2008). In the case of beetles, hind wing geometric morphometrics were successfully used to describe the geographical variation among populations (Mikac et al. 2016, Rossa et al. 2016) and for species identification (Su et al. 2015, Goczał et al. 2016, Li et al. 2016, Rossa et al. 2017), as well as in evolutionary investigations (Bai et al. 2012; Ren et al. 2017). The results presented here confirmed that this approach is suitable for describing the geographic pattern of morphological variation in longhorn beetles and allows detection of divergent morphotypes. These findings highlight the potential of the geometric morphometric method in studying morphological variation in Coleoptera.

It is well known that habitat specialization constitutes an important factor affecting distribution patterns and diversification of organisms (Caillaud 1999, Wood et al. 1999, Stireman et al. 2005). In general, opportunistic species are in many cases characterised by a more homogeneous population structure than highly specialized taxa (Smith and Fujio 1982, Mustaparta 1992, Stein et al. 2014). If the case of longhorn beetles, it was shown that host specialization was an important factor influencing the distribution patterns and diversification of this group (Shoda et al. 2003b, Vitali and Schmitt 2017, Wallin et al. 2017). Our investigation on *L. annularis* showed a homogenous morphological structure of the studied species over a large distribution range. A similar conclusion was drawn for the other opportunistic longhorn beetle *Anoplophora glabripennis* (Motschulsky, 1853) after the genetic investigation (Carter et al. 2009). In contrary, several studies on host-specific longhorn beetles revealed more complex morphological and genetic population structures that cannot be explained simply by the geographical distance (Shoda et al. 2003a, 2003b, Kawai et al. 2006, Rossa et al. 2016). These findings underscore the importance of host specialization in the distribution patterns and diversification of longhorn beetles.

Acknowledgments

We would like to express our gratitude to the Akiko Saito, Natural History Museum and Institute, Chiba and to the anonymous reviewers for valuable comment on the earlier version of the manuscript. We are also immensely grateful to Daniel Kubisz from the Nature Museum at the Institute of Systematics and Evolution of Animals of the Polish Academy of Science in Krakow for providing specimens for this study. This research was supported by the Ministry of Science and Higher Education of The Republic of Poland under the grant number DS-3416/ZOLEKL/2017 and DS-WL/3400.

References

Abbasi R (2009) Geometric morphometric study of populations of the social wasp, *Polistes dominulus* (Christ, 1791) from Zanjan province, north-west Iran. New Zealand Journal of Zoology 36: 41–46. https://doi.org/10.1080/03014220909510138

Adams DC, Rohlf FJ, Slice DE (2004) Geometric morphometrics: Ten years of progress following the 'revolution.' Italian Journal of Zoology 71: 5–16. https://doi.org/10.1080/11250000409356545

Bai M, Beutel RG, Song K-Q, Liu W-G, Malqin H, Li S, Hu X-Y, Yang X-K (2012) Evolutionary patterns of hind wing morphology in dung beetles (Coleoptera: Scarabaeinae). Arthropod structure & Development 41: 505–513. https://doi.org/10.1016/j.asd.2012.05.004

Baselga A (2008) Determinants of species richness, endemism and turnover in European longhorn beetles. Ecography 31: 263–271. https://doi.org/10.1111/j.0906-7590.2008.5335.x

Bates HW (1884) Longicorn beetles of Japan. Additions, chiefly from the later Collections of Mr. George Lewis; and notes on the synonymy, distribution, and habits of the previously known species. Journal of the Linnean Society of London, Zoology 18: 205–262. https://doi.org/10.1111/j.1096-3642.1884.tb02047.x

Caillaud MC (1999) Behavioural correlates of genetic divergence due to host specialization in the pea aphid , *Acyrthosiphon pisum*. Entomologia Experimentalis et Applicata 91: 227–232. https://doi.org/10.1046/j.1570-7458.1999.00487.x

Carter ME, Smith MT, Harrison RG (2009) Patterns of Genetic Variation Among Populations of the Asian Longhorned Beetle (Coleoptera: Cerambycidae) in China and Korea. Annals of the Entomological Society of America 102: 895–905. https://doi.org/10.1603/008.102.0516

Chazot N, Panara S, Zilbermann N, Blandin P, Le Poul Y, Cornette R, Elias M, Debat V (2016) *Morpho* morphometrics: Shared ancestry and selection drive the evolution of wing size and shape in *Morpho* butterflies. Evolution 70: 181–194. https://doi.org/10.1111/evo.12842

Cherepanov AI (1988) Cerambycidae of northern Asia. Vol. 1. American Publishing, New Delhi, 642 pp. https://doi.org/10.5962/bhl.title.46344

Danilevsky ML (2014) Longicorn beetles (Coleoptera, Cerambycoidea) of Russia and adjacent countries. Part 1. HSC, Moscow, 522 pp.

Fabricius JC (1801) Systema eleutheratorum secundum ordines, genera, species adiectis synonymis, locis, observationibus, descriptionibus. Tomus II. Bibliopoli Academici Novi, Kiel, 687 pp.

Francoy TM, Grassi ML, Imperatriz-Fonseca VL, de Jesús May-Itzá W, Quezada-Euán JJG (2011) Geometric morphometrics of the wing as a tool for assigning genetic lineages and geographic origin to *Melipona beecheii* (Hymenoptera: Meliponini). Apidologie 42: 499–507. https://doi.org/10.1007/s13592-011-0013-0

Fruciano C (2016) Measurement error in geometric morphometrics. Development Genes and Evolution 226: 139–158. https://doi.org/10.1007/s00427-016-0537-4

Gaston K, Blackburn T (2000) Macroecology: pattern and process. Blackwell Science Ltd, Oxford, 371 pp. https://doi.org/10.1002/9780470999592

Gilchrist AS, Azevedo RBR, Partridge L, O'Higgins P (2000) Adaptation and constraint in the evolution of *Drosophila melanogaster* wing shape. Evolution and Development 2: 114–124. https://doi.org/10.1046/j.1525-142X.2000.00041.x

Goczał J, Rossa R, Sweeney J, Tofilski A (2016) Citizen monitoring of invasive species: wing morphometry as a tool for detection of alien *Tetropium* species. Journal of Applied Entomology 141: 496–506. https://doi.org/10.1111/jen.12370

Haas HL, Tolley KA (1998) Geographic variation of wing morphology in three Eurasian populations of the fruit fly, *Drosophila lummei*. Journal of Zoology 245: 197–203. https://doi.org/10.1111/j.1469-7998.1998.tb00087.x

Hoffmann AA, Shirriffs J (2002) Geographic variation for wing shape in *Drosophila serrata*. Evolution 56: 1068. https://doi.org/10.1554/0014-3820(2002)056[1068:GVFWSI]2.0.CO;2

Kaszab Z (1971) Cincérek-Cerambycidae. Fauna Hungariae IX, 5. Akadémiai Kiadó, Budapest Budapest, 283 pp.

Kawai M, Shoda-Kagaya E, Maehara T, Zhou Z, Lian C, Iwata R, Yamane A, Hogetsu T (2006) Genetic Structure of Pine Sawyer *Monochamus alternatus* (Coleoptera: Cerambycidae) Populations in Northeast Asia: Consequences of the Spread of Pine Wilt Disease. Environmental Entomology 35: 569–579. https://doi.org/10.1603/0046-225X-35.2.569

Koutroumpa FA, Rougon D, Bertheau C, Lieutier F, Roux-Morabito G (2013) Evolutionary relationships within European *Monochamus* (Coleoptera: Cerambycidae) highlight the role of altitude in species delineation. Biological Journal of the Linnean Society 109: 354–376. https://doi.org/10.1111/bij.12042

Lawing AM, Polly PD (2010) Geometric morphometrics: recent applications to the study of evolution and development. Journal of Zoology 280: 1–7. https://doi.org/10.1111/j.1469-7998.2009.00620.x

Li L, Qi Y, Yang Y, Bai M (2016) A new species of *Falsopodabrus* Pic characterized with geometric morphometrics (Coleoptera, Cantharidae). ZooKeys 614: 97–112. https://doi.org/10.3897/zookeys.614.6156

Löbl I, Smetana A (2010) 6 Catalogue of Palaearctic Coleoptera Catalogue of Palaearctic Coleoptera. Volume 6. Chrysomeloidea. Apollo Books, Stenstrup, 924 pp.

MacArthur R (1972) Geographical ecology: patterns in the distribution of species. Harper & Row, New York, 288 pp.

Makihara H, Saito A (1985) Studies on *Leptura arcuata* (1), (Coleopt., Cerambycidae). Elytra 12: 5–10.

Makihara M, Saito A, Satô M (1991) Studies on the *Leptura arcuata* species-group (2), (Coleoptera, Cerambycidae). Elytra 19: 5–18.

Mikac KM, Lemic D, Bažok R, Benítez HA (2016) Wing shape changes: a morphological view of the *Diabrotica virgifera virgifera* European invasion. Biological Invasions 18: 3401–3407. https://doi.org/10.1007/s10530-016-1252-9

Mitteroecker P, Gunz P (2009) Advances in Geometric morphometrics. Evolutionary Biology 36: 235–247. https://doi.org/10.1007/s11692-009-9055-x

Mustaparta H (1992) Specialization in herbivorous insects. In: Proceedings of the 8th International Symposium on Insect-Plant Relationships. Springer Netherlands, Dordrecht, 395–399. https://doi.org/10.1007/978-94-011-1654-1_127

Panin S, Săvulescu N (1961) Insecta. Coleoptera. Familia Cerambycidae (Croitori). Fauna Republicii populare Române 10, 5. Bucureşti, 523 pp.

Perrard A, Baylac M, Carpenter JM, Villemant C (2014) Evolution of wing shape in hornets: Why is the wing venation efficient for species identification? Journal of Evolutionary Biology 27: 2665–2675. https://doi.org/10.1111/jeb.12523

Pezzoli MC, Guerra D, Giorgi G, Garoia F, Cavicchi S (1997) Developmental constraints and wing shape variation in natural populations of *Drosophila melanogaster*. Heredity 79: 572–577. https://doi.org/10.1038/hdy.1997.201

Prudhomme J, Gunay F, Rahola N, Ouanaimi F, Guernaoui S, Boumezzough A, Bañuls AL, Sereno D, Alten B (2012) Wing size and shape variation of *Phlebotomus papatasi* (Diptera: Psychodidae) populations from the south and north slopes of the Atlas Mountains in Morocco. Journal of Vector Ecology 37: 137–147. https://doi.org/10.1111/j.1948-7134.2012.00210.x

R Core Team (2015) R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing. https://www.r-project.org

Ren J, Bai M, Yang X-K, Zhang R-Z, Ge S-Q (2017) Geometric morphometrics analysis of the hind wing of leaf beetles: proximal and distal parts are separate modules. ZooKeys: 131–149. https://doi.org/10.3897/zookeys.685.13084

Rohlf F, Marcus L (1993) A revolution morphometrics. Trends in Ecology and Evolution 8: 129–132. https://doi.org/10.1016/0169-5347(93)90024-J

Rohlf F, Slice D (1990) Extensions of the Procrustes Method for the Optimal Superimposition of Landmarks. Systematic Zoology 39: 40–59. https://doi.org/10.2307/2992207

Rossa R, Goczał J, Tofilski A (2016) Within- and between -species variation of wing venation in genus *Monochamus* (Coleoptera: Cerambycidae). Journal of Insect Science 16: 5. https://doi.org/10.1093/jisesa/iev153

Rossa R, Goczał J, Tofilski A (2017) Hind wing morphology facilitates discrimination between two sibling species: *Leiopus nebulosus* and *L. linnei* (Coleoptera: Cerambycidae). Zootaxa 4227: 266. https://doi.org/10.11646/zootaxa.4227.2.7

Sadeghi S, Adriaens D, Dumont HJ (2009) Geometric morphometric analysis of wing shape variation in ten European populations of *Calopteryx splendens* (Harris, 1782) (Zygoptera: Calopterygidae). Odonatologica 38: 341–357.

Saito S, Saito A, Kim C-G, Su Z-H, Osawa S (2002) Phylogeny of the *Leptura arcuata* Complex (Coleoptera, Cerambycidae) as deduced from mitochondrial ND5 gene sequences. Special bulletin of the Japanese Society of Coleopterology 5: 381-391.

Sama G (2002) Atlas of the Cerambycidae of Europe and the Mediterranean Area. Vol.1. Nakladatelství Kabourek, Zlín, 173 pp.

Schliep KP (2011) Phangorn: phylogenetic analysis in R. Bioinformatics 27: 592–593. https://doi.org/10.1093/bioinformatics/btq706

Shoda E, Kubota K, Makihara H (2003a) Geographical structure of morphological characters in *Semanotus japonicus* (Coleoptera: Cerambycidae) in Japan. Applied Entomology and Zoology 38: 369–377. https://doi.org/10.1303/aez.2003.369

Shoda E, Kubota K, Makihara H (2003b) Geographical structuring of mitochondrial DNA in *Semanotus japonicus* (Coleoptera: Cerambycidae). Applied Entomology and Zoology 38: 339–345. https://doi.org/10.1303/aez.2003.339

Sláma M (1998) Tesaříkovití – Cerambycidae České republiky a Slovenské republiki (Brouci-Coleoptera). Krhanice, 383 pp.

Smith PJ, Fujio Y (1982) Genetic variation in marine teleosts: High variability in habitat specialists and low variability in habitat generalists. Marine Biology 69: 7–20. https://doi.org/10.1007/BF00396955

Stein ED, Martinez MC, Stiles S, Miller PE, Zakharov EV (2014) Is DNA barcoding actually cheaper and faster than traditional morphological methods: results from a survey of freshwater bioassessment efforts in the United States? PloS one 9: e95525. https://doi.org/10.1371/journal.pone.0095525

Stillwell RC, Fox CW (2009) Geographic variation in body size, sexual size dimorphism and fitness components of a seed beetle: Local adaptation versus phenotypic plasticity. Oikos 118: 703–712. https://doi.org/10.1111/j.1600-0706.2008.17327.x

Stillwell RC, Morse GE, Fox CW (2007) Geographic variation in body size and sexual size dimorphism of a seed-feeding beetle. The American Naturalist 170: 358–369. https://doi.org/10.1086/520118

Stireman JO, Nason JD, Heard SB (2005) Host-associated genetic differentiation in phytophagous insects: general phenomenon or isolated exceptions? Evidence from a goldenrod-insect community. Evolution; international journal of organic evolution 59: 2573–2587. https://doi.org/10.1111/j.0014-3820.2005.tb00970.x

Su J, Guan K, Wang J, Yang Y (2015) Significance of hind wing morphology in distinguishing genera and species of cantharid beetles with a geometric morphometric analysis. ZooKeys 502: 11–25. https://doi.org/10.3897/zookeys.502.9191

Tofilski A (2004) DrawWing, a program for numerical description of insect wings. Journal of Insect Science 4: 17–17. https://doi.org/10.1093/jis/4.1.17

Tofilski A (2008) Using geometric morphometrics and standard morphometry to discriminate three honeybee subspecies. Apidologie 39: 558–563. https://doi.org/10.1051/apido:2008037

Vitali F, Schmitt T (2017) Ecological patterns strongly impact the biogeography of western Palaearctic longhorn beetles (Coleoptera: Cerambycoidea). Organisms Diversity & Evolution 17: 163–180. https://doi.org/10.1007/s13127-016-0290-6

Wallin H, Kvamme T, Bergsten J (2017) To be or not to be a subspecies: description of *Saperda populnea lapponica* ssp. n. (Coleoptera, Cerambycidae) developing in downy willow (*Salix lapponum* L.). ZooKeys 691: 101–148. https://doi.org/10.3897/zookeys.691.12880

Wood TK, Tilmon KJ, Shantz AB, Harris CK, Pesek J (1999) The role of host-plant fidelity in initiating insect race formation. Evolutionary Ecology Research 1: 317–332.

Yom-Tov Y, Geffen E (2006) Geographic variation in body size: the effects of ambient temperature and precipitation. Oecologia 148: 213–218. https://doi.org/10.1007/s00442-006-0364-9

Zelditch ML, Swiderski DL, Sheets HD, Fink WL (2004) Geometric morphometrics for biologists: A primer. Elsevier, Amsterdam, 457 pp. https://doi.org/10.1016/B978-0-12-386903-6.00001-0

ZooKeys 724: 43–52 (2017)
doi: 10.3897/zookeys.724.21057
http://zookeys.pensoft.net

RESEARCH ARTICLE

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

Two new species of *Thyridosmylus* Krüger, 1913 from Madagascar (Neuroptera, Osmylidae)

Han Xu[1], Shaun L. Winterton[2], Yongjie Wang[3], Zhiqi Liu[1]

1 *Department of Entomology, China Agricultural University, Beijing 100094, China* **2** *California State Collection of Arthropods, California Department of Food & Agriculture, Sacramento, California, USA* **3** *College of Life Sciences, Capital Normal University, Beijing 100048, China*

Corresponding author: *Zhiqi Liu* (liuzhiqi@cau.edu.cn); *Yongjie Wang* (wangyjosmy@foxmail.com)

Academic editor: *A. Contreras-Ramos* | Received 19 September 2017 | Accepted 21 November 2017 | Published 21 December 2017

http://zoobank.org/B145E24E-B7DF-48D7-BE68-2EEA4E082CC4

Citation: Xu H, Winterton SL, Wang Y, Liu Z (2017) Two new species of *Thyridosmylus* Krüger, 1913 from Madagascar (Neuroptera, Osmylidae). ZooKeys 724: 43–52. https://doi.org/10.3897/zookeys.724.21057

Abstract

The lance lacewing genus *Thyridosmylus* Krüger (Osmylidae: Spilosmylinae) is found in Madagascar and Southeast Asia. Two new Malagasy species are described herein, *Thyridosmylus fuscomarginatus* Xu, Wang & Winterton, **sp. n.**, and *Thyridosmylus longiprocessus* Xu, Wang & Winterton, **sp. n.** A key to differentiate the Malagasy species of *Thyridosmylus* is provided.

Keywords

lacewing, Malagasy species, Osmylidae

Introduction

Thyridosmylus Krüger is a small genus of lance lacewings assigned to the subfamily Spilosmylinae. Krüger (1913) established the genus based on the species *Osmylus langii* McLachlan, 1870, characterized by distinctively marked forewings commonly with fenestrate spots around the outer gradate cross-veins. In 1917, Navás erected the genus *Centrolysmus* based on *Osmylus perspicillaris*, but in the subsequent revision of *Thyridosmylus* Kimmins (1942) suggested that *O. perspicillaris* (and subspecies) should be instead placed in *Thyridosmylus*. Unfortunately, Kimmins mistook *Centrolysmus* *epiphanes* as the type species of *Centrolysmus* and thus inadvertently maintained the validity of *Centrolysmus*. Oswald and Penny (1991) clarified this mistake and formally synonymized *Centrolysmus* with *Thyridosmylus*.

Presently there are 19 species described in *Thyridosmylus*, including 17 species from South East Asia and two from Madagascar, suggesting the conspicuously disjunct geographical distribution (Gerstaecker 1884; Navás 1933; Kimmins 1942; Fraser 1955; Yang 1987, 1988, 1992, 1993, 1999, 2002; Yang et al. 1995; Wang et al. 2008, 2011). The congeneric status of all species in the genus has been routinely accepted by subsequent authors (Wang et al. 2008, 2011; Winterton et al. 2017); in a cladistics analysis of *Thyridosmylus*, Wang et al. (2011) concluded the Malagasy species occupy a sister position to the Oriental species, suggesting the southern origin of this genus should be no later than Late Cretaceous. Indeed, in their phylogenetic analyses of Osmylidae, Winterton et al. (2017) deduced that the divergence of *Thyridosmylus* from its sister genus *Spilosmylus* Kolbe occurred during the Middle Jurassic (177 Mya), and that early splits in both genera were caused by vicariance resulting from the subsequent rafting of India.

The Malagasy *Thyridosmylus* species have been mentioned seldom in the literature since their description. Based on recently collected material from Madagascar, two new species are described, *Thyridosmylus fuscomarginatus* Xu, Wang & Winterton, sp. n. and *Thyridosmylus longiprocessus* Xu, Wang & Winterton, sp. n.

Materials and methods

The specimens observed in this study are deposited in the California Academy of Science, San Francisco (CASC), California State Collection of Arthropods, Sacramento (CSCA) and Entomological Museum of China Agricultural University, Beijing (CAU). Terminalia preparations were made by macerating the apex of the abdomen in hot 10% KOH for 3–5 min, neutralized with 10% acetic acid. The apex of the abdomen was then transferred to glycerol for further dissection and examination. After examination, they were moved to fresh glycerol and stored in a microvial pinned below the specimens. Image of wings were taken with a Nikon D7000 digital camera. Drawings were made under a light microscope. The terminology for wing venation and genitalia follows Winterton and Wang (2016) and Winterton et al. (2017).

Taxonomy

Genus *Thyridosmylus* Krüger

Thyridosmylus Krüger, 1913: 87. Type species: *Osmylus langii* McLachlan, 1870: 197. Original designation. Type locality: Masuri (India).

Centrolysmus Navás, 1917: 15. Type species: *Osmylus perspicillaris* Gerstaecker, 1884: 46. Original designation. Type locality: Darjeeling (India).

Diagnosis. Medium sized species (forewing length 13–24 mm), wings narrow (maximum width of forewing 4–7 mm). Ocelli present. Forewing strongly patterned with distinctive fenestrate spots close to the outer gradate series, with numerous suffusions, some of these forming a large macula, numerous crossveins. Costal crossveins simple, subcostal space with single crossvein. At least two distinct gradate series. Area between M and Cu lacking crossveins between them basally, thus a large cell is present. Hindwing with Cu forked at base, CuP short and not pectinate. Male ectoproct bearing a dorsal digitiform projection, gonarcus symmetrical, amalgamated distally, sclerotized marginally; baculum present; mediuncus C-shaped, linked by membranes; parameres present. Female genitalia with sternite 8 small, gonapophyses 9 as paired sclerites closely associated with gonocoxites 9, spermatheca simple or with a complicated lobed morphology.

Redescription. Body length 10–15 mm. Head brown or dark brown; antennae yellow and shorter than or equal to half of length of forewing, scape and pedicel dark brown, flagellum yellow; compound eyes black; ocellar tubercles yellowish to brown; labrum brown or dark brown. Thorax dark brown with long setae; meso- and metathorax dark brown. Legs yellow with brown setae. Forewing length 13–24 mm, width 4–7 mm. Forewing generally with characteristic fenestrate spots near the outer gradate series and with numerous fuscous markings, membrane hyaline or with light infuscate suffusion; pterostigma brown with a light brown centre; two nygmata as brown spots; venation brown, some cross-veins edged with brown markings; costal cross-veins simple and occasionally bifurcate; cross-vein sc-r1 close to the base of forewing; forewing Rs with 10–15 branches, cross-veins among Rs branches forming more than two series of gradates; basal mp-cu cross-vein only one, forming a large cell. Hindwing length 12–22 mm, width 4–7 mm. Hindwing generally hyaline with few spots; pterostigma light yellow; nygmata inconspicuous and light brown; base of MP with a spur. Male genitalia. Tergite 8 and sternite 8 approximately quadrate. Tergite 9 commonly narrow, sternite 9 approximately trapezoidal or triangular; ectoproct with a dorsal process, callus cercus round; gonarcus sclerotized marginally, symmetrical and fused distally and base connected with a goblet-shaped anterior apodeme; entoprocesses bent in middle; mediuncus lobes bent into C-shape laterally and fused at base; parameres arch-like with medial thickening and invariant within genus. Female genitalia. tergite 8 broad and approximately quadrate; sternite 8 reduced and small; tergite 9 narrow and commonly constricted in middle articulated with gonopophysis 9 + gonocoxite 9; gonocoxite 9 finger-like in lateral view; each spermatheca connected with a spermathecal duct.

Comments. The distinction between the closely related *Thyridosmylus* and *Spilosmylus* has been historically ambiguous, although their reciprocally monophyletic sister-group relationship was confirmed in the phylogeny of the family by Winterton et al. (2017). Traditionally, *Thyridosmylus* was characterized by numerous markings of forewings with the often presence of distinct fenestrations around the outer gradate cross veins, while the forewings of *Spilosmylus* are characterised by having fewer maculations and an embossed spot along the posterior wing margin, or intermittent dark streaks between Sc and R_1. As more species have been described it seems that these characters could not completely separate these genera, with numerous instances where the diagnostic feature of either genus is lacking. With regard to *Thyridosmylus*, fenestrate markings are not found in several species such as *T. fuscus* Yang, 1999, *T. longiprocessus* Xu, Wang & Winterton, sp. n., *T. maolanus* Yang, 1993, *T. marmoratus* Fraser, 1955, *T. pallidius* Yang, 2002 and *T. trifasciatus* Yang, 1993. Still, the forewings of these species exhibit extensive fragmental markings and do not possess embossed spots and intermittent streaks typical among *Spilosmylus* species. Additionally, the spermathecae in some *Thyridosmylus* species (e.g., *T. langii*, *T. paralangii* and *T. fuscomarginatus* Xu, Wang & Winterton, sp. n.) are complex and multilobed, resembling those of some *Spilosmylus* species. The shape of the external genitalia in the males of *Thyridosmylus* varies less compared with *Spilosmylus*.

The forewing of *Thyridosmylus* has two m-cu cross veins between the stem of the medial vein (before the split into MA and MP) and cubital vein to form single large cell, while the forewing of *Thaumatosmylus* has few fuscous spots, and three m-cu cross veins to form two basal cells. Also, the spermathecae in females of *Thyridosmylus* are elliptical or multilobed while the spermathecae in *Thaumatosmylus* tend to be large with a basal club-like sac, or with a small and apical finger-like to ovoid sac. Although the definition of genus *Glenosmylus* has been obscure since it was erected by Krüger (1913), it can be distinguished from *Thyridosmylus* based on three m-cu cross veins in the forewing character, similar to that found in *Thaumatosmylus*.

Key to *Thyridosmylus* species in Madagascar

1	Outer margin of forewing with extensive fuscous markings with a distinct fenestration around the outer gradate cross veins (Fig. 1) .... ***Thyridosmylus fuscomarginatus* Xu, Wang & Winterton, sp. n.**
–	Outer margin of forewing extensively marked but lacking distinct fenestration near outer gradates **2**
2	Hindwing with series of small dark spots along the posterior margin towards the wing apex............................ ***Thyridosmylus punctulatus* (Navás, 1933)**
–	Hindwing without series of spots along posterior margin towards the wing apex (Fig. 3).. **3**
3	Basal half of forewing with two brown bands (Fig. 3) .... ***Thyridosmylus longiprocessus* Xu, Wang & Winterton, sp. n.**
–	Forewing without brown band-like markings.. .... ***Thyridosmylus marmoratus* Fraser, 1955**

***Thyridosmylus fuscomarginatus* Xu, Wang & Winterton, sp. n.**
http://zoobank.org/D9B51BB6-96F2-4285-A62C-1A291EF370F7
Figs 1–2

Diagnosis. Pronotum light yellow with three longitudinal dark brown stripes; posterior margin of forewing with brown markings, branches of vein A_1 marked with a dark brown spot, area around outer gradate cross-veins fenestrate with pale venation;

Figure 1. Wings of *Thyridosmylus fuscomarginatus* Xu, Wang & Winterton, sp. n. Abbreviations: ng, nygmata; pt, pterostigma; og, outer gradates. Scale bar: 0.5 mm.

sternite 8 in female reduced, extending anteriorly to form a forward process in lateral view; spermatheca complex with 11–12 sacs, basal sac large.

Description. *Head.* Vertex yellowish-brown with black setae; compound eyes black, ocelli yellow, each one anteriorly edged with a black spot. Antennal flagellum light yellow with dark yellow apex; scape and pedicel light yellow; frons brown. *Thorax.* Pronotum light yellow with a dark brown longitudinal stripe in middle and parallel two dark brown markings on both sides, three markings linked by a latitudinal light brown stripe; meso- and metanotum brown. *Legs.* Yellow with brown setae; claws brown. *Wings* (Fig. 1). Forewing length 17–18 mm, width 5–6 mm; membrane hyaline; cross-veins in the basal half of costal field dark brown, paler distally; pterostigma light brown; Rs with 13–14 branches; distal part of branches of vein Rs, M and Cu edged with brown markings, branches of A_1 edged with an irregular and clear dark brown spot; area around outer gradate cross-veins hyaline with pale venation, appearing fenestrate; cross-veins among branches of Rs, M, Cu and A edged with fuscous markings. Hindwing length 15–16 mm, width 4–5 mm; membrane hyaline; veins yellowish; pterostigma light brown; Rs with 11 branches, cross-veins among Rs branches forming two series of gradates; basal MP with a spur. *Male genitalia* (Fig. 2a–g). Tergite 8 and sternite 8 quadrangular with brown setae; tergite 9 narrow and extended distally in dorsal view; sternite 9 subtriangular in lateral view; ectoproct with a dorsal rod-like process (Fig. 2b), base inflated and distal part with numerous brown setae; callus cercus approximately rounded; gonarcus approximately triangular in lateral view (Fig. 2d) and narrow arch-like in dorsal view (Fig. 2e), basally articulated internally with tergite 9, gonarcus dorsally sclerotized and ventrally membranous (Fig. 2d); entoprocessus narrow and reflexed dorsally with a backward process at the corner of bend, distal margin membranous (Fig. 2d); gonarcus anterior apodeme goblet-shaped; mediuncus lobes C-shaped in lateral view (Fig. 2f), thickened basally and sclerotized well but distal part translucent and expanding dorsal-medially and ventrally (Fig. 2g); parameres sclerotized, horn-shaped, and thickened medially (Fig. 2c). *Female genitalia* (Fig. 2h–i). Tergite 8 quadrate, sternite 8 reduced, close to tergite 9 and extending anteriorly to form a forward process in lateral view; tergite 9 narrow and constricted at the level of ectoproct; gonopophyses 9 and gonocoxite 9 closely associated, gonocoxite 9 thick finger-like with gonostylus 9 distally; ectoproct coniform, callus cercus rounded; spermathecae complex, each comprised of 11–12 sacs, basal sac large and long (Fig. 2h).

Material examined. Holotype. Female. MADAGASCAR: Mahajanga Prov., Parc National de Baie de Raly, 12.4 km, 337° NNW Soalala, elev. 10 m, 16°00'36"S, 45°15'54"E, 26–30.xi.2002, coll. Fisher, Griswold et al., collected at night, tropical dry forest (CASC). **Paratypes.** 1 male. MADAGASCAR: Mahajanga Prov., Forêt de Tsimembo, 8.7 km, 336° NHW Soatana, elev. 20 m, 19°1'17"S, 44°26'26"E, 21–25.xi.2001, coll. Fisher, Griswold et al., collected at night, tropical dry forest (CASC). 1 female. MADAGASCAR: Mahajanga Prov., Parc National de Baie de Raly, 12.4 km, 337° NNW Soalala, elev. 10 m, 16°00'36"S, 45°15'54"E, 26–30.xi.2002, coll. Fisher, Griswold et al. Collected at night, tropical dry forest (CASC). 1 female. MADAGASCAR: Antsiranana Prov., Ankarana National Park, Aurelien Hotel, 140 m, 12°58'07.5"S 49°08'12.8"E, 16.xii.2016, coll. Hu Li. (CAU). 1 male. MADAGASCAR: Antsiranana Prov., 3 km, W Sakalava Beach, 12°17'10"S 49°22'00"E, 40 m, 21–23.i.2001, coll. M. E. Irwin, E. I. Schilinger, R. Harin' Hala. (CASC).

Etymology. The specific name "*fuscomarginatus*", a compound from Latin *fusco-* (fuscus) and *marginatus-* (margin), in reference to the colour and pattern of markings on the outer and posterior margin of forewings.

Distribution. Madagascar (Antsiranana, Mahajanga)

Remarks. The forewings markings of *Thyridosmylus fuscomarginatus* sp. n. are characteristic, clearly differed from other *Thyridosmylus* species by the dark posteromarginal stripe.

Thyridosmylus longiprocessus Xu, Wang & Winterton, sp. n.

http://zoobank.org/BA10CB95-0E12-4E12-AF4F-4699EC2F838F
Figs 3–4

Diagnosis. Frons brown with two dark brown markings; forewing hyaline, basal half with two brown stripes; male genitalia with ectoproct bearing a long dorsal rod-like

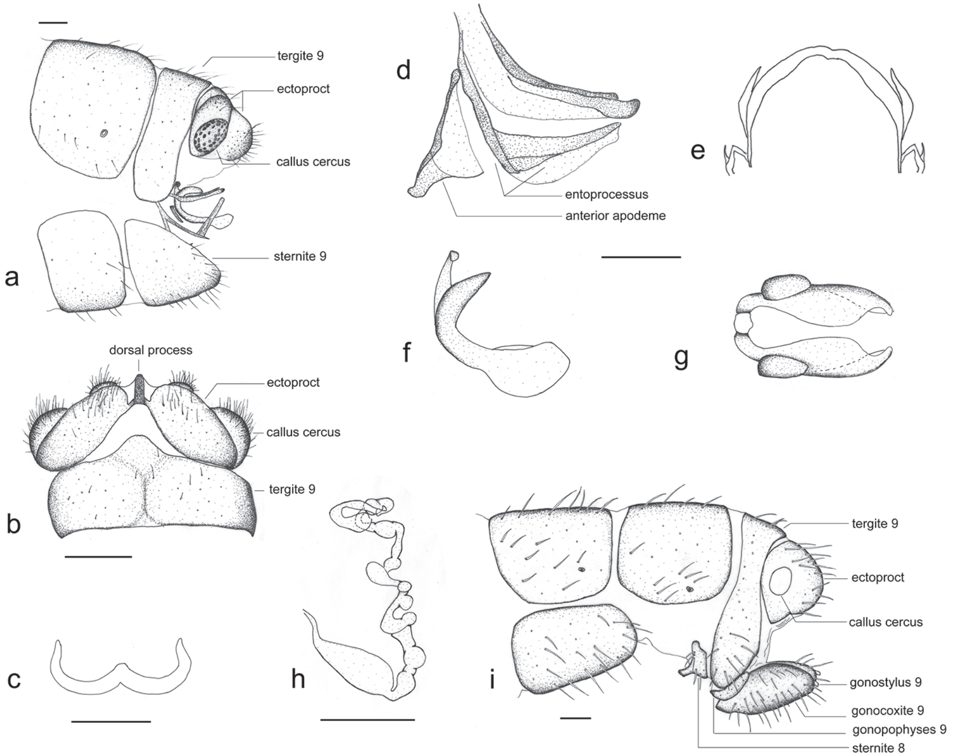


Figure 2. *Thyridosmylus fuscomarginatus* Xu, Wang & Winterton, sp. n. Male : **a, b** abdomen terminalia, lateral view (**a**) and dorsal view (**b**) **c** parameres, dorsal view **d–e** gonarcus, lateral view (**d**) and dorsal view (**e**) **f ,g** mediuncus, lateral view (**f**) and dorsal view (**g**). Female: **h** spermatheca **i** abdomen terminalia, lateral view. Scale bars: 0.2 mm.

process; distal part of gonarcus with abundant pilosity; basal part of mediuncus laterally with heart-shaped structures in dorsal view; spermatheca complex, with 13 sacs, basal one small and oval.

Description. *Head.* Vertex brown with black setae; compound eyes grey, ocelli yellow, base edged with a dark brown spot. Antennal flagellum yellow; scape and pedicel brown; frons brown with two dark brown markings. *Thorax.* Pronotum black; meso- and metanotum brown with a longitudinal dark stripe in middle. *Legs.* Legs yellow with brown setae; claws brown. *Wings* (Fig. 3). Forewing length 17–18 mm, width 5–6 mm; membrane hyaline, basal half with 10 brown spots forming two stripes; veins brown; pterostigma light brown; Rs with 12 branches, cross-veins among Rs branches forming two series of gradates, outer gradate cross-veins edged with brown spots; forewing M branching more basally than the divergence of basal branch of Rs; nygmata clear, distal nygma edged with a rounded light brown spot. Hindwing length 15–16 mm, width 4–5 mm; membrane hyaline; veins brown; pterostigma light brown. Rs with 12 branches, cross-veins among Rs branches forming two series of gradates. Basal MP with a spur. *Male genitalia* (Fig. 4a–g). Tergite 8 and

Figure 3. Wings of *Thyridosmylus longiprocessus* Xu, Wang & Winterton, sp. n. Scale bar: 0.5 mm.

sternite 8 quadrangular with brown setae; tergite 9 narrow; sternite 9 quadrangular; ectoproct with a long dorsal rod-like process (Fig. 4a); callus cercus approximately oval; gonarcus approximately triangular in lateral view and narrow and arched in dorsal view; gonarcus membranous posterolaterally with dense setal pile, dorsal margin well sclerotized (Fig. 4b–c); entoprocessus narrow, bent dorsad, with a posteroventral pointed projection, distal region membranous (Fig. 4b); mediuncus lobes C-shaped in lateral view (Fig. 4d), basally thickened and well sclerotized, distal part translucent and expanding dorsal-medially and ventrally; basal part laterally with heart-shaped structures in dorsal view (Fig. 4e); parameres sclerotized, horn-shaped in dorsal view, thickened medially and bent in lateral view (Fig. 4f–g). *Female genitalia* (Fig. 4h–i). Tergite 8 quadrate, sternite 8 reduced, close to tergite 9; tergite 9 narrow and constricted at the level of ventral margin of ectoproct; gonopophyses 9 and gonocoxite 9 closely associated, gonocoxite 9 finger-like with gonostylus 9 distally; ectoproct coniform, callus cercus rounded; spermathecae complex, each comprised of 13 sacs, basal sac small and oval (Fig. 4i).

Material examined. Holotype. Male. MADAGASCAR: Fianarantsoa Prov., S. E. Fandriana Korikory, elev. 1670 m, 20°23'S, 47°40'E, 13.iii.2002, coll. Michael E. Irwin & Evert I. Schlinger (CASC). **Paratype**. Female. Data same as holotype.

Etymology. Thve specific name "*longiprocessus*", a compound from Latin *longi-* (long) and *processus-* (process), which refers to the long dorsal process of ectoproct in male.

Distribution. Madagascar (Fianarantsoa).

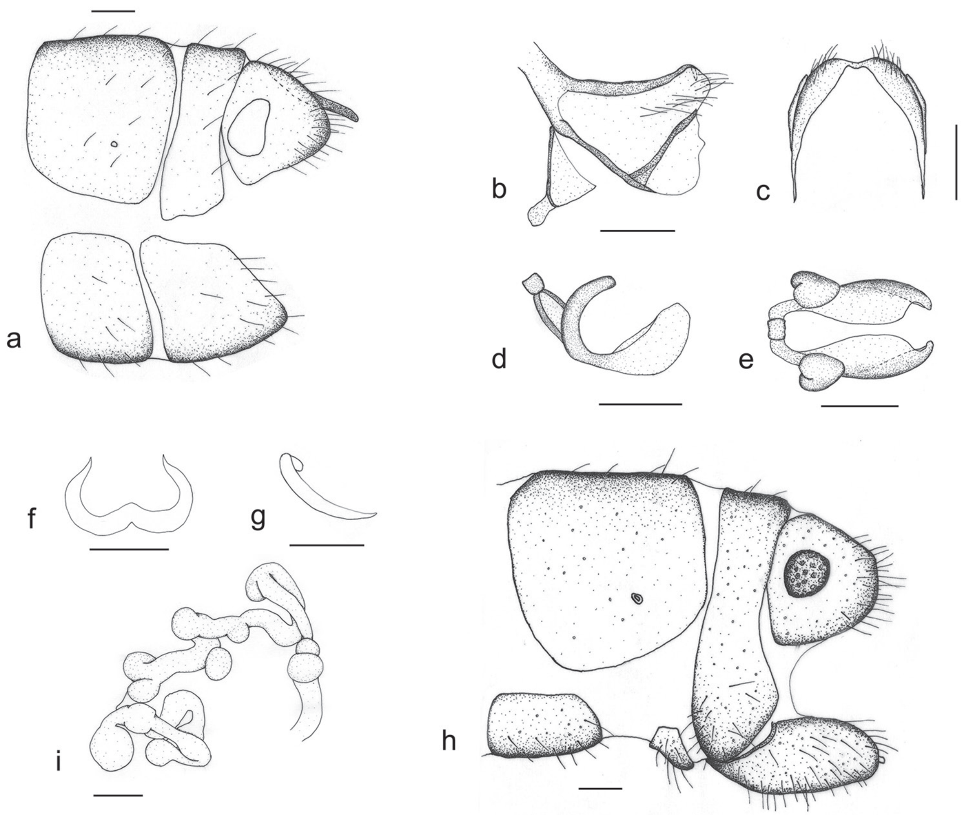


Figure 4. *Thyridosmylus longiprocessus* Xu, Wang & Winterton, sp. n. Male : **a** abdomen terminalia, lateral view; **b, c** gonarcus, lateral view (**b**) and dorsal view (**c**) **d, e** mediuncus, lateral view (**d**) and dorsal view (**e**) **f, g** parameres, dorsal view (**f**) and lateral view (**g**). Female: **h** abdomen terminalia, lateral view **i** spermatheca. Scale bars: 0.2 mm.

Remarks. The male genitalia are not well sclerotized probably because it was teneral when it was collected. The sternite 8 in *T. longiprocessus* sp. n. is reduced into a sclerite without processes and the spermatheca is complex, consisting of 13 sacs, of which, the basal one is small and oval. Moreover, the dorsal process of ectoproct in male is quite long, clearly distinguished from other *Thyridosmylus* species, in which it is inconspicuous when it is observed in lateral view.

Acknowledgements

We thank Dr. Brian L Fisher and Dr. Hu Li for providing specimens for examination. This research was supported by the National Natural Science Foundation of China (Grants 31272352, 31301905 and 41372013), the Beijing Natural Science Foundation (Grant 5132008), Ph.D. Programs Foundation of Ministry of Education of China (Grant 20131108120005) and the United States National Science Foundation (DEB1144119).

References

Fraser FC (1955) Nouvelles notes sur les Nevropteres de Madagascar. Naturaliste Malgache 7: 127–137.

Gerstaecker A (1884): Vier decaden von Neuropteren aus der Familie Megaloptera Burm. Mittheilungen aus dem Naturwissenschaftlichen Verein für Neu-Vorpommern und Rugen 16: 46–47.

Kimmins DE (1942) LXVIII. —The Genus *Thyridosmylus* Krüger, with Notes on the Subfamily Spilosmylinæ (Neuroptera Osmylidae). Journal of Natural History Series 11(9): 848–855. https://doi.org/10.1080/03745481.1942.9755527

Krüger L (1913) Osmylidae. Beiträge zu einer Monographie der Neuropteren-Familie der Osmyliden. II. Charakteristik der Familie, Unterfamilien und Gattungen auf Grund des Geäders. Stettiner Entomologische Zeitung 74: 3–123.

Navás L (1917) Notas sobre la familia de los Osmílidos (Ins. Neur.). Musei Barcinonensis Scientiarum Naturalium Opera 4(1): 1–21.

Navás L (1933) Neurópteros exóticos [1.a serie]. Memorias de la Real Academia de Ciencias y Artes de Barcelona 23: 203–216.

Oswald JD, Penny ND (1991) Genus-group names of the Neuroptera, Megaloptera and Raphidioptera of the world. Occasional papers of the California Academy of Sciences (USA) 147: 1–94. https://doi.org/10.5962/bhl.part.3428

Wang YJ, Du XG, Liu ZQ (2008) Two new species of *Thyridosmylus* Krüger, 1913 (Neuroptera Osmylidae) from China. Zootaxa 1793: 65–68

Wang YJ, Winterton SL, Liu ZQ (2011) Phylogeny and biogeography of *Thyridosmylus* (Neuroptera Osmylidae). Systematic Entomology 36: 330–339. https://doi.org/10.1111/j.1365-3113.2010.00565.x

Winterton SL, Wang YJ (2016) Revision of the genus *Gryposmylus* Krüger, 1913 (Neuroptera Osmylidae) with a remarkable example of convergence in wing disruptive patterning. Zookeys 617: 31–45. https://doi.org/10.3897/zookeys.617.10165

Winterton SL, Zhao J, Garzón-Orduña IJ, Wang YJ, Liu ZQ (2017) The phylogeny of lance lacewings (Neuroptera Osmylidae). Systematic Entomology 42(3): 555–574. https://doi.org/10.1111/syen.12231

Yang CK (1987) Neuroptera. In: Zhang S (Ed.) Agricultural insects, spiders, plant diseases and weeds of Xizang. Vol. 1. Xizang Renmin Press House, Tibet, 191–194.

Yang CK (1988) Neuroptera Osmylidae, Dilaridae, Hemerobiidae, Chrysopidae, Mantispidae, Myrmeleontidae, Ascalaphidae, Corydalidae. In: Huang FS (Ed.) Insects of Mt. Namjagbarwa Region of Xizang, Science Press, Beijing, 195–196. [In Chinese]

Yang CK (1992) Neuroptera. In: Chen S (Ed.) Insects of the Hengduan Mountains Region, Vol. 1. Science Press, Beijing, 440–441. [in Chinese]

Yang CK (1993) Three new species of Osmylidae (Neuroptera) from Guizhou. Entomotaxonomia 15: 261–264.

Yang CK (1999) Osmylidae. In: Huang BK. (Ed.) Fauna of Insects Fujian Province of China, Vol. 3. Fujian Science and Technology Press, Fuzhou, 96–99. [In Chinese]

Yang CK (2002) Neuroptera Osmylidae. In: Huang FS (Ed.) Forest Insects of Hainan. Science Press, Beijing, 282–283. [In Chinese]

Yang CK, Liu ZQ, Yang XK (1995) Neuroptera. In: Wu H (Ed.) Insects of Baishanzu Mountain, eastern China. China Forestry Publishing House, Beijing, 276–285. [In Chinese]

ZooKeys 724: 53–100 (2017)
doi: 10.3897/zookeys.724.21415
http://zookeys.pensoft.net

RESEARCH ARTICLE

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

Aquatic dance flies (Diptera, Empididae, Clinocerinae and Hemerodromiinae) of Greece: species richness, distribution and description of five new species

Marija Ivković[1], Josipa Ćevid[2], Bogdan Horvat[†], Bradley J. Sinclair[3]

1 Division of Zoology, Department of Biology, Faculty of Science, University of Zagreb, Rooseveltov trg 6, 10000 Zagreb, Croatia **2** *Zagrebačka 21, 22320 Drniš, Croatia* **3** *Canadian National Collection of Insects & Canadian Food Inspection Agency, Ottawa Plant Laboratory – Entomology, Ottawa, Canada* **†** *Deceased, formerly with Slovenian Museum of Natural History*

Corresponding author: *Bradley J. Sinclair* (bradley.sinclair@inspection.gc.ca)

Academic editor: *D. Whitmore* | Received 3 October 2017 | Accepted 6 December 2017 | Published 21 December 2017

http://zoobank.org/BCDF3F20-7E27-4CCF-A474-67DA61308A78

Citation: Ivković M, Ćevid J, Horvat B, Sinclair BJ (2017) Aquatic dance flies (Diptera, Empididae, Clinocerinae and Hemerodromiinae) of Greece: species richness, distribution and description of five new species. ZooKeys 724: 53–100. https://doi.org/10.3897/zookeys.724.21415

Abstract

All records of aquatic dance flies (37 species in subfamily Clinocerinae and 10 species in subfamily Hemerodromiinae) from the territory of Greece are summarized, including previously unpublished data and data on five newly described species (*Chelifera horvati* Ivković & Sinclair, **sp. n.**, *Wiedemannia iphigeniae* Ivković & Sinclair, **sp. n.**, *W. ljerkae* Ivković & Sinclair, **sp. n.**, *W. nebulosa* Ivković & Sinclair, **sp. n.** and *W. pseudoberthelemyi* Ivković & Sinclair, **sp. n.**). The new species are described and illustrated, the male terminalia of *Clinocera megalatlantica* (Vaillant) are illustrated and the distributions of all species within Greece are listed. The aquatic Empididae fauna of Greece consists of 47 species, with the following described species reported for the first time: *Chelifera angusta* Collin, *Hemerodromia melangyna* Collin, *Clinocera megalatlantica*, *Kowarzia plectrum* (Mik), *Phaeobalia dimidiata* (Loew), *W.* (*Chamaedipsia*) *beckeri* (Mik), *W.* (*Philolutra*) *angelieri* Vaillant and *W.* (*P.*) *chvali* Joost. A key to species of aquatic Empididae of Greece is provided for the first time. Information related to the European Ecoregions in which species were found is given. Compared to the other studied countries in the Balkans, the Greek species assemblage is most similar to that of the Former Yugoslav Republic of Macedonia.

Keywords

Clinocerinae, Hemerodromiinae, new species, key to species, faunistics, European Ecoregions, Greece

Introduction

The aquatic dance flies of the family Empididae (Diptera) comprise the subfamilies Clinocerinae and Hemerodromiinae. Larvae mostly live in aquatic habitats and both larvae and adults are predators, primarily feeding on Simuliidae (Vaillant 1952, 1953, Werner and Pont 2003) and Chironomidae (Vaillant 1967, Harkrider 2000, Ivković et al. 2007). Adult Hemerodromiinae are distinguished by raptorial forelegs and live and hunt in riparian vegetation. On the other hand, adult Clinocerinae are primarily found on the surface of emergent wet stones or in moss mats (Wagner 1997, Ivković et al. 2007).

The aquatic dance fly fauna of Greece has been sporadically investigated during the last few decades. The first records were noted by Vaillant and Wagner (1990), Wagner (1981, 1990, 1995), Wagner and Horvat (1993), and recently by Ivković et al. (2012).

Distribution and diversity studies are of immense importance in studying factors that influence and determine diversity hotspots (Ivković and Plant 2015, Schmidt-Kloiber et al. 2017). The present paper is based on detailed analysis of all publications on Greek aquatic dance flies known to the authors. The authors have also contributed additional records of Greek aquatic dance flies resulting from the examination of specimens collected by colleagues who surveyed 258 sites sampled in the late 1980s and early 1990s. In addition, one new species of *Chelifera* Macquart and four new species of *Wiedemannia* Zetterstedt are herein described.

Material and methods

Specimen records. This paper is based on a review of the literature, and primarily on unpublished data and specimens from Bogdan Horvat's study of the aquatic dance fly fauna of Greece. Wherever possible, each literature record and specimen record was georeferenced as precisely as possible using ArcGIS software. The names of taxa reflect current nomenclature and classifications (Sinclair 1995, Yang et al. 2007). The literature used for identifications included Engel (1939, 1940), Vaillant and Wagner (1990), Wagner (1981, 1990, 1995), Wagner and Horvat (1993) and Ivković et al. (2012). Locality records are listed for each species. A list of locality names including latitude, longitude, altitude and number codes (site ID) for the localities is presented in Table 1 and a map showing the locations of all the georeferenced sites is also provided (Fig. 1). Specimens were collected using sweep nets and by aspirator. They were preserved in 80% ethanol (EtOH). For the purpose of determination, male terminalia were dissected, boiled in 10% KOH and afterwards neutralized with acetic acid, rinsed in water and identified to species level; or they were macerated in hot 85% lactic acid and stored in 80% ethanol along with the remaining body parts in the same tube. In the genitalia illustrations, only the sockets of the setae are shown on the epandrium; the setae are not drawn. All specimens listed in the material examined sections were collected by Bogdan Horvat, Ignac Sivec, Hans Malicky and

Table 1. List of sampling sites in Greece. European Ecoregions are taken from Illies (1978): Hellenic Western Balkan (6) and Eastern Balkan (7).

Site ID	Site name	Latitude	Longitude	Altitude (m)	Ecoregion
1	Thrace, E of Mega Derio	N41°13'10"	E26°03'03"	200	7
2	Thrace, W of Mega Derio	N41°11'29"	E25°57'30"	710	7
3	Thrace, Lesitse Mts.	N41°07'28"	E25°57'04"	760	7
4	Thrace, E of Sapka Mts., big stream in the valley	N41°08'	E25°57'	600	7
5	Thrace, N of Avas	N41°00'07"	E25°55'36"	200	7
6	Thrace, Sapka Mts. 1	N41°09'56"	E25°55'17"	735	7
7	Thrace, 3 km N of Alexandroupoli	N40°54'	E25°55'	100	7
8	Thrace, Sapka Mts. 2	N41°11'02"	E25°54'40"	545	7
9	Thrace, Sapka Mts., Nea Sanda 1	N41°07'02"	E25°50'02"	200	7
10	Thrace, Sapka Mts., Nea Sanda 2	N41°07'06"	E25°49'43"	220	7
11	Thrace, Anatoliki Rodopi, E od Drimi	N41°13'26"	E25°35'35"	240	7
12	Thrace, Anatoliki Rodopi, Drimi	N41°12'52"	E25°34'34"	180	7
13	Thrace, Anatoliki Rodopi, E of Gratini 1	N41°10'10"	E25°34'29"	100	7
14	Thrace, Anatoliki Rodopi, E of Gratini 2	N41°10'10"	E25°34'29"	160	7
15	Thrace, Samothrace, hygropetric at the church of Kreminotissa	N40°25'	E25°34'	400	7
16	Thrace, Miki	N41°14'	E24°55'	340	7
17	Thrace, 8 km N of Sminthi	N41°14'49"	E24°51'44"	300	7
18	Thrace, N of Xanthi	N41°11'39"	E24°51'08"	200	7
19	Thrace, N of Dipotama 1	N41°24'28"	E24°40'10"	1430	7
20	Thrace, N of Dipotama 2	N41°24'50"	E24°38'51"	1310	7
21	Thrace, Dit. Rodopi, N of Dipotama 1	N41°25'07"	E24°38'22"	1290	7
22	Thrace, N of Dipotama 3	N41°23'53"	E24°38'06"	1030	7
23	Thrace, N of Dipotama 4	N41°24'47"	E24°37'56"	1340	7
24	Thrace, N of Dipotama 5	N41°24'24"	E24°37'19"	1400	7
25	Thrace, Dit. Rodopi, N of Dipotama 2	N41°23'	E24°37'	1000	7
26	Thrace, Dit. Rodopi, N of Dipotama 3	N41°24'14"	E24°36'45"	1415	7
27	Thrace, S of Dipotama	N41°21'22"	E24°36'20"	440	7
28	Thrace, S of Silli	N41°20'40"	E24°33'50"	315	7
29	Thrace, Rodopi, Skaloti	N41°24'	E24°17'	1090	7
30	Thrace, Rodopi 1	N41°33'00"	E24°16'25"	1400	7
31	Thrace, N of Sidironero 1	N41°26'42"	E24°14'46"	930	7
32	Thrace, Rodopi 2	N41°28'48"	E24°14'40"	945	7
33	Thrace, N of Sidironero 2	N41°22'50"	E24°13'04"	910	7
34	Thrace, W of Sidironero	N41°23'13"	E24°12'03"	500	7
35	Thrace, Rodopi, E of Mikromilia	N41°25'22"	E24°10'04"	670	7
36	Thrace	Unspecified			7
37	Macedonia, Dit. Rodopi, Elatia forest	N41°29'	E24°19'	1450	7
38	Macedonia, E of Mikroklisoura	N41°23'14"	E24°03'48"	370	7
39	Macedonia, N of Stavros	N40°40'	E23°39'	100	7
40	Macedonia, R. Mavroneri, 10 km W of Katerini	N40°11'	E22°24'	160	6
41	Macedonia, Olympus Mts. above Agios Dyonysos, Prionia	N40°04'	E22°22'	1050–1700	6
42	Macedonia, Pieria Mts., 2 streams on Ritini	N40°17'	E22°16'	800	6
43	Macedonia, N of Agios Dimitrios	N40°10'	E22°16'	660	6
44	Macedonia, Pieria Mts., S of Elatohori	N40°15'	E22°15'	1010	6

Site ID	Site name	Latitude	Longitude	Altitude (m)	Ecoregion
45	Macedonia, S of Agios Dimitrios	N40°08'37"	E22°13'07"	860	6
46	Macedonia, Pieria Mts., E of Fteri	N40°11'52"	E22°12'42"	840	6
47	Macedonia, Pieria Mts., Fteri	N40°11'	E22°09'	1080	6
48	Macedonia, Pieria Mts., W of Fteri	N40°11'49"	E22°08'20"	1440	6
49	Macedonia, W of Daskio	N40°19'32"	E22°08'14"	460	6
50	Macedonia, Pieria Mts., E of Velventos	N40°14'05"	E22°07'51"	1330	6
51	Macedonia, Pieria Mts., 1	N40°10'35"	E22°06'54"	1500	6
52	Macedonia, Pieria Mts., 2	N40°13'42"	E22°06'37"	1270	6
53	Macedonia, Pieria Mts., 3	N40°11'35"	E22°05'31"	1480	6
54	Macedonia, E of Velventos	N40°16'54"	E22°05'11"	420	6
55	Macedonia, Phalacro Mts., N of Livadero	N40°03'	E21°53'	690	6
56	Macedonia, Grevena, Milea	N40°08'	E21°31'	480	6
57	Macedonia, Grevena, 6 km S of Milea	N40°07'	E21°30'	470	6
58	Macedonia, Grevena, stream S of R. Aliakmon by Kamilas Pigi	N40°02'	E21°27'	600	6
59	Macedonia, Kozani, Polilako (Paraveti), Neapolis	N40°18'	E21°25'	550	6
60	Macedonia, Grevena, R. Venetikos, Kipourio	N39°59'	E21°22'	500	6
61	Macedonia, Vernon, influx of Aliakmon between Gavros and Aposkepos	N40°39'	E21°11'	450	6
62	Macedonia, Kastoria, Nestorio	N40°24'	E21°04'	800	6
63	Macedonia, Smokilas Mts., main stream near the bridge, 2 km E of Agia Paraskevi	N40°08'	E21°00'	1100	6
64	Macedonia, Kastoria, Grammos Mts., 7 km S Chrisi	N40°14'	E20°52'	650	6
65	Macedonia, Kastoria, Grammos Mts., 6 km N Pefkofito	N40°19'	E20°50'	1500	6
66	Macedonia, Chalkidiki, Chlomon Oros., Paleokastron, Vatonia P. 1	Unspecified		550	/
67	Macedonia, Chalkidiki, Chlomon Oros., Paleokastron, Vatonia P. 2	Unspecified		1500	/
68	Macedonia, Chalkidiki, Chlomon Oros., valley on the southern slope	Unspecified		650	/
69	Macedonia, Xanthi, NE Pass Str. Xanthi-Stavroupolis	Unspecified		800	7
70	Thessaly, Portaria	N39°23'	E23°01'	700	6
71	Thessaly, Ossa Mts., stream Apataniana	N39°50'	E22°42'	1200	6
72	Thessaly, Karya	N40°00'	E22°26'	750–800	6
73	Thessaly, S of Kallithea	N39°58'35"	E22°12'49"	510	6
74	Thessaly, Pieria Mts., S of Livadi	N40°06'20"	E22°10'11"	800	6
75	Thessaly, 5 km W of Palea Giannitsou	N39°03'	E22°01'	500	6
76	Thessaly, Deskati	N39°56'53"	E21°54'30"	690	6
77	Thessaly, Trikala, Longiai	N39°34'	E21°45'	100	6
78	Thessaly, S of Asprokklisia	N39°49'56"	E21°42'48"	500	6
79	Thessaly, Trikala, Moshofito, Avra	N39°42'	E21°42'	200	6
80	Thessaly, Kalambaka, Agios Nikolaos	N39°43'	E21°35'	200	6
81	Thessaly, Trikala, Stournareika	N39°26'	E21°31'	400	6
82	Thessaly, Trikala, Kato Palagokaria	N39°25'	E21°30'	600	6
83	Thessaly, Kalambaka, 5 km E of Paleochori	N39°37'	E21°28'	600	6

Site ID	Site name	Latitude	Longitude	Altitude (m)	Ecoregion
84	Thessaly, Kalambaka, Paleochori	N39°36'	E21°25'	1000	6
85	Thessaly, Kalambaka, Trigona	N39°46'	E21°24'	400	6
86	Thessaly, Kalambaka, Koridallos	N39°46'	E21°22'	450	6
87	Thessaly, Trikala, Arta, Pahtouri	N39°27'	E21°16'	600	6
88	Thessaly, Trikala, Arta, R. Ahelos, Kapsala	N39°22'	E21°16'	500	6
89	Thessaly, Trikala, Arta, Korifi	N39°25'	E21°15'	600	6
90	Thessaly, Trikala, 9 km S of Chrisomilea	Unspecified			6
91	Thessaly, Kalambaka, 4 km S of Ambelia	Unspecified			6
92	Epirus, Metsovo, 14 km S of Milea	N39°44'	E21°17'	900	6
93	Epirus, Metsovo, Lakmos Mts., Anilio (5 km S bellow river)	N39°43'	E21°16'	1300	6
94	Epirus, Pindus Mts., Metsovo, meadow source easthang	N39°46'	E21°12'	1350	6
95	Epirus, N of Katarapass, 1 km SW Milea	N39°50'	E21°11'	1300	6
96	Epirus, Metsovo, Katara Pass	N39°48'	E21°10'	1350	6
97	Epirus, Metsovo, Lakmos Mts., 2 km S of Anilio (bellow left tributary)	N39°44'	E21°10'	840	6
98	Epirus, Metsovo, 12 km W Milea	N39°51'	E21°09'	1250	6
99	Epirus, Metsovo, R. Metsovitikos	N39°44'	E21°09'	800	6
100	Epirus, Metsovo, Lakmos Mts., Anthohori, (bellow rapid river)	N39°44'	E21°08'	780	6
101	Epirus, Lakmos Mts., 10 km S of Anilio	N39°36'	E21°07'	1150	6
102	Epirus, Metsovo, Lakmos Mts., Anilio (15 km S influx)	N39°33'	E21°06'	500	6
103	Epirus, Metsovo, 14 km W of Milea	N39°55'	E21°03'	1000	6
104	Epirus, Ioannina, Megalo Peristeri	N39°44'	E21°03'	600	6
105	Epirus, Xerovouni Mts., Plaka, R. Arachthos, u. Agnatha	N39°20'	E21°02'	200	6
106	Epirus, Ioannina, R. Zagoritikos, Karies	N39°44'	E20°56'	500	6
107	Epirus, Konitsa, Smolikas Mts., Pournia	N40°08'	E20°54'	1100	6
108	Epirus, Konitsa, R. Saradaporos, Drosopigi	N40°08'	E20°53'	900	6
109	Epirus, Konitsa, Asimohori	N40°02'	E20°44'	450	6
110	Epirus, 10 km N of Louros	N39°14'22"	E20°42'05"	200	6
111	Epirus, S of Seriziana	N39°17'07"	E20°41'37"	200	6
112	Epirus, Ioannina, R. Voidomatis, Aristi	N39°56'	E20°41'	400	6
113	Epirus, Preveza, Zalongu, stream 2 km E of Mirsini	N39°07'	E20°39'	180	6
114	Epirus, W of Kriopigi	N39°09'30"	E20°38'18"	170	6
115	Epirus, R. Aheron, N of Gliki	N39°21'34"	E20°37'52"	200	6
116	Epirus, Kanallaki, Skepaston	N39°13'	E20°37'	100	6
117	Epirus, Mirsini	N39°08'	E20°37'	120	6
118	Epirus, R. Aheron, Gliki	N39°19'	E20°36'	50	6
119	Epirus, R. Kokitos, W of Gardiki	N39°21'	E20°33'	50	6
120	Epirus, R. Kokitos, Themelo	N39°15'	E20°31'	40	6
121	Epirus, Igoumenitsa, Thesprotia, R. Thiamis, Neohori	N39°31'	E20°22'	30	6
122	Epirus, Igoumenitsa, R. Thiamis, Soulopoulo	N39°33'	E20°12'	5	6
123	Epirus, Ioannina, R. Vardas, Abelos	Unspecified			6
124	Epirus, Ioannina, Balndouma	Unspecified			6

Site ID	Site name	Latitude	Longitude	Altitude (m)	Ecoregion
125	North Aegean islands, Samos, below Manolates	N37°47'	E26°49'	160	6
126	North Aegean islands, Samos, E of Pirgos	N37°43'	E26°49'	300	6
127	North Aegean islands, Lesbos, 7 km E of Plomari	N38°59'	E26°26'	110	6
128	North Aegean islands, Lesbos, 1 km W of Ippion	N39°08'	E26°24'	70	6
129	North Aegean islands, Lesbos, 1 km SW of Megalochori	N39°01'	E26°21'	280	6
130	North Aegean islands, Lesbos, 3 km NW of Agiasos	N39°06'	E26°20'	320	6
131	North Aegean islands, Lesbos, 4 km W of Agiasos	N39°06'	E26°20'	400	6
132	North Aegean islands, Lesbos, 2 km N of Akrassi	N39°03'	E26°19'	370	6
133	North Aegean islands, Lesbos, S of Neochorion	N39°01'	E26°19'	270	6
134	North Aegean islands, Lesbos, Ambeliko	N39°04'	E26°18'	340	6
135	North Aegean islands, Lesbos, E of Lepetimnos	N39°22'	E26°16'	330	6
136	North Aegean islands, Icaria, W of Chrisostomos	N37°35'	E26°13'	270	6
137	North Aegean islands, Chios, 2 km N of Fita	N38°32'	E26°00'	510	6
138	North Aegean islands, Chios, N of Keramos	N38°34'	E25°56'	60	6
139	North Aegean islands, Chios, 5 km N of Pirama	N38°32'	E25°54'	170	6
140	North Aegean islands, Icaria	Unspecified			6
141	North Aegean islands, Lesbos	Unspecified			6
142	Central Greece, Euboea, S of Komiton	N38°30'	E24°00'	540	6
143	Central Greece, Euboea, Steni Dirfyos (former Ano Steni)	N38°35'	E23°49'	550	6
144	Central Greece, Polydrosos	N38°36'	E22°34'	1060–1250	6
145	Central Greece, Etolia, Lamia, Ieraklia	N38°49'	E22°26'	25	6
146	Central Greece, Parnassus Mts., above Polydrosos	N38°33'	E22°26'	1000	6
147	Central Greece, Oeta Mts., between Kastanea and Katafygio	N38°50'	E22°17'	1400	6
148	Central Greece, Etolia, Vardousia Mts., Stromi	N38°42'	E22°15'	820	6
149	Central Greece, Etolia, Vardousia Mts., Mousonitsa	N38°41'	E22°12'	650	6
150	Central Greece, Etolia, Vardousia Mts., Athanasios Diakos	N38°42'	E22°11'	830	6
151	Central Greece, Etolia, Vardousia Mts., Paleovraha	N38°55'	E22°04'	170	6
152	Central Greece, Etolia, Nafpaktos, 9 km S of Krokilio	N38°28'	E22°04'	1000	6
153	Central Greece, Etolia, Vardousia Mts., 5 km N of Grammeni Oxia	N38°45'	E22°00'	1150	6
154	Central Greece, Etolia, Vardousia Mts., R. Evinos, Grammeni Oxia	N38°43'	E22°00'	800	6
155	Central Greece, Etolia, Vardousia Mts., 9 km N of Grammeni Oxia	N38°47'	E21°59'	1050	6

Site ID	Site name	Latitude	Longitude	Altitude (m)	Ecoregion
156	Central Greece, Etolia, Vardousia Mts., 7 km N of Grammeni Oxia	N38°46'	E21°59'	1400	6
157	Central Greece, Etolia, Vardousia Mts., 7 km S of Gardiki	N38°45'	E21°59'	1300	6
158	Central Greece, Etolia, Vardousia Mts., Terpsithea	N38°33'	E21°59'	570	6
159	Central Greece, Etolia, Nafpaktos, R. Mornos, Limnitsa	N38°30'	E21°59'	200	6
160	Central Greece, Etolia, Vardousia Mts., Elatovrisi	N38°39'	E21°58'	750	6
161	Central Greece, Etolia, Vardousia Mts., Elato	N38°35'	E21°58'	1000	6
162	Central Greece, Etolia, Vardousia Mts., 6 km S of Lefkada	N38°52'	E21°57'	500	6
163	Central Greece, Etolia, Vardousia Mts., Gardiki	N38°51'	E21°57'	580	6
164	Central Greece, Etolia, Vardousia Mts., 13 km S of Gardiki	N38°43'	E21°57'	700	6
165	Central Greece, Etolia, Vardousia Mts., Pougkakia	N38°51'	E21°56'	600	6
166	Central Greece, Etolia, Vardousia Mts., 2 km W of Gardiki	N38°49'	E21°56'	1100	6
167	Central Greece, Etolia, Vardousia Mts., Grigorio	N38°38'	E21°56'	1400	6
168	Central Greece, Tymfristos Mts., R. Sperhios, Lamia	N38°54'	E21°55'	550	6
169	Central Greece, Etolia, Vardousia Mts., Ano Chora	N38°36'	E21°55'	700	6
170	Central Greece, Etolia, Panaitoliko Mts., Klepa	N38°41'	E21°54'	700	6
171	Central Greece, Etolia, Panaitoliko Mts., R. Evinos, Klepa	N38°40'	E21°54'	500	6
172	Central Greece, Etolia, Vardousia Mts., 3 km W of Kryoneri	N38°38'	E21°54'	1100	6
173	Central Greece, Etolia, Vardousia Mts., Kato Chora	N38°36'	E21°53'	600	6
174	Central Greece, Etolia, Nafpaktos, Anthofito	N38°28'	E21°52'	100	6
175	Central Greece, Karpenisi, Agios Nikolaos	N38°53'	E21°51'	1000	6
176	Central Greece, Etolia, Nafpaktos, tributory of R. Evinos, 6 km N of Pokista	N38°35'	E21°51'	460	6
177	Central Greece, Etolia, R. Mornos, Nafpaktos	N38°23'	E21°51'	10	6
178	Central Greece, Etolia, Agrinio, Panaitoliko Mts., R. Evinos, Agios Dimitros	N38°39'	E21°49'	400	6
179	Central Greece, Etolia, Nafpaktos, 2 km N of Pokista	N38°34'	E21°48'	350	6
180	Central Greece, Etolia, Nafpaktos, Simos	N38°30'	E21°48'	350	6
181	Central Greece, Etolia, Nafpaktos, Pokista	N38°34'	E21°47'	370	6
182	Central Greece, Etolia, Agrinio, Peristra, 1 km S of Perkos	N38°38'	E21°45'	300	6
183	Central Greece, Etolia, Agrinio, R. Evinos, Kato Hrisovitsa, Diasellaki	N38°34'	E21°43'	230	6
184	Central Greece, Panaitoliko Mts., R. Tavropos, Kalesmeno	N38°56'	E21°40'	300	6

Site ID	Site name	Latitude	Longitude	Altitude (m)	Ecoregion
185	Central Greece, Etolia, Agrinio, Panaitoliko Mts. R. Trikeriotis, Dermatio	N38°47'	E21°40'	400	6
186	Central Greece, Etolia, Panaitoliko Mts., Prousos	N38°44'	E21°39'	660	6
187	Central Greece, Etolia, Panaitoliko Mts., Chaliki, Ladikon	N38°41'	E21°39'	900	6
188	Central Greece, Etolia, Panaitoliko Mts., Chaliki, Nerosirtis	N38°40'	E21°39'	750	6
189	Central Greece, Etolia, Agrinio, Panaitoliko Mts., Anatoliki Frangista	N38°56'	E21°37'	800	6
190	Central Greece, Etolia, Agrinio, Panaitoliko Mts., Potamoula	N38°44'	E21°26'	200	6
191	Central Greece, Etolia, Agrinio, Agia Soufia	N38°36'	E21°26'	100	6
192	Central Greece, Etolia, Lamia, Pavliani	N38°44'	E21°21'	100	6
193	Central Greece, Etolia, Agrinio, Panaitoliko Mts., Megali Chora	N38°38'	E21°21'	40	6
194	Central Greece, Etolia, Giona Mts., Sikia	N38°38'	E21°11'	510	6
195	Central Greece, Oeta Mts., stream Valorema, Pavliani	Unspecified		1600	6
196	Central Greece, Etolia, Agrinio, Ahlavokastro	Unspecified			6
197	Central Greece, Etolia, Arta, Loutraki	Unspecified			6
198	Central Greece, Etolia, Agrinio, Panaitoliko Mts., Houni	Unspecified			6
199	Central Greece, Etolia, Agrinio, Panaitoliko Mts., Palagohori	Unspecified			6
200	Central Greece, Etolia, Nafpaktos, Avrorema bridge	Unspecified			6
201	Central Greece, Central Euboea	Unspecified			6
202	Central Greece, Etolia, Agrinio, Panaitoliko Mts., 3 km N of Hani Lioliou	Unspecified			6
203	Central Greece, Etolia, Nafpaktos, Koutsopanneika	Unspecified			6
204	Dodecanese islands, Rhodes, 3 km E of Archipolis	N36°15'	E28°06'	100	6
205	Dodecanese islands, Rhodes, near Archipolis	N36°15'	E28°03'	200	6
206	Cyclades islands, Naxos, S of Koronis	N37°08'	E25°32'	630	6
207	Cyclades islands, Andros, Apikia	N37°51'	E24°54'	220	6
208	Cyclades islands, Andros	Unspecified			6
209	Peloponnese, Taygetos Mts. (below summit)	N36°56'	E22°23'	900	6
210	Peloponnese, village Akrata	N38°09'	E22°18'	80	6
211	Peloponnese, R. Krathis, Voutsimos	N38°08'	E22°16'	160	6
212	Peloponnese, Aroania Mts., 2 km S of Zarouchla	N37°58'	E22°16'	1200	6
213	Peloponnese, 3 km N of Agia Varvara	N38°01'	E22°15'	900	6
214	Peloponnese, R. Krathis, 7 km N of Peristera	N38°05'	E22°14'	600	6
215	Peloponnese, tributary of R. Krathis, 7 km N of Peristera	N38°03'	E22°14'	720	6
216	Peloponnese, 2 km N of Peristera	N38°02'	E22°14'	800	6
217	Peloponnese, R. Krathis, Peristera	N38°00'	E22°14'	1000	6

Site ID	Site name	Latitude	Longitude	Altitude (m)	Ecoregion
218	Peloponnese, Aroania Mts., 4 km S of Solos	N37°59'	E22°14'	1250	6
219	Peloponnese, Ano Potames, Kalivitis	N38°07'	E22°13'	670	6
220	Peloponnese, Aroania Mts., Zarouhla	N37°59'	E22°13'	1100	6
221	Peloponnese, Aroania Mts., below Xelmos , Valtos, Zarelia	N37°55'	E22°12'	830	6
222	Peloponnese, Likouria (below village)	N37°51'	E22°12'	700	6
223	Peloponnese, Aroania Mts., Kalivia	N37°50'	E22°10'	470	6
224	Peloponnese, Aroania Mts., Krinofita	N37°49'	E22°10'	460	6
225	Peloponnese, Pagrati	N37°49'	E22°09'	450	6
226	Peloponnese, Aroania Mts., Kastria	N37°56'	E22°08'	670	6
227	Peloponnese, Kato Klitoria	N37°53'	E22°08'	500	6
228	Peloponnese, Aroania Mts., Xelmos (above)	N38°02'	E22°06'	700	6
229	Peloponnese, Labia Mts., Amigdalia	N37°49'	E22°06'	440	6
230	Peloponnese, R. Piro, Elliniko	N37°30'	E22°02'	220	6
231	Peloponnese, Panachaiko Mts., tributory of R. Selinous, Leontio	N38°06'	E21°56'	700	6
232	Peloponnese, Panachaiko Mts., Leontio	N38°06'	E21°55'	640	6
233	Peloponnese, Erymanthos Mts., Lechouri	N37°54'	E21°55'	660	6
234	Peloponnese, Panachaiko Mts., Veteika	N38°08'	E21°54'	970	6
235	Peloponnese, Erymanthos Mts., Kato Vlasia	N38°00'	E21°54'	740	6
236	Peloponnese, Panachaiko Mts., Kounaveika (near village)	N38°08'	E21°53'	950	6
237	Peloponnese, Panachaiko Mts., Moira	N38°09'	E21°51'	750	6
238	Peloponnese, Panachaiko Mts., Moira (after village)	N38°08'	E21°51'	800	6
239	Peloponnese, Erymanthos Mts., Profitis Ilias	N38°02'	E21°51'	480	6
240	Peloponnese, Ano Kastritsi, stream	N38°16'	E21°50'	500	6
241	Peloponnese, Erymanthos Mts., Stavrohori, Eliniko	N38°03'	E21°50'	380	6
242	Peloponnese, Panachaiko Mts., Souli	N38°11'	E21°48'	380	6
243	Peloponnese, Erymanthos Mts., S of Spartia	N37°58'	E21°46'	800	6
244	Peloponnese, Erymanthos Mts., Manesi	N37°59'	E21°43'	350	6
245	Peloponnese, Stavrodromi	N37°56'	E21°40'	280	6
246	Peloponnese, Abelokipi	Unspecified			6
247	Peloponnese, E of Olympia	Unspecified		630	6
248	Peloponnese, Panachaiko Mts., Kristalovrisi (stream)	Unspecified			6
249	Peloponnese, Erymanthos Mts., Kalamata	Unspecified			6
250	Crete, E of Agios Ioannis	N35°03'	E25°50'	400	6
251	Crete, E of Ierepetra	N35°00'	E25°47'	0	6
252	Crete, stream next to Sises	N35°24'	E24°54'	50	6
253	Crete, Passas valley near Pass	N35°12'	E24°54'	1300	6
254	Crete, S of Retimnon	N35°20'	E24°27'	230	6
255	Crete, Georgioupolis	N35°22'	E24°15'	0	6
256	Crete, Xyloskalon	N35°18'	E23°56'	620	6
257	Crete, stream near Kotsifiana	N35°24'	E23°45'	500	6
258	Laschtabend (Alpen)	Unspecified		1200	/

Reinhard Gerecke. Taxonomic diversity is considered at the level of subfamily, genus, subgenus and species. The European Ecoregions are those of Limnofauna Europaea (Illies 1978), where they are defined at a large European scale and based on the biogeography of aquatic macroinvertebrates.

Label data for primary types are cited from the top of the pin downward, with the data from each label in quotation marks. Labels are cited in full, with original spelling, punctuation, and dates, and label lines are delimited by a slash (/). Additional information is included in square [ ] brackets. The repository of each type is given in parentheses. Secondary type data are abridged and listed alphabetically. This study is based on material housed in the following institutions: Canadian National Collection of Insects, Ottawa, Canada (CNC); col. M. Ivković, University of Zagreb, Croatia (UZC); col. Empididae, Slovenian Museum of Natural History, Ljubljana, Slovenia (SMNH). Terms used for adult structures primarily follow those of Cumming and Wood (2009), except for the antenna and wing venation, where the terminologies of Stuckenberg (1999) and Saigusa (2006) are used, respectively. In the system outlined by Saigusa (2006), the dipteran wing vein A_1 (as used in McAlpine 1981) is homologized with the mecopteran vein CuP, and consequently CuA_1 (of McAlpine) is termed M_4, whereas CuA_2 is CuA, the anal cell is cell cua and the anal vein (A_1+CuA_2) is CuA+CuP. Homologies of the male terminalia follow those of Sinclair and Cumming (2006). Species of *Wiedemannia* described herein will not be assigned to a subgenus because we consider current subgeneric concepts confused and mostly not monophyletic (Ivković et al. 2012).

Data analysis. A list of species was compiled from all specimen data (Table 2). Comparison of species richness and assemblage composition with published records from studied countries in the Balkans (Slovenia, Croatia, Bosnia & Herzegovina, Montenegro and Former Yugoslav Republic of Macedonia) was conducted by compiling species lists for those countries taken from Wagner (1981, 1995), Horvat (1993, 1995a, 1995b, 1997) and Ivković et al. (2013a, 2013b, 2014). A species by country matrix was constructed and the Sørensen Index of Similarity of each pairwise comparison (Table 3) was calculated using the Primer v6 software (Clarke and Gorley 2006).

Taxonomy

Clinocerinae

Wiedemannia iphigeniae Ivković & Sinclair, sp. n.

http://zoobank.org/584FDF48-D85B-4953-9F7E-079DF489B9C5
Figs 1, 6, 7

Type locality. Greece: Peloponnese, Aroania Mts., Krinofita, 37°49'00"N, 22°10'00"E.

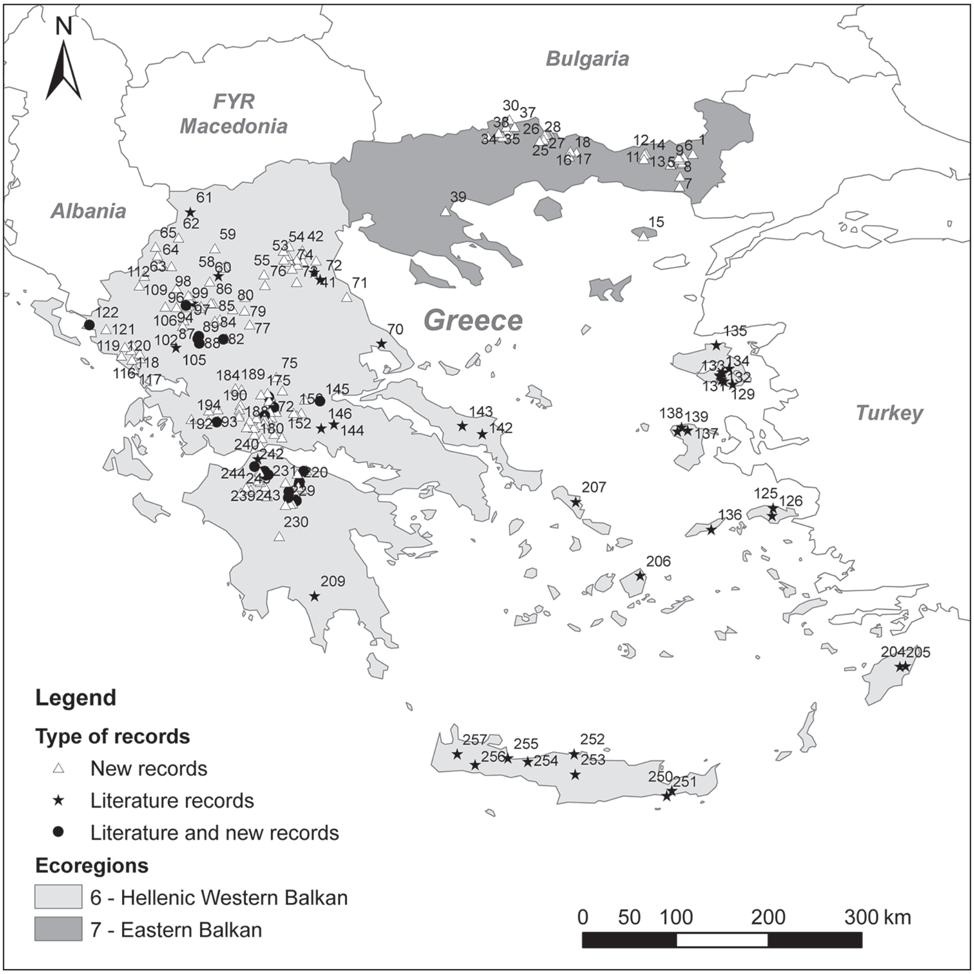


Figure 1. Sampling sites of aquatic Empididae recorded from Greece (see Table 1 for codes).

Type material. Holotype ♂, labelled: "GREECE, Peloponnese/ Aroania Mts., Krinofita/ 37°49'00"N, 22°10'00"E/ 20.iv.1990/ leg. B. Horvat, I. Sivec"; "HOLOTYPE/ *Wiedemannia/ iphigeniae/* Ivković & Sinclair" (CNC, dried from alcohol).

Diagnosis. This species of *Wiedemannia* is distinguished by the apically pointed unilobed cercus with small basal projection and a narrow pterostigma on the wings.

Description. Male. Body length approx. 3.5 mm (holotype dissected prior to measurement), wing length 3.7 mm (colouration bleached by prolonged storage in alcohol). Head in lateral view higher than long; gena narrow, nearly one-third height of eye. Frons short, broader than face. Face wide, with distinct carina on lower margin, bare, lacking setae. One pair of ocellar and one pair of vertical setae; about 5 distinct upper postoculars, subequal in size; lower postocular setae finer and merging

Table 2. List of Greek aquatic dance flies and summary of their distribution. European Ecoregions are taken from Illies (1978): Hellenic Western Balkan (6) and Eastern Balkan (7).

Species	Distribution	Ecoregion
Hemerodromiinae		
Chelifera angusta Collin, 1927	Europe, Asia	6
Chelifera barbarica Vaillant, 1982	Southern Europe, North Africa	6
Chelifera horvati sp. n.	Greece	6
Chelifera precabunda Collin, 1961	Widespread in Europe	6, 7
Chelifera precatoria (Fallén, 1816)	Widespread in Europe	6
Chelifera stigmatica (Schiner, 1862)	Widespread in Europe	6, 7
Chelifera trapezina (Zetterstedt, 1838)	Widespread in Europe	6
Hemerodromia melangyna Collin, 1927	Europe	6
Hemerodromia oratoria (Fallén, 1816)	Widespread in Europe, Asia	6, 7
Hemerodromia unilineata Zetterstedt, 1842	Europe	6, 7
Clinocerinae		
Clinocera megalatlantica (Vaillant, 1957)	Greece, Morocco	7
Clinocera nigra Meigen, 1804	Europe, North Africa, Asia	6
Clinocera stagnalis (Haliday, 1833)	Europe, North Africa, Asia, and northern North America	6, 7
Clinocerella siveci (Wagner & Horvat, 1993)	Greece	6
Dolichocephala cretica Wagner, 1995	Greece (Crete)	6
Dolichocephala guttata (Haliday, 1833)	Widespread in Europe	6, 7
Dolichocephala ocellata (Costa, 1854)	Europe, North Africa	6
Dolichocephala vaillanti Wagner, 1995	Greece (Crete)	6
Dolichocephala zwicki Wagner, 1995	Balkan region, Greece Islands	6
Kowarzia barbatula (Mik, 1880)	Europe, Asia Minor	6, 7
Kowarzia bipunctata (Haliday, 1833)	Widespread in Europe, North Africa	6, 7
Kowarzia madicola (Vaillant, 1965)	Central and southern Europe	6
Kowarzia plectrum (Mik, 1880)	Europe, Asia Minor	6
Phaeobalia dimidiata (Loew, 1869)	Europe	6, 7
Roederiodes malickyi Wagner, 1981	Greece (Crete)	6
Wiedemannia (*Chamaedipsia*) *aequilobata* Mandaron, 1964	Southern Europe	6
Wiedemannia (*Chamaedipsia*) *ariadne* Wagner, 1981	Balkan region, Greece Islands	6
Wiedemannia (*Chamaedipsia*) *beckeri* (Mik, 1889)	Europe	7
Wiedemannia (*Chamaedipsia*) *lota* Walker, 1851	Europe, Asia	6, 7
Wiedemannia (*Eucelidia*) *zetterstedti* (Fallén, 1826)	Europe, Asia Minor	6, 7
Wiedemannia (*Philolutra*) *angelieri* Vaillant, 1967	Southern Europe	6
Wiedemannia (*Philolutra*) *chvali* Joost, 1981	Russia (Kabardino-Balkaria), Greece	7

Species	Distribution	Ecoregion
Wiedemannia (Philolutra) fallaciosa (Loew, 1873)	Europe, Asia Minor, Middle East, North Africa	6, 7
Wiedemannia (Pseudowiedemannia) lamellata (Loew, 1869)	Europe	6, 7
Wiedemannia (Pseudowiedemannia) microstigma (Bezzi, 1904)	Balkan region	6
Wiedemannia (Roederella) czernyi (Bezzi, 1905)	Southern Europe	7
Wiedemannia (Wiedemannia) andreevi Joost, 1982	Balkan region, Poland	6
Wiedemannia (Wiedemannia) bilobata Oldenberg, 1910	Central and southern Europe	6
Wiedemannia (Wiedemannia) dinarica Engel, 1940	Balkan region	6
Wiedemannia (Wiedemannia) dyonysica Wagner, 1990	FYR Macedonia, Greece	6
Wiedemannia (Wiedemannia) graeca Vaillant & Wagner, 1990	Greece	6, 7
Wiedemannia (Wiedemannia) tricuspidata (Bezzi, 1905)	Central and southern Europe	6, 7
Wiedemannia artemisa Ivković & Plant, 2012	Balkan region	6
Wiedemannia iphigeniae sp. n.	Greece	6
Wiedemannia ljerkae sp. n.	Greece	6
Wiedemannia nebulosa sp. n.	Greece	7
Wiedemannia pseudoberthelemyi sp. n.	Greece	6

Table 3. Sørensen Index of Similarity between aquatic dance fly assemblages of studied Balkan countries in relation to Greece. Abbreviations: SLO = Slovenia, HR = Croatia, B&H = Bosnia & Herzegovina, MN = Montenegro, FYRM = FYR Macedonia, GR = Greece.

	SLO	HR	B&H	MN	FYRM	GR
SLO	0					
HR	71.56	0				
B&H	54.16	62.92	0			
MN	41.3	61.17	61.11	0		
FYRM	47.83	56.47	61.11	52.94	0	
GR	45.71	48.97	51.76	34.56	51.85	0

with longer setae on middle and lower occiput; many setulae present on vertex and between ocellar area. Antenna brownish; postpedicel and stylus minutely pubescent; pedicel slightly longer than scape; scape with complete circlet of subapical setae; postpedicel apically pointed; stylus nearly twice length of postpedicel; scape with setulae dorsally.

Scutum with pale central vitta between dorsocentral rows. Mesonotum with 5 dorsocentral setae, with short setulae intermixed. Acrostichal setae small and fine, biserial, extending to 2nd dorsocentral seta; 1 strong postpronotal seta and 1–4 short setulae; 2 notopleural setae and several setulae; 1 presutural supra-alar seta and many small anterior setulae; 1 postalar seta. Antepronotum with 1 pair of strong setae and 1 pair of smaller setae. Proepisternum with some fine setulae. Laterotergite with several fine, pale setulae. One pair of strong marginal scutellar setae; disc without setae.

Wing membrane clear, veins darker; 1 long basal costal seta, extending almost to humeral crossvein. Cell dm produced anteroapically. M_1 and M_2 with long stem vein proximal to M_{1+2} fork. CuA+CuP not visible. Pterostigma elongate, faint. Squama with setulae. Halter pale.

Legs brownish; fore femur with two stronger anterior setae on apical fourth; uniformly covered with rows of small dark setulae. All coxae with longer setae anteriorly; fore coxae with several erect setae. Fore and mid femora ventrally with some longer setulae on proximal half, some longer than width of segment.

Abdomen covered in small setae. Terminalia (Figs 6, 7): hypandrium subequal in length with epandrium; narrow, with 8 pairs of short setae. Epandrium subrectangular, covered with long setae especially ventrally and laterally; surstylus thumb-like on inner face apically. Clasping cercus unilobed, pointed apically; finger-like, with small basal projection on inner face with setae; fine on outer face near anterior margin and apex; inner face with stouter setae, especially near posterior margin. Phallus more or less linear, slender; distiphallus similar to phallus shaft, narrow, without swellings.

Female. Unknown.

Etymology. The species is named after the Greek mythology character Iphigenia, the priestess of the Greek Goddess Artemis.

Remarks. *Wiedemannia iphigeniae* sp. n. is known only from the type locality in Greece. The shape of the clasping cercus is similar to that of *W. aerea* Vaillant, 1967 (Pyrenees), but a distinct basal projection is lacking in the latter species.

Wiedemannia ljerkae Ivković & Sinclair, sp. n.

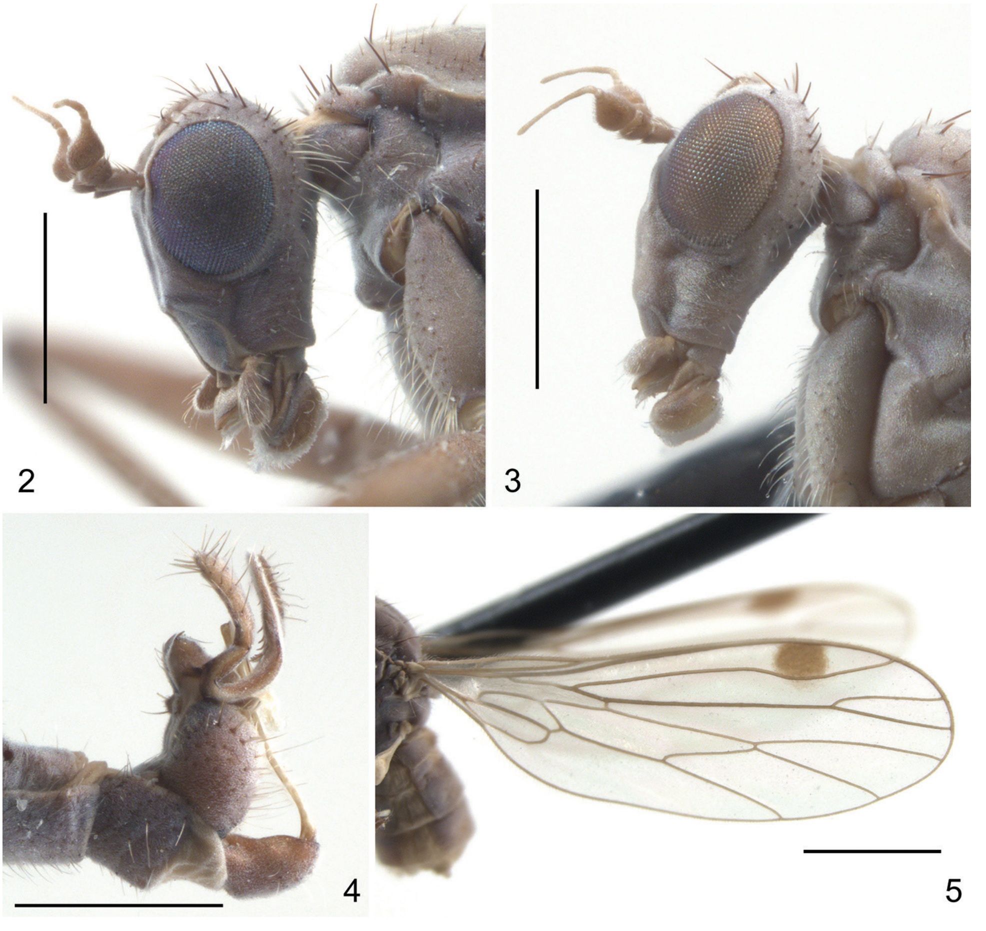
http://zoobank.org/F9A07ACC-BB76-4D11-8736-FDD2414413B7

Figs 1, 2, 4, 5, 8

Type locality. Greece: Epirus, Igoumenitsa, River Thiamis, Soulopoulo, 39°32'00"N, 20°12'00"E.

Type material. Holotype ♂ (in 80% ethanol), labelled: "HOLOTYPE/ *Wiedemannia// ljerkae* IVKOVIĆ et SINCLAIR// GREECE, Epirus,/ Igoumenitsa, R. Thiamis,/ Soulopoulo// 39°32'00"N, 20°12'00"E, 30.iv.1989,/ leg. B. Horvat, I. Sivec" (UZC). **Paratypes:** same data as holotype (2 ♂, 6 ♀, UZC; 3 ♂, 9 ♀, CNC (dried from alcohol); 2 ♂, 16 ♀, SMNH).

Additional material. GREECE: Central Greece, Etolia, Peristera, Agrinio, 1 km S of Perkos, 300 m, 38°38'00"N, 21°45'00"E, 24.iv.1990 (SMNH); Peloponnese, Kato

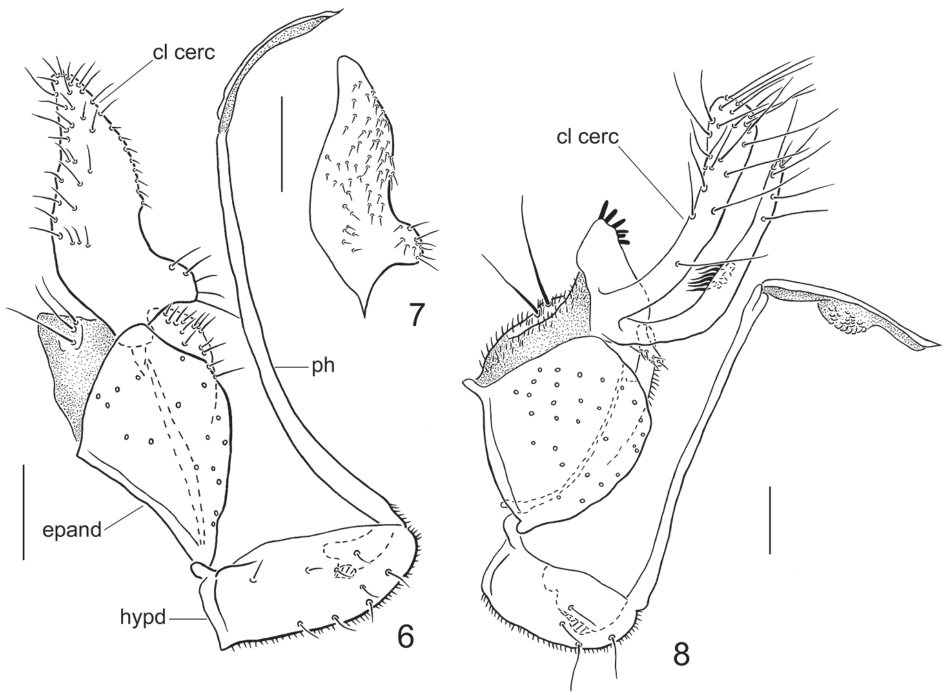


Figures 2–5. Heads, male terminalia and wing of *Wiedemannia* spp. **2** *W. ljerkae* Ivković & Sinclair, sp. n., male paratype, head, lateral view **3** *W. pseudoberthelemyi* Ivković & Sinclair, sp. n., male paratype, head, lateral view **4** *W. ljerkae* Ivković & Sinclair, sp. n., paratype, male terminalia, lateral view **5** *W. ljerkae* Ivković & Sinclair, sp. n., male paratype, wing, Scale bar: 0.5 mm (**2, 3, 4**); 1.0 mm (**5**).

Klitoria, 450 m, 37°50'00"N, 22°10'00"E, 20.iv.1990 (SMNH); Peloponnisos, R. Kratis, 7 km N of Peristera, 600 m, 38°05'00"N, 22°14'00"E, 22.iv.1990 (SMNH); Peloponnese, Aroania Mts., Kastria, 21.iv.1990 (UZC).

Diagnosis. This species of *Wiedemannia* is distinguished by the cercus with two long finger-like processes and a rounded pterostigma on the wings.

Description. Male. Body length 3.5–4.5 mm, wing length 4.0–4.3 mm (colouration bleached by prolonged storage in alcohol). Head (Fig. 2) in lateral view higher than long; gena broad, more than half height of eye. Frons short, broader than face. Face wide, with distinct carina on lower margin, bare, lacking setae. Ocellar setae short and fine; one pair of vertical setae; about 7–8 distinct upper postocular setae; lower postocular setae finer and merging with longer setae on middle and lower occiput;



Figures 6–8. Male terminalia of *Wiedemannia* spp., lateral view. **6** *W. iphigeniae* Ivković & Sinclair, sp. n., holotype **7** *W. iphigeniae* Ivković & Sinclair, sp. n., holotype, clasping cercus, inner view **8** *W. ljerkae* Ivković & Sinclair, sp. n., paratype.

numerous dark setulae on vertex and between ocellar area and eye margin. Antenna brown; postpedicel and stylus minutely pubescent; pedicel slightly shorter than half length of scape, with complete circlet of subapical setae; postpedicel apically pointed, stylus nearly twice length of postpedicel; scape with setulae dorsally.

Mesonotum with 5 pairs of dorsocentral setae with short setulae interspersed. Acrostichal setae small and fine, biserial, extended onto prescutellar depression; 1 strong postpronotal seta and 2–4 small setulae; 2 notopleural setae with several short setulae; 1 presutural supra-alar seta and many small anterior setulae; 1–2 postsutural supra-alar setulae; 1 postalar seta. Antepronotum with 3–4 pairs of dark, strong setae and some smaller setae. Proepisternum with some fine, long setae. Katepisternum with some short setulae on posterior margin. Laterotergite with fine, pale setae. One pair of strong marginal scutellar setae, with many scattered setulae on disc.

Wing (Fig. 5) membrane infuscate, veins darker; 1 long basal costal seta extending almost to humeral crossvein. R_{2+3} dipped beneath pterostigma. Cell dm produced anteroapically. M_1 and M_2 originating separately, together or sometimes with a very short stem vein proximal to M_{1+2} fork. CuA+CuP appearing as crease. Pterostigma broad, circular to squarish, dark brown, extending faintly beyond R_{2+3}. Squama with setulae. Halter pale, yellowish.

Legs mostly brown; fore femur with one stronger preapical anterior seta; uniformly covered with rows of small dark setulae. All coxae with longer setae anteriorly. Fore and mid femora ventrally with some longer setulae on proximal half.

Abdomen concolourous with thorax, covered in short setae. Terminalia (Figs 4, 8): hypandrium shorter than epandrium, bearing 4 pairs of setae. Epandrium subquadrate, covered with long dark setae especially ventrally and laterally; surstylus slender, digitiform. Clasping cercus with two long, slender, finger-like processes and small basal lobe with crown of spine-like setae on inner face apically; finger-like lobes with long setae distally; posterior finger-like lobe with inner cluster of stout setae at mid-length. Phallus more or less linear, very slender; distiphallus with distinct swelling at mid-length.

Female. Similar to male except pterostigma smaller, more elliptical, not extending beyond R_{2+3}; cercus short, ovate and minutely pilose.

Etymology. The species is named after the first author's mother, Katica Ljerka Ivković, for all those things that mothers do for all of us.

Remarks. *Wiedemannia ljerkae* sp. n. is known only from several localities in Greece. On the basis of the multiple slender lobes of the clasping cercus and distinct pterostigma, *W. ljerkae* sp. n. appears closely related to *W. braueri* (Mik, 1880) and *W. tricuspidata* (Bezzi, 1905) (see Engel 1918, 1940).

Wiedemannia nebulosa Ivković & Sinclair, sp. n.

http://zoobank.org/61BC89BA-016F-43BC-A59F-BA5B5259EAD9
Figs 1, 9

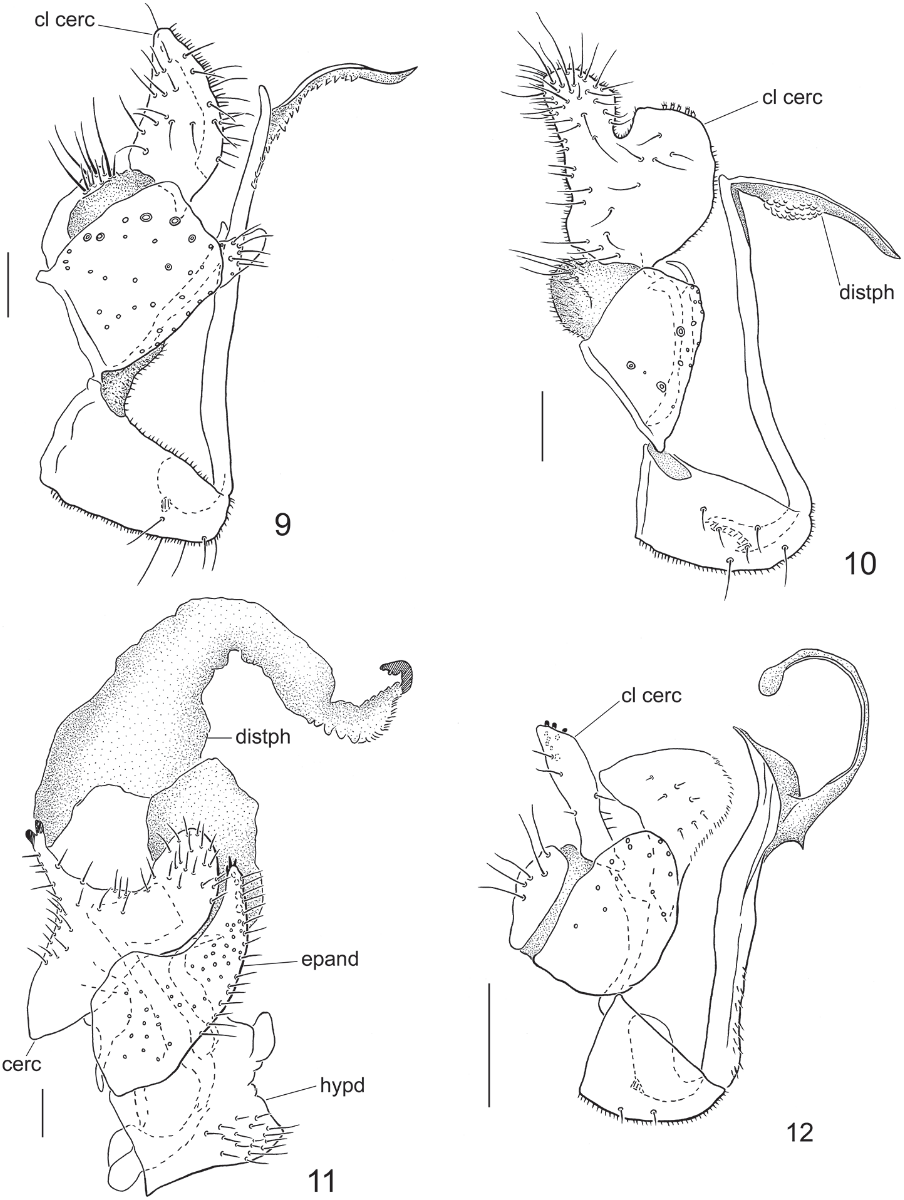
Type locality. Greece: Thrace, north of Dipotama, 41°24'24"N, 24°37'19"E, 1400 m.

Type material. Holotype ♂, labelled: "GREECE: Thrace/ N of Dipotama/ 41°24'24"N, 24°37'19"E/ 23.v.1994; 1400 m/ leg. B. Horvat, I. Sivec"; "HOLOTYPE/ *Wiedemannia/ nebulosa/* Ivković & Sinclair" (CNC, dried from alcohol). **Paratypes:** same data as holotype (1 ♂, 1 ♀, CNC, dried from alcohol).

Diagnosis. This species of *Wiedemannia* is distinguished by the faint clouding about crossveins and base of radial fork, shape of the clasping cercus and position of distiphallus on the phallic shaft.

Description. Male. Body length 3.8–4.5 mm, wing length 5.2–5.3 mm (colouration slightly bleached by prolonged storage in alcohol). Head dark with brown frons and vertex, remainder of head with blue pruinescence; head higher than long; gena narrow, one-quarter height of eye. Frons short, broader than face. Face wide, with distinct carina on lower margin, bare, lacking setae. One pair of long ocellar setae and one pair of vertical setae; 6–7 distinct upper postoculars; lower postocular setae finer and merging with longer setae on middle and lower occiput; a few small setulae present on vertex and in ocellar area. Antenna brown; postpedicel and stylus minutely pubescent; scape longer than pedicel, with setulae dorsally; pedicel with complete circlet of apical setae; postpedicel apically pointed; stylus twice length of postpedicel.

Scutum dark brown with pair of faint black vittae between dorsocentral row and acrostichals and bluish stripe medially; prescutellar depression with blue pruinescence.



Figures 9–12. Male terminalia of *Wiedemannia* spp., lateral view **9** *W. nebulosa* Ivković & Sinclair, sp. n., paratype **10** *W. pseudoberthelemyi* Ivković & Sinclair, sp. n., paratype **11** *Chelifera horvati* Ivković & Sinclair, sp. n., holotype **12** *Clinocera megalatlantica* (Vaillant).

Pleura clothed with blue pruinescence. Mesonotum with 5 pairs of dorsocentral setae without short setulae interspersed. Acrostichal setae short and fine, biserial, extending onto prescutellar depression; 1 strong postpronotal seta; 2 notopleural setae and several short setae; 1 presutural supra-alar seta and several small anterior setulae; 1 postalar seta. Antepronotum with 1 pair of strong setae. Proepisternum with some fine setulae. Katepisternum without setulae. Laterotergite with fine, pale setae. One pair of strong marginal scutellar setae; disc bare.

Wing membrane infuscate with darkening at apex of cell dm, radial fork and r-m crossvein; veins darker; 1 short basal costal seta ending before humeral crossvein. Cell dm produced anteroapically. M_1 and M_2 originating separately from cell dm. CuA+CuP in form of short streak. Pterostigma broad and elongate, very distinct. Squama with setulae. Halter yellowish brown.

Legs mostly brown; fore femur with 2–3 strong anterior setae on apical quarter; uniformly covered with rows of small dark setulae. All coxae with longer setae anteriorly; fore coxa with 1–2 erect setae. Fore and mid femora ventrally with some longer setulae on proximal half.

Abdomen concolourous with thorax, covered in short setae. Pruinescence darker on tergites than sternites. Terminalia (Fig. 9): hypandrium subequal in length with epandrium, with 5 pairs of setae. Epandrium irregularly subquadrate, with several stouter and longer setae (shown by enlarged sockets) in addition to normal setae ventrally and laterally; surstylus short, digitiform with rounded apex; subepandrial sclerite projecting slightly beyond epandrium near surstylus. Clasping cercus pale brown, broad, gradually tapered to rounded apex; inner posterior margin with long peg-like setae. Phallus more or less linear, slender; distiphallus without swelling at mid-length; distiphallus with serrate membranous margin, extending onto shaft.

Female. Similar to male. Terminalia: cercus short ovate and minutely pilose.

Etymology. The species name is derived from the Latin *nebulosus* (misty, cloudy, dark), in reference to the clouding about the crossveins.

Remarks. *Wiedemannia nebulosa* sp. n. is known only from the type locality in Greece. On the basis of the shape of the clasping cercus, this new species is similar to *W. carpathica* Vaillant, 1967 (eastern Carpathians), *W. pyrenaica* Vaillant, 1967 (Pyrenees) and perhaps *W. wachtli* (Mik, 1880).

Wiedemannia pseudoberthelemyi Ivković & Sinclair, sp. n.

http://zoobank.org/BD1AFAB9-06BD-4BEC-A08F-F3D80E8FAFE0

Figs 1, 3, 10

Type locality. Greece: Etolia, River Mornos, Nafpaktos, 38°23'N, 21°51'E.

Type material. Holotype ♂ (in 80% ethanol), labelled: "HOLOTYPE/ *Wiedemannia// pseudoberthelemyi* IVKOVIĆ// et SINCLAIR/, GREECE, Etolia,// River Mornos,/ Nafpaktos,/ 38°23'N, 21°51'E, 23.iv.1990,// leg. B. Horvat, I. Sivec" (UZC). **Paratypes:** same data as holotype (1 ♂, 3 ♀, UZC; 3 ♂, 6 ♀, CNC, dried from alcohol).

Additional material. GREECE: Central Greece, Panaitoliko Mts., R. Tavropos, Kalesmeno, 300 m, 38°56'N, 21°40'E, 29.iv.1989 (SMNH); Central Greece, Etolia, Agrinio, Agia Soufia, 100 m, 38°36'N, 21°26'E, 24.iv.1990 (SMNH);

Etolia, Vardousia Mts., R. Evinos, Grammeni Oxia, 800 m, 38°43'N, 22°00'E, 28.iv.1990 (SMNH).

Diagnosis. This species of *Wiedemannia* is distinguished by the long gena and the mitten-shaped clasping cercus, which is extremely similar to that of *Wiedemannia* (*Chamaedipsia*) *berthelemyi* Vaillant & Vinçon, 1987.

Description. Male. Body length 3.5–4.1 mm, wing length 3.5–3.6 mm (colouration bleached by prolonged storage in alcohol). Head (Fig. 3) in lateral view higher than long; gena broad, three-quarters height of eye. Frons short, broader than face. Face wide, with distinct carina on lower margin, bare, lacking setae. One pair of short ocellar setae and one pair of vertical setae; about 6 distinct upper postocular setae; lower postocular setae finer and merging with longer setae on middle and lower occiput; few small setulae present on vertex and between ocellar area. Antenna brown; postpedicel and stylus minutely pubescent; scape longer than pedicel, with setulae dorsally; pedicel with complete circlet of apical setae; postpedicel apically pointed; stylus nearly twice length of postpedicel.

Mesonotum with 5 pairs of dorsocentral setae with short setulae interspersed. Acrostichal setae short and fine, biserial, extending to prescutellar depression; 1 strong postpronotal seta; 2–3 notopleural setae and several short setae of variable size; 1 presutural supra-alar seta and numerous small setulae; 1 postalar seta. Antepronotum with 1 pair of strong setae and a few shorter setae. Proepisternum with some fine setulae. Katepisternum with a few (1–3) setulae. Laterotergite with fine, pale setae. One pair of strong marginal scutellar setae with many scattered setae on disc.

Wing membrane infuscate, veins darker; 1 short basal costal seta ending before humeral crossvein. Cell dm produced anteroapically. Veins M_1 and M_2 originating together with short stem vein proximal to M_{1+2} fork. Vein CuA+CuP extremely faint. Pterostigma elongate, indistinct. Squama with setulae. Halter yellowish.

Legs mostly brown; fore femur with 1 strong preapical anterior seta; uniformly covered with rows of small dark setulae. All coxae with longer setae anteriorly. Fore and mid femora ventrally with some longer setulae on proximal half.

Abdomen concolourous with thorax, covered in short setae. Pubescence darker on tergites than sternites. Terminalia (Fig. 10): hypandrium subequal in length with epandrium, with 6 pairs of setae. Epandrium irregularly subquadrate, with 2–3 stouter and longer setae (shown by enlarged sockets) in addition to regular setae ventrally and laterally; surstylus very slender, hook-shaped. Clasping cercus yellowish-brown, broad, mitten-shaped, with thumb-like anterior lobe; posterior lobe truncate apically; thumb-like lobe with long outer setae; stout setae with multi-branched apex covering most of inner face of cercus. Phallus more or less linear, slender; distiphallus with swelling at mid-length.

Female. Similar to male. Terminalia: cercus short ovate and minutely pilose.

Etymology. The species name is derived from the name *Wiedemannia* (*Chamaedipsia*) *berthelemyi* because of the similarity of the clasping cercus with that of this species.

Remarks. *Wiedemannia pseudoberthelemyi* sp. n. is known only from parts of Greece. This new species differs from *W. berthelemyi* on the basis of the truncate posterior lobe of the clasping cercus (pointed in *W. berthelemyi*) and in having only a single preapical seta on the fore femur (2 in *W. berthelemyi*). The odd stout setae with multi-branched tips on the inner face of the clasping cercus were not noted by Vaillant and Vinçon (1987) and the absence of the swelling on the distiphallus (Vaillant and Vinçon 1987, fig. 32) is likely an artefact caused by the acid clearing process. The holotype of *W. berthelemyi* was not examined.

Additional similar species that could be included in this group based on the shape of the clasping cercus include: *W. angelieri* Vaillant, 1967 (Pyrenees), *W. vedranae* Ivković & Sinclair, 2014 (Sierra Nevada, Spain), and *W. queyrasiana* Vaillant, 1956 (European Alps).

Hemerodromiinae

Chelifera horvati Ivković & Sinclair, sp. n.

http://zoobank.org/9DE403F2-5A28-4E6F-A485-A4D42308165D
Figs 1, 11

Type locality. Greece: Central Greece, Etolia, Arta, Loutraki.

Type material. HOLOTYPE ♂, labelled: "GREECE: Central Greece/ Etolia, Arta, Loutraki/ 16.iv.1990/ leg. B. Horvat, I. Sivec"; "HOLOTYPE/ *Chelifera/ horvati/* Ivković & Sinclair" (CNC, dried from alcohol).

Diagnosis. A yellow-brown species with distinct, brown and rounded pterostigma, characterized in the male by dark brown cercus with elongate, slender forked process at mid-length, posteriorly tapered epandrium with stout inner setae and membranous distiphallus with two elongate lobes.

Description. Male. Body length 4 mm, wing length 3.6 mm. Head dorsoventrally flattened, dark brown; ocellar triangle dark brown; all setae whitish. Eyes iridescent black; narrowly separated on face. Face with thick, whitish pubescence. One pair of postocular setae and scattered fine setae on vertex. Occiput bearing scattered fine setulae; gena with rather dense short, downwardly directed whitish pile. Antenna whitish, with scape and pedicel bearing distinct short dorsal setulae; postpedicel about 1.5× as long as wide, stylus much shorter than postpedicel.

Thorax elongate; yellow, all setae yellowish. Mesonotum with pair of brown vittae, extending around prescutellar depression; small dark spot posterior to postpronotal lobe and larger dark spot near wing base. Holotype missing most thoracic setae.

Wing (slightly damaged) membrane transparent, veins yellow; pterostigma dark, rounded, with R_{2+3} arched around it; fork of R_{4+5} less than 90°; cell r_4 rather long, R_5 nearly 2× as long as R_4. Halter pale.

Legs whitish yellow, apical two tarsal segments on all legs brown. Fore coxa about 8× longer than wide with several pale dorsoapical setae. Fore femur slightly longer than fore coxa, more than 4× longer than wide, evenly inflated, widest at middle.

Fore femur with two rows of black ventral denticles and two rows of strong outer brownish-yellow ventral setae, with following chaetotaxy: 20 anteroventral denticles, 6 anteroventral spine-like setae, 21 posteroventral denticles, 6 posteroventral spine-like setae; denticles closely spaced and rows converging distally; posteroventral spine-like setae shorter distally. Fore tibia 0.6× as long as fore femur, evenly curved with anteroventral row of short, spine-like setae; with apicoventral dark spur-like seta, longer than width of tibia. Mid and hind femora with anteroventral row of short, slender setae.

Abdomen yellow ventrally, brown dorsally, with pale setae most conspicuous on hind margin of posterior sternites. Terminalia (Fig. 11): cercus dark brown, thick, with narrow, elongate process at mid-length with forked apex (process folded horizontally in non-macerated condition); anterior end of cercus pointed and curved medially, with long setae, posterior end of cercus rounded; cercus wider then epandrium. Epandrium yellowish-brown, concave medially, posteriorly pointed with 5 stout setae on inner apical margin directed medially; entire epandrium covered in numerous setae. Hypandrium yellow, quadrate, with posteroapical lobe and concave posterior margin; pale setae on posteroventral face. Postgonite slender, sickle-shaped. Distiphallus membranous, expanded into two elongate lobes; apex of posterior lobe with pigmented arch-shaped sclerotization.

Female. Unknown.

Etymology. The new species is named after the late Dr Bogdan Horvat, mentor of the first author, colleague and during his life a leading expert on the genus *Chelifera* Macquart.

Remarks. *Chelifera horvati* sp. n. is known only from one site in Greece. The narrow pigmented and sclerotized apex of the distiphallus of *C. horvati* sp. n. is similar in *C. concinnicauda* Collin, 1927, *C. diversicauda* Collin, 1927, *C. giraudae* Vaillant, 1982 and *C. subangusta* Collin, 1961 (see Collin 1961 and Vaillant 1982).

Key to species of aquatic Empididae of Greece

(written primarily for male specimens; some couplets modified from Collin (1961) and Vaillant (1982); *Wiedemannia* (*Philolutra*) *hygrobia* (Loew) is included in the key, although Greek records not confirmed)

1	Fore femur with one or two rows of black, peg-like setae ventrally; fore femur width 2–3 times that of fore tibia .... **Hemerodromiinae**...**2**
–	Fore femur without black, peg-like setae ventrally; fore femur width less than 1.5 times that of fore tibia .... **Clinocerinae**...**11**
2	Cell cua (anal cell) and crossvein bm-cu absent (discal cell absent); R_1 meeting costa before middle of wing .... ***Hemerodromia* Meigen**...**3**
–	Cells cua (anal cell) and dm present (crossvein bm-cu present); R_1 meeting costa beyond middle of wing .... ***Chelifera* Macquart**...**5**

3 Scutum with dark spot posterior to postpronotal lobe; cercus inflated, kidney-shaped in dorsal view (Collin 1961, fig. 302) .... ***Hemerodromia melangyna* Collin**

– Scutum without dark spot posterior to postpronotal lobe; cercus not inflated... **4**

4 Cercus with shallow, semi-circular apical excision (Collin 1961, fig. 299)..... .... ***Hemerodromia oratoria* (Fallén)**

– Cercus without apical excision, apex rounded with short, stout inner setae (Collin 1961, fig. 300a) ....***Hemerodromia unilineata* Zetterstedt**

5 Pterostigma very indistinct, long ovate and pale yellow (male terminalia: Collin 1961, fig. 295)............................. ***Chelifera trapezina* (Zetterstedt)**

– Pterostigma distinct, circular and black or brownish **6**

6 Male cercus simple, without lobe in lateral view **7**

– Male cercus with lobe in lateral view..**9**

7 Male cercus small and thin, narrower than epandrium (Collin 1961, fig. 292) .... ***Chelifera angusta* Collin**

– Male cercus as broad as epandrium **8**

8 Male cercus, viewed from above, with a distinct projection near middle of inner edge (Collin 1961, fig. 287).................. ***Chelifera precabunda* Collin**

– Male cercus, viewed from above, without a distinct projection near middle of inner edge (Collin 1961, fig. 286)..................***Chelifera precatoria* (Fallén)**

9 Male cercus with narrow, elongate dorsal process at mid-length, with forked apex (Fig. 11)... ***Chelifera horvati* sp. n.**

– Male cercus without dorsal process at mid-length **10**

10 Posterior lobe of male cercus arched; hypandrium in lateral view tapered and narrowed posteriorly (Vaillant 1982, figs 5g, 7a)...... ***Chelifera stigmatica* (Schiner)**

– Posterior lobe of male cercus conical; hypandrium in lateral view rouned and broadly prolonged posteriorly (Vaillant 1982, figs 5i, 9a)............................. .... ***Chelifera barbarica* Vaillant**

11 Neck arising high on occiput, from near top of head ....***Dolichocephala* Macquart...12**

– Neck arising near centre of occiput or level with centre of eye..................**16**

12 Wings without white rounded spots or irrorations, at most only faint white streaks in cells .... ***Dolichocephala guttata* (Haliday)**

– Wings with white rounded spots or irrorations **13**

13 Wings with only white streak in cell r_{2+3} (proximal section) (Wagner 1995, fig. 4); clasping cercus elongate and straight, narrow on apical half (Wagner 1995, fig. 10)..***Dolichocephala cretica* Wagner**

– Wings with pair of white spots in cell r_{2+3} (proximal section) (Wagner 1995, figs 3, 6); clasping cercus arched **14**

14 Surstylus unforked; clasping cercus strongly arched (Engel 1939, fig. 46) .... ***Dolichocephala ocellata* (Curtis)**

– Surstylus forked (Wagner 1995, figs 8, 13); clasping cercus gradually arched **15**

15 Clasping cercus L-shaped, with peg-like seta at inner apex (Wagner 1995, fig. 7) .... ***Dolichocephala vaillanti*** **Wagner**

– Clasping cercus arched medially, with peg-like seta subapically (Wagner 1995, fig. 12) .... ***Dolichocephala zwicki*** **Wagner**

16 Tarsomeres 2–4 of foreleg subequal in length **17**

– Tarsomere 2 of foreleg much longer than tarsomeres 3 or 4, often twice length of tarsomere 4 .... **18**

17 Proboscis as long as head; labrum long and slender; labellum not sucker-like (Wagner 1981, fig. 8) .... ***Roederiodes malickyi*** **Wagner**

– Proboscis shorter than head; labrum subtriangular; labellum sucker-like (Engel 1939, text fig. 92) .... ***Clinocerella siveci*** **(Wagner & Horvat)**

18 Lower margin of face lacking notch or deep cleft above mouthparts; apical phallus filament not articulated .... ***Clinocera*** **Meigen...19**

– Lower margin of face with notch or deep cleft; apical phallic filament articulated **21**

19 Comb of preapical anterior setae on fore femur absent; postpronotal seta reduced, shorter and thinner than notopleural setae; postsutural supra-alar setae absent .... ***Clinocera nigra*** **Meigen**

– Comb of preapical anterior setae on fore femur present; postpronotal seta well developed, similar to scutal setae; postsutural supra-alar setae present **20**

20 Wings with faint clouding about crossveins; apex of femora (“knees”) light brown, compared to bluish pruinescent femur; surstylus elongate, apex rounded (Collin 1961, fig. 311b) .... ***Clinocera stagnalis*** **(Haliday)**

– Wings without clouding; apex of femora not paler than remaining femur; surstylus subtriangular, with narrow anterior apex (Fig. 12) .... ***Clinocera megalatlantica*** **(Vaillant)**

21 Face with setulae along inner margin of eye .... ***Kowarzia*** **Mik...22**

– Face bare, without setulae along inner margin of eye **25**

22 Coxae and femora dark, brown (male terminalia: Vaillant 1965, figs 3e, f) ... . ***Kowarzia plectrum*** **(Mik)**

– Coxae and femora pale, yellowish **23**

23 Surstylus deeply forked (Collin 1961, fig. 314c) .... ***Kowarzia bipunctata*** **(Haliday)**

– Surstylus unforked **24**

24 Surstylus as broad as clasping cercus; clasping cercus digitiform, strongly curved at middle, generally similar in width until apex (Vaillant 1965, figs 3b, d) .... ***Kowarzia madicola*** **(Vaillant)**

– Surstylus long and slender, much thinner than clasping cercus; clasping cercus broad, gently curved (Collin 1961, fig. 314a) .... ***Kowarzia barbatula*** **Mik**

25 Wings with distinct spots; pterostigma clearly outlined, elliptical .... ***Phaeobalia dimidiata*** **(Loew)**

– Wings lacking spots; pterostigma usually either both faint and elongate or dark and circular .... ***Wiedemannia*** **Zetterstedt...26**

26 Pterostigma rounded, usually very distinct and large (Fig. 5) **27**
– Pterostigma elongate and narrow, often indistinct..................................... **35**
27 Gena width more than half vertical diameter of eye (Fig. 2)...................... **28**
– Gena width less than half vertical diameter of eye **34**
28 Clasping cercus deeply divided into 2 or 3 elongate finger-like lobes (Fig. 4) **29**
– Clasping cercus not divided into elongate finger-like lobes **30**
29 Clasping cercus with 2 elongate lobes and shorter, broad anterior lobe bearing peg-like apical setae (Fig. 8) .... ***Wiedemannia ljerkae* sp. n.**
– Clasping cercus with 3 elongate lobes, anterior lobe narrower and slightly shorter than posterior lobes, without peg-like setae (Engel 1940, fig. 95)...... .... ***Wiedemannia* (*Wiedemannia*) *tricuspidata* (Bezzi)**
30 Base of clasping cercus prolonged anteriorly, arched around epandrium.... **31**
– Base of clasping cercus not prolonged anteriorly around epandrium **33**
31 Apex of clasping cercus tapered and narrow (Engel 1940, fig. 88)................ .... ***Wiedemannia* (*Wiedemannia*) *bilobata* Oldenberg**
31 Apex of clasping cercus bluntly rounded and broad **32**
32 Apex of clasping cercus prolonged; base of clasping cercus with stout setae confined to upper inner edge (Vaillant and Wagner 1990, figs 1, 2)............. .... ***Wiedemannia* (*Wiedemannia*) *graeca* Vaillant & Wagner**
– Apex of clasping cercus slightly expanded, not prolonged anteriorly; base of clasping cercus with stout setae covering most of inner face (Wagner 1990, figs 3, 4)....................... ***Wiedemannia* (*Wiedemannia*) *dyonysica* Wagner**
33 Clasping cercus with posterior margin deeply invaginated, forming pair of narrow basal lobes (Joost 1982, figs 1, 2) .... ***Wiedemannia* (*Wiedemannia*) *andreevi* Joost**
– Clasping cercus L-shaped (Engel 1940, fig. 91).. .... ***Wiedemannia* (*Wiedemannia*) *dinarica* Engel**
34 Clasping cercus broad in lateral view, expanded at mid-length (Engel 1940, fig. 97)................. ***Wiedemannia* (*Pseudowiedemannia*) *lamellata* (Loew)**
– Clasping cercus very narrow on basal half in lateral view, with short lobe at mid-length directed medially (Engel 1940, fig. 98) .... ***Wiedemannia* (*Pseudowiedemannia*) *microstigma* (Bezzi)**
35 All femora with distinct anterior and posterior preapical setae (male terminalia: Engel 1940, fig. 78) ..... ***Wiedemannia* (*Eucelidia*) *zetterstedti* (Fallén)**
– Femora without distinct preapical setae, or at least only anterior seta present on fore femur... **36**
36 Acrostichals only present anterior to second dorsocentral seta (male terminalia: Engel 1940, fig. 79) .... ***Wiedemannia* (*Roederella*) *czernyi* (Bezzi)**
– Acrostichals extending to at least prescutellar depression........................... **37**
37 Gena width more than half vertical diameter of eye (Fig. 3)......................... .... ***Wiedemannia pseudoberthelemyi* sp. n.**
– Gena width less than half vertical diameter of eye **38**

38 Clasping cercus short and broad, height and width of lobe subequal......... **39**
– Clasping cercus prolonged dorsally, distinctly higher than wide **43**
39 Clasping cercus circular, without lobes (Mandaron 1964, figs B, E)............. .... ***Wiedemannia* (*Chamaedipsia*) *aequilobata* Mandaron**
39 Clasping cercus bilobed, mitten-shaped **40**
40 Anterior lobe of clasping cercus narrow, thumb-like (Vaillant 1967, figs 2.3, 2.4).......................... ***Wiedemannia* (*Philolutra*) *angelieri* Vaillant**
– Anterior lobe of clasping cercus broad, subequal in width to posterior lobe or small, not longer than wide.. **41**
41 Anterior lobe of clasping cercus broad, subequal in width to posterior lobe (Joost 1981, figs 7, 8) .... ***Wiedemannia* (*Philolutra*) *chvali* Joost**
– Anterior lobe of clasping cercus small, not longer than wide **42**
42 Clasping cercus without long setae anteriorly at base (Wagner 1981, figs 5, 6).......................... ***Wiedemannia* (*Chamaedipsia*) *ariadne* Wagner**
– Clasping cercus with long setae anteriorly at base (Engel 1940, fig. 102) .... ***Wiedemannia* (*Philolutra*) *hygrobia* (Loew)**
43 Clasping cercus mitten-shaped, with thumb-like anterior lobe (Engel 1940, fig. 101) .... ***Wiedemannia* (*Philolutra*) *fallaciosa* (Loew)**
– Clasping cercus not mitten-shaped **44**
44 Fore femur with a single distinct anterior seta at about one-sixth from apex.... **45**
– Fore femur without setae or with several distinct anterior setae at about one-sixth from apex **46**
45 Clasping cercus long, slender and parallel-sided, yellow, nearly twice as long as width of epandrium (Collin 1961, fig. 313c; Engel 1940, fig. 86) .... ***Wiedemannia* (*Chamaedipsia*) *lota* Walker**
– Clasping cercus slightly longer than width of epandrium and tapered apically with narrow basal lobe-like expansion (Fig. 6) .... ***Wiedemannia iphigeniae* sp. n.**
46 Clasping cercus with broad base, bent at nearly right angles, L-shaped (Ivković et al. 2012, figs 2, 3) .... ***Wiedemannia artemisa* Ivković & Plant**
– Clasping cercus with broad base and gradually tapered apically................. **47**
47 Phallus shaft extended well beyond base of distiphallus; clasping cercus with stout, blunt-tipped setae along inner posterior margin (Fig. 9); wing with faint clouding about crossveins .... ***Wiedemannia nebulosa* sp. n.**
– Phallus shaft not extended beyond base of distiphallus; clasping cercus with long thick setae along inner margin (Vaillant 1967, fig. 2.9); wing without faint clouding about crossveins .... ***Wiedemannia* (*Chamaedipsia*) *beckeri* (Mik)**

List of Empididae of Greece (Clinocerinae & Hemerodromiinae)

The following format is used for the distributional data: Literature references – name of the site and in brackets the reference citation and site ID; New records – name of the site and in brackets the site ID. All the sites and their numbers are listed in Table 1.

Subfamily Clinocerinae

Clinocera megalatlantica (Vaillant, 1957)

New records. Thrace, Samothrace, hygropetric zone of stream at the church of Kreminotissa (15).

Remarks. This species is newly recorded from Greece. The male terminalia of this species are illustrated (Fig. 12) to highlight additional detail not shown in the original drawing of Vaillant (1957, fig. IIC).

Clinocera nigra Meigen, 1804

New records. Macedonia, Pieria Mts. 2 (52); Epirus, R. Aheron, N of Gliki (115); Central Greece, Etolia, Vardousia Mts., 13 km S of Gardiki (164); Central Greece, Etolia, Panaitoliko Mts., Klepa (170); Central Greece, Etolia, Nafpaktos, Anthofito (174); Central Greece, Etolia, Agrinio, R. Evinos, Kato Hrisovitsa, Diasellaki (183); Central Greece, Etolia, Agrinio, Agia Soufia (191); Central Greece, Etolia, Nafpaktos, Koutsopanneika (203); Peloponnese, tributary of R. Krathis, 7 km N of Peristera (215); Peloponnese, 2 km N of Peristera (216); Peloponnese, Ano Potames, Kalivitis (219).

Clinocera stagnalis (Haliday, 1833)

Literature references. Macedonia, Grevena, stream S of R. Aliakmon by Kamilas Pigi (Wagner 1995) (58); Macedonia, Vernon, influx of Aliakmon between Gavros and Aposkepos (Wagner 1995) (61); Macedonia, Chalkidiki, Chlomon Oros., valley on the southern slope (Wagner 1995) (68); Epirus, Pindus Mts., Metsovo, meadow source easthang (Wagner 1995) (94); Epirus, Xerovouni Mts., Plaka, R. Arachthos, u. Agnatha (Wagner 1995) (105).

New records. Thrace, N of Xanthi (18); Thrace, N of Dipotama, 1 (19); Thrace, N of Dipotama 3 (22); Thrace, Dit. Rodopi, Skaloti (29); Thrace, Dit. Rodopi 1 (30); Thrace, Dit. Rodopi, E of Mikromilia (35); Macedonia, Dit. Rodopi, Elatia forest (37); Macedonia, E of Mikroklisoura (38); Macedonia, N of Stavros (39); Macedonia, N of Agios Dimitrios (43); Macedonia, Pieria Mts., S of Elatohori (44); Macedonia, Pieria Mts., E of Fteri (46); Macedonia, Pieria Mts., Fteri (47); Macedonia, Pieria Mts., W of Fteri (48); Macedonia, Pieria Mts., E of Velventos (50); Macedonia, Pieria Mts., 1 (51); Macedonia, Pieria Mts. 2 (52); Macedonia, Pieria Mts., 3 (53); Macedonia, E of Velventos (54); Macedonia, Phalacro Mts., N of Livadero (55); Macedonia, Grevena, Milea (56); Macedonia, Grevena, 6 km S of Milea (57); Macedonia, Kastoria, Nestorio (62); Thessaly, Pieria Mts., S of Livadi (74); Thessaly, 5 km W of Palea Giannitsou (75); Thessaly, Deskati (76); Thessaly, S of Asprokklisia (78); Thessaly, Kalambaka, Agios Nikolaos (80); Thessaly, Trikala, Stournareika (81); Thessaly, Trikala, Kato Palagokaria (82); Thessaly, Trikala, 9 km

S of Chrisomilea (90); Epirus, Metsovo, Katara Pass (96); Epirus, Metsovo, R. Metsovitikos (99); Epirus, Metsovo, Lakmos Mts., Anthohori, (bellow rapid river) (100); Epirus, Metsovo, Lakmos Mts., Anilio (15 km S influx) (102); Epirus, Metsovo, 14 km W of Milea (103); Epirus, Ioannina, R. Zagoritikos, Karies (106); Epirus, 10 km N of Louros (110); Epirus, Ioannina, R. Voidomatis, Aristi (112); Central Greece, Etolia, Lamia, Ieraklia (145); Central Greece, Oeta Mts., between Kastanea and Katafygio (147); Central Greece, Etolia, Vardousia Mts., 5 km N of Grammeni Oxia (153); Central Greece, Etolia, Vardousia Mts., R. Evinos, Grammeni Oxia (154); Central Greece, Etolia, Vardousia Mts., 9 km N of Grammeni Oxia (155); Central Greece, Etolia, Vardousia Mts., 7 km N of Grammeni Oxia (156); Central Greece, Etolia, Vardousia Mts., 2 km W of Gardiki (166); Central Greece, Tymfristos Mts., R. Sperhios, Lamia (168); Central Greece, Etolia, Panaitoliko Mts., Klepa (170); Central Greece, Karpenisi, Agios Nikolaos (175); Central Greece, Etolia, Nafpaktos, tributory of R. Evinos, 6 km N of Pokista (176); Central Greece, Etolia, Lamia, Pavliani (192); Central Greece, Etolia, Agrinio, Panaitoliko Mts., Palagohori (199); Central Greece, Etolia, Nafpaktos, Koutsopanneika (203); Peloponnese, R. Krathis, 7 km N of Peristera (214); Peloponnese, tributary of R. Krathis, 7 km N of Peristera (215); Peloponnese, R. Krathis, Peristera (217); Peloponnese, Aroania Mts., Zarouhla (220); Peloponnese, Aroania Mts., Xelmos (bellow), Valtos, Zarelia (221); Peloponnese, Pagrati (225); Peloponnese, Aroania Mts., Kastria (226); Peloponnese, Kato Klitoria (227); Peloponnese, Labia Mts., Amigdalia (229); Peloponnese, R. Piro, Elliniko (230); Peloponnese, Panachaiko Mts., tributory of R. Selinous, Leontio (231); Peloponnese, Erymanthos Mts., Lechouri (233); Peloponnese, Panachaiko Mts., Veteika (234); Peloponnese, Erymanthos Mts., Kato Vlasia (235); Peloponnese, Panachaiko Mts., Kounaveika (near village) (236); Peloponnese, Erymanthos Mts., Profitis Ilias (239); Peloponnese, Erymanthos Mts., Stavrohori, Eliniko (241); Peloponnese, Erymanthos Mts., S of Spartia (243); Peloponnese, Stavrodromi (245); Peloponnese, Abelokipi (246); Peloponnese, Panachaiko Mts., Kristalovrisi (stream) (248).

Clinocerella siveci (Wagner & Horvat, 1993)

Literature references. Central Greece, Etolia, Panaitoliko Mts., Klepa (Wagner and Horvat 1993) (170); Central Greece, Etolia, Agrinio, Agia Soufia (Wagner and Horvat 1993) (191); Central Greece, Etolia, Agrinio, Panaitoliko Mts., 3 km N of Hani Lioliou (Wagner and Horvat 1993) (202); Central Greece, Etolia, Nafpaktos, Koutsopanneika (Wagner and Horvat 1993) (203); Peloponnese, 2 km N of Peristera (Wagner and Horvat 1993) (216); Peloponnese, Aroania Mts., Kalivia (Wagner and Horvat 1993) (223); Peloponnese, Panachaiko Mts., Kounaveika (near village) (Wagner and Horvat 1993) (236); Peloponnese, Panachaiko Mts., Kristalovrisi (stream) (Wagner and Horvat 1993) (248); Peloponnese, Erymanthos Mts., Kalamata (Wagner and Horvat 1993) (249).

Dolichocephala cretica Wagner, 1995

Literature references. Crete, stream near Kotsifiana (Wagner 1995) (257).

Dolichocephala guttata (Haliday, 1833)

Literature references. Crete, E of Ierepetra (Wagner 1981) (251).

New records. Thrace, Sapka Mts. 1 (6); Thrace, Dit. Rodopi, N of Dipotama 3 (26); Macedonia, Pieria Mts., 1 (51); Macedonia, Pieria Mts. 3 (53); Epirus, N of Katarapass, 1 km SW Milea (95); Epirus, Metsovo, Katara Pass (96); Cyclades islands, Andros (206); Peloponnese, 2 km N of Peristera (216); Peloponnese, Aroania Mts., 4 km S of Solos (218); Peloponnese, Ano Potames, Kalivitis (219).

Dolichocephala ocellata (Costa, 1854)

Literature references. North Aegean islands, Lesbos, 3 km NW of Agiasos (Wagner 1981) (130); North Aegean islands, Icaria (Wagner 1981) (140); Crete, E of Ierepetra (Wagner 1981) (251).

New records. Epirus, 10 km N of Louros (110); Epirus, R. Aheron, N of Gliki (115); Central Greece, Etolia, Agrinio, Agia Soufia (191).

Dolichocephala vaillanti Wagner, 1995

Literature references. Crete, stream near Sises (Wagner 1995) (252).

Dolichocephala zwicki Wagner, 1995

Literature references. North Aegean islands, Lesbos, 3 km NW of Agiasos (Wagner 1995) (130).

New records. Cyclades islands, Andros (206).

Kowarzia barbatula (Mik, 1880)

Literature references. Thrace (Wagner 1981) (36); Macedonia, Xanthi, NE Pass Str. Xanthi-Stavroupolis (Wagner 1995) (69); North Aegean islands, Lesbos, 7 km E of Plomari (Wagner 1981) (127); North Aegean islands, Lesbos, 4 km W of Agiasos (Wagner 1981) (131); North Aegean islands, Icaria, W of Chrisostomos (Wagner 1981) (136); North Aegean islands, Chios, 2 km N of Fita (Wagner 1981) (137);

North Aegean islands, Chios, N of Keramos (Wagner 1981) (138); North Aegean islands, Chios, 5 km N of Pirama (Wagner 1981) (139); North Aegean islands, Icaria (Wagner 1981) (140); Central Greece, Euboea, S of Komiton (Wagner 1995) (142).

New records. Thrace, W of Mega Derio (2); Thrace, Lesitse Mts. (3); Thrace, Sapka Mts., 1 (6); Thrace, 3 km N of Alexandroupoli (7); Thrace, Sapka Mts. 2 (8); Thrace, Sapka Mts., Nea Sanda 2 (10); Thrace, Anatoliki Rodopi, E od Drimi (11); Thrace, Dit. Rodopi, N of Dipotama 1 (21); Thrace, N of Dipotama 4 (23); Thrace, N of Dipotama 5 (24); Macedonia, Pieria Mts., 2 streams on Ritini (42); Macedonia, N of Agios Dimitrios (43); Macedonia, Pieria Mts., S of Elatohori (44); Macedonia, Pieria Mts., E of Fteri (46); Macedonia, Pieria Mts., 1 (51); Macedonia, Pieria Mts., 2 (52); Macedonia, Phalacro Mts., N of Livadero (55); Epirus, 10 km N of Louros (110); Epirus, R. Aheron, N of Gliki (115); Central Greece, Etolia, Vardousia Mts., Ano Chora (169); Central Greece, Etolia, Panaitoliko Mts., Klepa (170); Central Greece, Etolia, Nafpaktos, Simos (180); Central Greece, Etolia, Panaitoliko Mts., Prousos (186); Central Greece, Etolia, Panaitoliko Mts., Chaliki, Nerosirtis (188); Peloponnese, Aroania Mts., Kalivia (223); Peloponnese, Erymanthos Mts., S of Spartia (243).

Kowarzia bipunctata (Haliday, 1833)

Literature references. North Aegean islands, Lesbos, 2 km N of Akrassi (Wagner 1981) (132); North Aegean islands, Lesbos, Ambeliko (Wagner 1981) (134); North Aegean islands, Lesbos, E of Lepetimnos (Wagner 1981) (135); Crete, E of Agios Ioannis (Wagner 1995) (250); Crete, Passas valley near Pass (Wagner 1995) (253); Crete, S of Retimnon (Wagner 1981) (254).

New records. Thrace, 3 km N of Alexandroupoli (7); Thrace, Sapka Mts., Nea Sanda, 2 (10); Epirus, 10 km N of Louros (110); Epirus, R. Aheron, N of Gliki (115); Central Greece, Etolia, Agrinio, Agia Soufia (191); Central Greece, Etolia, Arta, Loutraki (197); Peloponnese, village Akrata (210); Peloponnese, Aroania Mts., Kalivia (223); Peloponnese, Erymanthos Mts., Stavrohori, Eliniko (241); Peloponnese, Abelokipi (246).

Kowarzia madicola (Vaillant, 1965)

New records. Peloponnese, Erymanthos Mts., Stavrohori, Eliniko (241).

Kowarzia plectrum (Mik, 1880)

New records. Macedonia, Pieria Mts., E of Velventos (50); Macedonia, Pieria Mts., 1 (51); Macedonia, Pieria Mts., 2 (52); Epirus, 10 km N of Louros (110).

Remarks. This species is newly recorded from Greece.

Phaeobalia dimidiata (Loew, 1869)

New records. Thrace, N of Dipotama 3 (22); Thrace, N of Dipotama 4 (23); Thrace, Dit. Rodopi, N of Dipotama 2 (25); Macedonia, Pieria Mts., E of Fteri (46); Macedonia, Pieria Mts., Fteri (47); Macedonia, Pieria Mts., W of Fteri (48); Macedonia, Pieria Mts., E of Velventos (50); Macedonia, Pieria Mts., 2 (52).

Remarks. This species is newly recorded from Greece.

Roederiodes malickyi Wagner, 1981

Literature references. Crete, Xyloskalon (Wagner 1981) (256).

Wiedemannia (*Chamaedipsia*) *aequilobata* Mandaron, 1964

New records. Epirus, Lakmos Mts., 10 km S of Anilio (101).

Wiedemannia (*Chamaedipsia*) *ariadne* Wagner, 1981

Literature references. Cyclades islands, Naxos, S of Koronis (Wagner 1981) (207); Cyclades islands, Andros, Apikia (Wagner 1981) (208).

Wiedemannia (*Chamaedipsia*) *beckeri* (Mik, 1889)

New records. Thrace, Rodopi, N of Dipotama 1 (21); Thrace, N of Dipotama 3 (22); Thrace, Rodopi, N of Dipotama 3 (26); Thrace, N of Sidironero 1 (31).

Remarks. This species is newly recorded from Greece.

Wiedemannia (*Chamaedipsia*) *lota* Walker, 1851

Literature references. Macedonia, Olympus Mts. above Agios Dyonysos, Prionia (Wagner 1981) (41); Dodecanese islands, Rhodes, 3 km E of Archipolis (Wagner 1981) (204).

New records. Thrace, Anatoliki Rodopi, Drimi (12); Thrace, Anatoliki Rodopi, E of Gratini 1 (13); Thrace, Anatoliki Rodopi, E of Gratini 2 (14); Thrace, 8 km N of Sminthi (17); Thrace, N of Xanthi (18); Thrace, N of Dipotama 1 (19); Thrace, N of Dipotama 3 (22); Macedonia, N of Stavros (39); Macedonia, R. Mavroneri, 10 km W of Katerini (40); Macedonia, S of Agios Dimitrios (45); Macedonia, Pieria Mts., E of Fteri (46); Macedonia, Pieria Mts., 2 (52); Macedonia, E of Velventos (54); Macedonia, Kastoria, Nestorio (62); Macedonia, Kastoria, Grammos Mts., 7 km S Chrisi

(64); Thessaly, S of Kallithea (73); Thessaly, Pieria Mts., S of Livadi (74); Thessaly, Deskati (76); Thessaly, Trikala, Longiai (77); Thessaly, S of Asprokklisia (78); Epirus, Ioannina, R. Zagoritikos, Karies (106); Epirus, Konitsa, Asimohori (109); Epirus, 10 km N of Louros (110); Epirus, S of Seriziana (111); Epirus, W of Kriopigi (114); Epirus, R. Aheron, N of Gliki (115); Epirus, Mirsini (117); Epirus, R. Kokitos, W of Gardiki (119); Epirus, Igoumenitsa, R. Thiamis, Soulopoulo (122); Epirus, Ioannina, Balndouma (124); Central Greece, Etolia, Lamia, Ieraklia (145); Central Greece, Etolia, Vardousia Mts., Paleovraha (151); Central Greece, Etolia, Nafpaktos, 9 km S of Krokilio (152); Central Greece, Etolia, Vardousia Mts., 5 km N of Grammeni Oxia (153); Central Greece, Etolia, Vardousia Mts., R. Evinos, Grammeni Oxia (154); Central Greece, Etolia, Vardousia Mts., Terpsithea (158); Central Greece, Etolia, Nafpaktos, R. Mornos, Limnitsa (159); Central Greece, Etolia, Vardousia Mts., 6 km S of Lefkada (162); Central Greece, Etolia, Vardousia Mts., 13 km S of Gardiki (164); Central Greece, Etolia, Vardousia Mts., Pougkakia (165); Central Greece, Etolia, Vardousia Mts., 2 km W of Gardiki (166); Central Greece, Etolia, Panaitoliko Mts., R. Evinos, Klepa (171); Central Greece, Etolia, R. Mornos, Nafpaktos (177); Central Greece, Etolia, Agrinio, Panaitoliko Mts., R. Evinos, Agios Dimitros (178); Central Greece, Etolia, Agrinio, Peristra, 1 km S of Perkos (182); Central Greece, Etolia, Agrinio, Panaitoliko Mts. R. Trikeriotis, Dermatio (185); Central Greece, Etolia, Agrinio, Panaitoliko Mts., Potamoula (190); Central Greece, Etolia, Lamia, Pavliani (192); Central Greece, Etolia, Agrinio, Ahlavokastro (196); Central Greece, Etolia, Arta, Loutraki (197); Central Greece, Etolia, Nafpaktos, Koutsopanneika (203); Peloponnese, R. Krathis, Voutsimos (211); Peloponnese, 3 km N of Agia Varvara (213); Peloponnese, R. Krathis, 7 km N of Peristera (214); Peloponnese, tributary of R. Krathis, 7 km N of Peristera (215); Peloponnese, R. Krathis, Peristera (217); Peloponnese, Aroania Mts., Kalivia (223); Peloponnese, Pagrati (225); Peloponnese, Aroania Mts., Kastria (226); Peloponnese, Kato Klitoria (227); Peloponnese, Aroania Mts., Xelmos (above) (228); Peloponnese, R. Piro, Elliniko (230); Peloponnese, Panachaiko Mts., tributory of R. Selinous, Leontio (231); Peloponnese, Panachaiko Mts., Leontio (232); Peloponnese, Erymanthos Mts., Lechouri (233); Peloponnese, Panachaiko Mts., Veteika (234); Peloponnese, Erymanthos Mts., Kato Vlasia (235); Peloponnese, Panachaiko Mts., Kounaveika (near village) (236); Peloponnese, Erymanthos Mts., Profitis Ilias (239); Peloponnese, Erymanthos Mts., Stavrohori, Eliniko (241); Peloponnese, Panachaiko Mts., Souli (242); Peloponnese, Erymanthos Mts., Manesi (244); Peloponnese, E of Olympia (247).

***Wiedemannia* (*Eucelidia*) *zetterstedti* (Fallén, 1826)**

Literature references. Thrace (Wagner 1981) (36); Macedonia, Olympus Mts., above Agios Dyonysos, Prionia (Wagner 1981) (41); Epirus, Preveza, Zalongu, stream 2 km E of Mirsini (Wagner 1995) (113); North Aegean islands, Samos, below Manolates (Wagner 1981) (125); North Aegean islands, Samos, E of Pirgos (Wagner 1981) (126);

North Aegean islands, Lesbos, 1 km SW of Megalochori (Wagner 1981) (129); North Aegean islands, Lesbos, S of Neochorion (Wagner 1981) (133); Central Greece, Euboea, S of Komiton (Wagner 1995) (142); Central Greece, Euboea, Steni Dirfyos (former Ano Steni) (Wagner 1995) (143); Central Greece, Parnassus Mts., above Polydrosos (Wagner 1981) (146); Central Greece, Central Euboea (Wagner 1981) (201); Cyclades islands, Andros, Apikia (Wagner 1981) (208); Peloponnese, Taygetos Mts. (below the summit) (Wagner 1981) (209); Laschtabend (Alpen) (Wagner 1981) (258).

New records. Thrace, E of Mega Derio (1); Thrace, N of Avas (5); Thrace, Sapka Mts. 1 (6); Thrace, Sapka Mts. 2 (8); Thrace, Sapka Mts., Nea Sanda 1 (9); Thrace, Sapka Mts., Nea Sanda 2 (10); Thrace, Anatoliki Rodopi, E od Drimi (11); Thrace, Anatoliki Rodopi, Drimi (12); Thrace, Anatoliki Rodopi, E of Gratini 1 (13); Thrace, Miki (16); Thrace, 8 km N of Sminthi (17); Thrace, N of Xanthi (18); Thrace, N of Dipotama 1 (19); Thrace, N of Dipotama 2 (20); Thrace, Dit. Rodopi, N of Dipotama 1 (21); Thrace, N of Dipotama 3 (22); Thrace, N of Dipotama 5 (24); Thrace, S of Dipotama (27); Thrace, S of Silli (28); Thrace, Dit. Rodopi, Skaloti (29); Thrace, W of Sidironero (34); Thrace, Rodopi, E of Mikromilia (35); Macedonia, E of Mikroklisoura (38); Macedonia, N of Stavros (39); Macedonia, R. Mavroneri, 10 km W of Katerini (40); Macedonia, Pieria Mts., 2 streams on Ritini (42); Macedonia, N of Agios Dimitrios (43); Macedonia, S of Agios Dimitrios (45); Macedonia, Pieria Mts., E of Fteri (46); Macedonia, Pieria Mts., Fteri (47); Macedonia, Pieria Mts., W of Fteri (48); Macedonia, W of Daskio (49); Macedonia, Pieria Mts., 1 (51); Macedonia, Pieria Mts., 2 (52); Macedonia, Pieria Mts., 3 (53); Macedonia, Phalacro Mts., N of Livadero (55); Macedonia, Grevena, 6 km S of Milea (57); Macedonia, Kozani, Polilako (Paraveti), Neapolis (59); Macedonia, Smokilas Mts., main stream near the bridge, 2 km E of Agia Paraskevi (63); Thessaly, Ossa Mts., stream Apataniana (71); Thessaly, S of Kallithea (73); Thessaly, Deskati (76); Thessaly, S of Asprokklisia (78); Thessaly, Kalambaka, Agios Nikolaos (80); Thessaly, Trikala, Kato Palagokaria (82); Thessaly, Kalambaka, 5 km E of Paleochori (83); Thessaly, Kalambaka, Trigona (85); Thessaly, Kalambaka, Koridallos (86); Thessaly, Trikala, Arta, Pahtouri (87); Thessaly, Kalambaka, 4 km S of Ambelia (91); Epirus, Metsovo, 14 km S of Milea (92); Epirus, Metsovo, R. Metsovitikos (99); Epirus, Metsovo, Lakmos Mts., Anthohori, (bellow rapid river) (100); Epirus, Ioannina, R. Zagoritikos, Karies (106); Epirus, 10 km N of Louros (110); Epirus, S of Seriziana (111); Epirus, Ioannina, R. Voidomatis, Aristi (112); Epirus, R. Aheron, N of Gliki (115); Epirus, Kanallaki, Skepaston (116); Epirus, Mirsini (117); Epirus, R. Aheron, Gliki (118); Epirus, R. Kokitos, W of Gardiki (119); Epirus, Igoumenitsa, R. Thiamis, Soulopoulo (122); Central Greece, Etolia, Lamia, Ieraklia (145); Central Greece, Etolia, Vardousia Mts., Mousonitsa (149); Central Greece, Etolia, Vardousia Mts., Athanasios Diakos (150); Central Greece, Etolia, Vardousia Mts., Paleovraha (151); Central Greece, Etolia, Nafpaktos, 9 km S of Krokilio (152); Central Greece, Etolia, Vardousia Mts., 7 km N of Grammeni Oxia (156); Central Greece, Etolia, Nafpaktos, R. Mornos, Limnitsa (159); Central Greece, Etolia, Vardousia Mts., Elato (161); Central Greece, Etolia, Vardousia Mts., Pougkakia (165); Central Greece, Etolia, Vardousia Mts., 2 km W of Gardiki (166); Central Greece, Etolia, Vardousia

Mts., Grigorio (167); Central Greece, Etolia, Vardousia Mts., Ano Chora (169); Central Greece, Etolia, Panaitoliko Mts., Klepa (170); Central Greece, Etolia, Panaitoliko Mts., R. Evinos, Klepa (171); Central Greece, Etolia, Vardousia Mts., 3 km W of Kryoneri (172); Central Greece, Etolia, Vardousia Mts., Kato Chora (173); Central Greece, Etolia, Nafpaktos, Anthofito (174); Central Greece, Etolia, Nafpaktos, tributory of R. Evinos, 6 km N of Pokista (176); Central Greece, Etolia, R. Mornos, Nafpaktos (177); Central Greece, Etolia, Nafpaktos, Simos (180); Central Greece, Etolia, Nafpaktos, Pokista (181); Central Greece, Etolia, Agrinio, Peristra, 1 km S of Perkos (182); Central Greece, Etolia, Agrinio, R. Evinos, Kato Hrisovitsa, Diasellaki (183); Central Greece, Etolia, Panaitoliko Mts., Chaliki, Ladikon (187); Central Greece, Etolia, Agrinio, Agia Soufia (191); Central Greece, Etolia, Lamia, Pavliani (192); Central Greece, Etolia, Giona Mts., Sikia (194); Central Greece, Oeta Mts., stream Valorema, Pavliani (195); Central Greece, Etolia, Agrinio, Ahlavokastro (196); Central Greece, Etolia, Arta, Loutraki (197); Central Greece, Etolia, Agrinio, Panaitoliko Mts., Palagohori (199); Central Greece, Etolia, Nafpaktos, Avrorema bridge (200); Central Greece, Etolia, Agrinio, Panaitoliko Mts., 3 km N of Hani Lioliou (202); Central Greece, Etolia, Nafpaktos, Koutsopanneika (203); Peloponnese, Aroania Mts., 2 km S of Zarouchla (212); Peloponnese, Aroania Mts., Zarouhla (220); Peloponnese, Aroania Mts., Kalivia (223); Peloponnese, Kato Klitoria (227); Peloponnese, Panachaiko Mts., tributory of R. Selinous, Leontio (231); Peloponnese, Erymanthos Mts., Lechouri (233); Peloponnese, Panachaiko Mts., Veteika (234); Peloponnese, Panachaiko Mts., Kounaveika (near village) (236); Peloponnese, E of Olympia (247).

***Wiedemannia* (*Philolutra*) *angelieri* Vaillant, 1967**

New records. Central Greece, Etolia, Vardousia Mts., Athanasios Diakos (150).

Remarks. This species is newly recorded from Greece.

***Wiedemannia* (*Philolutra*) *chvali* Joost, 1981**

New records. Thrace, N of Dipotama 3 (22); Thrace, N of Sidironero 1 (31).

Remarks. This species is newly recorded from Greece.

***Wiedemannia* (*Philolutra*) *fallaciosa* (Loew, 1873)**

Literature references. Macedonia, Olympus Mts. above Agios Dyonysos, Prionia (Wagner 1981) (41); Epirus, Preveza, Zalongu, stream 2 km E of Mirsini (Wagner 1995) (113).

New records. Thrace, E of Mega Derio (1); Thrace, Miki (16); Thrace, N of Dipotama 1 (19); Thrace, Dit. Rodopi, Skaloti (29); Macedonia, R. Mavroneri, 10 km

W of Katerini (40); Macedonia, Pieria Mts., S of Elatohori (44); Macedonia, S of Agios Dimitrios (45); Macedonia, Pieria Mts., E of Fteri (46); Macedonia, W of Daskio (49); Macedonia, Pieria Mts., 2 (52); Macedonia, E of Velventos (54); Macedonia, Grevena, Milea (56); Macedonia, Grevena, 6 km S of Milea (57); Macedonia, Kozani, Polilako (Paraveti), Neapolis (59); Macedonia, Grevena, R. Venetikos, Kipourio (60); Macedonia, Kastoria, Nestorio (62); Macedonia, Kastoria, Grammos Mts., 7 km S Chrisi (64); Macedonia, Kastoria, Grammos Mts., 6 km N Pefkofito (65); Thessaly, Deskati (76); Thessaly, S of Asprokklisia (78); Thessaly, Trikala, Moshofito, Avra (79); Thessaly, Kalambaka, Agios Nikolaos (80); Thessaly, Trikala, Stournareika (81); Thessaly, Trikala, Kato Palagokaria (82); Thessaly, Kalambaka, 5 km E of Paleochori (83); Thessaly, Kalambaka, Paleochori (84); Thessaly, Kalambaka, Trigona (85); Thessaly, Trikala, Arta, Pahtouri (87); Thessaly, Trikala, Arta, R. Ahelos, Kapsala (88); Thessaly, Trikala, Arta, Korifi (89); Epirus, Metsovo, 14 km S of Milea (92); Epirus, Metsovo, Lakmos Mts., Anilio (5 km S bellow river) (93); Epirus, Metsovo, 12 km W Milea (98); Epirus, Metsovo, R. Metsovitikos (99); Epirus, Metsovo, Lakmos Mts., Anthohori, (bellow rapid river) (100); Epirus, Lakmos Mts., 10 km S of Anilio (101); Epirus, Ioannina, Megalo Peristeri (104); Epirus, Ioannina, R. Zagoritikos, Karies (106); Epirus, Konitsa, Asimohori (109); Epirus, 10 km N of Louros (110); Epirus, Ioannina, R. Voidomatis, Aristi (112); Epirus, W of Kriopigi (114); Epirus, R. Aheron, N of Gliki (115); Epirus, Kanallaki, Skepaston (116); Epirus, Mirsini (117); Epirus, R. Kokitos, W of Gardiki (119); Epirus, Ioannina, Balndouma (124); Central Greece, Etolia, Lamia, Ieraklia (145); Central Greece, Etolia, Vardousia Mts., Stromi (148); Central Greece, Etolia, Vardousia Mts., Mousonitsa (149); Central Greece, Etolia, Vardousia Mts., Athanasios Diakos (150); Central Greece, Etolia, Nafpaktos, 9 km S of Krokilio (152); Central Greece, Etolia, Vardousia Mts., 5 km N of Grammeni Oxia (153); Central Greece, Etolia, Vardousia Mts., R. Evinos, Grammeni Oxia (154); Central Greece, Etolia, Vardousia Mts., 9 km N of Grammeni Oxia (155); Central Greece, Etolia, Vardousia Mts., 7 km N of Grammeni Oxia (156); Central Greece, Etolia, Vardousia Mts., Terpsithea (158); Central Greece, Etolia, Nafpaktos, R. Mornos, Limnitsa (159); Central Greece, Etolia, Vardousia Mts., Elatovrisi (160); Central Greece, Etolia, Vardousia Mts., Elato (161); Central Greece, Etolia, Vardousia Mts., 6 km S of Lefkada (162); Central Greece, Etolia, Vardousia Mts., Gardiki (163); Central Greece, Etolia, Vardousia Mts., 13 km S of Gardiki (164); Central Greece, Etolia, Vardousia Mts., Pougkakia (165); Central Greece, Etolia, Vardousia Mts., 2 km W of Gardiki (166); Central Greece, Etolia, Vardousia Mts., Grigorio (167); Central Greece, Etolia, Panaitoliko Mts., Klepa (170); Central Greece, Etolia, Panaitoliko Mts., R. Evinos, Klepa (171); Central Greece, Etolia, Vardousia Mts., 3 km W of Kryoneri (172); Central Greece, Etolia, Vardousia Mts., Kato Chora (173); Central Greece, Etolia, Nafpaktos, Anthofito (174); Central Greece, Etolia, Nafpaktos, tributory of R. Evinos, 6 km N of Pokista (176); Central Greece, Etolia, R. Mornos, Nafpaktos (177); Central Greece, Etolia, Agrinio, Panaitoliko Mts., R. Evinos, Agios Dimitros (178); Central Greece, Etolia, Nafpaktos, 2 km N of Pokista (179); Central Greece, Etolia, Nafpaktos, Simos (180); Central Greece, Etolia, Nafpaktos, Pokista

(181); Central Greece, Etolia, Agrinio, Peristra, 1 km S of Perkos (182); Central Greece, Etolia, Agrinio, R. Evinos, Kato Hrisovitsa, Diasellaki (183); Central Greece, Etolia, Agrinio, Panaitoliko Mts. R. Trikeriotis, Dermatio (185); Central Greece, Etolia, Lamia, Pavliani (192); Central Greece, Etolia, Giona Mts., Sikia (194); Central Greece, Etolia, Agrinio, Ahlavokastro (196); Central Greece, Etolia, Arta, Loutraki (197); Central Greece, Etolia, Agrinio, Panaitoliko Mts., Palagohori (199); Central Greece, Etolia, Nafpaktos, Avrorema bridge (200); Central Greece, Etolia, Agrinio, Panaitoliko Mts., 3 km N of Hani Lioliou (202); Central Greece, Etolia, Nafpaktos, Koutsopanneika (203); Peloponnese, R. Krathis, Voutsimos (211); Peloponnese, 3 km N of Agia Varvara (213); Peloponnese, R. Krathis, 7 km N of Peristera (214); Peloponnese, tributary of R. Krathis, 7 km N of Peristera (215); Peloponnese, 2 km N of Peristera (216); Peloponnese, R. Krathis, Peristera (217); Peloponnese, Ano Potames, Kalivitis (219); Peloponnese, Aroania Mts., Zarouhla (220); Peloponnese, Likouria (under the village) (222); Peloponnese, Aroania Mts., Kalivia (223); Peloponnese, Aroania Mts., Kastria (226); Peloponnese, Kato Klitoria (227); Peloponnese, Aroania Mts., Xelmos (above) (228); Peloponnese, R. Piro, Elliniko (230); Peloponnese, Panachaiko Mts., tributory of R. Selinous, Leontio (231); Peloponnese, Panachaiko Mts., Leontio (232); Peloponnese, Erymanthos Mts., Lechouri (233); Peloponnese, Panachaiko Mts., Veteika (234); Peloponnese, Erymanthos Mts., Kato Vlasia (235); Peloponnese, Panachaiko Mts., Kounaveika (near village) (236); Peloponnese, Panachaiko Mts., Moira (237); Peloponnese, Panachaiko Mts., Moira (after village) (238); Peloponnese, Panachaiko Mts., Souli (242); Peloponnese, Abelokipi (246); Peloponnese, E of Olympia (247).

Wiedemannia (*Pseudowiedemannia*) *lamellata* (Loew, 1869)

Literature references. Thessaly, Karya (Wagner 1981) (72); North Aegean islands, Lesbos, 1 km W of Ippion (Wagner 1981) (128).

New records. Thrace, Sapka Mts., Nea Sanda 1 (9); Thrace, Anatoliki Rodopi, E od Drimi (11); Thrace, Anatoliki Rodopi, Drimi (12); Thrace, Anatoliki Rodopi, E of Gratini 1 (13); Thrace, 8 km N of Sminthi (17); Thrace, S of Silli (28); Thrace, Dit. Rodopi, Skaloti (29); Thrace, Dit. Rodopi 1 (30); Thrace, N of Sidironero 1 (31); Thrace, Dit. Rodopi 2 (32); Thrace, N of Sidironero 2 (33); Thrace, W of Sidironero (34); Macedonia, N of Stavros (39); Macedonia, R. Mavroneri, 10 km W of Katerini (40); Macedonia, Phalacro Mts., N of Livadero (55); Macedonia, Kozani, Polilako (Paraveti), Neapolis (59); Thessaly, Trikala, Kato Palagokaria (82); Thessaly, Kalambaka, 5 km E of Paleochori (83); Thessaly, Kalambaka, Paleochori (84); Thessaly, Kalambaka, Koridallos (86); Epirus, Metsovo, Lakmos Mts., Anthohori, (bellow rapid river) (100); Epirus, Ioannina, R. Vardas, Abelos (123); Central Greece, Etolia, Lamia, Ieraklia (145); Central Greece, Etolia, Vardousia Mts., 7 km N of Grammeni Oxia (156); Central Greece, Etolia, Vardousia Mts., 7 km S of Gardiki (157); Central Greece, Etolia, Vardousia Mts., Terpsithea (158); Central Greece, Etolia, Vardousia

Mts., 13 km S of Gardiki (164); Central Greece, Etolia, Vardousia Mts., Pougkakia (165); Central Greece, Etolia, Vardousia Mts., 2 km W of Gardiki (166); Central Greece, Etolia, Agrinio, Panaitoliko Mts., Megali Chora (193); Central Greece, Etolia, Nafpaktos, Avrorema bridge (200); Peloponnese, Aroania Mts., Kalivia (223); Peloponnese, Aroania Mts., Kastria (226); Peloponnese, Panachaiko Mts., tributory of R. Selinous, Leontio (231); Peloponnese, Panachaiko Mts., Leontio (232); Peloponnese, Erymanthos Mts., Lechouri (233); Peloponnese, Panachaiko Mts., Veteika (234); Peloponnese, Erymanthos Mts., Kato Vlasia (235); Peloponnese, Panachaiko Mts., Kounaveika (near village) (236); Peloponnese, Erymanthos Mts., Manesi (244); Peloponnese, E of Olympia (247).

***Wiedemannia* (*Pseudowiedemannia*) *microstigma* (Bezzi, 1904)**

New records. Thessaly, Trikala, Kato Palagokaria (82); Central Greece, Etolia, Vardousia Mts., Stromi (148).

***Wiedemannia* (*Roederella*) *czernyi* (Bezzi, 1905)**

Literature references. Macedonia, Chalkidiki, Chlomon Oros., Paleokastron, Vatonia P. 1 (Wagner 1995) (66).

New records. Thrace, E of Sapka Mts., big stream in the valley (4); Macedonia, Chalkidiki, Chlomon Oros., Paleokastron, Vatonia P. 2 (67).

***Wiedemannia* (*Wiedemannia*) *andreevi* Joost, 1982**

New records. Thrace, S of Silli (28).

***Wiedemannia* (*Wiedemannia*) *bilobata* Oldenberg, 1910**

Literature references. Macedonia, Olympus Mts. above Agios Dyonysos, Prionia (Wagner 1981) (42); Central Greece, Parnassus Mts., above Polydrosos (Wagner 1981) (146).

***Wiedemannia* (*Wiedemannia*) *dinarica* Engel, 1940**

New records. Epirus, Ioannina, R. Voidomatis, Aristi (112); Epirus, R. Aheron, N of Gliki (115); Epirus, R. Aheron, Gliki (118); Peloponnese, Likouria (under the village) (222); Peloponnese, Aroania Mts., Krinofita (224); Peloponnese, Aroania Mts., Kastria (226); Peloponnese, Kato Klitoria (227).

Wiedemannia (*Wiedemannia*) *dyonysica* Wagner, 1990

Literature references. Macedonia, Olympus Mts. above Agios Dyonysos, Prionia (Wagner 1990) (41).

Wiedemannia (*Wiedemannia*) *graeca* Vaillant & Wagner, 1990

Literature references. Central Greece, Polydrosos (Vaillant and Wagner 1990) (144).

New records. Thrace, Rodopi, Skaloti (29); Thessaly, Trikala, Stournareika (81); Thessaly, Kalambaka, 5 km E of Paleochori (83); Thessaly, Kalambaka, Paleochori (84); Thessaly, Trikala, Arta, R. Ahelos, Kapsala (88); Epirus, Metsovo, Lakmos Mts., 2 km S of Anilio (bellow left tributary) (97); Epirus, Metsovo, Lakmos Mts., Anthohori, (bellow rapid river) (100); Central Greece, Etolia, Vardousia Mts., Stromi (148).

Wiedemannia (*Wiedemannia*) *tricuspidata* (Bezzi, 1905)

New records. Thrace, S of Silli (28); Macedonia, Grevena, R. Venetikos, Kipourio (60); Macedonia, Kastoria, Grammos Mts., 7 km S Chrisi (64); Thessaly, Trikala, Longiai (77); Thessaly, Trikala, Kato Palagokaria (82); Epirus, Konitsa, R. Saradaporos, Drosopigi (108); Central Greece, Etolia, Nafpaktos, R. Mornos, Limnitsa (159); Central Greece, Etolia, Panaitoliko Mts., R. Evinos, Klepa (171); Central Greece, Etolia, Nafpaktos, tributory of R. Evinos, 6 km N of Pokista (176); Central Greece, Etolia, R. Mornos, Nafpaktos (177); Central Greece, Etolia, Agrinio, Panaitoliko Mts., R. Evinos, Agios Dimitros (178); Central Greece, Etolia, Agrinio, Peristra, 1 km S of Perkos (182).

Wiedemania artemisa Ivković & Plant, 2012

Literature references. Thessaly, Trikala, Kato Palagokaria (Ivković et al. 2012) (82); Thessaly, Trikala, Arta, Pahtouri (Ivković et al. 2012) (87); Thessaly, Trikala, Arta, R. Ahelos, Kapsala (Ivković et al. 2012) (88); Thessaly, Trikala, Arta, Korifi (Ivković et al. 2012) (89); Epirus, Metsovo, Lakmos Mts., Anthohori, (bellow rapid river) (Ivković et al. 2012) (100); Epirus, Igoumenitsa, R. Thiamis, Soulopoulo (Ivković et al. 2012) (122); Central Greece, Etolia, Lamia, Ieraklia (Ivković et al. 2012) (145); Central Greece, Etolia, Vardousia Mts., 7 km S of Gardiki (Ivković et al. 2012) (157); Central Greece, Etolia, Vardousia Mts., Pougkakia (Ivković et al. 2012) (165); Peloponnese, R. Krathis, Voutsimos (Ivković et al. 2012) (211); Peloponnese, R. Krathis, Peristera (Ivković et al. 2012) (217); Peloponnese, Likouria (under the village) (Ivković et al. 2012) (222); Peloponnese, Aroania Mts., Kastria (Ivković et al. 2012) (226); Peloponnese, Kato Klitoria (Ivković et al. 2012) (227); Peloponnese, Panachaiko Mts., tributory of R. Selinous, Leontio (Ivković et al. 2012) (231); Peloponnese, Panachaiko Mts., Leontio (Ivković et al. 2012) (232); Peloponnese, Panachaiko Mts., Veteika (Ivković et al. 2012) (234); Peloponnese, Panachaiko Mts., Souli (Ivković et al. 2012) (242).

New records. Thessaly, Kalambaka, 4 km S of Ambelia (91); Epirus, Metsovo, Lakmos Mts., 2 km S of Anilio (bellow left tributary) (97); Epirus, Konitsa, Smolikas Mts., Pournia (107); Epirus, Mirsini (117); Central Greece, Etolia, Vardousia Mts., Stromi (148); Central Greece, Etolia, Vardousia Mts., Athanasios Diakos (150); Central Greece, Etolia, Nafpaktos, 9 km S of Krokilio (152); Central Greece, Etolia, Vardousia Mts., R. Evinos, Grammeni Oxia (154); Central Greece, Etolia, Vardousia Mts., 7 km N of Grammeni Oxia (156); Central Greece, Etolia, Vardousia Mts., Terpsithea (158); Central Greece, Etolia, Nafpaktos, R. Mornos, Limnitsa (159); Central Greece, Etolia, Vardousia Mts., 13 km S of Gardiki (164); Central Greece, Etolia, Vardousia Mts., 2 km W of Gardiki (166); Central Greece, Etolia, Vardousia Mts., Grigorio (167); Central Greece, Etolia, Vardousia Mts., Kato Chora (173); Central Greece, Karpenisi, Agios Nikolaos (175); Central Greece, Etolia, Nafpaktos, tributory of R. Evinos, 6 km N of Pokista (176); Central Greece, Etolia, Nafpaktos, Pokista (181); Central Greece, Etolia, Agrinio, Peristra, 1 km S of Perkos (182); Central Greece, Etolia, Panaitoliko Mts., Prousos (186); Central Greece, Etolia, Panaitoliko Mts., Chaliki, Ladikon (187); Central Greece, Etolia, Agrinio, Panaitoliko Mts., Anatoliki Frangista (189); Central Greece, Etolia, Lamia, Pavliani (192); Central Greece, Etolia, Agrinio, Panaitoliko Mts., Megali Chora (193); Central Greece, Etolia, Agrinio, Panaitoliko Mts., Houni (198); Central Greece, Etolia, Nafpaktos, Koutsopanneika (203); Peloponnese, 3 km N of Agia Varvara (213); Peloponnese, R. Krathis, 7 km N of Peristera (214).

Wiedemannia iphigeniae Ivković & Sinclair, sp. n.

Records. Peloponnese, Aroania Mts., Krinofita (224).

Wiedemannia ljerkae Ivković & Sinclair, sp. n.

Records. Epirus, Igoumenitsa, R. Thiamis, Soulopoulo (122); Central Greece, Etolia, Agrinio, Peristra, 1 km S of Perkos (182); Peloponnese, Aroania Mts., Kastria (226); Peloponnese, Kato Klitoria (227).

Wiedemannia nebulosa Ivković & Sinclair, sp. n.

Records. Thrace, N of Dipotama 5 (24).

Wiedemannia pseudoberthelemyi Ivković & Sinclair, sp. n.

Records. Central Greece, Etolia, Vardousia Mts., R. Evinos, Grammeni Oxia (154); Central Greece, Etolia, R. Mornos, Nafpaktos (177); Central Greece, Panaitoliko Mts., R. Tavropos, Kalesmeno (184); Central Greece, Etolia, Agrinio, Agia Soufia (191).

Subfamily Hemerodromiinae

Chelifera angusta Collin, 1927

New records. North Aegean islands, Lesbos (141).

Remarks. This species is newly recorded from Greece.

Chelifera barbarica Vaillant, 1982

Literature references. Dodecanese islands, Rhodes, near Archipolis (Wagner 1995) (205).

Chelifera horvati Ivković & Sinclair, sp. n.

Records. Central Greece, Etolia, Arta, Loutraki (197).

Chelifera precabunda Collin, 1961

New records. Thrace, Sapka Mts., 1 (6); Thrace, Dit. Rodopi, Skaloti (29); Thrace, Rodopi, E of Mikromilia (35); Macedonia, Pieria Mts., E of Velventos (50); Peloponnese, R. Krathis, 7 km N of Peristera (214).

Chelifera precatoria (Fallén, 1816)

Literature references. Crete, Georgioupolis (Wagner 1981) (255).

Chelifera stigmatica (Schiner, 1862)

Literature references. North Aegean islands, Samos, E of Pirgos (Wagner 1981) (126).

New records. Thrace, N of Sidironero 2 (33); Thessaly, Trikala, Kato Palagokaria (82); Epirus, 10 km N of Louros (110); Epirus, R. Aheron, N of Gliki (115); Central Greece, Etolia, Vardousia Mts., Stromi (148); Central Greece, Etolia, Panaitoliko Mts.,

R. Evinos, Klepa (171); Central Greece, Etolia, Agrinio, Peristra, 1 km S of Perkos (182); Central Greece, Etolia, Nafpaktos, Koutsopanneika (203); Peloponnese, Erymanthos Mts., Stavrohori, Eliniko (241); Peloponnese, E of Olympia (247).

Chelifera trapezina (Zetterstedt, 1838)

Literature references. North Aegean islands, Samos, E of Pirgos (Wagner 1981) (126).

Hemerodromia melangyna Collin, 1927

New records. Epirus, 10 km N of Louros (110); Epirus, R. Aheron, N of Gliki (115).

Remarks. This species is newly recorded from Greece.

Hemerodromia oratoria (Fallén, 1816)

Literature references. Peloponnese, Ano Kastritsi, stream (Wagner 1995) (240).

New records. Thrace, Lesitse Mts. (3); Thrace, Anatoliki Rodopi, E od Drimi (11); Thrace, Anatoliki Rodopi, Drimi (12); Thrace, Miki (16); Thrace, 8 km N of Sminthi (17); Epirus, 10 km N of Louros (110); Epirus, W of Kriopigi (114); Epirus, Mirsini (117); Central Greece, Etolia, Lamia, Ieraklia (145).

Hemerodromia unilineata Zetterstedt, 1842

Literature references. Thessaly, Portaria (Wagner 1995) (70).

New records. Thrace, Anatoliki Rodopi, E od Drimi (11); Thrace, Anatoliki Rodopi, Drimi (12); Thrace, Anatoliki Rodopi, E of Gratini, 1 (13); Thrace, 8 km N of Sminthi (17); Thrace, S of Silli (28); Thrace, W of Sidironero (34); Macedonia, E of Mikroklisoura (38); Macedonia, W of Daskio (49); Epirus, 10 km N of Louros (110); Epirus, R. Aheron, N of Gliki (115); Epirus, Mirsini (117); Epirus, R. Kokitos, Themelo (120); Epirus, Igoumenitsa, Thesprotia, R. Thiamis, Neohori (121).

Results and discussion

Species richness and assemblage composition. A total of 47 species of aquatic empidids are recorded from Greece (Table 2), collected from 258 sites (Fig. 1, Table 1). The subfamily Clinocerinae is represented by 37 species, in seven genera: *Clinocera* Meigen (3 species), *Clinocerella* Engel (1 species), *Dolichocephala* Macquart (5 species), *Kowarzia* Mik (4 species), *Phaeobalia* (1 species), *Roederiodes* Coquillett (1 species) and

Wiedemannia Zetterstedt (22 species). The subfamily Hemerodromiinae is represented by 10 species, in two genera: *Chelifera* (7 species) and *Hemerodromia* Meigen (3 species) (Table 2). The Clinocerinae genus *Wiedemannia* is most species rich (46.8%), followed by the Hemerodromiinae genus *Chelifera* (14.9%) (Fig. 13). The Hellenic Western Balkan (Ecoregion 6) is the richest European Ecoregion with 42 species, while 20 species are recorded from the Eastern Balkan (Ecoregion 7), and 15 species occur in both ecoregions (Table 2). Most aquatic Empididae inhabiting Greece are widely distributed in Europe or more broadly, but 10 species are only known from mainland Greece or its islands (Table 2).

Greece supports at least 47 species, but this is unlikely to be the final number. Slovenia, situated in the northwest part of the Balkans, supports 58 species, Croatia 51 species, while Bosnia & Herzegovina, Montenegro and FYR Macedonia have 38, 34 and 34, respectively (Fig. 14). The Sørensen Index of Similarity showed that the Empididae fauna of Greece is most similar to that of FYR Macedonia followed by Bosnia & Herzegovina, whereas it is the least similar to that of Montenegro (Table 3).

We compared our list of Greek species with existing checklists in "Fauna Europaea" (Chvála 2012) and the World Catalogue of Empididae (Yang et al. 2007). The following species were not recorded from Greece in both these works: *Chelifera angusta* and *Hemerodromia melangyna* from the subfamily Hemerodromiinae, and *Clinocera megalatlantica*, *Kowarzia plectrum*, *Phaeobalia dimidiata*, *W.* (*Chamaedipsia*) *beckeri*, *W.* (*Philolutra*) *angelieri* and *W.* (*P.*) *chvali* from the subfamily Clinocerinae. They represent new country records. On the other hand, some species that are listed in Chvála (2012) and Yang et al. (2007) are not included in the present checklist. We omitted *Wiedemannia* (*Philolutra*) *hygrobia* (Loew) because its presence has not been confirmed in Greece. However, it is possible that it does occur in Greece as it is present in surrounding countries (Chvála 2012, Horvat 1995b, 1997) and consequently it was included in the above key to species. Altogether, 13 species (including the new species) are recorded for the first time from Greece. The species richness of both subfamilies varies between European Ecoregions.

Clinocerinae show greater species richness in mountainous areas of Europe (Vaillant 1982, Wagner and Gathmann 1996), and they are also more species rich in streams and rivers in the Balkans (Horvat 1993, 1995b, 1997, Ivković et al. 2007, 2010, 2012, 2013a, 2013b, 2014).

Comparison with neighbouring faunas. Greece has been divided into two ecoregions: Hellenic Western Balkan (Ecoregion 6) and Eastern Balkan (Ecoregion 7). The higher species richness is in the Hellenic Western Balkan Ecoregion, but the Eastern Balkan Ecoregion in Greece is much smaller, so this was an expected result. Greece supports at least 47 species, of which 10 are currently endemic to the country (*Dolichocephala cretica*, *D. vaillanti*, *Clinocerella siveci*, *Roederiodes malickyi*, *Wiedemannia* (*W.*) *graeca*, *W. iphigeniae*, *W. ljerkae*, *W. nebulosa*, *W. pseudoberthelemyi*, *Chelifera horvati*). The higher number of species recorded for Slovenia and the far fewer species recorded, for instance, in Montenegro, FYR Macedonia and Bosnia & Herzegovina should be viewed with caution. Slovenia was well studied (Horvat 1995a) in comparison to other

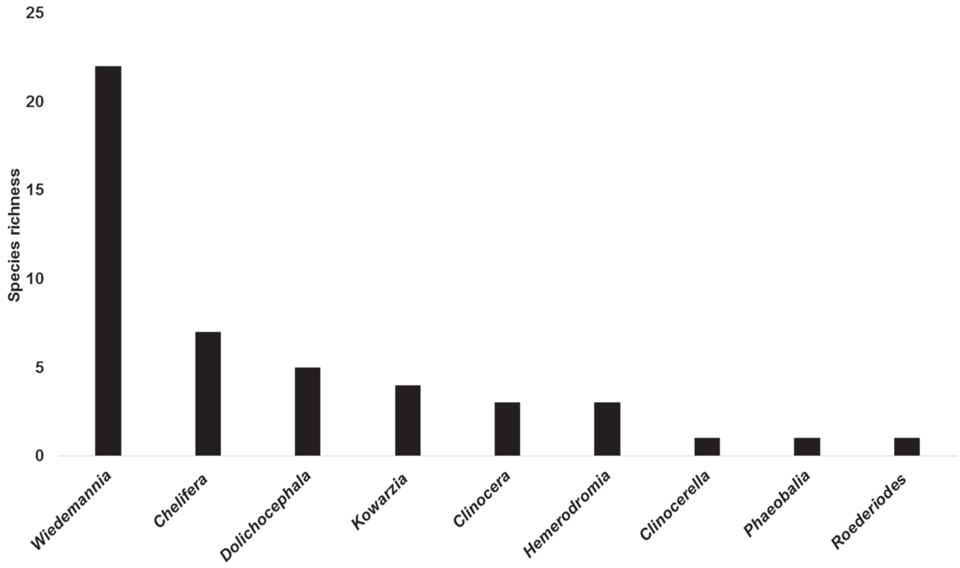


Figure 13. Species richness of aquatic Empididae genera from Greece.

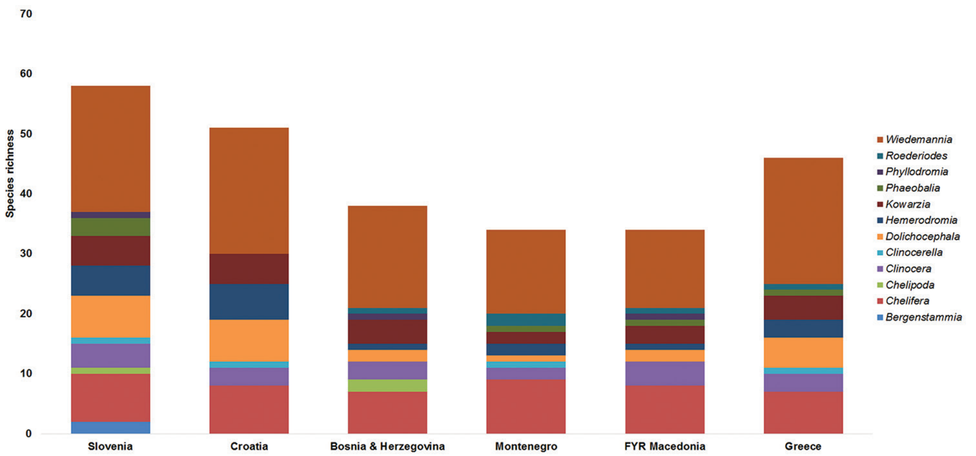


Figure 14. Comparison of the Greek aquatic Empididae assemblage with those of other Balkan countries.

Balkan countries, which were only studied sporadically (Horvat 1993, 1995b, 1997, Ivković et al. 2012, 2013b, 2014).

Our comparison of Sørensen Similarity indices shows that the FYR Macedonia assemblage has the greatest similarity with the Greek assemblage. This was expected since FYR Macedonia borders with Greece, so they have many species in common. The lowest similarity is with Montenegro, which was not expected as it is geographically much closer to Greece, but this could be due to undersampling of that country (Ivković et al. 2014).

Concluding remarks

The Greek aquatic Empididae fauna is composed of exclusively Palearctic taxa with the exception of *C. stagnalis*, which is the most widespread clinocerine (known from North America, Asia, and North Africa) (Sinclair 2008). Most of the species are restricted to Europe or South Europe and some of them are only found in the Balkans and Greek islands (e.g., *Dolichocephala zwicki*, *Wiedemannia* (*Chamaedipsia*) *ariadne*, *W.* (*Pseudowiedemannia*) *microstigma*, *W.* (*Wiedemannia*) *dinarica* and *W. artemisa*). Some species have a small area of distribution, occurring in just one or a few sites (e.g., *Chelifera horvati*, *Clinocerella siveci*, *Dolichocephala cretica*, *D. vaillanti*, *Roederiodes malickyi*, *Wiedemannia* (*W.*) *graeca*, *W. iphigeniae*, *W. ljerkae*, *W. nebulosa* and *W. pseudoberthelemyi*), and can be considered as Greek endemics.

There are still some genera of Clinocerinae and Hemerodromiinae that have not been recorded in Greece and that might be present, as they occur in surrounding countries (e.g., *Bergenstammia* Mik, *Chelipoda* Macqaurt and *Phyllodromia* Zetterstedt). Within Greece, most species were reported from the Hellenic Western Balkan Ecoregion; this was expected as this European Ecoregion covers most of the surface area of the country (Illies 1978) and it is considered a biodiversity hotspot (Kryštufek and Reed 2004). The checklist presented here only includes species for which good evidence exists of their presence in Greece. As explained previously, we have omitted any ambiguous or doubtful data and references. This paper may serve as a baseline for planning future work in Greece, but also in surrounding countries for which knowledge of the aquatic dance fly fauna is poor, such as Albania, Bulgaria and Turkey.

Acknowledgements

We would like to thank Dr Ignac Sivec, Dr Hans Malicky and Dr Reinhard Gerecke who helped collect some of the specimens; without their help this paper would lack some of its data. We would like to thank Dr Igor Stanković for his help with the ArcGIS software and the making of the map. We would like to thank the Slovenian Museum of Natural History and curator Dr Tomi Trilar for giving us access to the collection. Jessica Hsiung (CNC) kindly inked the genitalia illustrations.

References

Bezzi M (1904) Empididae novae Palaearcticae ex Museo Nationali Hungarico. Annales Historico-Naturales Musei Nationalis Hungarici 2: 198–202.

Bezzi M (1905) Clinocerae tres novae ex Europa. Annales Historico-Naturales Musei Nationalis Hungarici 3: 362–366.

Chvála M (2012) Fauna Europaea: Empididae. In: Pape T, Beuk P (Eds) Fauna Europaea: Diptera Brachycera. Available from: http://www.fauna-eu.org [Accessed 2 May 2017]

Clarke KR, Gorley RN (2006) PRIMER v6: User Manual/Tutorial. PRIMER-E, Plymouth, 192 pp. http://www.primer-e.com/index.htm

Collin JE (1927) Notes on the Empididae (Diptera) with additions and corrections to the British list. Entomologist's Monthly Magazine 63: 2–29, 61–67, 93–98.

Collin JE (1961) Empididae. British flies. Volume 6. University Press, Cambridge, 782 pp.

Cumming JM, Wood DM (2009) Adult morphology and terminology [Chapter] 2. In: Brown BV, Borkent A, Cumming JM, Wood DM, Woodley NE, Zumbado MA (Eds) Manual of Central American Diptera. Volume 1. NRC Research Press, Ottawa, 9–50.

Engel EO (1918) Das Dipterengenus *Atalanta* Mg. (*Clinocera* ol.). Deutsche Entomologische Zeitschrift 1918: 1–80, 197–268.

Engel EO (1939) 28. Empididae. In: Lindner E (Ed.) Die Fliegen der Palaearktischen Region. Band IV (4) [Lieferung 130]. E. Schweizerbart, Stuttgart, 105–152. [Taf. II–VI]

Engel EO (1940) 28. Empididae. In: Linder, E. (Ed.) Die Fliegen der palaearktischen Region. Band IV (4) [Lieferung 132]. E. Schweizerbart, Stuttgart, 153–192. [Taf. VII–XIII]

Fallén CF (1816) Empidiae Sveciae. Lundae, 17–34.

Fallén CF (1826) Supplementum Dipterorum Sveciae. Lundae, 16 pp.

Haliday AH (1833) Catalogue of Diptera occurring about Holywood in Downshire. The Entomological Magazine 1: 147–180.

Harkrider JR (2000) Predation of *Neoplasta* Coquillett larvae (Diptera: Empididae) on larval midges in the genus *Rheotanytarsus* Bause (Diptera: Chironomidae). Pan-Pacific Entomologist 76: 176–183.

Horvat B (1993) Aquatic Empididae fauna (Diptera) in Bosnia and Herzegovina. Scopolia 28: 1–25.

Horvat B (1995a) Checklist of the aquatic Empididae recorded from Slovenia, with the description of one new species (Diptera). Acta Entomologica Slovenica 3: 25–35.

Horvat B (1995b) Aquatic Empididae Fauna (Diptera) in Macedonia. Acta Musei Macedonici Scientiarum Naturalium 19: 147–170.

Horvat B (1997) New records of aquatic Empididae (Diptera) from Macedonia. Studia Dipterologica 4: 491–496.

Illies J (1978) Limnofauna Europaea. A checklist of the animals inhabiting European inland waters, with account of their distribution and ecology. G. Fischer, Stuttgart, New York and Swets & Zeitlinger, Amsterdam, 532 pp.

Ivković M, Gračan R, Horvat B (2013a) Croatian aquatic dance flies (Diptera: Empididae: Clinocerinae and Hemerodromiinae): species diversity, distribution and relationship to surrounding countries. Zootaxa 3686: 255–276. https://doi.org/10.11646/zootaxa.3686.2.7

Ivković M, Matoničkin Kepčija R, Mihaljević Z, Horvat B (2007) Assemblage composition and ecological features of aquatic dance flies (Diptera, Empididae) in the Cetina River system, Croatia. Fundamental and Applied Limnology 170: 223–232. https://doi.org/10.1127/1863-9135/2007/0170-0223

Ivković M, Mihaljević Z, Miliša M, Previšić A (2013b) Aquatic dance flies fauna (Diptera, Empididae: Clinocerinae and Hemerodromiinae) of Montenegro. Natura Croatica 22: 243–252.

Ivković M, Miliša M, Mihaljević Z (2010) The aquatic dance flies fauna (Diptera, Empididae: Hemerodromiinae and Clinocerinae) of the Plitvice Lakes National Park. Natura Croatica 19: 133–139.

Ivković M, Plant A (2015) Aquatic insects in the Dinarides: identifying hotspots of endemism and species richness shaped by geological and hydrological history using Empididae (Diptera). Insect Conservation and Diversity 8: 302–312. https://doi.org/10.1111/icad.12113

Ivković M, Plant A, Horvat B (2012) A new species of *Wiedemannia* (Diptera: Empididae: Clinocerinae) from Balkan Peninsula. Zootaxa 3478: 581–585.

Ivković M, Vojvoda Zeljko T, Previšić A (2014) New records of aquatic Dance flies (Empididae: Clinocerinae and Hemerodromiinae) from Bosnia and Herzegovina. Natura Croatica 23: 401–406.

Joost W (1981) Beitrag zur Kenntnis der Hemerodromiinae des Kaukasus (1) (Diptera, Empididae). Reichenbachia 19: 183–191.

Joost W (1982) Beitrag zur Kenntnis der Hemerodromiinae Bulgariens (Insecta, Diptera, Empididae). Faunistische Abhandlungen Staatliches Museum für Tierkunde in Dresden 9: 121–124.

Kryštufek B, Reed JM (2004) Pattern and process in Balkan biodiversity – an overview. In: Griffiths HI, Kryštufek B, Reed JM (Eds) Balkan Biodiversity: Pattern and Process in the European Hotspot. Kluwer Academic Publishers, Dordrecht, 1–8. https://doi.org/10.1007/978-1-4020-2854-0_1

Loew H (1869) Beschreibungen europäischer Dipteren. Systematische Beschreibung der bekannten europäischen zweiflügeligen Insecten, von Johann Wilhelm Meigen. Halle 1: 1–310.

Loew H (1873) Diptera nova, in Pannonia inferiori et in confinibus Daciae regionsibus a Ferd. Kowarzio capta. Berliner Entomologische Zeitschrift 17: 33–52.

Mandaron P (1964) Un nouveau Diptère récolté en Dauphiné *Wiedemannia* (*Chamaedipsia*) *aequilobata* n. sp. Travaux du Laboratoire d'Hydrobiologie et de Pisiculture de l'Université de Grenoble 56: 81–84.

McAlpine JF (1981) Morphology and terminology – adults. In: McAlpine JF, Peterson BV, Shewell GE, Teskey HJ, Vockeroth JR, Wood DM (Coords) Manual of Nearctic Diptera. Volume 1. Agriculture Canada Monograph 27: 9–63.

Meigen JW (1804) Klassifikazion und Beschreibung der europäischen zweiflügeligen Insekten (Diptera Linn.). Erster Band. Reichard, Braunschweig. 152 pp [Abt. I]; 153–314 [Abt. II].

Mik J (1880) Beschreibung neuer Dipteren. I. Eilf neue europäische *Clinocera*-Arten. Verhandlungen der Kaiserlich-Königlichen Zoologisch-Botanischen Gesellschaft in Wein 30: 347–358.

Mik J (1889) Eine neue schweizerische Art aus der alten Gattung *Clinocera* Meig. (Ein dipterologischer Beitrag.). Wiener Entomologische Zeitung 8: 71–72. https://doi.org/10.5962/bhl.part.20027

Oldenberg L (1910) Einige europäische Empididen. Annales Historico-Naturales Musei Nationalis Hungarici 8: 344–352.

Saigusa T (2006) Homology of wing venation of Diptera. Privately published handout distributed at the 6th International Congress of Dipterology, Fukuoka, Japan, 26 pp.

Schmidt-Kloiber A, Neu PJ, Malicky M, Pletterbauer F, Malicky H, Graf W (2017) Aquatic biodiversity in Europe: a unique dataset on the distribution of Trichoptera species with important implications for conservation. Hydrobiologia 797: 11–27. https://doi.org/10.1007/s10750-017-3116-4

Sinclair BJ (1995) Generic revision of the Clinocerinae (Empididae), and description and phylogenetic relationships of the Trichopezinae, new status (Diptera: Empidoidea). The Canadian Entomologist 127: 665–752. https://doi.org/10.4039/Ent127665-5

Sinclair BJ (2008) The systematics of New World *Clinocera* Meigen (Diptera: Empididae: Clinocerinae). NRC Research Press, Ottawa, 245 pp. https://doi.org/10.1139/9780660198002

Sinclair BJ, Cumming JM (2006) The morphology, higher-level phylogeny and classification of the Empidoidea (Diptera). Zootaxa 1180: 1–178.

Stuckenberg BR (1999) Antennal evolution in the Brachycera (Diptera), with a reassessment of terminology relating to the flagellum. Studia Dipterologica 6: 33–48.

Vaillant F (1952) Un empidide destructeur de simulies. Bulletin de la Société Zoologique de France 76[1951]: 371–379.

Vaillant F (1953) *Hemerodromia seguyi*, nouvel empidide d'Algérie destructeur de simulies. Hydrobiologia 5: 180–188. http://dx.doi.org/10.1007/bf00023589

Vaillant F (1957) Contribution à l'étude des Diptères Empididae du Grand-Atlas Marocain. Société des Sciences Naturelles et Physiques du Maroc, Bulletin 36(1)(1956): 61–71.

Vaillant F (1965) Revision des Empididae Hemerodromiinae de France, d'Espagne et d'Afrique du Nord [Dipt.]. Annales de la Société Entomologique de France 133(1964): 143–173.

Vaillant F (1967) La répartition des *Wiedemannia* dans les cours d'eau et leur utilisation comme indicateurs de zones écologiques (Diptera, Empididae). Annales de Limnologie 3(2): 267–293. http://dx.doi.org/10.1051/limn/1967016

Vaillant F (1982) Diptères Empididae Hemerodromiinae nouveaux ou per connus de la région paléarctique (première partie). Bonner Zoologische Beiträge 32[1981]: 351–408. [published January 1982]

Vaillant F, Vinçon G (1987) Quelques Clinocerini (Diptera, Empididae, Hemerodromiinae) nouveaux ou mal connus des Pyrénées. Annales de Limnologie 22(3)[1986]: 261–275.

Vaillant F, Wagner R (1990) Notes on Empididae (6), *Wiedemannia graeca* sp.n. Aquatic Insects 12: 95–96. http://dx.doi.org/10.1080/01650429009361394

Wagner R (1981) Über einige Hemerodromiinae vom Balkan und aus der Ägäis. Spixiana 4: 297–304.

Wagner R (1990) Neue *Wiedemannia*-Arten aus der *rhynchops*-Gruppe (Diptera, Empididae, Clinocerinae). Entomofauna 11: 229–237.

Wagner R (1995) Empididen aus dem Mittelmeerraum (Diptera, Empididae: Hemerodromiinae und Clinocerinae). Acta Entomologica Slovenica 3: 5–23.

Wagner R (1997) Diptera Empididae, dance flies. In: Nilsson A (Ed.) Aquatic insects of North Europe, a taxonomic handbook, Volume 2. Apollo Books, Stenstrup, 333–344.

Wagner R, Gathmann O (1996) Long-term studies on aquatic Dance Flies (Diptera, Empididae) 1983–1993: Distribution and size patterns along the stream, abundance changes between years and the influence of environmental factors on the community. Archiv für Hydrobiologie 137: 385–410.

Wagner R, Horvat B (1993) The genus *Roederiodes* Coquillett, 1901 (Diptera, Empididae: Clinocerinae) in Europe, with descriptions of four new species. Bonner Zoologische Beiträge 44: 33–40.

Walker F (1851) Insecta Britannica, Diptera. Volume 1. Reeve and Benham, London, 314 pp.

Werner D, Pont AC (2003) Dipteran predators of Simuliid blackflies: a worldwide review. Medical and Veterinary Entomology 17: 115–132. http://dx.doi.org/10.1046/j.1365-2915.2003.00431.x

Yang D, Zhang KY, Yao G, Zhang JH (2007) World catalog of Empididae (Insecta: Diptera). China Agricultural University Press, Beijing, 599 pp.

Zetterstedt JW (1838) Sectio tertia. Diptera. Dipterologis Scandinaviae amicis et popilaribus carissimus. Insecta Lapponica, Lipsiae (= Leipzig), 477–868.

Zetterstedt JW (1842) Diptera Scandinaviae deposita et descripta. Lundae (Lund) 1: 1–440.

ZooKeys 724: 101–118 (2017)
doi: 10.3897/zookeys.724.13262
http://zookeys.pensoft.net

RESEARCH ARTICLE

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

Review of the genus *Locastra* Walker, 1859 from China, with descriptions of four new species (Lepidoptera, Pyralidae, Epipaschiinae)

Hua Rong[1], Houhun Li[1]

1 *College of Life Sciences, Nankai University, Tianjin 300071, P. R. China*

Corresponding author: *Houhun Li* (lihouhun@nankai.edu.cn)

Academic editor: *Y. Mutafchiev* | Received 16 April 2017 | Accepted 27 November 2017 | Published 21 December 2017

http://zoobank.org/5CC0385F-6197-4831-A05B-10F28324C82C

Citation: Rong H, Li H (2017) Review of the genus *Locastra* Walker, 1859 from China, with descriptions of four new species (Lepidoptera, Pyralidae, Epipaschiinae). ZooKeys 724: 101–118. https://doi.org/10.3897/zookeys.724.13262

Abstract

The genus *Locastra* Walker, 1859 from China is reviewed. Of the five species treated, four species are described as new: *L. nigrilineata* **sp. n.**, *L. solivaga* **sp. n.**, *L. subtrapezia* **sp. n.** and *L. viridis* **sp. n.** A diagnosis of *L. muscosalis* (Walker, 1866) is given. Photographs of adults and the genitalia are provided, along with a key to the five Chinese species treated.

Keywords

Description, diagnosis, key, morphology, taxonomy

Introduction

Locastra Walker, 1859 was established in the Noctuoidea to accommodate four species: *L. maimonalis* Walker, 1859, *L. phereciusalis* Walker, 1858, *L. sagarisalis* Walker, 1858, and *L. haraldusalis* Walker, 1859. Only the first species, *L. maimonalis*, still remains in this genus. Hampson (1896a) designated *L. maimonalis* as the type species and transferred *Locastra* to the Epipaschiinae in the Pyralidae. He also placed *Eurois crassipennis* Walker, 1857, a nominal species not originally included in *Locastra*, as a senior synonym of *L. maimonalis* (see Fletcher and Nye 1984). Hampson (1896a) transferred *Taurica muscosalis* Walker, 1866 from Northern China to *Locastra*, and considered *Taurica sikkima* Moore, 1888 from India and *Locastra cristalis* Hampson, 1893 from Sri Lanka as its junior synonyms. Subsequently, other species were added to this genus: *L. pachylepidalis* from Bhutan (Hampson 1896b), *L. ardua* from Fiji (Swinhoe 1902), and *L. bryalis* from Vietnam (Joannis 1930).

Locastra currently comprises five species worldwide (Solis 1992; Nuss et al. 2003–2017) occurring in the Oriental Region, except *L. muscosalis* from China occurring in both Palaearctic and Oriental regions. Prior to this study, *L. muscosalis* was the only species recorded in China. The aim of the present paper is to review *Locastra* in China, including descriptions of four new species.

Material and methods

Specimens examined in the present study were collected by light traps. Adults were examined using an Olympus SZX9 stereomicroscope. Permanent mounting methods of genitalia and venation follow the techniques introduced by Li (2002). Images of adults were taken with a Leica M205A stereomicroscope coupled with Leica Application Suite 4.2 software, and images of genitalia were prepared with a Leica DM750 microscope equipped with the same software and refined in Photoshop CS5.

All specimens studied, including the types of the new species, are deposited in the Insect Collection of Nankai University (NKU), Tianjin, China and the Biology Museum, Sun Yat-sen University, Guangzhou, Guangdong, China (SYSBM) as mentioned.

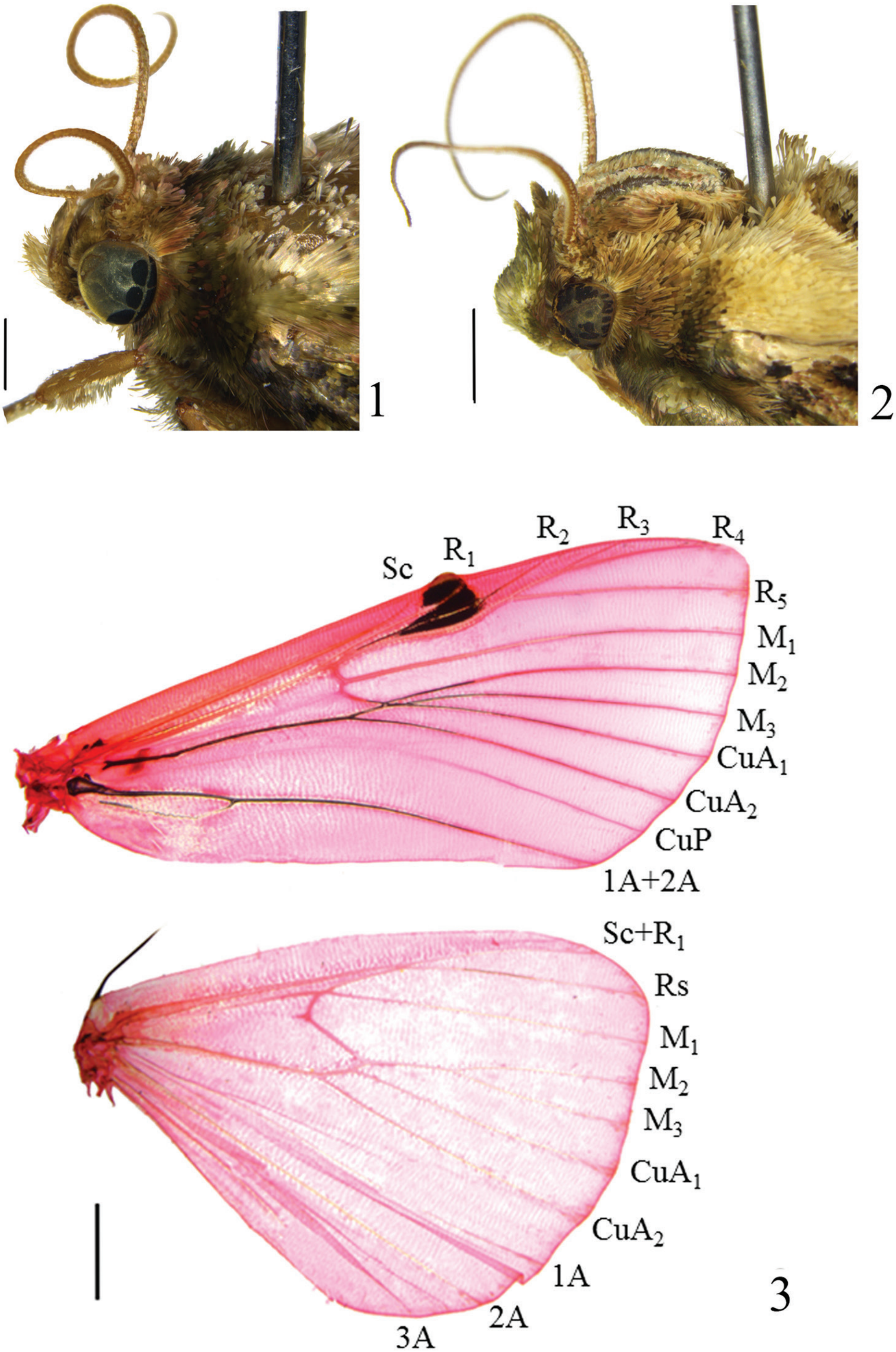
Taxonomy

Locastra Walker, 1859

Locastra Walker, 1859. Type species: *Locastra maimonalis* Walker, 1859.
Taurica Walker, 1866. Type species: *Taurica muscosalis* Walker, 1866.

Diagnosis. *Locastra* can be distinguished externally by the large body and sub-globose scape extension in males; in male genitalia by the basally separated juxta; and in female genitalia by the usually distally S-shaped ductus bursae with longitudinal sclerotized ridges.

Generic characters. Body large, ranging from 29.0 to 50.0 mm. Head (Figs 1–2): Labial palpus upturned in male, slightly porrect in female, second segment with hair-like scales on inner side. Maxillary palpus short, compressed in both male and female. Antenna with cilia on ventral surface in both male and female; male usually with scape extension extremely short, sub-globose, developed in a few species. Forewing (Figs 4–8) usually with distinct antemedian and postmedian lines, with glandular swelling at costal margin before postmedian line; discal spot absent; discocellular spot



Figures 1–3. Heads and venation of *Locastra* spp. **1–2** Heads **1** *L. viridis* sp. n. **2** *L. nigrilineata* sp. n. **3** Venation of *L. muscosalis*, male, slide No. RH15249. Scale bars: 2.0 mm.

small, represented by black tuft; tuft usually placed below middle of lower margin of cell. Wing venation (Fig. 3): Forewing with R_3, R_4 and R_5 stalked, M_1 from below upper angle of cell, M_2, M_3 and CuA_1 from lower angle of cell, glandular swelling on costa causing veins around it to curve somewhat; hindwing with $Sc+R_1$ and Rs adjacent, Rs and M_1 from upper angle of cell, M_2 and M_3 from lower angle of cell, CuA_1 from near lower angle of cell. Tibiae with long hair-like scales on outer side.

Male genitalia (Figs 9–13). Uncus sub-rectangular or trapezoidal. Gnathos distal process hooked. Valva with costa developed, ventral margin bluntly arched, with curved band from ventrobasal corner to base of juxta; costa and sacculus developed. Vinculum rather long in some species. Juxta separated basally, forming two well-sclerotized and narrowly banded lateral arms, merged medially or distally, usually concave on posterior margin; posterolateral lobes joined at apex; slender arms usually extending from lateral margin to vinculum in a right angle. Phallus with ovate sclerotized plates on ventral and dorsal surfaces before apex, with dense denticles; cornutus present or absent.

Female genitalia (Figs 14–16). Eighth tergite with anterior margin shallowly concave medially; eighth sternite narrow, membranous medially. Apophyses anteriores longer than apophyses posteriores, usually expanded basally. Antrum weakly sclerotized. Ductus bursae usually S shaped distally, with longitudinal sclerotized ridges. Corpus bursae ovate; signa two, ovate, with strongly sclerotized ridge medially.

Key to *Locastra* species based on external characters and male genitalia

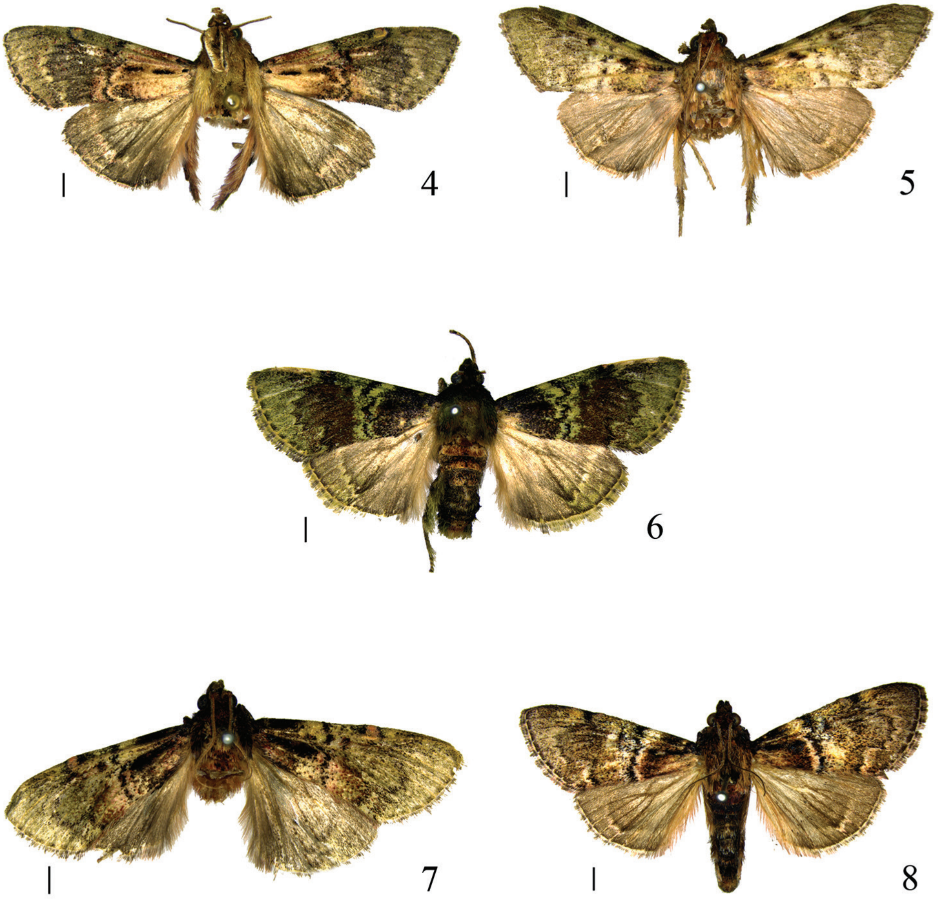
1	Vinculum approx 2.0 times length of uncus	**2**
–	Vinculum approx equal to length of uncus	**3**
2	Scape extension reaching mesothorax (Fig. 2)	***L. nigrilineata* sp. n.**
–	Scape extension extremely short, reaching before patagium (Fig. 1)	***L. subtrapezia* sp. n.**
3	Valva with triangular process at basal 1/3 of ventral margin (Fig. 13)	***L. muscosalis* (Walker)**
–	Valva without process at basal 1/3 of ventral margin	**4**
4	Uncus approx 5.0 times as long as maximum width (Fig. 12)	***L. solivaga* sp. n.**
–	Uncus approx 1.7 times as long as maximum width (Fig. 11)	***L. viridis* sp. n.**

Locastra nigrilineata sp. n.

http://zoobank.org/31953FC2-6002-496D-8CE1-F24EA7E67D0C

Figs 4, 9, 14

Type material. ***Holotype*: ♂ – CHINA,** Lao'an (30.33°N, 119.4°E), Mt. Tianmu, Zhejiang, 555 m, 5.VII.2014, coll. Aihui Yin, Xuemei Hu and Qingyun Wang, slide No. RH15430.



Figures 4–8. Adults of *Locastra* spp. **4** *L. nigrilineata* sp. n. holotype, male **5** *L. subtrapezia* sp. n. paratype, male **6** *L. viridis* sp. n. holotype, male **7** *L. solivaga* sp. n. paratype, male **8** *L. muscosalis*, male. Scale bars: 2.0 mm.

***Paratypes*:** (17♂, 3♀) – **Guizhou:** 1♂, Neila, Limingguan, Libo County, 800 m, 18.VII.2015, coll. Meiqing Yang and Gaeun Lee, slide No. RH15425; 1♂, Limingguan, Libo County, 820 m, 21.VII.2015, coll. Meiqing Yang and Gaeun Lee, slide No. RH15428; **Hainan:** 1♀, Diaoluoshan Nature Reserves, 922 m, 26.V.2015, coll. Peixin Cong, Wei Guan and Sha Hu, slide No. RH16152; **Jiangxi:** 1♀, Mt. Jiulian, 21.VII.2006, coll. Jiasheng Xu and Weichun Li; **Zhejiang:** 2♂, Mt. Tianmu, 325 m, 26.VI.2013, coll. Aihui Yin and Xiuchun Wang; 5♂, Huangtanyu, Mt. Jiulong, 467 m, 3–9.VII.2013, coll. Aihui Yin and Xiuchun Wang; 1♂, Yanping, Mt. Jiulong, 530 m, 4.VII.2013, coll. Aihui Yin and Xiuchun Wang; 2♂, Zhangkengkou, Mt. Jiulong, 623 m, 5.VII.2013, coll. Aihui Yin and Xiuchun Wang; 3♂, Jiufu, Mt. Longtang, 520 m, 26.VII.2014, coll. Aihui Yin, Xuemei Hu and Qingyun Wang, slide No. RH15247;

1♂, Mt. Tianmu, 335 m, 20.VII.2015, coll. Aihui Yin, Kang Lou and Tao Wang, slide No. RH15429; 1♀, Laofoyan, Shuangxikou, Jiangshan, 424 m, 7.VIII.2016, coll. Qingyun Wang, Meiqing Yang and Ping Liu; 1♂, Linkeng, Yongjia, 387 m, 24.VIII.2016, coll. Qingyun Wang, Meiqing Yang and Ping Liu, slide No. RH16455.

Diagnosis. This species is similar to *L. subtrapezia* sp. n. in both forewing pattern and male genitalia. It can be distinguished by the long scape extension apically reaching the mesothorax; in male genitalia by the straight posterior margin of the juxta and the very short cornutus approx 1/14 length of the phallus. In *L. subtrapezia* sp. n., the extremely short sub-globose scape extension doesn't apically reach the patagium; the posterior margin of the juxta is concave medially and the long cornutus is approx 2/7 length of the phallus.

Description. Adult (Fig. 4) wingspan 41.0–46.0 mm. Head earthy yellow in male, yellowish white in female. Male labial palpus white on inner side, grayish green mixed with reddish fuscous on outer side; first segment half length of second; second segment reaching vertex apically, inner side with dense long hair-like scales white on basal half and grayish green on distal half; third segment approx 1/6 length of second, tapering. Female labial palpus slightly porrect, widened distally, white on inner side, reddish fuscous mixed with black on outer side; first segment approx 1/4 length of second; second segment with inner side bearing long white hair-like scales on distal half; third segment approx 1/5 length of second, tapering. Maxillary palpus compressed, short, white mixed with reddish fuscous and grayish green. Antenna with ventral surface yellowish fuscous, with short pale gray cilia longer in male than in female; dorsal surface dirty white mixed with fuscous; scape extension strongly developed, reaching mesothorax, dirty white mixed with reddish fuscous, also with grayish green basally, with long dirty white mixed with reddish fuscous hair-like scales ventrally and apically. Thorax and tegula dirty white mixed with black. Forewing with basal area dirty white mottled reddish fuscous, grayish green with reddish fuscous on anterior 1/4, mixed with black along dorsum; median area blackish gray, grayish green on anterior 1/4; distal area grayish green mixed with black; antemedian line black, wavy, extending from basal 1/3 of costal margin slightly oblique outward to before middle of dorsum; postmedian line slightly darker than median area, ill defined, serrate, from 2/3 of costal margin directed obliquely inward to anterior 1/5 from costa, then outward to M_3, inward to CuP, finally straight to 5/6 of dorsum and forming a right angle with dorsum, edged with grayish white along outer margin; glandular swelling yellowish fuscous; longitudinal black line from base to before antemedian line below lower margin of cell, interrupted with white and black tuft beyond middle; discocellular spot small, indistinct, represented by black mixed with reddish fuscous tuft; terminal line dirty white, with uniform black rectangular spots evenly spaced along its inner side, interrupted with dirty white on veins. Hindwing gray, darkening from base toward apex; postmedian line dark gray, edged with dirty white along outer margin, ill-defined, extending from M_1 slightly arched outward to 1A. Cilia of both wings pale pink, interrupted with black on extension of veins. Legs white on inner side; on outer side, fore femur dirty white mixed with reddish fuscous and grayish green, tibia and tarsus grayish green mixed with black, mid femur grayish green mixed with black, tibia dirty white mixed with grayish green, with dense long pale pink hair-like scales, tarsus black mixed with grayish green, hind femur grayish green mixed with black and reddish fuscous, tibia pale pink mixed with black, with dense long pale pink hair-like scales, tarsus black mixed with grayish green, all tarsi white at apex of each tarsomere. Abdomen black, mixed with white and grayish green, 3rd to 6th segments white posteriorly on dorsal surface.

Male genitalia (Fig. 9). Uncus sub-rectangular, approximately 1.8 times longer than wide, slightly widened distally, distal 1/3 with dense short setae dorsally. Gnathos lateral arms slender, joined from 3/5; distal process hooked. Valva approximately twice as long as maximum width, with dense long hairs; costa straight, reaching before apex of valva; ventral margin obtuse, curved band from ventrobasal corner to base of juxta approximately 1.3 times length of ventral margin. Vinculum approximately twice as long as uncus. Juxta horizontally extended outward in triangle proximally, basal 3/5 separated, lateral arms straight and parallel from near proximal base; distal 2/5 merged sub-rectangularly, straight on posterior margin; posterolateral lobe almost membranous, semicircular, with short hairs; slender lateral arm extending from basal 2/3 at right angle not reaching vinculum. Phallus membranous in basal 2/3, weakly sclerotized in distal 1/3, approximately 1.3 times length of valva; dorsal sclerotized plate sub-rounded, much smaller than ventral plate; cornutus very short, approx 1/14 length of phallus.

Female genitalia (Fig. 14). Papillae anales shovel-shaped, narrowly rounded posteriorly, with dense fine hairs. Eighth segment sub-rectangular, with sparse long hairs posteriorly; tergite almost membranous anteriorly and posteriorly; sternite narrow, membranous medially. Apophyses anteriores approximately 1.2 times length of apophyses posteriores. Antrum annular. Ductus bursae with basal 3/5 straight, distal 2/5 S shaped, with longitudinal ridges. Corpus bursae sub-circular, approx 2/5 length of ductus bursae; signa long, ovate, with longitudinal ridge along central line.

Distribution. China (Guizhou, Hainan, Jiangxi, Zhejiang).

Etymology. The specific name is derived from the Latin *nigr-* and *lineatus*, referring to the forewing with black line from the base to before the antemedian line below the lower margin of the cell.

Locastra subtrapezia **sp. n.**

http://zoobank.org/3B4AFB80-B8A3-4331-8686-653E97BE3433
Figs 5, 10

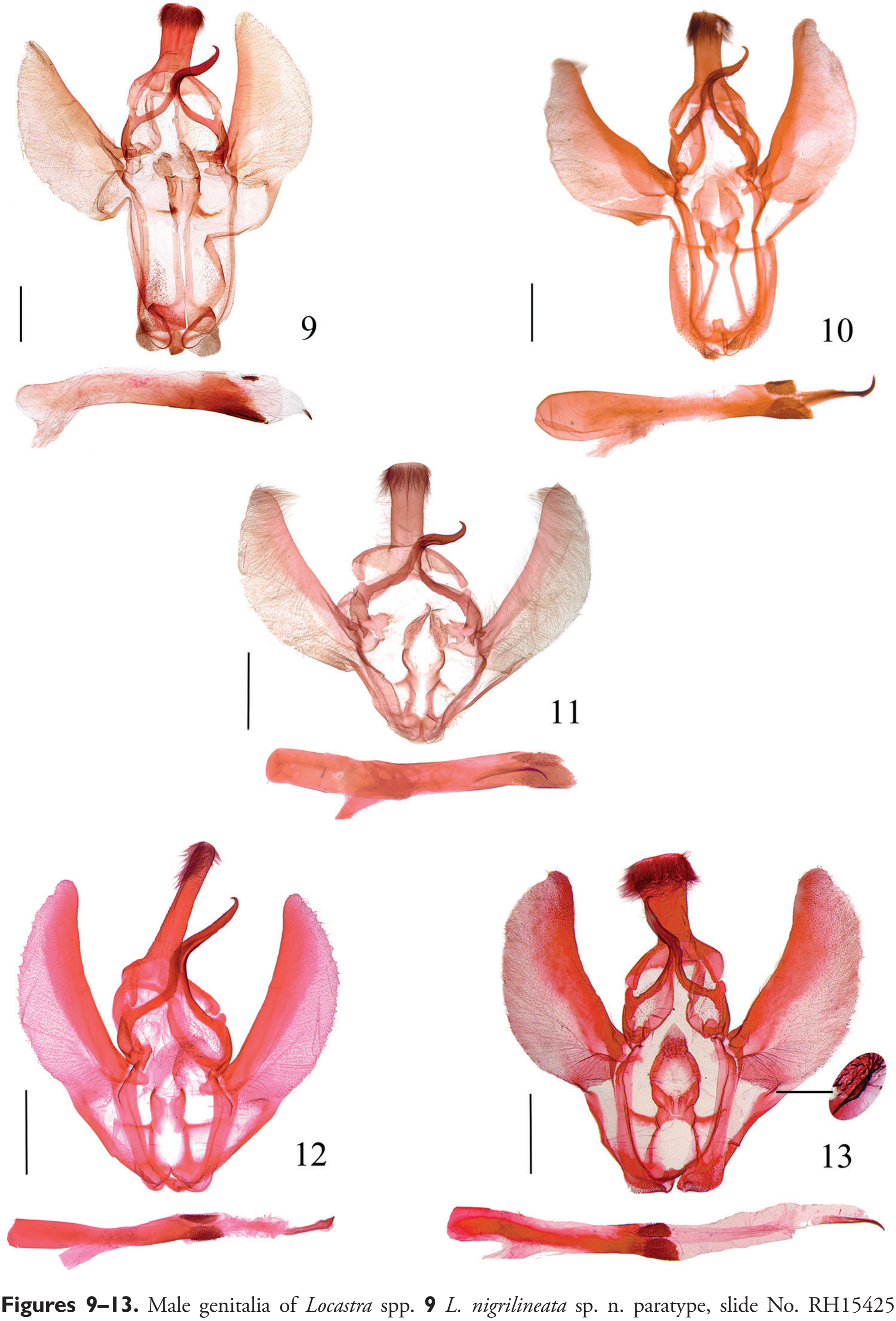
Type material. ***Holotype*****:** ♂ – **CHINA,** Huaping (25.6°N, 109.9°E), Guangxi, 950 m, 7.VIII.2006, coll. Weichun Li, slide No. WYP05141.

Paratypes**:** (3♂) – **Guizhou:** 1♂, Heiwan, Jiangkou, 600 m, 28.VII.2001, coll. Houhun Li and Xinpu Wang, slide No. WYP06033; 1♂, Maolan Nature Reserves, 1.IX.2011, coll. Jinwei Li, slide No. RH16457; **Zhejiang:** 1♂, Jiufu, Mt. Longtang, 520 m, 26.VII.2014, coll. Aihui Yin, Xuemei Hu and Qingyun Wang, slide No. RH15248.

Diagnosis. This species is characterized by the juxta sub-trapezoidal in distal 1/3. It is similar to the previous species *L. nigrilineata* sp. n. in both forewing pattern and male genitalia. The differences between the two species are given under *L. nigrilineata* sp. n.

Description. Adult (Fig. 5) wingspan 38.0–42.0 mm. Frons grayish green, vertex yellowish fuscous. Labial palpus grayish green mixed with white and black; first segment approx 1/3 length of second; second segment reaching vertex apically, inner side with hair-like scales grayish green on basal half, yellowish fuscous on distal half; third segment 1/3 length of second, tapering. Maxillary palpus compressed, short, dirty white on inner side, grayish green on outer side. Antenna with ventral surface yellowish fuscous, with short pale gray cilia; dorsal surface dirty white mixed with black; scape extension extremely short, sub-globose, reaching before patagium, grayish green. Thorax and tegula dirty white mixed with yellowish fuscous and black. Forewing grayish green mixed with black, slightly paler near termen; basal area with posterior half dirty white, suffused with reddish fuscous and black scales; antemedian line black, wavy, running from 2/5 of costal margin obliquely outward to before middle of dorsum; postmedian line black (worn), serrate, from 2/3 of costal margin oblique inward to anterior 1/5 from costa, then outward to M_3, inward to CuP, finally straight to 3/4 of dorsum, edged with dirty white along its outer margin; glandular swelling yellowish white; discocellular spot small, represented by black mixed with fuscous tuft; black tuft placed below 2/3 of lower margin of cell, with white scales on inner edge; terminal line white, with uniform black mixed with reddish fuscous narrow rectangular spots evenly spaced along its inner side, interrupted with white on veins. Hindwing gray, darkening from base toward apex; postmedian line gray, extending from middle of M_1 slightly arched outward to CuA_2, edged with obscure grayish white along its outer margin. Cilia of both wings grayish white with pale red, interrupted with black on extension of veins. Legs grayish white mixed with fuscous and grayish green on inner side; on outer side, fore femur white mixed with grayish green, tibia and tarsus black mixed with grayish green, mid leg black mixed with grayish green, tibia with long black mixed with white hair-like scales, hind leg black mixed with grayish green, tibia with long grayish white hair-like scales, all tarsi white at apex of each tarsomere.

Male genitalia (Fig. 10). Uncus sub-rectangular, approximately 1.5 times as long as wide, slightly widened distally, distal 1/3 with dense short setae dorsally. Gnathos arms slender, joined from 2/3; distal process hooked. Valva approximately 1.6 times as long as maximum width, with dense long hairs; costa reaching before apex of valva; ventral margin obtusely arched, curved band from ventrobasal corner to base of juxta as long as ventral margin. Vinculum ap approximately approximately 2.0 times as long as uncus. Juxta with basal 2/3 separated, lateral arms widely apart basally, extending inward from base to basal 2/3, then outward before mergence; distal 1/3 merged sub-trapezoidally, concave medially on posterior margin; posterolateral lobe almost membranous, sub-triangular, with short hairs; slender lateral arm extending from basal 2/3 at right angle to vinculum. Phallus narrower medially, approximately 1.4 times length of valva; sclerotized dorsal plate sub-rounded, smaller than ventral plate; cornutus long, hooked, approx 2/7 length of phallus.



Figures 9–13. Male genitalia of *Locastra* spp. **9** *L. nigrilineata* sp. n. paratype, slide No. RH15425 **10** *L. subtrapezia* sp. n. paratype, slide No. RH16457 **11** *L. viridis* sp. n. paratype, slide No. RH15321 **12** *L. solivaga* sp. n. paratype, slide No. RH16484 **13** *L. muscosalis*, slide No. RH15249. Scale bars: 1.0 mm.

Female unknown.

Distribution. China (Guangxi, Guizhou, Zhejiang).

Etymology. The specific name is derived from the Latin *sub-* and *trapezius*, referring to the shape of the juxta in distal 1/3.

Locastra viridis sp. n.

http://zoobank.org/761B4764-3A87-45D3-AB5A-D166CEC36F51

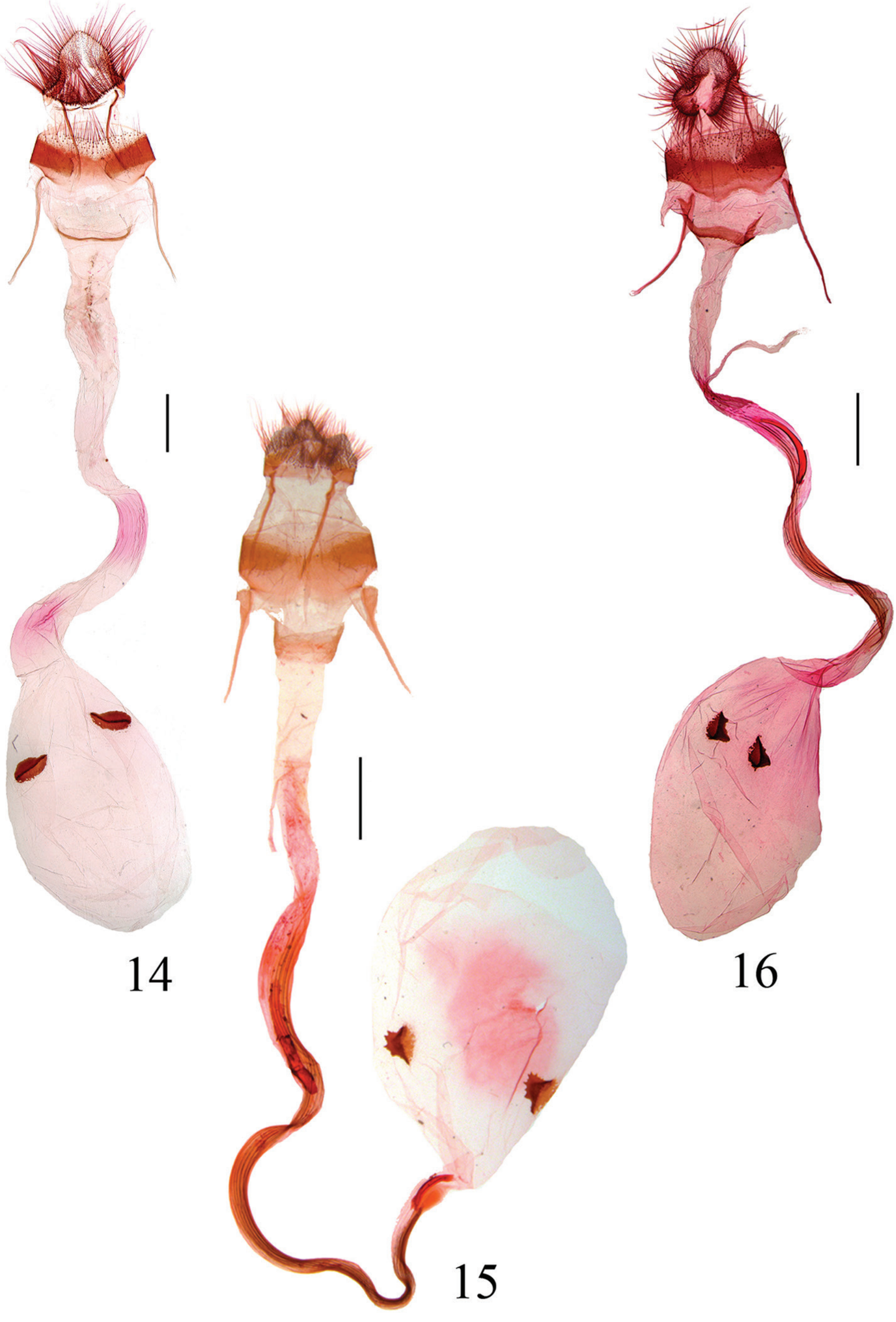
Figs 6, 11, 15

Type material. ***Holotype***: ♂ – **CHINA,** Xiajinchang (23°10'N, 104°48'E), Malipo County, Wenshan, Yunnan, 1470 m, 26.VII.2016, coll. Kaijian Teng, Gaeun Lee and Tao Wang.

Paratypes: (24♂, 2♀) – **Guangxi:** 8♂, Yangmei'ao, Huajiang County, Hechi, 1180 m, 23–26.VII.2015, Meiqing Yang and Gaeun Lee, slide Nos. RH15427, RH15321; **Henan:** 3♂, Mt. Baiyun, Luoyang, 1560 m, 22.VII.2001, coll. Dandan Zhang, slide Nos. WYP05074, WYP06031; 1♂, 1♀, Mt. Wangwu, Jiyuan, 800 m, 30.VII.2006, coll. Hui Zhen and Denghui Kuang, slide No. WYP06036♀; **Hubei:** 1♂, Shayuan, Hefeng, 1260 m, 18.VII.1999, coll. Houhun Li *et al.*, slide No. WYP06034; 1♂, Bapingying, Xianfeng, 1280 m, 22.VII.1999, coll. Houhun Li *et al.*, slide No. WYP05077; **Yunnan:** 6♂, 1♀, 26–29.VII.2016, other data same as holotype, slide Nos. RH16459♂, RH16460♀; 4♂, Taiyanghe Nature Reserves, Pu'er, 1450 m, 14.VII.2016, coll. Kaijian Teng, Gaeun Lee and Tao Wang.

Diagnosis. This species is similar to *L. muscosalis* in male genitalia. It can be distinguished by the sub-rectangular uncus, the valva without a process at the base of the ventral margin, and the juxta concave in V shape on the posterior margin; the sub-rectangular antrum and the corpus bursae approx 2/5 as long as the ductus bursae. In *L. muscosalis*, the uncus is inverted sub-trapezoidal, the valva bears a triangular process at basal 1/3 of the ventral margin (Fig. 13), the juxta concave in U shape on the posterior margin; the antrum is narrower, and the shorter corpus bursae is approx 1/3 as long as the ductus bursae.

Description. Adult (Fig. 6) wingspan 29.0–38.0 mm. Head black mixed with grayish green. Male labial palpus pale grayish green, mixed with black on outer side; first segment half length of second; second segment reaching vertex, inner side with blackish green hair-like scales grayish white basally; third segment black, approx 1/4 length of second, tapering. Female labial palpus shorter than in male, slightly porrect; second segment with short grayish white hair-like scales on ventral surface; third segment approx 2/3 length of second. Maxillary palpus compressed, short, grayish green mixed with black. Antenna with ventral surface yellowish fuscous, with short pale gray cilia denser in male than in female; dorsal surface white mixed with black; scape extension extremely short, sub-globose, reaching before patagium, with grayish green scales. Thorax and tegula grayish green mixed with black and yellowish fuscous. Forewing with basal area black mixed with grayish green and fuscous; median area fuscous mixed



Figures 14–16. Female genitalia of *Locastra* spp. **14** *L. nigrilineata* sp. n. paratype, slide No. RH16152 **15** *L. viridis* sp. n., paratype, slide No. RH16460 **16** *L. muscosalis*, slide No. RH15424. Scale bars: 1.0 mm.

with black, pale green mixed with black along costal margin; distal area pale green mixed with black; antemedian line black, wavy, running from 1/3 of costal margin slightly oblique outward to 2/5 of dorsum, edged with pale green fascia on both inner and outer margins; postmedian line black, serrate, running from 2/3 of costal margin oblique outward to CuA_1, then inward to CuP, finally slightly outward to 4/5 of dorsum; glandular swelling small, yellowish fuscous, surrounded by black scales; black tuft placed below middle of lower margin of cell; discocellular spot small, represented by fuscous mixed with black tuft; terminal line grayish white, with uniform black rectangular spots evenly spaced along its inner side, interrupted with grayish white on veins. Hindwing gray, darkening from base toward apex; postmedian line ill-defined, blackish gray, serrate, extending from 2/3 of costal margin oblique outward to CuA_2, edged with grayish white along its outer margin. Cilia of both wings pale grayish green, interrupted with black on extension of veins. Legs grayish white on inner side; on outer side black mixed with grayish green, fore tibia with grayish green hair-like scales, mid tibia with dense black mixed with grayish green hair-like scales, hind tibia with sparse grayish white mixed with grayish green hair-like scales, all tarsi white at apex of each tarsomere. Abdomen grayish white mixed with black on ventral surface; dorsal surface with 1st and 2nd segments yellowish fuscous, suffused with white and black scales, remaining segments black, suffused with white and yellowish fuscous scales.

Male genitalia (Fig. 11). Uncus sub-rectangular, app approximately rox 1.7 times as long as wide; distal 1/3 slightly widened, with dense short setae dorsally. Gnathos arms slender, joined from 3/5; distal process hooked, narrowed to pointed apex. Valva approximately 1.6 times as long as maximum width, with dense long hairs; costa reaching apex of valva; ventral margin arched obtusely, with narrow band from ventrobasal corner to base of juxta half length of ventral margin. Vinculum approximately as long as uncus. Juxta dilated proximally, its basal half separated, lateral arms relatively wide, sub-parallel; distal half merged sub-rectangularly, concav in U shape on posterior margin; posterolateral lobe membranous, elongate triangular, with short hairs; slender lateral arm extending from middle at 60° angle to vinculum. Phallus approximately 1.7 times as long as maximum length of valva; sclerotized sub-ovate dorsal plate smaller; cornutus long, slightly curved ventrad.

Female genitalia (Fig. 15). Papillae anales sub-triangular, obtuse posteriorly, with dense long hairs. Eighth tergite shallowly concave anterior margin medially; sternite sub-rectangular, membranous medially, with sparse setae on posterior margin. Apophyses anteriores slightly longer than apophyses posteriores, with basal 1/5 expanded triangularly; apophyses posteriores thinner, basal 1/5 slightly wavy. Antrum sub-rectangular, approx 1/2 as long as wide, weakly sclerotized. Ductus bursae membranous, basal 1/3 wide, distal 2/3 narrower, curved, with longitudinal ridges. Corpus bursae ovate, approx 2/5 length of ductus bursae; signa sub-ovate, with semicircular ridge medially, serrate on one edge.

Distribution. China (Guangxi, Henan, Hubei, Yunnan).

Etymology. The specific name is derived from the Latin *viridis*, referring to the forewing with more green scales.

***Locastra solivaga* sp. n.**
http://zoobank.org/609975D1-CEAB-4D9A-8966-DBAEF8FAE4A4
Figs 7, 12

Type material. ***Holotype*: ♂ – CHINA,** Laofoyan (28°21'N, 118°41'E), Shuangxikou, Jiangshan, Zhejiang, 424 m, 7.VIII.2016, coll. Qingyun Wang, Meiqing Yang and Ping Liu, slide No. RH16458.

***Paratype*: – Fujian:** 1♂, Guadun, Wuyishan, 1100 m, 29.VII.2008, coll. Weichun Li, Yongling Sun and Haiyan Bai, slide No. RH16484.

Diagnosis. This species is similar to *L. muscosalis* in the forewing pattern. It can be distinguished in male genitalia by the sub-rectangular uncus nearly 5.0 times as long as wide at maximum and the valva without a process at the base of the ventral margin. In *L. muscosalis*, the inverted sub-trapezoidal uncus is approximately 1.5 times as long as wide at maximum, and the valva bears a triangular process at the base of the ventral margin (Fig. 13).

Description. Adult (Fig. 7) wingspan 31.0–33.0 mm. Frons black, vertex yellowish fuscous mixed with yellowish white. Labial palpus grayish green mixed with black; first segment white basally, approx 1/4 length of second; second segment reaching vertex apically, inner side with dark grayish green hair-like scales shortening from base to tip; third segment short, approx 1/7 length of second, tapering, dirty white at apex. Maxillary palpus compressed, short, white mixed with fuscous on basal half, grayish green on distal half. Antenna with ventral surface brownish yellow, with short pale gray cilia; dorsal surface white; scape extension extremely short, sub-globose, reaching before patagium, with yellowish fuscous scales. Thorax and tegula dirty white mixed with black, or black mixed with dirty white and fuscous. Forewing with basal 1/3 black, mixed with reddish fuscous on posterior half; distal 2/3 pale grayish green, suffused with black and reddish fuscous scales, with more reddish fuscous scales near dorsum medially; antemedian line black, extending from 1/3 of costal margin slightly arched outward to near middle of wing, then arched outward to 2/5 of dorsum; postmedian line black, running from 2/3 of costal margin, slightly arched outward to anterior 1/4 from costa, then obliquely outward to CuA_1, inward to CuP, finally straight to 3/4 of dorsum; glandular swelling large, yellowish fuscous; black mixed with reddish fuscous tuft placed below middle of lower margin of cell; discocellular spot small, represented by black mixed with reddish fuscous tuft; terminal line dirty white, with uniform black rectangular spots evenly spaced along its inner side, interrupted with dirty white on veins. Hindwing gray, darkening from base toward apex; postmedian line ill-defined, grayish white, running from 2/3 of costal margin obliquely outward to CuA_2, then inward to 2A. Cilia of both wings grayish white with pale red, interrupted with black on extension of veins. Legs grayish white on inner side; on outer side, fore femur white mixed with black and reddish fuscous, tibia black mixed with grayish green and fuscous, tarsus grayish green mixed with black, mid femur black mixed with fuscous, tibia with basal 2/3 black, distal 1/3 white mixed with grayish green, with grayish white hair-like scales, tarsus grayish green mixed with black, hind leg black mixed with white, tibia with grayish white hair-like scales, all tarsi white at apex of each tarsomere.

Male genitalia (Fig. 12). Uncus narrowly elongate, nearly 5.0 times longer than wide, slightly narrowed medially, obtuse apically, distal 1/3 with dense short setae dorsally. Gnathos arms slender, joined from 3/5; distal process tapering to hooked apex. Valva relatively narrow, approximately 3.0 times as long as maximum width, with dense long hairs; costa reaching apex of valva; ventral margin obtusely arched, with narrow band from ventrobasal corner to base of juxta approximately 0.7 times length of ventral margin. Vinculum as long as uncus. Juxta dilated proximally, basal 2/5 separated, lateral arms straight and parallel; distal 3/5 merged sub-rectangularly, concave in V shape on posterior margin; posterolateral lobe sub-rectangular, almost membranous, with short hairs; slender lateral arm extending from middle at right angle to vinculum. Phallus approximately as long as valva; sub-ovate plates subapical, dorsal plate smaller; cornutus long, slightly curved, distally enlarged.

Female unknown.

Distribution. China (Fujian, Zhejiang).

Etymology. The specific name is derived from the Latin *solivagus*, referring to the narrow and elongate uncus.

Locastra muscosalis (Walker, 1866)

Figs 8, 13, 16

Taurica muscosalis Walker, 1866: 1269. Type locality: North China.
Taurica sikkima Moore, 1888: 202.
Stericta sikkima Snellen, 1890: 563.
Locastra cristalis Hampson, 1893: 157.
Locastra muscosalis (Walker, 1866): Mutuura 1957: 105.

Material examined. (241♂, 53♀). **CHINA, Fujian:** 1♂, Chishuizhan, Mt. Daiyun, 1015 m, 22.V.2012, coll. Jinwei Li, slide No. RH16463; **Guangdong:** 1♂, Mt. Dadong, Lian County, 5.VII.2008, coll. Fengxia He (SYSBM); 1♂, Niupoling, Yangchun, 18.VIII.2009, coll. Fengxia He, slide No. RH16461; 1♂, Heishiding, Fengkai, 1.VII.2010, coll. Haidong Chen, Dandan Zhang and Bo Tong (SYSBM); 1♂, Guangming, Fengkai, 2.VII.2010, coll. Haidong Chen, Dandan Zhang and Bo Tong (SYSBM); 1♂, Guangming, Fengkai, 14.VIII.2010, coll. Haidong Chen, Dandan Zhang and Bo Tong (SYSBM); 1♂, Mt. Danxia, Shaoguan, 96 m, 7.VI.2012, coll. Jinwei Li (SYSBM); **Guangxi:** 1♂, Jiman, Anchui, Rongshui, 650 m, 16.VII.2004, coll. Jiasheng Xu; 24♂, Huaping, 950 m, 1–8.VIII.2006, coll. Weichun Li, slide No. WYP06032; 13♂, Mt. Yuanbao, 700 m, 10–12.VIII.2006, coll. Weichun Li; 2♂, Longrui Nature Reserves, 18–19.VIII.2011, coll. Dandan Zhang (SYSBM); 1♂, Longrui Nature Reserves, 19.VIII.2011, coll. Muchun Cheng (SYSBM); 1♂, Nonggang Nature Reserves, 20.VIII.2011, coll. Dandan Zhang (SYSBM); 1♂, Nonggang Nature Reserves, 20.VIII.2011, coll. Muchun

Cheng (SYSBM); 1♀, Peixiu, Rongshui, 30.VIII.2011, coll. Jinwei Li (SYSBM); 1♂, Mt. Dayao, Jinxiu, 561 m, 7.VII.2013, coll. Xiaohua Chen (SYSBM); 9♂, 1♀, Hekou, Mt. Dayao, Jinxiu, 823 m, 18–20.VII.2015, coll. Mujie Qi and Shengnan Zhao, slide Nos. RH15423♂, RH15424♀; 1♂, Jiuniutang, Mt. Mao'er, Guilin, 1012 m, 23.VII.2015, coll. Mujie Qi and Shengnan Zhao; 1♂, Yangmei'ao, Huanjian County, Hechi, 1180 m, 23.VII.2015, coll. Meiqing Yang and Gaeun Lee; 2♂, Yangmei'ao, Huanjian County, Hechi, 1180 m, 24.VII.2015, coll. Meiqing Yang and Gaeun Lee; **Guizhou:** 8♂, Daheba, Mayanghe, 430 m, 10.VI.2007, coll. Xicui Du; 2♂, 2♀, Mt. Fanjing, Jiangkou County, 26.VIII.2012, coll. Jinwei Li and Xiaohua Chen (SYSBM); 1♂, Taojiang, Leishan County, 27.VIII.2012, coll. Jinwei Li and Xiaohua Chen (SYSBM); 5♂, 1♀, Maolan Nature Reserves, 797 m, 12.VII.2013, coll. Xiaohua Chen (SYSBM); 1♂, Mt. Leigong, 1198 m, 14.VII.2013, coll. Xiaohua Chen (SYSBM); 1♂, Neila, Limingguan, Libo County, 800 m, 18.VII.2015, coll. Meiqing Yang and Gaeun Lee, slide No. RH15426; 11♂, 2♀, Dongdai, Limingguan, Libo County, 720 m, 19.VII 2015, coll. Meiqing Yang and Gaeun Lee; 15♂, Pobao, Limingguan, Libo County, 740 m, 20.VII.2015, coll. Meiqing Yang and Gaeun Lee; **Hainan:** 1♂, Jianfengling Nature Reserves, 143 m, 6.IX.2013, coll. Weicai Xie (SYSBM); 2♂, Luoshuai, Yuanmen, Baisha County, 284 m, 18.V.2013, coll. Jinwei Li (SYSBM); 2♂, Hongxin, Yuanmen, Baisha County, 460 m, 1.VII.2014, coll. Peixin Cong, Linjie Liu and Sha Hu; 1♂, Wuzhishan Nature Reserves, 742 m, 5.VII.2014, coll. Peixin Cong, Linjie Liu and Sha Hu; 6♂, 1♀, Sanfenzhan, Mt. Limu, 240 m, 26–27.VII.2014, coll. Peixin Cong, Linjie Liu and Sha Hu, slide No. RH15249♂; 3♂, Wuzhishan Nature Reserves, 742 m, 19.V.2015, coll. Peixin Cong, Linjie Liu and Sha Hu; 2♂, Diaoluoshan Nature Reserves, 922 m, 24–25.V.2015, coll. Peixin Cong, Linjie Liu and Sha Hu; 2♂, Hongkan, Yinggeling, 508 m, 15–17.VI.2015, coll. Peixin Cong, Wei Guan and Sha Hu; 1♂, Wuzhishan Nature Reserves, 738 m, 4.VII.2015, coll. Qingyun Wang, Suran Li and Mengting Chen; 1♂, Yajia, Bawangling, 261 m, 20.VII.2015, coll. Qingyun Wang, Suran Li and Mengting Chen; 1♂, Hongxin, Yuanmen, Baisha County, 445 m, 31.VII.2015, coll. Qingyun Wang, Suran Li and Mengting Chen; 3♂, 3♀, Limushan Forest Park, 607 m, 20.VII.2016, coll. Xia Bai, Shuonan Qian and Wanding Qi, slide No. RH16454♀; 15♂, 1♀, Wuzhishan Nature Reserves, 738 m, 22–30.VII.2016, coll. Xia Bai, Shuonan Qian and Wanding Qi; 3♂, Lizu Hall, Shuiman, Wuzhishan, 766 m, 2.VIII.2016, coll. Xia Bai, Shuonan Qian and Wanding Qi; 4♂, 1♀, Nankai, Yinggeling, 210 m, 11–14.VIII.2016, coll. Xia Bai, Shuonan Qian and Wanding Qi; 2♂, Tianchi, Jianfengling, 787 m, 9–10.VIII.2016, coll. Xia Bai, Shuonan Qian and Wanding Qi; **Hebei:** 4♂, 1♀, Shuangyuanfeng, Mt. Wuling, Xinglong County, 800 m, 15–29.VII.2011, coll. Houhun Li and Yanpeng Cai; **Henan:** 10♂, 1♀, Mt. Jigong, Xinyang, 700 m, 13–15.VII.2001, coll. Dandan Zhang, slide Nos. WYP05047♂, WYP05140♀; 1♂, Shuiliandong, Tongbai, 300 m, 16.VII.2001, coll. Dandan Zhang; 1♂, Shiziping, Lushi, 1200 m, 19.VII.2001, coll. Dandan Zhang, slide No. WYP05048; 1♂, Shibanyan, Linzhou, 550 m, 22.VII.2006, coll. Hui Zhen and Denghui Kuang; 2♂, Xiuwu, Mt. Yuntai, Jiaozuo, 1028 m, 7–9.VIII.2014, coll. Peixin Cong, Linjie Liu and Sha Hu, slide No. RH15245; **Hubei:** 2♂, Maoba, Lichuan, 700 m, 30.VII.1999, coll. Houhun Li *et. al.*; **Hunan:** 5♂, 1♀, Yueyan, Dao County, 21–22.VIII.2012, coll. Jinwei Li and

Xiaohua Chen, slide No. RH16462♂; 1♀, Zhupo, Huitong County, 23.VIII.2012, coll. Jinwei Li and Xiaohua Chen (SYSBM); **Jiangxi:** 1♂, 7♀, Mt. Jinpen, 18–19.VII.2006, coll. Jiasheng Xu and Weichun Li; 1♂, Xiangshan, 23.VII.2006, coll. Jiasheng Xu and Weichun Li, slide No. WYP06037; 3♀, Mt. Feng, 26.VII.2006, coll. Jiasheng Xu and Weichun Li;1♀, Panlong, Ganzhou, 28.VII.2006, coll. Jiasheng Xu and Weichun Li; **Liaoning:** 1♂, Laotuding, Huanren County, 30.VII.2012, coll. Dandan Zhang and Lijun Yang; 1♂, Mt. Bailang, Jianchang County, 658 m, 9.VIII.2016, coll. Mujie Qi, Juan Li and Yanyan Jia; **Shaanxi:** 1♂, Haopingsi, Yingtou, 1251 m, 17.VII.2012, coll. Jinwei Li (SYSBM); **Sichuan:** 1♂, Caoping, Sanjiang, Wenchuan, 1557 m, 9.VII.2014, coll. Kaijian Teng, Wei Guan, Xiuchun Wang and Shurong Liu; 2♂, Wanniansi, Mt. E'mei, 830 m, 13.VII.2014, coll. Kaijian Teng, Wei Guan, Xiuchun Wang and Shurong Liu; 1♂, Bifengxia, Ya'an, 1115 m, 28.VI.2016, coll. Kaijian Teng and Xiaofei Yang; 1♀, Hailuogou, Luding, 1695 m, 1.VII.2016, coll. Kaijian Teng and Xiaofei Yang, slide No. RH16464; **Tianjin:** 1♀, Mt. Jiulong, Ji County, 10–12.VII.2009, coll. Weichun Li; **Tibet:** 7♂, Motuo County, 1103 m, 8.VII.2013, coll. Jinwei Li (SYSBM); 1♂, 1♀, Dexing, Motuo County, 835 m, 9.VII.2013, coll. Jinwei Li (SYSBM); **Yunnan:** 1♂, Ruili Rare Botanic Garden, 1000 m, 7.VIII.2005, coll. Yingdang Ren, slide No. WYP06038; 1♂, Bubang, Mengla, 650 m, 22.VIII.2005, coll. Yingdang Ren, slide No. WYP06035; 2♂, Bawan, Baoshan, 1040 m, 9.VIII.2007, coll. Dandan Zhang (SYSBM); 1♂, Baihualing, Baoshan, 1520 m, 13.VIII.2007, coll. Dandan Zhang (SYSBM); 1♂, Baihualing, Baoshan, 1520 m, 13.VIII.2007, coll. Dayong Xue (SYSBM); 1♂, 1♀, Mt. Jizu, Binchuan, 1831 m, 29.VI.2012, coll. Jinwei Li (SYSBM); 1♀, Mt. Weibao, Dali, 2205 m, 1.VII.2014, coll. Kaijian Teng, Wei Guan, Xiuchun Wang and Shurong Liu, slide No. RH15246; 7♂, Mt. Jizu, Dali, 2228 m, 27–28.VII.2014, coll. Kaijian Teng, Wei Guan, Xiuchun Wang and Shurong Liu; 3♂, Baihualing, Baoshan, 1474 m, 5–7.VIII.2014, coll. Kaijian Teng, Shurong Liu and Hua Rong; 10♂, 1♀, Xiajinchang, Malipo County, Wenshan, 1470 m, 26–29.VII.2016, coll. Kaijian Teng, Gaeun Lee and Tao Wang; 2♂, Daluo, Menghai, Jinghong, 640 m, 2.VIII.2016, coll. Kaijian Teng, Gaeun Lee and Tao Wang; 1♂, Mt. Bulang, Menghai, Jinghong, 1178 m, 4.VIII.2016, coll. Kaijian Teng, Gaeun Lee and Tao Wang, slide No. RH16483; 1♂, Lvshilin, Menglun, Jinghong, 580 m, 6.VIII.2016, coll. Kaijian Teng, Gaeun Lee and Tao Wang; **Zhejiang:** 1♀, Mt. Tianmu, 325 m, 28.VI.2013, coll. Aihui Yin and Xiuchun Wang; 1♂, Zhangkengkou, Mt. Jiulong, 623 m, 5.VII.2013, coll. Aihui Yin and Xiuchun Wang; 2♂, Huangtanyu, Mt. Jiulong, 467 m, 6.VII.2013, coll. Aihui Yin and Xiuchun Wang; 3♂, Lao'an, Mt. Tianmu, 555 m, 3.VII.2014, coll. Aihun Yin, Xuemei Hu and Qingyun Wang; 1♂, Mt. Tianmu, 335 m, 19.VII.2015, coll. Aihun Yin, Kang Lou and Tao Wang, slide No. RH15322; 1♀, Simingshan National Forest Park, Ningbo, 822 m, 31.VII.2016, coll. Qingyun Wang, Meiqing Yang and Ping Liu; 3♂, 17♀, Taohuadao, Zhoushan, 62.9 m, 4.VIII.2016, coll. Qingyun Wang, Meiqing Yang and Ping Liu; 1♀, Huangtianhu, Jingning, 787 m, 11.VIII.2016, coll. Qingyun Wang, Meiqing Yang and Ping Liu, slide No. RH16456; 1♀, Baishanzu Nature Reserves, Qingyuan, 1149 m, 14.VIII.2016, coll. Qingyun Wang, Meiqing Yang and Ping Liu.

Diagnosis. Adult (Fig. 8) wingspan 32.0–41.0 mm. This species is characterized by the uncus inverted trapezoidal and the valva with a triangular process at basal 1/3 of the ventral margin (Fig. 13). It is similar to *L. solivaga* sp. n. in the forewing pattern and to *L. viridis* sp. n. in the male genitalia. The differences between the three species are stated above under the treatments of the latter two species.

Variation. Specimens collected from Guizhou and Guangxi are darker than those from other localities.

Host plants. Anacardiaceae: *Pistacia chinensis* Bunge, *Rhus chinensis* Mill., *R. sylvestris* Sieb. *et* Zucc., *R. verniciflua* Stokes; Juglandaceae: *Juglans mandshurica* Maxim., *J. mandshurica* var. *sieboldiana* Makino, *J. sinensis* (C. DC.) Dode., *Pterocarya stenoptera* C. DC.; Simaroubaceae: *Ailanthus altissima* (Mill.) Swingle (Bae and Paek 2006).

Distribution. China (Fujian, Guangdong, Guangxi, Hainan, Hebei, Henan, Hongkong, Hubei, Hunan, Jiangxi, Liaoning, Shaanxi, Sichuan, Tianjin, Tibet, Yunnan, Zhejiang), Japan, India, Sri Lanka (Wang et al. 2003).

Remarks. Walker (1866) described this species based upon the external characters, and our specimens match the wing pattern of his description. *Locastra muscosalis* resembles *L. crassipennis* in the male genitalia, as given by Janse (1931), but can be distinguished from the latter by its short and sub-globose scape extension distinct from that of *L. crassipennis* which is large, very broad at the base, and sickle-shaped in the distal 2/3.

Acknowledgements

We express our cordial thanks to those who participated in the field collection and to Dr. D. D. Zhang (SYSBM) for lending us the specimens. We also thank Dr. M. A. Solis (Washington, DC, USA) and Dr. B. Landry (Genève, Switzerland) for their pertinent comments and suggestions on the manuscript. Special thanks are given to Ms Wang YP, who studied *Locastra* and other genera of the subfamily Epipaschiinae from 2004 to 2007 when she was doing her master's degree of science in Nankai University. This research was supported by the National Natural Science Foundation of China (No. 31672372).

References

Bae YS, Paek MK (2006) Host-plants for larvae of Pyraloidea (Lepidoptera). Insecta Koreana 33 (Suppl.): 1–181.

Fletcher DS, Nye IWB (1984) The generic names of moths of the world. Volume 5. Pyraloidea. Trustees of the British Museum (Natural History), London, 185 pp.

Hampson GF (1893) The Macrolepidoptera Heterocera of Ceylon. Illustrations of typical specimens of Lepidoptera Heterocera in the collection of the British Museum. Printed by order of the trustees 9: 157–176.

Hampson GF (1896a) On the classification of three subfamilies of moths of the family Pyralidae: The Epipaschiinae, Endotrichinae and Pyralinae. Transactions of the Entomological Society of London (Part IV) 1896: 451–550.

Hampson GF (1896b) Moths. Part 4. The Fauna of British India, including Ceylon and Burma. Taylor & Francis, London, 594 pp.

Janse AJT (1931) A contribution towards the study of genera of the Epipaschiinae (family Pyralidae). Transactions of the Entomological Society of London 79(3): 439–492. https://doi.org/10.1111/j.1365-2311.1931.tb00712.x

Joannis Jde (1930) Lépidoptères Hétérocères du Tonkin (3e partie). Annales de la Société Entomologique de France 98(1929): 559–834.

Li HH (2002) The Gelechiidae of China (I) (Lepidoptera: Gelechioidea). Nankai University Press, Tianjin, 504 pp.

Mutuura A (1957) Pyralidae. In: Esaki T, Issiki S, Mutuura A, Inoue H, Ogata H, Okagaki H, Kuroko H (Eds) Icones Heterocerorum Japonicorum in Coloribus Naturalibus. Hoikusya, Osaka, 1: 93–147.

Moore F (1888) Descriptions of new Indian lepidopterous insects from the collection of the late Mr. W.S. Atkinson. Heterocera (continued) (Pyralidae, Crambidae, Geometridae, Tortricidae, Tineidae). In: Hewitson WC, Moore F (Eds) Descriptions of new Indian lepidopterous Insects from the collection of the late Mr. W.S. Atkinson 3. Asiatic Society of Bengal/ Taylor & Francis, Calcutta / London, 199–299. [pls 6–8]

Nuss M, Landry B, Mally R, Vegliante F, Tränkner A, Bauer F, Hayden J, Segerer A, Schouten R, Li H, Trofimova T, Solis MA, De Prins J, Speidel W (2003–2017) Global Information System on Pyraloidea. Available from http://www.pyraloidea.org [accessed 23 February 2017]

Solis MA (1992) Check list of the Old World Epipaschiinae and the related New World genera *Macalla* and *Epipaschia* (Pyralidae). Journal of the Lepidopterists' Society 46(4): 280–297.

Snellen PCT (1890) A catalogue of the Pyralidina of Sikkim collected by Henry J. Elwes and the late Otto Möller, with notes by H. J. Elwes. Transactions of the Entomological Society of London 1890: 557–647.

Swinhoe C (1902) Descriptions of new eastern and Australian moths. Annals and Magazine of Natural History, including Zoology, Botany and Geology (ser. 7) 9(51): 165–182. https://doi.org/10.1080/00222930208678563

Walker F (1866) List of the Specimens of Lepidopterous Insects in the Collection of the British Museum, Part 34 (Supplement 4). British Museum (Natural History), London, 1121–1533.

Wang JS, Song SM, Wu YY, Chen TM (2003) Research of Biological Diversity of Pyralidae of Wuyishan Nature Reserve in China. Science and Technology of China Press, Beijing, 328 pp.

ZooKeys 724: 119–134 (2017)
doi: 10.3897/zookeys.724.12478
http://zookeys.pensoft.net

RESEARCH ARTICLE

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

Riparian Collembola (Hexapoda) communities of northern Moldova, Eastern Europe

Galina Buşmachiu[1], Ľubomír Kováč[2], Dana Miklisová[3] , Wanda Maria Weiner[4]

1 *Institute of Zoology, Academy of Sciences of Moldova, Academiei str. 1, 2028 Chişinău, Republic of Moldova* **2** *Institute of Biology and Ecology, Faculty of Science, P. J. Šafárik University, Moyzesova 11, 040 01 Košice, Slovakia* **3** *Institute of Parasitology SAS, Hlinkova 3, 040 01 Košice, Slovakia* **4** *Institute of Systematics and Evolution of Animals, Polish Academy of Sciences, Sławkowska 17, Pl–31 - 016 Kraków, Poland*

Corresponding author: *Galina Buşmachiu* (bushmakiu@yahoo.com)

Academic editor: *L. Deharveng* | Received 1 March 2017 | Accepted 29 September 2017 | Published 21 December 2017

http://zoobank.org/DF7C895F-9188-4577-B93A-9417115B0C61

Citation: Buşmachiu G, Kováč L, Miklisová D, Weiner WM (2017) Riparian Collembola (Hexapoda) communities of northern Moldova, Eastern Europe. ZooKeys 724: 119–134. https://doi.org/10.3897/zookeys.724.12478

Abstract

Collembola were studied in a well-preserved riverine section of the Prut River in the Republic of Moldova. The study was focused on species diversity and habitat preferences of the particular species at two localities. Riparian habitats of the Prut River near Branişte included open river bank, forest belt and meadow, and the shore of Lake Costeşti-Stânca included meadow, pasture and shrub vegetation. In total 77 collembolan species were recorded, of which *Neanura moldavica* and *Arrhopalites prutensis* were endemic to Moldova. Comparative analyses showed a specific community composition at Branişte, with *Anurida ellipsoides* and *Mesaphorura macrochaeta* being abundant on the river bank and *Hemisotoma thermophila* in the meadow. In contrast, the forest plantation at the same locality was similar to the shrub-land in Costeşti, with the common species *Mesaphorura critica*, *M. yosii*, *Deutonura albella* and *Isotomiella minor*. Hygrophilous species preferred the habitats of the river section in Branişte, with quiet backwaters, to the artificial shoreline of the large lake. Species diversity was relatively high in the natural meadow and forest in Branişte and also in shrub-land on the lake shore. The present study documented relatively high collembolan species diversity at the shoreline and running water sections in the upper catchment area of the Prut River in Moldova that involve naturally valuable inundated habitats of Eastern Europe.

Keywords

Soil fauna, riverine ecosystems, species diversity, community ecology

Introduction

Floodplain forests and wetlands are highly dynamic ecosystems that are very dependent on the flows and sedimentation patterns of their adjacent rivers, acting as a link between land and water (Hughes 2003). Although many wetland organisms are widespread, some riverine systems are known for their high levels of endemism (Primack 2010).

Collembola make up one of the most significant and important groups that can be found in the soil and sandy sediments of riverbanks, wetlands and floodplain forests. Deharveng and Lek (1995) noted high Collembola diversity in riparian habitats of the Pyrenean massif. The Collembola communities of riparian habitats and wetlands are primarily affected by differences in the hydrologic regime and moisture gradient (Rusek 1984, Rusek et al. 2009, Sterzyńska et al. 2014), especially by the duration of inundation (Russell et al. 2004, Russell and Griegel 2006) and also by the vegetation structure (Sterzyńska 2009, Sterzyńska et al. 2014). After inundated soils are dried out, the overall Collembola diversity and abundance of hygrophilic and hygrotolerant species rapidly decline (Lessel et al. 2011), replaced by more xerotolerant and ubiquitous species (Marx 2008). Collembola predominate in later successional stages of wet meadows (Sterzyńska and Pilipiuk 1999). Generally, riparian communities of Collembola are very heterogeneous at small spatial scales, with different responses to flooding intensities.

Data in the literature on soil invertebrates of wetland and riparian ecosystems in Eastern Europe is still very limited. The present study was focused on Collembola communities of the Prut River in Moldova, a 953 km long river that rises in the Eastern Carpathian Mts in Ukraine at an altitude of 1600 meters. It is an important tributary of the Danube River and forms a border between Moldova and Romania that has been guarded and thus protected for more than 50 years. Preliminary studies of Collembola diversity in the riparian habitats of the lower section of the Prut River (Buşmachiu 2006, 2008) revealed 51 species concerning natural steppe, forest belts, grasslands and humid habitats on the shores of lakes Manta and Beleu. We assumed that the relatively well-protected floodplain forests and meadows in the upper Prut River catchment area could sustain valuable Collembola diversity.

The objective of this contribution was to reveal the species diversity and habitat preferences of individual species of Collembola occupying riverine habitats of the Prut River near Branişte and the shore of Lake Costeşti-Stânca, situated in northern Moldova. The study also aimed to provide a basic comparison of the communities of the individual riverine habitats. We expected the habitat type to have an important influence on the composition of Collembola communities in the natural riparian ecosystems.

Materials and methods

Study sites

In 2013–2014 Collembola were studied in the riparian habitats of the Prut River upper catchment area, where fluvisols (FAO soil-type classification system) predominate

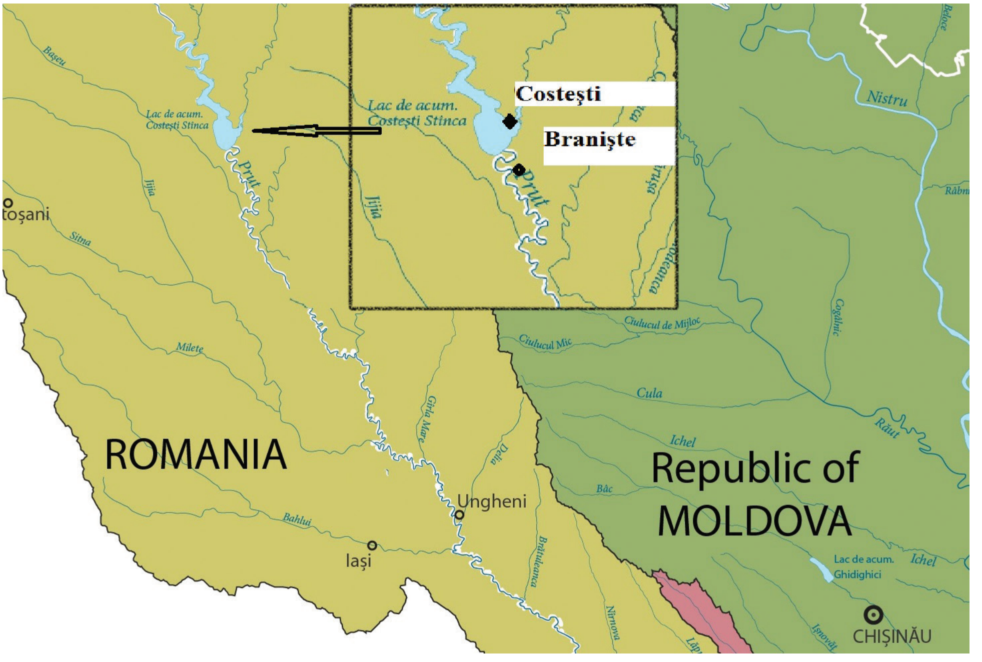


Figure 1. Location of the riparian habitats (colour: light green - upper catchment area of the Prut River, dark green - part of the Dniester (Nistru) River catchment area; the border between Romania and Moldova is represented by the Prut River).

with a clayey and silty clay structure and organic carbon content of 3.7–5.4%. The study included two localities with a distance of about 8 km between them (Fig. 1):

(1) Branişte village (47°49'1"N, 27°13'2"E; Fig. 2) - bank of the Prut River near the water; the level in July 2013 and June 2014 was high, sporadically flooding the bank covered by grassy vegetation. Further information on the water level of the river and temporal floods are provided by the State Hydrometeorological Service (http://www.meteo.md/mold).

The habitats selected on the distance gradient from the river were the following:

i) BB – 2–3 m wide, partially flooded river bank covered abundantly with herbaceous vegetation;

ii) BF – a 25–30 m wide protection forest belt plantation consisting mostly of *Quercus robur* mixed with *Populus alba*, *P. nigra*, *Salix alba*, *S. triandra* and *S. purpurea*, with moss and wooden debris; litter and humus layer ca. 3 cm thick;

iii) BM – a 45-meter wide belt of meadows along the banks with embankments for flood protection that separate the river from the meadows and nearby lake.

(2) Lake Costeşti–Stânca (47°55'1"N 27°08'3"E; Fig. 3), a water reservoir 70 km long and 59 km^2 in area, situated on the Prut River between Romania (Stânca village) and the Republic of Moldova (Costeşti village). The lake shore consists of a dam built in 2007 with limestone rocks poured into the water about 5 m off the bank to protect the shoreline. The habitats on the distance gradient from the lake were the following:

Figure 2. Bank of the Prut River near Branişte.

Figure 3. Shore of the Lake Costeşti-Stânca.

iv) CSB – a 1–2 m wide bank of the lake partially covered by hygrophilous grassy vegetation, in some places covered by algae and decaying residues of *Phragmites australis* (Cav.), partially inundated in June 2014;

v) CSP – a narrow belt of pasture about 20–25 m distance from the bank, covered with herbaceous plants (*Urtica dioica* L., *Artemisia* sp., *Plantago* sp., etc.) and with occasional small shrubs (*Rosa canina* L.), on a steep bank > 3 m above the water level.

vi) CSUB – a belt of shrub-land about 20–35 m distance from the shore formed by groups of individual shrubs, covered with small shrubs (*Rosa canina* L., *Lycium barbarum* L.) with 1.80 m high thickets of *Onopordum acanthium* L. behind the pasture; litter and humus layer ca. 1.5 cm thick.

Previously, the study area was part of a buffer zone of the former USSR state border, which was fenced off and strictly limited to visitors. The riverine zone of the Prut River thus remained virtually untouched by humans after 1945; in 2010 the wire fence was removed.

Sampling and extraction

The overall number of soil samples taken at Branişte and Costeşti was 25 and 27, respectively. The samples consisted of soil cores of size 5 × 5 × 5 cm taken by the first author in July and November 2013, and in June and July 2014; the sampling design is specified in Table 1. Some epiedaphic collembolan specimens were collected in the Branişte meadow and Costeşti shrub-land using an exhauster to catch epigeic species that are underestimated by the soil sampling.

The collembolans were extracted from the soil using the flotation method according to Buşmachiu et al. (2015). The specimens were fixed in 96% ethyl alcohol, sorted in a binocular stereomicroscope, cleared in lactic acid and KOH and mounted on permanent slides using Marc André II solution. The specimens were identified to the species level using a LEICA 2500 phase contrast microscope and the following principally taxonomical sources: Bretfeld (1999), Potapov (2001), Thibaud et al. (2004), Fjellberg (1998, 2007), Dunger and Schlitt (2011) and Jordana (2012). Geographic distribution and ecological data of the species were excerpted from the same literature. Collembola life forms were analyzed according to Gisin (1943) and Rusek (2007); the habitat preferences of species are provided in Table 2.

Data analyses

For the basic comparison of Collembola community structure between sites and habitats, data from the summer (June and July) of both years were used. Box-plots for number of specimens and species richness were depicted using STATISTICA for Windows version 12.0 (StatSoft, Inc. 2013). Non-metric multidimensional scaling (NMS) ordination processed average quantitative data to examine the community structure between 29 plots differentiated by locality (12 from B - Branişte and 17 from CS - Costeşti-

Table 1. Sampling design and Collembola community parameters in riparian habitats at Branişte and Costeşti–Stânca (Prut River) in 2013–2014.

Locality	Branişte					
Habitat	Bank		Forest		Meadow	
Month	Jul	Nov	Jul	Nov	Jun	Jul
Year	2013	2014	2013	2013	2014	2014
Sample nr.	6	2	6	3	3	5
Nr. of individuals	219	47	347	256	43	67
Species richness	4–8	6	11–18	10–13	15	12

Locality	Costeşti – Stânca										
Habitat	Bank			Pasture				Shrub-land			
Month	Jul	Jun	Jul	Jul	Nov	Jun	Jul	Jul	Nov	Jun	Jul
Year	2013	2014	2014	2013	2013	2014	2014	2013	2013	2014	2014
Sample nr.	4	2	2	4	4	2	1	4	1	1	2
Nr. of individuals	294	101	94	166	360	259	29	195	113	121	184
Species richness	12–13	11	7	11–12	5–6	14–15	10	12–15	11	16	14–16

Table 2. List of Collembola from the riparian habitats of the Prut River with overall numbers of individuals collected, biogeographic distribution (BD), life forms and ecological traits. Abbreviations: for locality and habitat see "Material and methods"; C – cosmopolitan, E – European, H – Holarctic, P – Palaearctic, M – Mediterranean, R – known from type locality only; e – epiedaphic, h – hemiedaphic, eu – euedaphic; * – species new to Moldova.

Species	Locality/Habitat						BD	Ecological traits	
	BB	BF	BM	CSB	CSP	CSUB		Life form	Habitat
Poduridae									
Podura aquatica Linné, 1758	3						C	e	hydrophile
Hypogastruridae									
Ceratophysella engadinensis (Gisin, 1949)		14			3	8	C	h	woodland
**Ceratophysella stercoraria* (Stach, 1963)					2		H	h	woodland
Ceratophysella succinea (Gisin, 1949)		2		14			C	h	grassland
Schoettella ununguiculata (Tullberg, 1869)	1	65	7	2	1	2	H	h	eurytopic
Willemia scandinavica Stach, 1949		2					H	eu	interstitial
Neanuridae									
Anurida ellipsoides Stach, 1920	126	34					P	h	humid soils
Anurida tullbergi Schött, 1891	1						H	h	humid soils
Deutonura albella (Stach, 1920)		3			1	21	E	h	woodland
Friesea truncata Cassagnau, 1958				15	6	13	P	h	woodland
**Pseudachorutes* sp.						1		h	
Pseudachorutes subcrassus Tullberg, 1871						1	P	h	woodland
Micranurida pygmaea Börner, 1901		3					C	h	woodland
Neanura moldavica Buşmachiu & Deharveng, 2008		4					R	e	woodland
Neanura muscorum (Templeton, 1835)		1					C	e	woodland
Onychiuridae									
Protaphorura armata (Tullberg, 1869)		5					C	h	eurytopic
Protaphorura sakatoi (Yosii, 1966)	9	167	8	144	512	58	E	h	eurytopic
Tullbergiidae									
Doutnacia xerophila Rusek, 1974		2					E	eu	interstitial
Mesaphorura critica Ellis, 1976	9	47	18	5	10	33	P	eu	grassland
Mesaphorura florae Simón et al., 1994	14	41			6	69	E	eu	interstitial
**Mesaphorura simoni* Jordana, Arbea, 1994				1	1		E	eu	humid soils
Mesaphorura hylophila Rusek, 1982		18					P	eu	interstitial
Mesaphorura macrochaeta Rusek, 1976	38	4					C	eu	eurytopic
**Mesaphorura rudolfi* Rusek, 1987					1		E	eu	grassland
Mesaphorura sylvatica Rusek, 1971	8	6				1	P	eu	woodland
Mesaphorura yosii (Rusek, 1967)	5	29		74	4	40	C	eu	grassland
Metaphorura affinis (Börner, 1902)	1		2	27	3	14	P	eu	grassland
Stenaphorura metaparisi (Traser & Weiner, 1999)				1		2	E	eu	grassland
Isotomidae									
Folsomia manolachei Bagnall, 1939		5	9				P	h	eurytopic
**Folsomides* sp.					1			eu	
Hemisotoma thermophila (Axelson, 1900)			24	95	11		C	h	eurytopic
Isotoma viridis (Bourlet, 1839)			16	13	15	2	H	e	grassland

Species	Locality/Habitat						BD	Ecological traits	
	BB	BF	BM	CSB	CSP	CSUB		Life form	Habitat
Isotomiella minor (Schäffer, 1896)	16	72	3	2	5	85	H	eu	woodland
Isotomodes productus (Axelson, 1906)			8	9	44	9	C	eu	grassland
**Isotomurus antennalis* Bagnall, 1940					1		E	e	grassland
Isotomurus sp. juv.	31	1		3			-	e	woodland
Parisotoma notabilis (Schäffer, 1896)		39		1	69	116	C	h	eturytopic
Proisotoma minuta (Tullberg, 1871)						9	C	h	woodland
Entomobryidae									
Entomobrya nigrocincta Denis, 1923						4	E	e	woodland
Entomobrya handschini Stach, 1922					2		E	e	grassland
Entomobrya quinquelineata Börner, 1901			2				E	e	grassland
Entomobrya marginata (Tullberg, 1871)			1			4	E	e	eurytopic
Entomobrya multifasciata (Tullberg, 1871)						2	H	e	grassland
Entomobrya violaceolineata Stach, 1913			6				E	e	grassland
Entomobrya juv.		3			4	12			
Heteromurus major (Moniez, 1889)			9			11	M	h	woodland
Heteromurus nitidus (Templeton, 1835)					1		C	eu	eurytopic
Orchesella albofasciata Stach, 1960			18	3			E	e	humid soils
Orchesella cincta (Linnaeus, 1758)		1					H	e	woodland
Orchesella multifasciata Stscherbakow, 1898				1	6	4	E	e	eurytopic
Orchesella orientalis Stach, 1960			1				E	e	grassland
**Orchesella villosa* (Geoffroy, 1762)				6			H	e	grassland
**Lepidocyrtus arrabonicus* Traser, 2000				32			E	e	grassland
Lepidocyrtus lignorum (Fabricius, 1793)			2				H	e	woodland
Lepidocyrtus paradoxus Uzel, 1890			1				H	e	humid soils
Lepidocyrtus violaceus (Lubbock, 1873)			6		3		H	e	woodland
Pseudosinella horaki Rusek, 1985	1	13					E	h	woodland
Pseudosinella imparipunctata Gisin, 1953			1	23	61	54	E	h	grassland
Pseudosinella octopunctata Börner, 1901			5	7	12	2	C	h	grassland
Tomoceridae									
Pogonognathellus flavescens (Tullberg, 1871)		1					H	e	woodland
Tomocerus vulgaris (Tullberg, 1871)		1					C	h	woodland
Cyphoderidae									
Cyphoderus albinus (Nicolet, 1842)					2		P	eu	grassland
Cyphoderus bidenticulatus (Parona, 1888)				1	1	3	M	eu	grassland
***Oncopoduridae**									
**Oncopodura crassicornis* Shoebotham, 1911					8	4	P	eu	grassland
Neelidae									
Neelus murinus Folsom, 1896		15		2	3	4	C	eu	woodland
Megalothorax minimus Willem, 1900		1				1	C	eu	woodland
Sminthurididae									
Sphaeridia pumilis (Krausbauer, 1898)	1		15	7	10	11	C	h	eurytopic
**Stenacidia violacea* (Reuter, 1881)			3				C	e	humid soils
Arrhopalitidae									
Arrhopalites prutensis Vargovitsh & Buşmachiu, 2015	4						R	eu	woodland

Species	Locality/Habitat						BD	Ecological traits	
	BB	BF	BM	CSB	CSP	CSUB		Life form	Habitat
Arrhopalites ulehlovae Rusek, 1970	1						E	eu	woodland
Pygmarrhopalites terricola (Gisin,1958)		7					E	eu	woodland
Katiannidae									
Sminthurinus aureus (Lubbock, 1862)					1	2	P	e	grassland
Sminthurinus bimaculatus Axelson, 1902	1	2					P	e	humid soils
Sminthurinus elegans (Fitch, 1863)			1			4	E	e	grassland
Bourletiellidae									
Deuterosminthurus sp.			1	1		2	-	e	grassland
Sminthuridae									
**Sminthurus nigromaculatus* (Tullberg, 1871)					4		H	e	grassland
Sminthurus viridis (Linné, 1758)		1	1			4	C	e	grassland
Caprainea marginata (Schött, 1893)						1	P	e	woodland
	270	**609**	**168**	**489**	**814**	**613**			
Life forms - dominance [%]									
epiedaphic	13.0	1.5	35.1	12.1	4.5	6.7			
hemiedaphic	51.4	57.6	46.4	62.9	84.4	50.0			
euedaphic	35.6	40.9	18.5	25.0	11.1	43.3			

Stânca) and habitat. The ordination covered 16 species in total; species with dominance < 1% were excluded from the analysis due to an unclear relationship with the studied habitats. The epiedaphic collembolan specimens collected by the exhauster in meadow and shrubland were also excluded from the analysis. Autopilot, with slow and thorough mode, and Sørensen (Bray-Curtis) distance, recommended for community data, were selected. After 250 randomized runs, a two-dimensional solution was accepted as optimal. PC-ORD software (McCune and Mefford 2011) was used for the NMS analysis.

Results

Collembola diversity

Altogether, 2963 individuals of Collembola belonging to 77 species were found in the habitats along the Prut River (Table 2): 1916 individuals were collected in the riverine habitats of Costești and 1047 individuals in that of Branişte. In spite of the difference between the numbers of individuals, the number of species was similar, i.e. 52 in Costeşti and 54 in Branişte. Although the sites are rather close to one another, being located on the same bank of the river, only 28 collembolan species were common to both.

According to the life forms, 26 collembolan species were epiedaphic, 22 hemiedaphic and 25 euedaphic. The largest portions were woodland (26) and grassland (25) species, followed by eurytopic species (10) and species preferring interstitial habitats (4). Moreover, the riparian communities of the Prut River area included seven hygrophilous and one hydrophilous (*Podura aquatica*) species, representing 10.3% of the total species number.

The majority of species have a wide geographic occurrence, namely European (29.5%), cosmopolitan (25.9%) and Palaearctic or Holarctic species (16.9%); two species have a Mediterranean distribution range and two species have a range limited to Moldova (*Neanura moldavica*, *Arrhopalites prutensis*).

Nine species, namely *Ceratophysella stercoraria*, *Mesaphorura rudolfi*, *M. simoni*, *Isotomurus antennalis*, *Orchesella villosa*, *Lepidocyrtus arrabonicus*, *Oncopodura crassicornis*, *Stenacidia violacea* and *Sminthurus nigromaculatus* were new for the fauna of the Republic of Moldova. Two species, *Folsomides* sp. and *Pseudocharutes* sp., are potentially new for science.

Comparison of communities at localities and habitats

Collembola in Branişte were more abundant in the forest belt, and in Costeşti higher numbers of them were recorded in pasture and under shrubs. *Protaphorura sakatoi*, *Isotomiella minor* and *Mesaphorura critica* were abundant and frequent in all habitats of both localities, representing hemiedaphic and/or euedaphic life forms. Similarly, *Schoettella ununguiculata*, *Mesaphorura yosii*, *M. florae*, *Parisotoma notabilis*, *Neelus murinus* and *Sphaeridia pumilis* were present in all or most habitats, but in lower number of specimens. *Anurida ellipsoides* was dominant in Branişte, and together with *A. tullbergi*, *Micranurida pygmaea*, *Neanura moldavica*, *N. muscorum*, *Tomocerus minor*, *Pogonognathellus flavescens* and *Podura aquatica* occurred exclusively in this locality (Table 2). In contrast, *Oncopodura crassicornis*, *Cyphoderus albinus* and *C. bidenticulatus* were found only in pasture soil in Costeşti. *Friesea truncata*, *Pseudosinella imparipunctata* and *Isotomodes productus* were abundant and frequent in the riparian habitats near the lake.

The low bank of the Prut River covered by forest belt in Branişte was associated with a higher number of hygrophilous species (7) than the pasture and shoreline of the lake (2 species; Table 2); hygrophilous *Anurida ellipsoides* was abundant on the flooded river bank.

High dominance of a few species was observed in the pasture, specifically *Protaphorura sakatoi*, *Parisotoma notabilis* and *Pseudosinella imparipunctata*, which shared 54.1% of the total community dominance.

A high proportion of epiedaphic collembolans was observed in the meadow near the river, but this was affected by additional collection with an exhauster. These forms were relatively numerous on both banks of the river and lake, consisting mainly of isotomid and entomobryid collembolans. The pasture near the lake showed a very high proportion of hemiedaphic forms, dominated by *P. sakatoi*, *P. notabilis* and *P. imparipunctata*. A lower dominance of euedaphic forms was evident in open habitats, such as meadow and pasture, compared to other habitats.

A box-plot diagram of Collembola number of specimens (Fig. 4a) showed higher median values in the forest belt in Branişte and in all three habitats near the lake, and

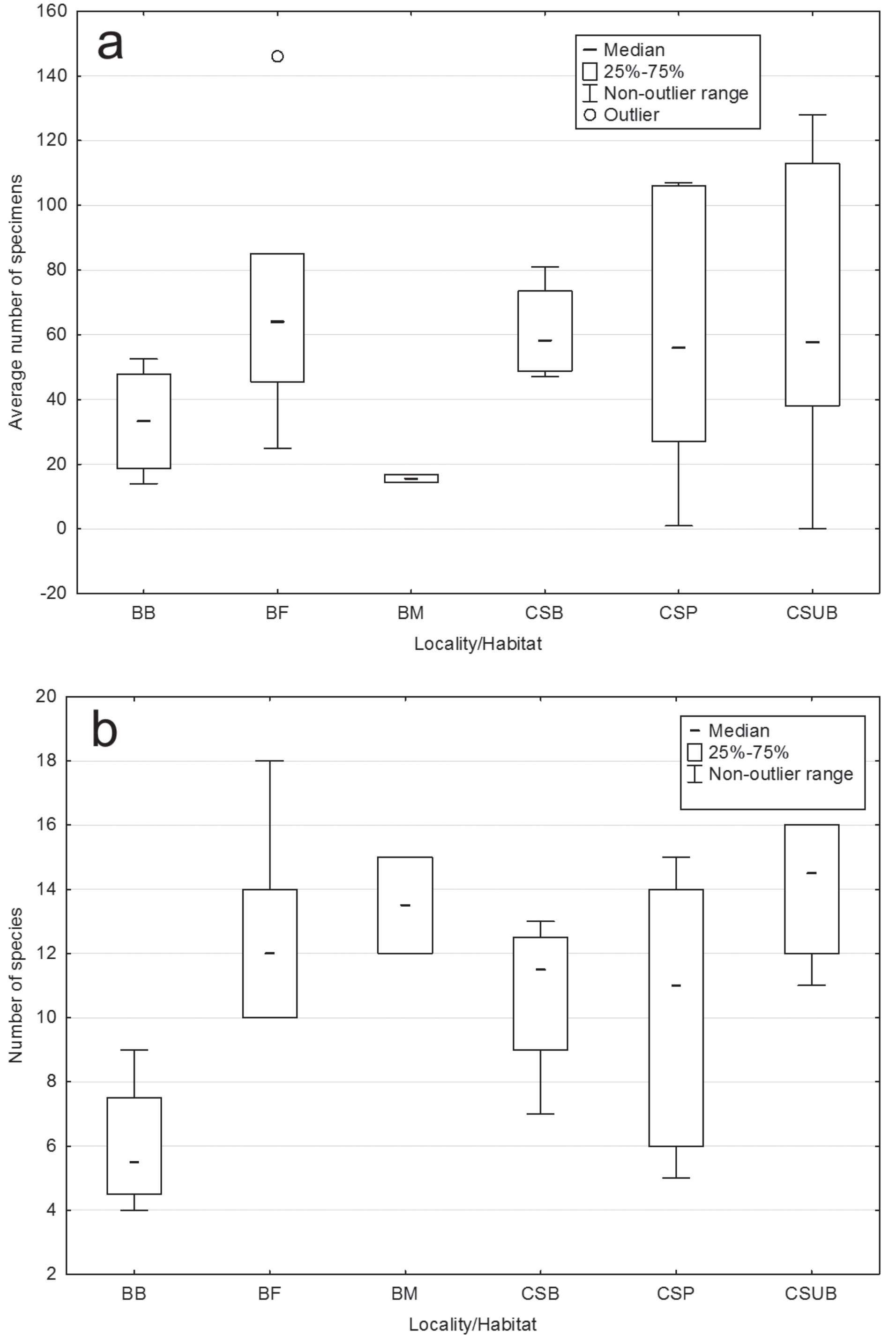


Figure 4. Box-plot diagram of Collembola specimens' number (**a**) and species richness (**b**) in riparian habitats of the Prut River. For abbreviations see Materials and methods.

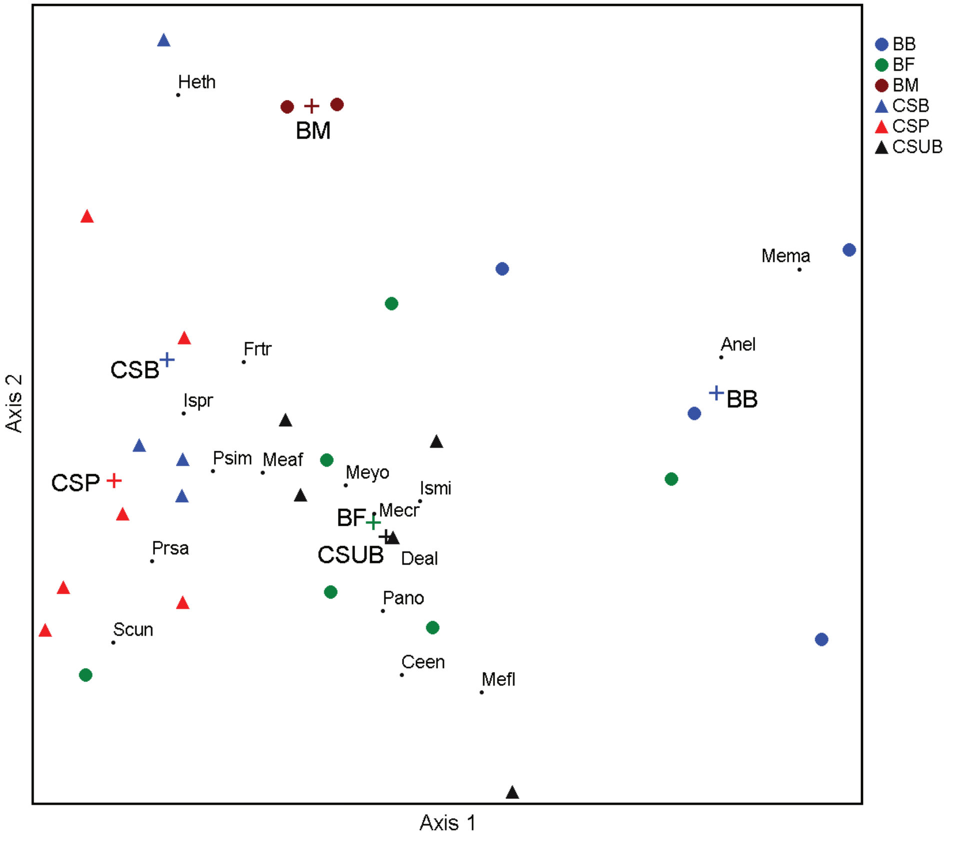


Figure 5. NMS ordination of Collembola species in riparian habitats of the Prut River from June–July 2013 and 2014, species with dominance ≥ 1% included. Colour circles and triangles represent localities and habitats, for abbreviations see Materials and methods, black dots represent species, for species abbreviations see Table 2. Variance explained by the first two axes was 38% and 34%, respectively.

lower values on the river bank and in the meadow near the river. The pasture and shrub-land near the lake had apparently higher non-outlier ranges of number of specimens compared with the others. A box-plot of species richness (Fig. 4b) documented the high median values in the shrub-land and meadow, while the lowest median was observed on the river bank. The pasture had a high non-outlier range of this community parameter.

An NMS ordination diagram (Fig. 5) outlines the Collembola community composition at localities/habitats during the summer (June and July) of both years. For the analysis, a two-dimensional solution was recommended by Autopilot and confirmed by the Monte Carlo permutation test, with a significant $P < 0.005$, a mean stress of 23.3 for real data and 250 runs for both real and randomized data. This best two-dimensional solution had a final stress of 17.8, $P < 0.00001$ after 110 iterations. The diagram shows that habitats along the river (Branişte) were rather dissimilar, with river bank and meadow communities showing a specific composition, where *Anurida ellipsoides* and *Mesaphorura macrochaeta* were abundant on the bank and *Hemisotoma thermophila* in the meadow. In contrast, forest plantation of the same locality was similar to the habitats of Costeşti, especially to the shrub-land with *Mesaphorura critica*, *M. yosii*, *Deutonura albella* and *Isotomiella minor* as the common species. In general, habitats near Lake Costeşti-Stânca had similar species composition.

Discussion

The present study has some limitations that can be inferred from the non-uniform sampling design across the studied habitats. Nevertheless, several peculiarities of collembolan species diversity and distribution were observed at the natural inundation habitats of the Prut River and the shoreline of a nearby lake. The study revealed a relatively high overall species number of Collembola, which is likely the result of the long-term preservation of these riparian habitats over more than six decades. The forest belt and meadow on the river bank and the shrub-land near the lake were the most diverse in species.

According to Čarnogurský (1998) species of alluvial habitats have a wide geographic distribution (cosmopolitan, Holarctic and Palaearctic), while endemic species are missing in these habitats. Similarly, Sterzyńska (2009) found that in floodplains widely distributed species were the most numerous in all habitat types, which was also observed in the present study. In contrast, Deharveng and Lek (1995) revealed high Collembola diversity with a larger number of rare and/or endemic species in habitats along running waters, the pattern probably characteristic for higher mountains in southern Europe with high endemism in the local fauna. Regarding endemic species recorded during the present study, *Neanura moldavica* is a species widespread in Moldova, while *Arrhopalites prutensis* is recently known only from the natural floodplain forests of the Prut River. *Lathriopyga nistru*, *Micraphorura gamae* and *A. prutensis* inhabit the banks of the Prut and Dniester Rivers in Moldova (Buşmachiu and Deharveng 2008, Buşmachiu and Weiner 2013, Vargovitsh and Buşmachiu 2015) and probably represent local endemic species.

A portion of the hygrophilous species preferred habitats of the river section in Branişte with quiet backwaters to the shoreline of the large Lake Costeşti-Stânca. The studies carried out in riparian habitats of the Dniester River in Moldova (Buşmachiu and Weiner 2013), and in the similar habitats in Ukraine (Sterzyńska et al. 2014) showed the portion of hygrophilous species to be 13% and 12%, respectively. In the Arize massif (Pyrenees, France) Deharveng and Lek (1995) recognized 16% hygrophilous species that had high abundance. In contrast, hygrophilous species were not abundant in the Prut area, with the distinction probably associated with the different types of riverine habitats involved in both studies and the local climatic conditions (mountain and lowland climate, respectively).

At both localities three habitats were selected for the study, representing gradients in terms of their distance from the water. Herbaceous marginal vegetation near the water, forest belt (plantation) and meadow were in gradient from the river, and grassy shoreline vegetation, pasture and shrub-land in gradient from the lake. NMS ordination showed that natural riverine habitats (river bank, natural meadow) had specific communities, while the secondary habitats near the lake were similar in the composition with the forest plantation on the river bank. The difference between the natural and secondary riparian habitats was also striking in the low number of the common species. Moreover, the community structure in pasture, with the dominance concentrated in a few eurytopic or grassland species, indicated a disturbed habitat.

A box-plot diagram documented the tendency of riverine habitats with shrub and tree vegetation with a litter layer to have higher number of specimens and species richness compared to the others. The accumulation of organic residues and decaying wood also supported a greater variety of collembolan species. Moreover, ordination showed that both habitats had a similar community structure. On the other hand, the grassy bank of the river had apparently lower number of specimens and species richness and was a relatively extreme habitat occupied by a limited number of species adapted to inundations.

The present study implies that intact patches with natural, undisturbed floodplain forests and mostly intact riverine meadows and grasslands in the higher Prut River catchment area are very valuable natural habitats in terms of preservation of soil-fauna diversity in inundated habitats and wetlands of Eastern Europe.

Acknowledgements

The work was supported by cooperation between the Moldavian and Polish Academies of Sciences and project № 15.817.02.12F. This work was also partly supported by the project "Centre of Excellence for Parasitology" (Code ITMS: 26220120022), based on the support of the "Operational Programme Research & Development" funded from the European Regional Development Fund (rate 0.4). The manuscript was proofread by Mr. David McLean (Prešov, Slovakia). The authors are grateful to reviewers David J. Russell and Maria Sterzyńska and to the subject editor Louis Deharveng for the valuable comments to the previous manuscript version.

References

Buşmachiu G (2006) The structure of collembolan communities from the riverine zone of the Lower Prut River. Collection of scientific articles. In memoriam of academician Leo Berg – 130 years. Bender, 142–146.

Buşmachiu G (2008) The species diversity of Collembolan from riverine ecosystems. International Conference "Management of Transboundary Dniester River and the Water Framework Directive of the European Union". Chişinău, 56–59.

Buşmachiu G, Deharveng L (2008) Neanurinae and Morulininae of Moldova (Collembola: Neanuridae), with description of *Neanura moldavica* sp. n. Zootaxa 1714: 61–66.

Buşmachiu G, Weiner WM (2013) Collembola from the Moldavian banks of Dniester river. New records. Annales Zoologici 63 4): 529–535. https://doi.org/10.3161/000345413X676759

Buşmachiu G, Bedos A, Deharveng L (2015) Collembolan species diversity of calcareous canyons in the Republic of Moldova. ZooKeys 506: 95–108. https://doi.org/10.3897/zookeys.506.8643

Bretfeld G (1999) Synopses on Palaearctic Collembola. Vol. 2. Symphypleona. In: Dunger W. (Ed.) Abhandlungen und Berichte des Naturkundemuseum. Görlitz 71: 1–318.

Čarnogurský J (1998) Influence of the simulated flood on the collembolan communities in the former seasonally flooded Danubian forest near the Gabcikovo waterwork (Slovakia). In: Tajovský K, Pižl V (Eds) Soil Zoological Problems in Central Europe. České Budějovice, 13–17.

Deharveng L, Lek S (1995) High diversity and community permeability: the riparian Collembola (Insecta) of a Pyrenean massif. Hydrobiologia 312: 59–74. https://doi.org/10.1007/BF00018887

Dunger W, Schlitt B (2011) Synopses on Palaearctic Collembola.Vol. 6/1 Tullbergiidae. In: Dunger W (Ed.) Soil Organisms 83(1): 1–168.

Fjellberg A (1998) The Collembola of Fennoscandia and Denmark. Part. I: Poduromorpha. Fauna Entomologica Scandinavica 35: 1–183.

Fjellberg A (2007) The Collembola of Fennoscandia and Denmark. Part II: Entomobryomorpha and Symphypleona. Fauna Entomologia Scandinavica, 42. Brill, Leiden, 264 pp. https://doi.org/10.1163/ej.9789004157705.i-265

Gisin H (1943) Ökologie und Lebensgemeinschaften der Collembolen im schweizerischen Exkursionsgebiet Basels. Revue suisse de Zoologie 50: 131–224.

Hughes FMR (Ed) (2003) The Flooded Forest: Guidance for policy makers and river managers in Europe on the restoration of floodplain forests. FLOBAR2, Department of Geography, University of Cambridge, UK, 96 pp.

Jordana R (2012) Synopses on Palaearctic Collembola. Vol. 7/1. Capbryinae et Entomobryini. In: Dunger W, U Burkhardt (Eds) Soil Organisms 84(1): 1–390.

Lessel T, Marx MT, Eisenbeis G (2011) Effect of ecological flooding on the temporal and spatial dynamics of carabid beetles (Coleoptera, Carabidae) and springtails (Collembola) in a polder habitat. Zookeys 100: 421–446. https://doi.org/10.3897/zookeys.100.1538

Marx MT (2008) The collembolan population of a river bank reinforcement system in front of a middle Rhine region floodplain under influence of inundation and extreme drought. Peckiana 5: 115–125.

McCune B, Mefford MJ (2011) PC-ORD, multivariate analysis of ecological data, version 6.07. MjM Software. Gleneden Beach, Oregon, U.S.A. www.pcord.com

Potapov M (2001) Synopses on Paleartic Collembola. Vol. 3. Isotomidae. In: Dunger W (Ed.) Abdhandlungen und Berichte des Naturkundemuseums. Görlitz 73(2): 1–603.

Primack RB (2010) Essentials of conservation biology. Fifth edition. Sinauer Associates, city, 603 pp.

Rusek J (1984) Zur Bodenfauna in drei Typen von Überschwemmungswiesen in Süd-Mahren. Rozpravy Československé akademie věd, Řada, matematických a přírodních věd 94(3): 1–126.

Rusek J (2007) A new classification of Collembola and Protura life forms. *In*: K. Tajovský, J. Schlaghamerský, Pižl V(Eds) Contributions to Soil Zoology in Central Europe II. Biological Centre AS CR - Institute of Soil Biology, České Budějovice: 109–115.

Rusek J, Reithofer D, Schimd S, Truxa C, Weber J, Wilde U (2009) Collembola,Protura and Pauropoda in a riparian forest – mesic forest ecotone. In: Tajovský K, Schlaghamerský J, Pižl V (Eds) Contributions to soil zoology in Central Europe III. Biology Centre AS CR – Institute of Soil Biology, České Budějovice, 133–139.

Russell D, Hauth A, Fox O (2004) Community dynamics of soil Collembola in floodplains of the Upper Rhine Valley. Pedobiologia 48: 527–536. https://doi.org/10.1016/j.pedobi.2004.06.007

Russell DJ, Griegel A (2006) Influence of variable inundation regimes on soil Collembola. Pedobiologia 50: 165–175. https://doi.org/10.1016/j.pedobi.2006.02.002

StatSoft Inc. (2013) STATISTICA (Data Analysis Software System), version 12.0. www.statsoft.com

Sterzyńska M (2009) Assemblages of soil Collembola in wetlands in the floodplains of some Polish rivers. Museum and Institute of Zoology PAS, Warsaw, 96 pp.

Sterzyńska M, Shrubovych J, Kaprus I (2014) Effect of hydrologic regime and forest age on Collembolan in riparian forests. Applied Soil Ecology 75: 199–209. https://doi.org/10.1016/j.apsoil.2013.11.010

Sterzyńska M, Pilipiuk I (1999) Communities of soil fauna (Enchytraeidae, Collembola) in Biebrza river basin. In: Tajovský K, Pižl V (Eds) Soil Zoology in Central Europe. České Budějovice, 335–342.

Thibaud JM, Schulz HJ, Gama MM da (2004) Synopses on Paleartic Collembola. Vol. 4. Hypogastruridae. In: Dunger W (Ed.) Abhandlungen und Berichte des Naturkundemuseums. Görlitz 75: 1–287.

Vargovitsh R, Buşmachiu G (2015) A new species and new records of Arrhopalitidae (Collembola: Symphypleona) from the Republic of Moldova. Zootaxa 3973(3): 539–552. https://doi.org/10.11646/zootaxa.3973.3.8

ZooKeys 724: 135–153 (2017)
doi: 10.3897/zookeys.724.19383
http://zookeys.pensoft.net

RESEARCH ARTICLE

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

A new species of *Rana* from the Dabie Mountains in eastern China (Anura, Ranidae)

Chencheng Wang[1,*], Lifu Qian[1,*], Chenling Zhang[2], Weibo Guo[3], Tao Pan[1], Jun Wu[3], Hui Wang[1], Baowei Zhang[1]

1 *Key Laboratory of Eco-engineering and Bio-technique, School of Life Sciences, Anhui University, Hefei, 230601, China* **2** *College of life science and chemistry, Jiangsu second normal University, Nanjing, 210013, Jiangsu* **3** *Ministry of Environmental Protection, Nanjing Institute of Environmental Sciences, Nanjing 210042, Jiangsu, China*

Corresponding author: *Baowei Zhang* (zhangbw@ahu.edu.cn); *Hui Wang* (kikihui860425@163.com)

Academic editor: *A. Crottini* | Received 25 July 2017 | Accepted 15 November 2017 | Published 21 December 2017

http://zoobank.org/54989071-8B44-4817-93A1-26D14B2348DA

Citation: Wang C, Qian L, Zhang C, Guo W, Pan T, Wu J, Wang H, Zhang B (2017) A new species of *Rana* from the Dabie Mountains in eastern China (Anura, Ranidae). ZooKeys 724: 135–153. https://doi.org/10.3897/zookeys.724.19383

Abstract

A new species *Rana dabieshanensis* **sp. n.** is described from the Dabie Mountains in Anhui Province, China, based on morphological character differences and molecular analyses. The new species can be distinguished from its congeners by a combination of diagnostic characters. The results of phylogenetic analyses (based on 12s rRNA, 16s rRNA, ND2, Cyt *b*, RAG1, BDNF and Tyr) and genetic distances (based on Cyt *b*) indicate that the new species belongs to the *Rana longicrus* group, and is placed as the sister taxon to *R. hanluica*.

Keywords

Amphibians, morphology, molecular phylogeny, taxonomy

Introduction

The true frogs of the genus *Rana* Linnaeus are broadly distributed across Eurasia and the Americas (Amphibia Web 2017, Frost 2016, Yuan et al. 2016). Because of their body coloration and habitat preferences, the species of this genus are colloquially known as brown frogs or wood frogs (Boulenger 1920, Yan et al. 2011). To date, more than 100 species

* Both of the authors contribute equally to this work.

are attributed to this genus, with their distribution ranges across Asia (32 species), Europe and the Near East (12 species), and the Americas (57 species) with several lineages still being not formally described (Yuan et al. 2016, Amphibia Web 2017). In China, the genus *Rana* contained 17 species (Fei et al. 2012) that were divided into three groups (*R. longicrus* group, *R. chensinensis* group, and *R. amurensis* group) based on morphology and distribution (Fei et al. 2009). Molecular phylogenies, however, indicate presence of *R. longicrus*, *R. amurensis*, *R. chensinensis*, *R. sauteri*, *R. johnsi*, *R. shuchinae,* and *R. weiningensis* groups within the Chinese *Rana* sensu lato (Che et al. 2007, Yuan et al. 2016). And 24 species are contains in Chinese *Rana* genus (AmphibiaChina 2017, Yuan et al. 2016, Zhao et al. 2017). The species of the *R. longicrus* group are widely distributed in southern and eastern China, and the recent surge in new species descriptions suggests that these still insufficiently explored regions may contain many undescribed cryptic species (Lu and Li 2001, Lu et al. 2007, Shen et al. 2007, Li et al. 2008, Yan et al. 2011).

From 2015 to 2016, we collected 17 specimens of *Rana* sp. in montane forests of the Dabie Mountains. The specimens exhibited comparatively large body size and a straight dorsolateral fold from posterior corner of eye to groin. Initially, they were identified as *R. omeimontis* (according to the identification key by Ye et al. 1993). However, from the further detailed studies indicated that this record might represent a yet undescribed cryptic species of *Rana*.

Generally, the brown frogs are difficult to identify in the field because of their close morphological similarities especially when closely related species have overlapping distributions (Stuart et al. 2006, Che et al. 2007). According to the results of subsequent molecular analyses and morphological identification, we confirmed that the specimens of *Rana* sp. from Dabie Mountains were distinct from any species presently recognized in the genus of *Rana* and herein we describe them as a new species.

Materials and methods

Sampling: In total, 17 specimens of *Rana* sp. were collected from Yaoluoping National Nature Reserve in Dabie Mountains, Yuexi County, Anhui Province, China (30°58'16.92"N, 116°04'11.88"E, elevation 1150 m a.s.l.) (Fig. 1), in August 2015 and August 2016. Those individuals were dipped in 10% formalin (10 seconds) for fixation and subsequently transferred into 75 % ethanol for storage. Before fixing in formalin, liver tissues from all individuals were sampled and preserved in 100% ethanol for molecular analyses. All specimens and tissue samples were deposited in the Anhui University Museum, Research Center for Biology.

DNA extraction, PCR amplification and sequencing: Genomic DNA was extracted from liver tissues of seven *Rana* sp. specimens using the standard proteinase K/phenol-chloroform protocol (Sambrook et al. 1989). Four mitochondrial genes (12S rRNA, 16S rRNA, ND2, and Cyt *b*) and three nuclear DNA markers (Tyr, BDNF and RAG1) were sequenced for one individual, while for six remaining specimens only Cyt *b* mtDNA gene was sequenced. The primers used for PCR and sequencing are summarized in Table 1. All

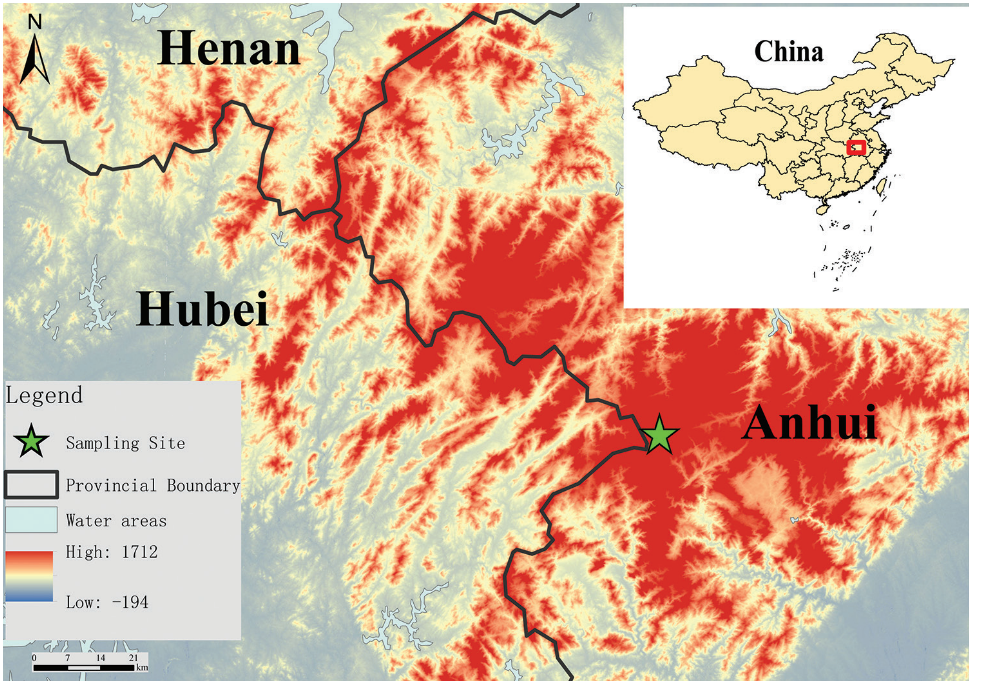


Figure 1. Distribution of *Rana dabieshanensis* sp. n. in Dabie Mountains (Anhui, Hubei, and Henan provinces, central China). Occurrence record is marked with green mark.

Table 1. Primers used for PCR and sequencing.

Locus	Primer Name	Sequences (5' end 3' end)	Temperature (°C)	Source
12S	L2519	AAACTGGGATTAGATACCCCACTAT	50	Kocher et al. (1989)
	H3296	GCTAGACCATKATGCAAAAGGTA	50	Kocher et al. (1989)
16S	16SAR	AACGCTAAGATGAACCCTAAAAAGTTCT	50	Kocher et al. (1989)
	R16	ATAGTGGGGTATCTAATCCCAGTTTGTTTT	50	Sumida et al. (2000)
ND2	HERP322	TYCGARGACAGAGGTTTRAG	42	Yuan et al. (2016)
	HERP323	CAYCCACGRGCYATYGAA	42	Yuan et al. (2016)
Cyt *b*	HERP328	GAAAARCTRTCGTTGTWATTCAACTA	50	Yuan et al. (2016)
	HERP329	CTACKGGTTGTCCYCCRATTCATGT	50	Yuan et al. (2016)
Tyr	Tyr1G	TGCTGGGCRTCTCTCCARTCCCA	50	Bossuyt and Milinkovitch (2000)
	Tyr1B	AGGTCCTCYTRAGGAAGGAATG	50	Bossuyt and Milinkovitch (2000)
RAG1	AmpF2	ACNGGNMGICARATCTTYCARCC	52	Hoegg et al. (2004)
	AmpR2	GGTGYTTYAACACATCTTCCATYTCRTA	52	Hoegg et al. (2004)
BDNF	BDNF 2F	GAGTGGGTCAAGAGGAGG	41	Zhou et al. (2012)
	BDNF_2R	ACTGGGTAGTTCGGCATT	41	Zhou et al. (2012)

PCRs were performed with the same conditions in 50 µL: 20 to 80ng of genomic DNA, 25 µL 2×EasyTaq PCR SuperMix polymerase (TransGen Biotech, containing 1.25U Ex Taq, 0.4mM dNTP, 4mM Mg^{2+}) and 0.4 µM of primers. Reactions were performed with

Table 2. Species, sample localities, voucher museum numbers and GenBank accession numbers for DNA sequences of *Rana* species used in the phylogenetic analyses.

Species	Locality	Voucher	GenBank No.						Reference
			12S-16S	Cyt *b*	ND2	RAG1	BDNF	Tyr	
R. dabieshanensis sp. n. (1)	China: Anhui Province: Dabie Mountains area	AHU2016R001	MF172963	MF172964	MF172974	MF172971	MF172972	MF172973	This Study
R. dabieshanensis sp. n. (2)	China: Anhui Province: Dabie Mountains area	AHU2016R002	N/A	MF172965	N/A	N/A	N/A	N/A	This Study
R. dabieshanensis sp. n. (3)	China: Anhui Province: Dabie Mountains area	AHU2016R003	N/A	MF172966	N/A	N/A	N/A	N/A	This Study
R. dabieshanensis sp. n. (4)	China: Anhui Province: Dabie Mountains area	AHU2016R004	N/A	MF172967	N/A	N/A	N/A	N/A	This Study
R. dabieshanensis sp. n. (5)	China: Anhui Province: Dabie Mountains area	AHU2016R005	N/A	MF172968	N/A	N/A	N/A	N/A	This Study
R. dabieshanensis sp. n. (6)	China: Anhui Province: Dabie Mountains area	AHU2016R006	N/A	MF172969	N/A	N/A	N/A	N/A	This Study
R. dabieshanensis sp. n. (7)	China: Anhui Province: Dabie Mountains area	AHU2016R007	N/A	MF172970	N/A	N/A	N/A	N/A	This Study
R. amurensis	Russia: Tomskaya: Tegul-detskii district	MSUZP-SLK-RUS49	KX269203	KX269349	KX269418	KX269568	KX269278	KX269795	Yuan et al. 2016
R. arvalis	Russia: Mordovia: Chamzin-skii district	MSUZP-SLK-MKR21	KX269197	KX269344	KX269413	KX269562	KX269272	KX269789	Yuan et al. 2016
R. asiatica	China: Xinjiang: 47tuan	KIZ-XJ0251	KX021945	KX021945	KX021945	KX269565	KX269275	KX269792	Yuan et al. 2016
R. chaochiaoensis	China: Sichuan: Zhaojue	SCUM0405170CJ	KX269192	KX269339	KX269408	KX269557	KX269267	KX269800	Yuan et al. 2016
R. chensinensis	China: Shaanxi: Huxian	KIZ-RD05SHX01	KX269186	KX269333	KX269402	KX269551	KX269261	KX269779	Yuan et al. 2016
R. culaiensis	China: Shandong: Culaishan shan	KIZ-SD080501	KX021986	KX021986	KX021986	KX269555	KX269265	KX269783	Yuan et al. 2016
R. dybowskii	Russia: Primorye region: Khasanskii District	MSUZP-IVM-1d	KX021949	KX021949	KX021949	KX269553	KX269263	KX269781	Yuan et al. 2016
R. hanluica	China: Guangxi: Maoershan shan	KIZGX07112915	KX269191	KX269338	KX269407	KX269556	KX269266	KX269784	Yuan et al. 2016
R. huanrenensis	South Korea	MMS 231	KX021944	KX021944	KX021944	KX269548	N/A	KX269776	Yuan et al. 2016

Species	Locality	Voucher	GenBank No.						Reference
			12S-16S	Cyt *b*	ND2	RAG1	BDNF	Tyr	
R. japonica	Japan: Isumi-shi: Chiba Prefecture	KIZ-YPX11775	KX269220	KX269364	KX269434	KX269585	KX269295	KX269811	Yuan et al. 2016
R. jiemuxiensis	China: Hunan: Jiemuxi	KIZ-HUN0708013	KX269221	KX269365	N/A	KX269586	KX269296	KX269812	Yuan et al. 2016
R. kukunoris	China: Qinghai: Qinghai Lake	KIZCJ06102001	KX021947	KX021947	KX021947	KX269550	KX269260	KX269778	Yuan et al. 2016
R. kunyuensis	China: Shandong: Kunyu shan	KIZ-HUI040001	KX269201	KX269347	KX269416	KX269566	KX269276	KX269793	Yuan et al. 2016
R. longicrus	China: Taiwan: Xiangtianhu: Miaosu	NMNS15022	KX269189	KX269336	KX269405	KX269554	KX269264	KX269782	Yuan et al. 2016
R. omeimontis	China: Sichuan: Zhangcun: Hongya	SCUM0405196CJ	KX021946	KX021946	KX021946	KX269558	KX269268	KX269785	Yuan et al. 2016
R. zhenhaiensis	China: Zhejiang: Zhenhai	KIZ0803271	KX269218	N/A	KX269433	KX269583	KX269293	KX269809	Yuan et al. 2016
R. coreana	South Korea	MMS 223	KX269202	KX269348	KX269417	KX269567	KX269277	KX269794	Yuan et al. 2016
R. sauteri	China: Taiwan: Kaohsiung	SCUM0405175CJ	KX269204	KX269350	KX269419	KX269569	KX269796	KX269279	Yuan et al. 2016
R. zhengi	China: Sichuan: Hongya: Zhangcun	SCUM0405190CJ	KX269206	KX269352	KX269421	KX269571	KX269798	KX269495	Yuan et al. 2016
R. johnsi	Vietnam: Lam Dong: Loc Bao	ABV 00203	KX269182	KX269328	KX269398	KX269546	KX269774	KX269471	Yuan et al. 2016
R.shuchinae	China: Sichuan: Zhaojue	CIB-HUI040009	KX269210	KX269356	KX269425	KX269575	DQ360057	KX269499	Yuan et al. 2016
R.weiningensis	China: Sichuan: Weining	SCUM0405171	KX269217	KX269362	KX269432	KX269582	KX269808	KX269506	Yuan et al. 2016
Pelophylax nigro-maculatus	China: Sichuan: Hongya	SCUM-045199CJ	KX269216	KX269361	KX269431	KX269581	KX269807	KX269505	Yuan et al. 2016

the following profile: PCR cycles were 5 min at 95 °C followed by 35 cycles of 30 s at 95 °C, 30 s at appropriate annealing temperature (Table 1), and 1 min at 72 °C, with a final extension at 72 °C for 10 min. The PCR products were purified using an EasyPure PCR Purification Kit (TransGene), and sequenced directly using the primers used in PCRs and the BigDye Terminator v3.0 Ready Reaction Cycle Sequencing Kit (Applied Biosystems) following the manufacturer's instructions on an ABI Prism 3730 automated sequencer.

Phylogenetic analyses: 147 sequences were used for genetic analysis, which include 135 sequences within the Chinese *Rana* were downloaded from NCBI and 12 sequences in this study. The data are summarized in Table 2. All nucleotide sequences were aligned using MUSCLE (Edgar 2004) with default parameters and checked manually with MEGA 5.0 (Tamura et al. 2011), the length of the fragments was trimmed; newly obtained sequences were deposited in GenBank (Table 2). Nucleotide sites with ambiguous alignments were deleted from the analyses. Bayesian inference (BI) and maximum likelihood (ML) analyses were conducted using the six concatenated gene fragments. BI analyses were performed in MRBAYES v3.1.2 (Ronquist and Huelsenbeck 2003) using the optimal partitioning strategy and best-fit nucleotide substitution model for each region (Table 3) selected by PARTITIONFINDER v1.1.1 (Lanfear et al. 2012). MRBAYES analyses simultaneously initiated two Markov Chain Monte Carlo (MCMC) model runs to provide additional confirmation of convergence of posterior probability distributions. Analyses were run for 10,000,000 generations. Chains were sampled every 1000 generations. The first 25% of the total trees were discarded as "burn-in" and the remaining trees were used to generate a majority-rule consensus tree and to calculate Bayesian posterior probabilities. Nodal support was further assessed with a maximum-likelihood (ML) analysis in RAXML V.7.0.3 with 1000 bootstraps. *Pelophylax nigromaculatus* sequences were downloaded from GenBank and used as outgroup.

Table 3. Sequence information (a) and results of model selection by PartitionFinder (b). "V" and "PI" indicated the variable sites and parsimony-informative sites of each locus, respectively.

(a)

Sequence name	Sequence length (bp)	V	PI
12-16s rRNA	1743	555	336
Cyt *b*	834	306	262
ND2	726	392	323
RAG1	1191	158	86
Tyr	456	73	31
BDNF	454	31	10

(b)

Best fit model	Partitions
GTR+I+G	12S-16S, ND2-2nd
HKY+I	RAG-3rd, Tyr-1st, Tyr-3rd, BDNF-1st, BDNF-2nd
SYM+I+G	Cyt *b*-1st
HKY+I+G	ND2-3rd, RAG1-1st, RAG1-2nd, Cyt *b*-2nd, Tyr-2nd
GTR+I	ND2-1st, Cyt *b*-3rd
K80+I	BDNF-3rd

Apart from phylogenetic tree-based methods, we also calculated pairwise sequence divergence based on uncorrected *p*-distance using MEGA 5.0 (Tamura et al. 2011) to determine the genetic distance between species. The analysis compared the 7 individuals of *Rana* sp. from the Dabie Mountains to other 22 species of the genus *Rana* inhabiting China.

Morphological analyses: The morphometric data were examined for 10 individuals. Measurements were made by Yanan Zhang using a vernier caliper with a precision of 0.1 mm. 17 linear measurements (Fei et al. 1999) were taken as follows:

SVL (snout-vent length, from tip of snout to vent);
HL (head length, from posterior corner of mandible to tip of snout);
HW (head width, the greatest cranial width);
SL (snout length, from tip of snout to the anterior corner of the eye);
IN (internarial distance);
ED (horizontal eye diameter);
IO (interorbital distance, the minimal distance between upper eyelids);
UE (upper eyelid width, the maximal width of upper eyelid);
TD (horizontal tympanic diameter);
LAHL (length of lower arm and hand, from the tip of finger III to the elbow joint);
HAL (hand length, from proximal end of outer palmar tubercle to tip of the third finger);
LAD (diameter of lower arm);
HLL (hind limb length, from the tip of the toe IV to groin);
TL (tibia length);
TW (tibia width, the greatest width of tibia);
FL (foot length, from the proximal end of the inner metatarsal tubercle to the tip of the toe IV) and
TFL (length of tarsus and foot, from the proximal end of tarsus to the tip of the fourth toe IV).

The description of toe webbing followed Savage (1975) (Table 4). The morphological characters of the individuals of *Rana* sp. from Dabie Mountains were compared with the members in the *R. longicrus* group, *R. chaochiaoensis* Liu, 1946, *R. culaiensis* Li, 2008, *R. hanluica* Shen, Jiang & Yang 2007, *R. jiemuxiensis* Yan, 2011, *R. longicrus* Stejneger, 1898, *R. maoershanensis* Lu, 2007, *R. omeimontis* and *R. zhenhaiensis* Ye, 1995. We also compared individuals collected in this area with other *Rana* species distributed in other parts of China *R. arvalis* Gislén, 1959 (previously listed as *R. altaica*, identification following Yang et al. 2010), *R. amurensis* Boulenger, 1886, *R. luanchuanensis* Zhao, 2017, *R. asiatica* Bedriaga, 1898, *R. chensinensis* David, 1875, *R. dybowskii* Guenther, 1876, *R. huanrenensis* Liu, 1993, *R. kukunoris* Nikolsky, 1918 and *R. kunyuensis* Lu, 2002. Considering the restrictions of samples, the morphological characteristics of the species in *Rana* were obtained from literature (Fei et al. 2009, Fei et al. 2010, Fei et al. 2012, Zhao et al. 2017, Li et al. 2008, Yan et al. 2011, Inger et al. 1989).

Table 4. Measurements [in mm; mean±SD (range)] of adult specimens of *Rana dabieshanensis* sp. n.

Character	*R. dabieshanensis* sp. n				
	Holotype	Males (8)	Mean±SD	Females (2)	Mean
SVL	62.8	50.9–62.8	57.1±4.1	53.0–68.3	60.7
HL	17.8	16.0–19.0	17.8±1.1	18.0–19.7	18.8
HW	17.6	15.3–18.9	17.4±1.1	16.7–18.8	17.8
SL	8.4	7.5–9.5	8.4±0.8	7.9–8.5	8.2
IN	5.5	3.9–5.5	4.5±0.6	4.3–4.6	4.5
IO	5.5	3.9–5.5	4.5±0.6	4.3–4.5	4.4
UE	3.6	2.9–3.8	3.4±0.4	3.6–3.7	3.6
ED	4.8	4.1–5.7	4.8±0.6	4.6–4.7	4.5
TD	4.0	3.5–5.2	4.4±0.6	4.2–4.3	4.3
LAHL	27.6	21.4–27.6	24.7±2.1	23.4–26.7	24.5
LAD	8.1	5.6–8.1	6.6±1.2	4.9–8.1	5.2
HAL	14.8	13.1–14.8	13.8±0.7	13.3–13.6	13.5
HLL	129.1	100.4–129.1	115.5±10.6	102.4–121.4	111.9
TL	40.6	31.4–40.6	35.1±3.3	30.4–37.6	34.0
TW	8.4	5.9–8.4	7.5±0.9	6.4–6.7	6.5
TFL	53.2	43.1–53.2	48.6±3.4	44.3–51.2	47.7
FL	35.5	27.6–35.1	32.8±2.8	27.8–35.6	31.7

Results

Molecular phylogenetic analyses: The BI and ML phylogenetic tree were constructed based on concatenated DNA sequences of the mitochondrial genes and nuclear genes (12S rRNA, 16S rRNA, ND2, Cyt *b*, Tyr, BDNF, and RAG1) with a total length of the final alignment 5414 bp. Besides, the variable sites and potentially parsimony informative sites are listed in Table 3. The results by BI and ML displayed the same topologies and strong node supporting values (Fig. 2). The major clades were similar to previous studies (Yuan et al. 2016). The individuals of *Rana* sp. from Dabie Mountains, clustered in the *R. longicrus* group and are reconstructed as a sister species of *R. hanluica* with high node support values (1.0/100 for BI posterior probabilities / ML bootstrap, respectively) (Fig. 2).

Furthermore, the nucleotide sequence divergences based on uncorrected pairwise distances model among the 23 brown frog species examined are shown in Table 5. The sequence divergences among the new populations from Dabie Mountains were 0.2%. Sequence divergences between the new populations from Dabie Mountains congeners ranged from 8.6% (*R. culaiensis*) to 27.7% (*R. weiningensis*). Within the *R. longicrus* group, divergence between were from 8.6% (*R. culaiensis*) to 16.0% (*R. chaochiaoensis*). Sequence divergence between the individuals of *Rana* sp. from Dabie Mountains and the sister species *R. hanluica* is 8.8% (Table 5).

Based on phylogenetic analysis of both nuDNA and mtDNA genetic markers and genetic distances in Cyt *b* mtDNA gene, it is demonstrated that the population of *Rana* sp. from the Dabie Mountains represents a phylogenetically independent evolutionary lineage, and a member of *R. longicrus* group. It represents a previously undescribed species which is described herein.

Table 5. The pairwise uncorrected *p*-distance (%) of the Cyt *b* partial sequence (834 bp) used in this study. 1: *Rana dabieshanensis* sp. n; 2: *R. culaiensis*; 3: *Rana longicrus*; 4:*R. zhenhaiensis*; 5:*R. chaochiaoensis*; 6: *R. hanluica*; 7: *R. huanrenensis*; 8: *R. japonica*; 9: *R. jiemuxiensis*; 10:*R. omeimontis*; 11:*R. chensinensis*; 12: *R. dybowskii*; 13: *R. kukunoris*; 14: *R. amurensis*; 15: *R. arvalis*; 16: *R. asiatica*; 17: *R. coreana*; 18: *R. johnsi*; 19: *R. kunyuensis*; 20 : *R. sauteri*; 21: *R. shuchinae*; 22: *R. weiningensis*; 23: *R. zhengi*. The number in bold present the distance between *Rana dabieshanensis* sp. n. and the species of *Rana* analyzed in this study.

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
1	**0.002**																						
2	**0.086**																						
3	**0.101**	0.042																					
4	**0.100**	0.032	0.053																				
5	**0.160**	0.148	0.159	0.141																			
6	**0.088**	0.086	0.086	0.091	0.133																		
7	**0.172**	0.197	0.208	0.190	0.171	0.186																	
8	**0.148**	0.139	0.161	0.141	0.144	0.138	0.172																
9	**0.104**	0.109	0.112	0.116	0.156	0.093	0.193	0.145															
10	**0.093**	0.090	0.102	0.106	0.167	0.085	0.193	0.150	0.111														
11	**0.178**	0.178	0.190	0.176	0.156	0.180	0.063	0.160	0.186	0.191													
12	**0.164**	0.173	0.178	0.169	0.183	0.181	0.121	0.162	0.174	0.188	0.132												
13	**0.172**	0.173	0.181	0.171	0.156	0.175	0.059	0.151	0.178	0.182	0.066	0.112											
14	**0.184**	0.207	0.219	0.213	0.194	0.186	0.198	0.196	0.193	0.172	0.182	0.191	0.187										
15	**0.206**	0.206	0.226	0.213	0.201	0.204	0.174	0.166	0.214	0.211	0.186	0.177	0.168	0.188									
16	**0.160**	0.157	0.172	0.166	0.184	0.162	0.163	0.148	0.172	0.166	0.152	0.167	0.146	0.155	0.136								
17	**0.199**	0.197	0.206	0.195	0.194	0.190	0.209	0.204	0.191	0.196	0.191	0.189	0.189	0.144	0.199	0.180							
18	**0.185**	0.183	0.187	0.177	0.196	0.194	0.208	0.181	0.184	0.192	0.189	0.186	0.187	0.210	0.192	0.191	0.219						
19	**0.201**	0.199	0.208	0.200	0.199	0.197	0.212	0.199	0.202	0.193	0.197	0.196	0.190	0.152	0.200	0.185	0.022	0.220					
20	**0.193**	0.192	0.209	0.193	0.192	0.181	0.197	0.169	0.204	0.201	0.183	0.182	0.177	0.176	0.192	0.155	0.199	0.222	0.192				
21	**0.191**	0.207	0.235	0.210	0.220	0.210	0.193	0.205	0.211	0.197	0.198	0.189	0.182	0.202	0.194	0.182	0.206	0.197	0.194	0.204			
22	**0.277**	0.279	0.262	0.266	0.255	0.267	0.271	0.252	0.283	0.267	0.259	0.267	0.254	0.261	0.277	0.237	0.273	0.292	0.270	0.273	0.259		
23	**0.203**	0.195	0.202	0.185	0.192	0.201	0.198	0.194	0.193	0.211	0.191	0.203	0.185	0.217	0.192	0.194	0.226	0.046	0.222	0.229	0.204	0.282	

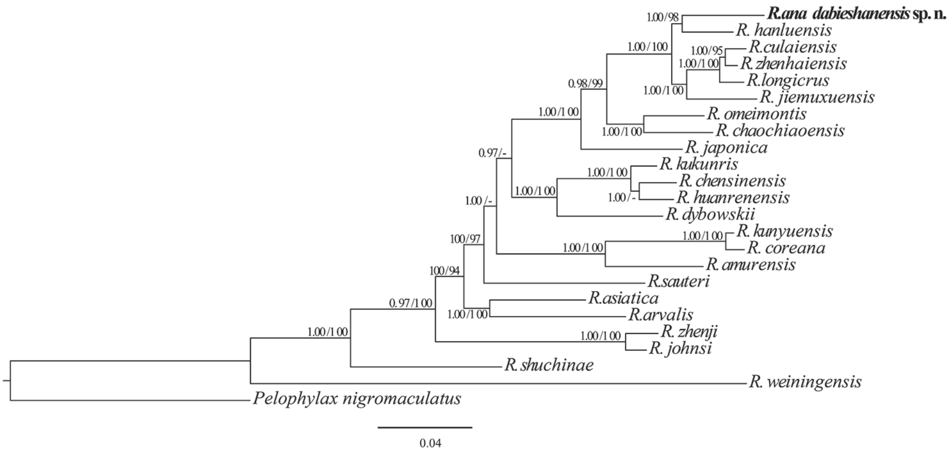


Figure 2. The Bayesian consensus tree resulting from analysis of four mitochondrial genes (12S rRNA, 16S rRNA, ND2 and Cyt *b* genes) and three nuclear genes (Tyr, RAG1 and BDNF) dataset for Chinese *Rana* species. The new species is in bold. Number near the nodes are Bayesian posterior probabilities / Maximum Likelihood bootstrap values but only when values are ≥ 0.95 and ≥ 70, respectively.

Taxon description

Rana dabieshanensis sp. n.

http://zoobank.org/B2595A92-AD54-433B-9F0A-C05DF5E68336

Holotype. Specimen AHU2016R001, an adult male (Figures 3, 4) from the Yaoluoping National Nature Reserve, Yuexi County, Anhui Province, China (30°58'16.92"N, 116°04'11.88"E, elevation 1150 m a.s.l.) (Fig. 1), leg. Lifu Qian, 8 August, 2016.

Paratypes. Seven males: AHU2016R002, AHU2016R003, AHU2016R004, AHU2016R005, AHU2016R006, AHU2016R007 and AHU2016R008, collected from the same locality as the holotype by Chencheng Wang between 15 and 20 August 2015. Two adult females, AHU2016R009 and AHU2016R010 collected by Lifu Qian at the same locality and time as the holotype.

Diagnosis. The new species is assigned to the genus *Rana* based on the morphological characteristics typical for this genus, including the possession of a prominent dorsolateral folds, dark temporal mask, and a body that is counter-shaded in various shades of brown. The species can be distinguished from its congeners by the following combination of morphological characteristics: (1) comparatively large body size (SVL 50.9–62.8 mm in males, N = 8 and females 53.0–68.3 mm, N = 2); (2) snout obtusely pointed in lateral view; (3) temporal fold distinct; (4) canthus rostralis distinct; (5) dark mask covering tympanum; (6) tympanum diameter equal to eye diameter (7) head length almost equal with head width (8) distinct transverse grayish brown bars on dorsal surface of lower arms, tarsus, thighs, and tibia; (9) dorsal skin smooth, small granules on legs, large tubercles absent; (10) tips of fingers not expanded, relative finger lengths III > I > IV > II, fingers webbing absent, toes two third webbed, toes webbing

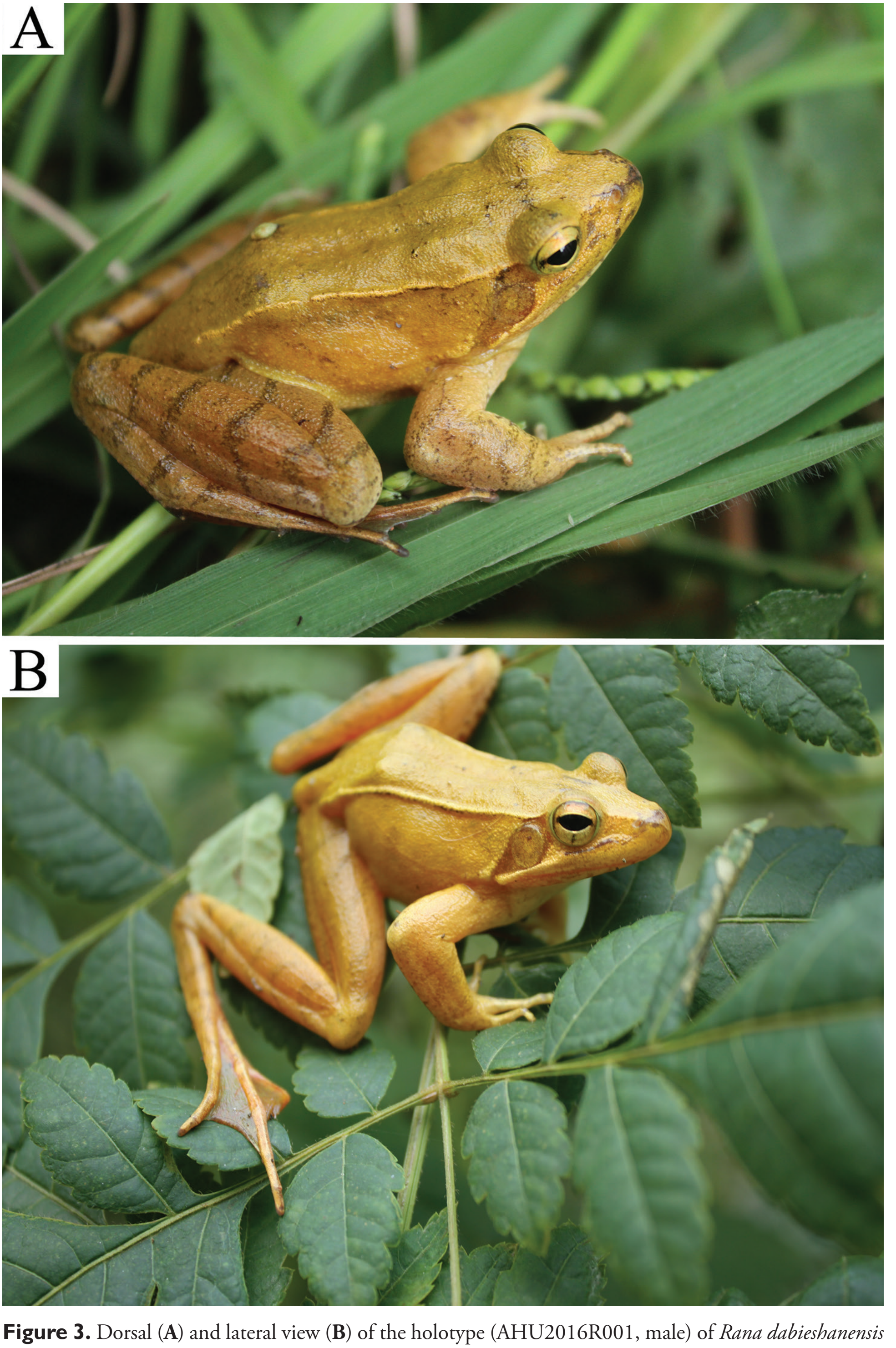


Figure 3. Dorsal (**A**) and lateral view (**B**) of the holotype (AHU2016R001, male) of *Rana dabieshanensis* sp. n. in life.

formula I 2–1– II 2$^+$– 1$^+$ III 3–2 IV 2–2$^+$ V; (11) gray-blackish nuptial pad prominent and forming two groups in males, with minute nuptial spines; (12) external vocal sac absent; (13) a straight dorsolateral fold from temporal area to groin. (14) dorsum coloration varies from golden to brown.

Description of Holotype. SVL 62.8 mm. Head length is approximately equal to the head width (HL/HW = 1.01); snout long and rounded in profile, projecting a little beyond the lower jaw; internarial space equal to the interorbital space (INS/IOS = 1); diameter of the eye larger than the width of upper eyelid (ED/UE=1.33); canthus rostralis distinct; tympanum rounded, with the obvious tympanic rim; tongue deeply notched behind; external vocal sacs not discernable; pupil horizontal.

Forelimbs: forearm robust, fingers slender, finger webbing absent; fingertips obtuse with no expansion and lacking circummarginal grooves; relative finger lengths III > I > IV > II; one prominent subarticular tubercle on fingers I and II, two small subarticular tubercles on fingers III and IV; the inner metatarsal tubercle oval-shaped and elongated; outer metatarsal tubercle small rounded; the nuptial pad appeared on the finger I, covered by small black spines and divided into two groups, one near tip lager than the other one.

Hindlimbs: hind limbs long (HLL 129.1 mm, 205.7% of SVL), about 4.7 times than length of forelimbs (LAHL 27.6 mm, 43.9% of SVL); heels overlapping when limbs are held at right angles to body; the tibio-tarsal joint reaches beyond the snout-tip when the hind limb is stretched forward; the relative toe lengths IV > III > V > II > I; toes two third webbed, toes webbing formula: I 2 – 1– II 2$^+$– 1$^+$ III 3 – 2 IV 2 – 2$^+$ V and the webbing of the toe IV reaches as far as the penultimate distal joint; toe tips rounded, lacking circummarginal grooves; three tubercles on the IV toes, two tubercles on II III and V toes, one tubercle on I toe; the inner metatarsal tubercle ovoid, small but distinct; without outer metatarsal tubercles.

Skin: skin on dorsum is smooth while some small tubercles present on the body flanks and mouth angle; a mass of small tubercles on the dorsal surfaces of thighs and shanks while little warts on forelimb basis; a triangular gray patch behind the eye and anterior to the temporal fold; temporal fold distinct, extending from posterior margin of eye above and behind tympanum to above arm insertion; dorsolateral fold obvious and straight from the temporal area to groin; the throat, chest, belly and ventral surfaces of thighs being smooth with irregular black spots.

Coloration: in life and in preservative: in life, the iris is golden with a black pupil, two dark spots near pupil edges in the anterior and posterior edges of eye and a dark vertical bar in the lower half of iris; the color of the dorsal side changes according to environment, from golden to light brown; lip is golden brown with darker brown markings lasting from the area under the eye towards nostrils and snout tip; the mandible whitish with unclear gray spots; large triangular brown patch behind the eye and anterior to temporal fold; forelimbs dorsally the same color as the dorsal surface of body, with four faint ash black stripe in the forearm; the dorsum of the thigh and tibia is a grayish brown, with nine ash black stripes; the sides of the tarsus and foot are grayish brown with three ash black bars; throat, chest, and belly white

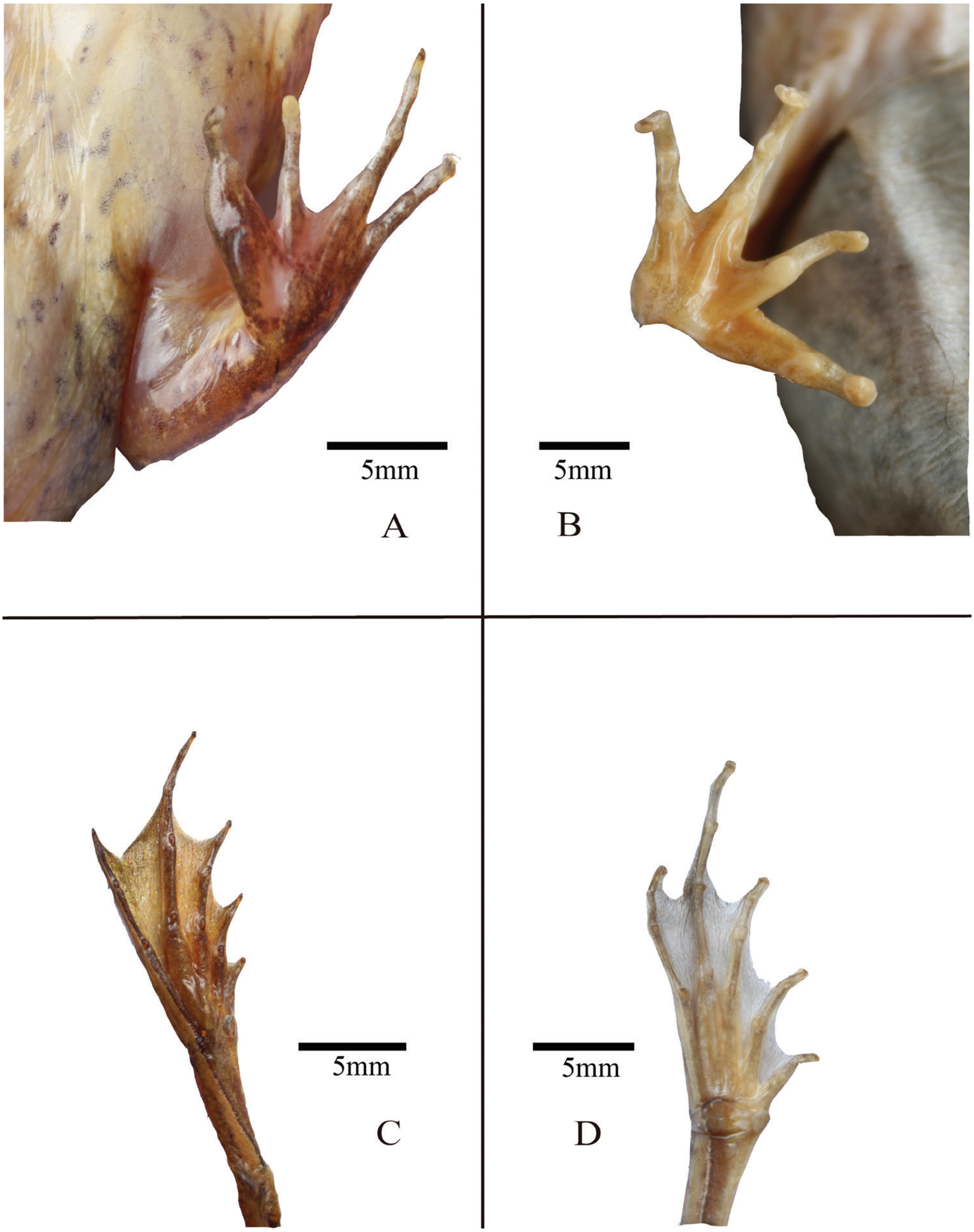


Figure 4. **A** volar view of the left hand of the holotype in life (AHU2016R001, male) **B** volar view of the right hand of female paratype in preservative (AHU2016R010, famle) **C** thenar view of the right foot of the holotype in life (AHU2016R001, male) **D** thenar view of the right foot of the female paratype in preservative (AHU2016R010, famle).

with irregular black spots; nuptial pad grayish brown. In preservative, dorsal surface gray-brown; all ash black fade to black; throat, chest, and abdomens fade to creamy white, with gray spots.

Variation and sexual dimorphism. Morphometric data were summarized in Table 4. Body size of males (SVL 50.1–62.8 mm) is smaller than that of females (SVL: 53.0–68.3 mm). Their dorsal color varied from golden to dark brown. Number of grayish brown crossbars on dorsal surface of lower arms, tarsus, thighs, and tibia varied. Nuptial pads are absent only in females.

Measurements (in mm) of the holotype. SVL: 62.8; HW: 17.6; HL: 17.8; SL: 8.4; IN: 5.5; IO: 5.5; UE: 3.6; ED: 4.8; TD: 4.0; LAHL: 27.6; LAD: 8.1; HAL: 14.8; HLL: 129.1; TL: 40.6; TW: 8.4; TFL: 53.2; FL: 35.5.

Etymology. The epithet of the new species "dabieshanensis" is a Latinized toponymic adjective derived from the Dabie Mountains in central China where the new species was discovered.

Common names. We recommend the "Dabie Mountain Brown Frog" as a common name of the new species in English; "Da Bie Shan Lin Wa" in Chinese.

Ecological notes. *Rana dabieshanensis* sp. n. appears closely associated with high altitudes of the southeastern mountains environments. Specimens were found at night between 20:00 and 01:00 h around a water pool in Yaoluoping National Nature Reserve, Yuexi, Anhui province, China (Figure. 1). The surrounding habitat consists of small hardwoods, mixed with shrubs and vines. Most of the specimens were found in grass nearby the water, few frogs were in the water. Air temperature was about 13.6 to 17.1 °C and water temperature about 12.1 °C to 14.7 °C. The relative humidity in this area was from 62 to 81%. Other amphibian species include *R. chensinensis*, *Rhacophorus anhuiensis*, *Pelophylax nigromaculata*, *Fejervarya multistriata*, and *Yerana yei* was also recorded during field survey in Yaoluoping National Nature Reserve (Pan et al. 2014).

Distribution. Currently, *Rana dabieshanensis* sp. n. is only found in the Yaoluoping National Nature Reserve (Anhui Province). This species might be found in other regions of the Dabie Mountains.

Comparisons. *Rana dabieshanensis* sp. n. differ from the Chinese species of the genus *Rana* by following morphological characters: (1) without black glandular ridge in scapular region (vs. an inverted V-shaped black glandular ridge in scapular region in *R. chaochiaoensis*, *R. hanluica*, *R. longicrus*, *R. omeimontis*, *R. maoershanensis*, *R. huanrenensis*, *R. japonica,* and *R. jiemuxiensis*); (2) smooth dorsum without tubercles (vs. many tubercles on the dorsolateral surface in *R. arvalis*, *R. amurensis*, *R. asiatica*, *R. dybowskii*, *R. japonica* and *R. kukunoris*); (3) tympanum diameter equal to eye diameter (TD 3.5–5.2 mm, ED 4.1–5.7 mm N=8) (vs. tympanum diameter being 2/3 times of eye diameter in *R. chaochiaoensis* (TD 3.0–5.5 mm, ED 4.3–6.3 mm N = 22), *R. hanluica* (TD 3.5–4.8 mm, ED 5.2–7.8 mm N = 16), *R. omeimontis* (TD 4.0–5.5 mm, ED 5.4–6.9 mm N = 20), *R. zhenhaiensis* (TD 2.5–4.0 mm, ED 5.0–6.4 mm N = 25) and *R. culaiensis* (TD 3.4–4.3 mm, ED 5.1–6.7 mm N = 5), *R. japonica* (described by Stejneger and Matsui in 1907); tympanum diameter being 1/2 times of eye diameter in *R. maoershanensis* (TD 3.4–3.8 mm, ED 6.1–6.7 mm N = 3), *R. huanrenensis* (TD 1.9–3.0 mm, ED 4.0–7.0 mm N = 15), *R. kunyuensis* and *R. chensinensis* (TD 2.5–3.0 mm, ED 5.3–6.0 mm N = 8); tympanum diameter being 3/4 times of the eye diameter in *R. jiemuxiensis* (TD 2.5–4.1 mm, ED 2.8–4.2 mm)); (4) internarial distances almost equal to interorbital distances (IOS 3.9–5.5 mm, INS 3.9–5.5 mm N = 8) (vs. interorbital distances larger than internarial distances of in *R. chaochiaoensis* (IOS 5.2–8.2 mm,

Figure 5. Typical habitat of *Rana dabieshanensis* sp. n. in Dabie Mountains, Anhui Province, China.

INS 2.7–4.7 mm N=20), *R. jiemuxiensis* (IOS 4.3–7.5 mm, INS 2.5–3.8 mm); internarial distances larger than interorbital distances of in *R. maoershanensis* (IOS 3.1–3.3 mm, INS 4.5–5.5 mm, N = 3)); (5) interorbital distances larger than width of upper eyelid in *R. dabieshanensis* (IOS 3.1–5.5 mm, UE 2.9–3.8 mm N = 8) (vs. interorbital distances almost equal to upper eyelid in *R. hanluensis* (IOS 3.3–4.5 mm, UE 3.1–4.3 mm N = 16), *R. huanrenensis* (IOS 2.9–4.0 mm, UE 3.0–4.0 mm N = 15) and *R. chensinensis* (IOS 2.9–4.0 mm, UE 3.0–4.0 mm N = 8); upper eyelid interorbital larger to interorbital distances in *R. zhenhaiensis* (IOS 2.3–3.4 mm, UE 3.5–4.5 mm N = 25), *R. kukunoris* (IOS 2.4–3.1 mm, UE 3.8–4.9 mm N = 5), *R. dybowskii* (IOS 3.0–4.0 mm, UE 4.1–5.8 mm N = 25) and *R. amurensis* (IOS 2.6–3.5 mm, UE 3.5–5.2 mm N = 21)); (6) distinct canthus rostralis (vs. not distinct canthus rostralis in *R. longicrus*); (7) the relative finger lengths IV > I > III > II in *Rana dabieshanensis* sp. n (vs. finger lengths III > IV> I > II of *R. hanluica*, *R. luanchuanensis,* and *R. longicrus*); (8) thicker lower arm, LAD 4.9–8.1 mm in males (LAD/SVL radio 0.13) and 5.1–5.3 mm in females (LAD/SVL radio 0.10) (vs. LAD 3.6–4.5 mm (LAD/SVL 0.09) in males (N = 8) and 3.4–4.5 mm (LAD/SVL 0.08) in females (N = 7) of *R. chensinensis*). (9) long hind limb (HLL 100.4–129.1 mm N = 8) (vs. in *R. chaochiaoensis* (HLL 92.0–100.0 mm N = 20), *R. longicrus* (HLL 70.8–84.8 mm N = 20), *R. zhenhaiensis* (HLL 73.4–100.0 mm N = 25), *R. chensinensis* (HLL 80.0–97.0 mm N = 8), *R. kukunoris* (HLL 80.0–99.0 mm N = 5), *R. arvalis* (HLL 61.1–82.4 mm N = 16) and *R. huanrenensis* (HLL 61.4–84.5 mm N = 15); (10) toes being webbed on two thirds (vs. toes fully webbed in *R. chaochiaoensis* and *R. huanrenensis*); (11) larger body sizes, SVL: males 50.9–62.8 mm, N = 8 and females 53.0–68.3 mm, N = 2 (vs. SVL: males 35.6–49.9 mm and females 34.1–53.6 mm in *R.*

jiemuxiensis, SVL: males 39.0–46.9 mm, N = 15 and females 42.4–49.0 mm, N = 8 in *R. huanrenensis*, SVL: males 27.2–33.0 mm, N = 12 and females 23.7–41.2 mm, N = 25 in *R. luanchuanensis*); (12) a straight distinct dorsolateral fold lasting from the temporal region to groin in *Rana dabieshanensis* sp. n (vs. dorsolateral fold curved above the tympanum of *R. longicrus*, *R. zhenhaiensis*, *R. maoershanensis*, *R. jiemuxiensis*, *R. chensinensis*, *R. huanrenensis*, *R. arvalis*, *R. amurensis*, *R. asiatica*, *R. dybowskii*, *R. kukunoris*, *R. kunyuensis R. luanchuanensis,* and *R. culaiensis*).

Discussion

The Chinese species of the genus *Rana* were divided into three species groups based on external morphology (Fei et al. 2009); however, previous studies have been hampered by sampling restricted geographic regions or limited species groups with limited gene markers, mostly based on mtDNA. For example, the European species *R. arvalis* and Central Asian species *R. asiatica* once were considered belong to *R. chensinensis* group (Fei et al. 2009), while phylogenetic analyses indicated that these two species belonged to the same clade with *R. temporaria*. The recent progress on multilocus phylogeny of the genus *Rana* (Yuan et al. 2017, Zhao et al. 2017) indicated seven groups within the Chinese *Rana sensu lato* which contained 24 species (AmphibiaChina 2017, Zhao et al. 2017). Species in the *R. longicrus* group mostly occur in the southern part of China and Taiwan with no significant changes, except that the number of species in this group has increased. The species of the *R. longicrus* group appear to have highly conserved morphological characteristics compared to other species groups of Chinese *Rana*, implying that this group contains many cryptic species (Yan et al. 2011). In recent years, many species were identified based on molecular identification methods, providing a new understanding of the taxa that were once misidentified. For example, *R. jiemuxiensis* was distinguished from *R. hanluica* based on results of molecular analyses and differing breeding habits (Yan et al. 2011).

In the last decades, different opinions have been proposed on the distribution of *Rana* species in the Dabie Mountains of central China. Initially, the brown frog species found in the Dabie Mountains was identified as *R. japonica* Boulenger, 1879 (Zhao and Wu 1974). Subsequently, *R. japonica* was often mentioned in reports and surveys on amphibian fauna of this area (Lu et al. 1999, Shi et al. 2011, Zhao and Wu 1974, Zhang et al. 2000). However, later it was shown that *R. japonica* is only distributed in Japan, while Chinese populations belong to a different species (Maeda and Matsui 1989). In 2011, the *R. zhenhaiensis* was recorded in the Jintangtai National Nature Reserve (Shi et al. 2011) and the Huangbaishan National Forest Park (Wang et al. 2011) during the monitoring of amphibians in the Dabie Mountains. Subsequently, *R. zhenhaiensis* was identified as *R. culaiensis* in Huangbaishan National Forest Park through phylogenetic analyses (Zhao et al. 2015). In addition, the species of *R. chensinensis* was also mentioned as inhabiting in Dabie Mountains during the monitoring of amphibians (Pan et al. 2014), and phylogeography analysis on *R. chensinensis* had never sampled in this mountains area (Che et al. 2007). So, with the help of phylogenetic analyses, three species (*Rana dabieshanensis* sp. n., *R. culaiensis, and R. chensinensis*) are now known to inhabit the Dabie Mountains (Fang 2011, Zhao et al. 2015, Zhou et al. 2012).

During recent research in the Dabie Mountains, many endemic species like *Moschus anhuiensis* (Su et al. 2000) and *Protobothrops dabieshanensis* (Huang et al. 2012) were discovered, indicating that natural resources and animal diversity of this area are still insufficiently studied. With the addition of *Rana dabieshanensis* sp. n the genus now contains 103 known species and 25 species in China. To date, the new species is only known from a small montane area in Anhui Province of central China. However, its range might include other montane areas of central and southern China, so further surveys are urgently needed for investigation of the current distribution and population status of this species.

Acknowledgements

For supporting our surveys, we would like to thank the Administration Office of the Yaoluoping National Nature Reserve of Anhui Province. We also want to thank Lifu Qian for his help with collecting specimens. We are especially appreciative for the guidance provided by Yanan Zhang on morphological measures. Editorial assistance provided by Stephen Maciejewski. And finally, we would like to thank the three reviewers (Xiaobing Wu, Nikolay Poyarkov, and an anonymous reviewer) for their constructive suggestions. This work was supported by the Graduate Student Academic Innovation Research Project of Anhui University (yqh100087) and National Key Research and Development Program (2016YFC1200705).

References

Amphibia Web (2017) Amphibia Web. University of California, Berkeley, CA. https://amphibiaweb.org [Accessed 29 Oct 2017]

AmphibiaChina (2017) An online database of Chinese Amphibians. Electroni. Kunming Institute of Zoology (CAS), Kunming, Yunnan, China. http://www.amphibiachina.org [Accessed 29 Oct 2017]

Boulenger GA (1920) A monograph of the South Asian, Papuan, Melanesian and Australian frogs of the genus *Rana*. Records of the Indian Museum 20: 1–226. https://doi.org/10.5962/bhl.title.12471

Che J, Pang JF, Zhao EM, Matsui M, Zhang YP (2007) Phylogenetic relationships of the Chinese brown frogs (genus *Rana*) inferred from partial mitochondrial 12S and 16S rRNA gene sequences. Zoological science 24(1): 71–80. https://doi.org/10.2108/zsj.24.71

Edgar RC (2004) Muscle: a multiple sequence alignment method with reduced time and space complexity. Bmc Bioinformatics 5(5): 113. https://doi.org/10.1186/1471-2105-5-113

Fang P (2011) The phylogenetic and phylogeography analysis on *Rana japonica* group. MA Thesis, Yunnan University, China.

Fei L, Ye CY, Huang YZ, Liu MY (1999) Atlas of Amphibians of China. Henan Science and Technology Press, Henan, 7–23.

Fei L, Hu SQ, Ye CY, Huang YZ (2009) Fauna Sinica – Amphibia (Vol. 2) – Anura. Science Press, Beijing, 969–1038.

Fei L, Ye CY, Jiang JP (2010) Colored atlas of Chinese Amphibians. Sichuan Publishing House of Science and Technology, Chengdu, 259–280.

Fei L, Ye CY, Jiang JP (2012) Colored Atlas of Chinese Amphibians and Their Distributions. Sichuan Publishing House of Science and Technology, Chengdu, 293–318.

Frost D (2016) Amphibian Species of the World: An Online Reference (Version 6).American Museum of Natural History, NY. http://research.amnh.org/vz/herpetology/amphibia123/index.php//Amphibia/Anura [accessed 05 May 2016].

Gislén T, Kauri H (1959) Zoogeography of the Swedish amphibians and reptiles: with notes on their growth and ecology. Copeia 4: 351. https://doi.org/10.2307/1439910

Huang X, Pan T, Han DM, Zhang L, Hou YX, Lei YU, Zheng HM, Zhang BW (2012) A new species of the genus *Protobothrops* (Squamata: Viperidae: Crotalinae) from the Dabie Mountains, Anhui, China. Asian Herpetological Research 3(3): 213–218. https://doi.org/10.3724/SP.J.1245.2012.00213

Inger RF, Maeda N, Matsui M (1989) Frogs and toads of Japan. Copeia 1990 (4): 1187. https://doi.org/10.2307/1446514

Lanfear R, Calcott B, Ho SY, Guindon S (2012) Partitionfinder: combined selection of partitioning schemes and substitution models for phylogenetic analyses. Molecular Biology & Evolution 29(6): 1695–1701. https://doi.org/10.1093/molbev/mss020

Li PP, Lu YY, Li A (2008) A new species of brown frog from Bohai, China. Asiatic Herpetological Research 11: 60–68.

Lu JQ, Lv YJ (1999) Cluster analysis on the geographical distribution of amphibians in Henan province. Sichuan Journal of Zoology 18: 137–139.

Lu YY, Li PP, Jiang DB (2007) A new species of *Rana* (Anura, Ranidae) from China. Acta Zootaxonomica Sinica 32(4): 792–801.

Lu Y, Li PP (2001) A new wood-frog of the genus *Rana* in Mt. Kunyu, Shandong Province, China (Amphibia: Anura: Ranidae). Acta Zootaxonomica Sinica 27(1): 162–166.

Pan T, Zhou WL, Shi WB, Zhao K, Chen JY, Wang WG, Chu J, Pu FG, Gu CM, Zhang BW (2014) Species Richness of Amphibians and Reptiles in Dabie Mountains,China. Chinese Journal of Zoology 49(2): 195–206.

Ronquist F, Huelsenbeck JP (2003) MrBayes 3: Bayesian phylogenetic inference under mixed models. Bioinformatics 19(12): 1572–1574.

Sambrook J, Fritsch EF, Maniatis T (1989) Molecular Cloning: A laboratory Manual (2nd edn). Cold Spring Harbor Laboratory Press, Cold Springs Harbor, 1659 pp.

Shen YH, Jiang JP, Yang DD (2007) A new species of the genus *Rana-Rana hanluica* sp. nov. from Hunan Province, China (Anura: Ranidae). Acta Zoologica Sinica 53(3): 481–488.

Shi L, Hou MG, Wang XW, Tao LK, Chen XH (2011) Protections and Resources of Amphibians in Jingangtai Nature Reserve, Henan Province. Sichuan Journal of Zoology 30(5): 828–830.

Stejneger L, Matsui M (1907) Herpetology of japan and adjacent territory. Science 26: 109–113. https://doi.org/10.5479/si.03629236.58.i

Stuart BL, Inger RF, Voris HK (2006) High level of cryptic species diversity revealed by sympatric lineages of Southeast Asian forest frogs. Biology Letters 2(3): 470–474. https://doi.org/10.1098/rsbl.2006.0505

Su B, Wang YX, Wang QS (2000) Mitochondrial DNA sequences imply Anhui musk deer a valid species in genus Moschus. Zoological Research 22(3): 169–173.

Tamura K, Peterson D, Peterson N, Stecher G, Nei M, Kumar S (2011) MEGA5: molecular evolutionary genetics analysis using maximum likelihood, evolutionary distance, and maximum parsimony methods. Molecular Biology and Evolution 28 (10): 2731–2739. https://doi.org/10.1093/molbev/msr121

Wang XW, Pei XJ, Xu YJ, Chen XH (2011) Species Diversity of Amphibians in Huangbaishan National Forest Park, Henan Province. Chinese Journal of Zoology 46(6): 53–56.

Yan F, Jiang K, Chen HM, Fang P, Jin JQ, Yi L, Wang SN, Murphy RW, Che J, Zhang YP (2011) Matrilineal history of the *Rana longicrus* species group (*Rana*, Ranidae, Anura) and the description of a new species from Hunan, southern China. Asian Herpetological Research 2(2): 61–71. https://doi.org/10.3724/SP.J.1245.2011.00061

Yang JX, Zhou WW, Rao DQ, Poyarkov AN, Kuzmin SL, Che J (2010) Validity and systematic position of *Rana altaica* (*Rana*: Ranidae): Results of a phylogenetic analysis. Zoological Research 31(4): 353–360.

Ye CY, Fei L, Hu SQ (1993) Rare and economic amphibians of China, Sichuan Publishing House of Science & Technology, 129–132.

Yuan ZY, Zhou WW, Chen X, Poyarkov NA, Chen HM, Jang NH, Chou WH, Matzke NJ, Iizuka K, Min MS (2016) Spatiotemporal Diversification of the True Frogs (Genus *Rana*): A Historical Framework for a Widely Studied Group of Model Organisms. Systematic Biology 65(5): 824–842. https://doi.org/10.1093/sysbio/syw055

Zhao EM, Wu GF (1974) A preliminary report on the survey of amphibians and reptiles in Anhui Province. Sichuan Institute of Biology 2: 48–57.

Zhao HP, Yang JX, Wang CP, Li PP, Murphy RW, Che J, Yuan ZY (2017) A new species of the genus *Rana* from Henan, central China (Anura, Ranidae). ZooKeys 694: 95–108. https://doi.org/10.3897/zookeys.694.12513

Zhao HP, Wang QH, Wang CP, Liu BX, Lu JQ (2015) Current Status and Fauna of Amphibian in Henan Province. Journal of Henan Normal University (Natural Science) 46(6): 705–711.

Zhang SZ, Lu W, Chen BH (2000) Cluster analysis on the geographical distribution of amphibians in Anhui Province. Journal of Anhui Normal University (Natural Science) 24(4): 359–360.

Zhou WW, Wen Y, Fu JZ, Xu YB, Jin JQ, Ding L, Min MS, Che J, Zhang YP (2012) Speciation in the *Rana chensinensis* species complex and its relationship to the uplift of the Qinghai-Tibetan Plateau. Molecular Ecology 21(4): 960–973. https://doi.org/10.1111/j.1365–294X.2011.05411.x