

Taxonomic and nomenclatural notes on *Geodiapria longiceps* Kieffer, 1911 (Hymenoptera, Diapriidae) and synonymy of the genus *Geodiapria* Kieffer, 1910

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Abstract

This paper reviews the status of *Geodiapria* and its nominotypical and only included species *G. longiceps*. *Geodiapria* was previously understood to be very similar to, and doubtfully separated from the genus *Basalys*. We use integrative taxonomy (morphology, DNA-barcoding, phylogenetic tree building) to show that the valid name for what was *G. longiceps* Kieffer, 1911 is now *Basalys rufocinctus* (Kieffer, 1911) and that *Geodiapria* is consequently a junior synonym of *Basalys* **syn. nov.** The following taxa are new synonyms of *B. rufocinctus*: *Loxotropa longiceps* Wasmann, 1909, **syn. nov.**, *G. longiceps* Kieffer, 1911, **syn. nov.**, *L. rufosignata* Kieffer, 1911, **syn. nov.** *Basalys rufocinctus* is newly reported from Corsica, Germany, Norway and Spain.

Key words: *Basalys rufocinctus*, DNA-barcoding, first record, integrative taxonomy, parasitoid wasp, species concepts



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Introduction

Parasitoid wasps of the family Diapriidae are speciose and distributed worldwide, and while about 50% of its diversity is estimated to be unknown to science, there are few experts working on this family. Small size (c. 1–4 mm), wide distribution, cryptic diversity, sexual dimorphism, and previous poor taxonomy and lack of critical study of types are some of the problems researchers face when dealing with Diapriidae. The taxonomy of this group still therefore presents many interesting challenges. The status of the genus *Geodiapria* and its single included species *G. longiceps* Kieffer, 1911 has been a taxonomic problem for some time because of its close relation to *Basalys*, in particular species such as *B. rufocinctus* (Kieffer, 1911) with similar distinctive reddish flattened petiolar hairs. The question this paper seeks to resolve is whether or not *Geodiapria* is valid. *Geodiapria* was first described in a key by Kieffer (1910) who separated it from *Loxotropa* auctt. (now *Basalys* in part) and *Basalys sensu stricto* simply by the lack of a basal vein, adding later (Kieffer 1911a)

that the form of the head, longer than wide and a little wider in front than behind, was also distinctive. It was clearly similar to *Basalys* because Kieffer had previously considered the same material to be a *Loxotropa* auctt. (Wasmann, 1909). Kieffer (1911b) then described two species of *Loxotropa* auctt. with the same distinctive reddish flattened petiolar hairs: *L. rufosignata* said to have a head slightly longer than wide and reduced wings without distinct veins; and *L. rufocincta* with an almost square head and with an almost hyaline basal vein. Pschorn-Walcher (1957) examined the type of *G. longiceps* and considered *Geodiapria* to be very close to *Loxotropa* auctt., noting that the absence of the basal vein could be a consequence of wing reduction, but did not make a decision on the validity of *Geodiapria* because of lack of material. Since more material is now available, it is timely to reexamine the question of the validity of *Geodiapria* using an integrative approach combining morphotaxonomy and DNA barcoding (Ratnasingham and Hebert 2007). We examined 18 examples including types of four relevant nominal species, including *L. rufosignata* and *L. rufocincta*, and provide an up to date nomenclatural summary, presenting the first genetic results, including the DNA-barcode placing *Geodiapria* in its proper context.

Material and methods

The specimens of *B. rufocinctus* used for the CO1 DNA barcoding were collected in July 2021 in the Dammbach Valley (Spessart Nature Park) on an orchard meadow, using a Malaise trap. The sequencing was conducted at Canadian Centre for DNA Barcoding (Guelph, Canada) using a voucher recovery protocol. Tree building was undertaken using IQ TREE (server version 1.6.12, Trifinopoulos et al. 2016) using the default settings with 1000 generations. MODELFINDER determined GTR+F+I+G4 to be the best fitting substitution model. The resulting tree was edited using FIGTREE v. 1.4.4 (Rambaut 2010) and INKSCAPE v. 1.1 (<https://inkscape.org/de/>).

Repository acronyms:

DNPC	David Notton personal collection, United Kingdom
MCSN	Museo Civico di Storia Naturale "Giacomo Doria", Genoa, Italy
MNHN	Muséum national d'Histoire naturelle, Paris, France
NHME	Natural History Museum, Maastricht, Netherlands
NHMUK	Natural History Museum, London, United Kingdom
SNSB-ZSM	Bavarian State Collection, Munich, Germany

Taxonomy

Basalys Westwood, 1833

Basalys Westwood, 1833: 343. Type species *Basalys fumipennis* Westwood, 1833 by monotypy.

Loxotropa auctt. nec Förster, 1856.

Geodiapria Kieffer, 1910: 707, syn. nov. Type species *G. longiceps* Kieffer, 1911 by subsequent monotypy.

Notes. Other generic synonyms are omitted from the above list for simplicity. A diagnosis and detailed description of *Basalys* was given by Masner and García (2002), hence, only a brief diagnosis is given here. Further information on synonyms can be obtained from Johnson (1992).

Diagnosis. Small, smooth and shining wasps; head and mesosoma with long scattered hairs; antennal shelf usually distinctly prominent; female antenna 12-segmented, with strongly abrupt 3- or 4-segmented clava; male antenna 14-segmented with A4 distinctly modified; fore wing with submarginal vein slightly remote from fore margin of wing, costal vein absent, stigmal vein often moderately developed, basal vein always present in macropterous forms, straight, usually strongly pigmented, perpendicular to but never contiguous with submarginal vein.

Remarks. We discovered that the type species of *Geodiapria*, that is *G. longiceps*, is a *Basalys*, a synonym of *B. rufocinctus* (see below) and so *Geodiapria* becomes a junior synonym of *Basalys* syn. nov.

***Basalys rufocinctus* (Kieffer, 1911)**

Loxotropa longiceps Wasmann, 1909: 68, 172, syn. nov., preoccupied nec *B. longiceps* (Ashmead, 1893).

Geodiapria longiceps Kieffer, 1911a: 897, syn. nov., preoccupied nec *B. longiceps* (Ashmead, 1893).

Loxotropa rufocincta Kieffer, 1911b: 916, 939 takes precedence over *L. rufosignata* by first revisor action.

Loxotropa rufosignata Kieffer, 1911b: 914, syn. nov.

BIN number. BOLD_BIN: AEW6196 (Ratnasingham and Hebert 2007).

Type material. **Holotype** ♀ of *Loxotropa longiceps* labelled: "Allotype ♂ (!)/ Solenopsis imitatrix/ Wasmann, err. det.!: Holotype ♀/ *Geodiapria longiceps*/ Kieffer, 1911; *Loxotropa/ longiceps* n. sp./ ♀ Kieff.; 5.98. Exaet./ b. Solenopsis; Solenopsis m/ Kol. 293. sang [=colony #293 of *Formica sanguinea*]." (NHME) (Fig. 2). **Holotype** ♀ of *Geodiapria longiceps* - the same specimen as the holotype of *Loxotropa longiceps* q.v. **Holotype** ♀ of *Loxotropa rufosignata* labelled: "Is. Giglio/ IV.1902/ G. Doria; *Loxotropa/ rufosignata*; ♀" (MCSN) (Fig. 3). **Syntypes** 2♀ 3♂ of *Loxotropa rufocincta*: 2♀ labelled: "Holotype [sic – there is no original designation]; Bitche; *Loxotropa/ rufocincta*; Muséum Paris/ 1957/ coll. Kieffer. 2♂ labelled: *Loxotropa/ rufocincta*; Bitche; ♂; Allotype; Muséum Paris/ 1957/ coll. Kieffer. ♂ labelled: Paratype; Muséum Paris/ 1957/ coll. Kieffer; Bitche" (MNHN).

Other material. **DENMARK** • ♀; N. E. Zealand, Tisvilde Hegn; 56°02'N, 12°04'E; 4 May 1994; P.N. Buhl leg. (DNPC). **FRANCE** • ♂; Corsica, Corse du Sud, Bastelicaccia nr. Ajaccio; 41°55'N, 08°30'E; 14–21 Jun. 1996; C. Villemant leg.; Malaise trap, *Quercus suber* stand (DNPC) • ♀; Gard, Mont Ventoux, Malaucène; 44°13'N, 05°08'E; 1–8 Jul. 1997; C. Villemant leg.; maquis, *Quercus ilex* (DNPC) • ♂; same locality; 5–12 Aug. 1997; C. Villemant leg.; maquis, *Quercus ilex* (DNPC). **GERMANY** • ♀; Bavaria, Dammbach, Dammbachtal; 49°51'58"N, 09°19'30"E; 338 m a.s.l.; 16 Jul. 2021; J. Hübner leg.; nutrient poor grassland; ZSM-HYM-42434-G02 (BOLDSYSTEMS Process ID: DTIII5299-22; GenBank

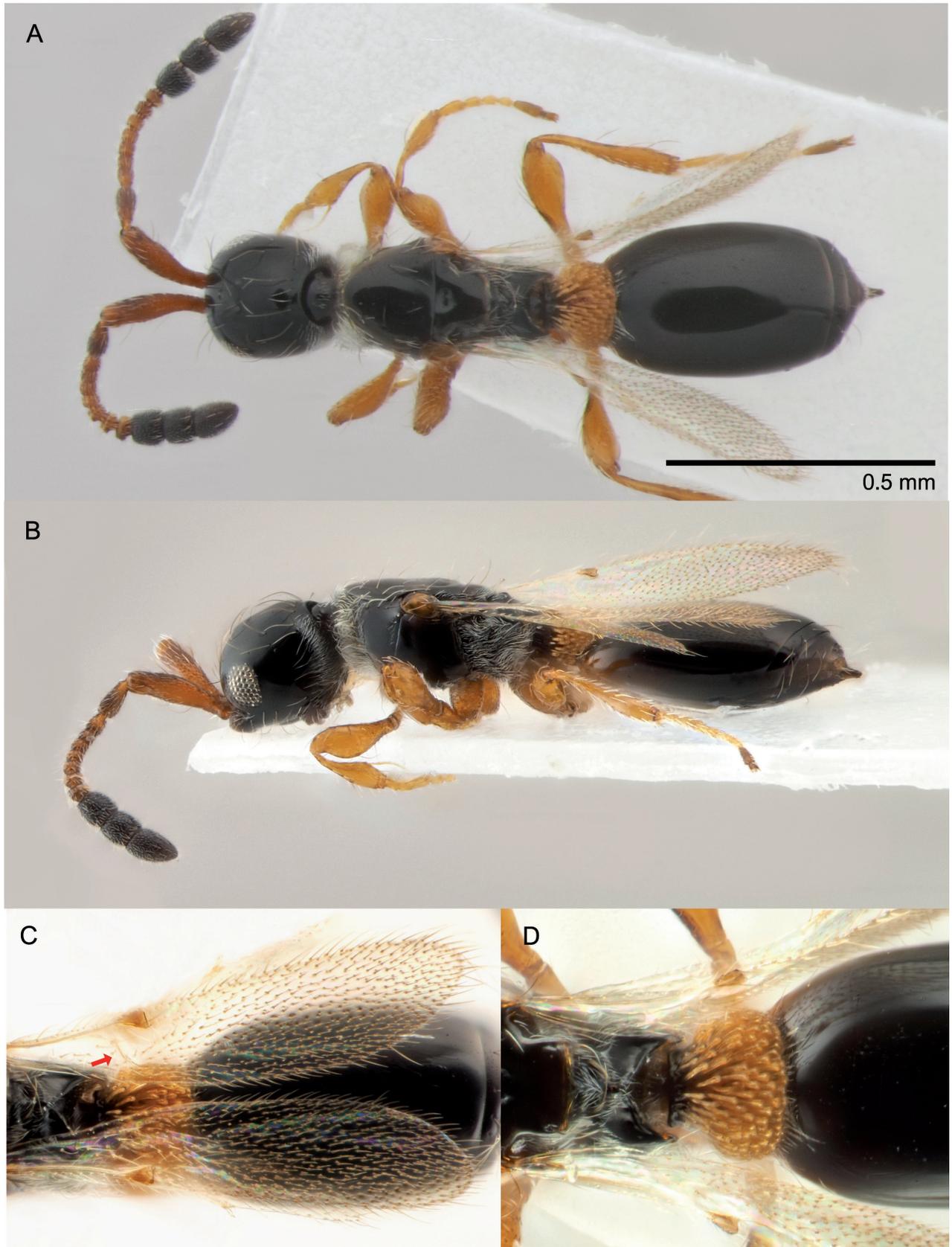


Figure 1. *Basalys rufocinctus* (Kieffer, 1911) ♀: **A** habitus, dorsal view **B** habitus, lateral view **C** wing with reduced venation (arrow) **D** close-up of petiole.



Figure 2. Holotype ♀ of *Loxotropa longiceps* (Wasmann, 1909), the same specimen is also the holotype ♀ of *Geodiapria longiceps* Kieffer, 1911: **A** habitus, lateral view **B** labels.

accession ID: OR450821) (SNSB-ZSM) • ♀ same locality; 16 Jul. 2021; J. Hübner leg.; nutrient poor grassland; ZSM-HYM-42433-H11 (BOLDSYSTEMS Process ID: DTIII5225-22; GenBank accession ID: OR450822) (DNPC). **NORWAY** • ♀; Onsøy, Hankø Bloksberg, EIS 20, Ø; 3–29 Jun. 1995; O. Hanssen & J.I.I. Båtvik leg.; pitfall trap (DNPC). **SPAIN** • ♀; Granada, Calahonda; Jul. 1987; L. Lockett leg.; Malaise trap, (DNPC) • ♀; Granada, Sierra Nevada; 1600 m a.s.l.; 10 Apr. 1959; C. Besuchet leg. (NHMUK). **UNITED KINGDOM** • ♀; Cheshire, Abbots Moss; 53°12'27"N, 02°36'23"W; 12 Oct. 1990; D.G. Notton leg.; swept, stream (DNPC) • 3♀; Norfolk, Santon Downham; 52°27'45"N, 00°40'29"E; 15 Aug. 1984; J. Field leg.; Malaise trap, heath with *Betula* and *Pinus* (DNPC) • 1♂; same locality; 18–25 Aug. 1983; J. Field leg. (DNPC).

Diagnosis. Female Head elongate, rounded, about 1.2 times as long as wide; frons without angles or teeth; antenna 12-segmented with abrupt 3-segmented clava; A11 transverse in lateral view, as long as wide in dorsal view; A6–A9 transverse in lateral view (Fig. 1A); mesonotum and scutellum slightly convex in longer winged individuals, almost flat in shorter winged individuals (Fig. 1B), anterior pronotum with a ruff of whitish setae; anterior scutellar pit small and transverse, less than one third the width of the scutellum; propodeum with medial keel slightly raised anteriorly, less so in short winged individuals; fore wing variable in length, at most extending well beyond apex of gaster, at least reaching anterior margin of petiole; basal vein present in longer winged individuals although hard to see as it is fine and barely pigmented, absent in shorter winged individuals; femora of all legs broadened medially, fore femora 2.2–2.3 times as long as wide in lateral view, with sharp keel ventrally; petiole densely covered dorsally and laterally with long orange flattened setae (Fig. 1D); basal margin of large tergite with two whitish hair tufts more or less concealed under petiolar setae; disc of large tergite normally bare, although the shortest winged individuals, e.g. the type of *L. rufosignata*, may have some long setae. **Male** As for female except antenna 14-segmented with A4 expanded posteriorly subtriangular with a fine flange; A5 elongate, flagellar segments becoming shorter towards apex, A13 more or less quadrate; fore wing variable in length at least reaching apex of gaster, at most extending well beyond it; basal vein present, fine, barely pigmented; femora slightly less broadened than female. Body length 1.3–2.2 mm (♀); 1.5–2.4 mm (♂).

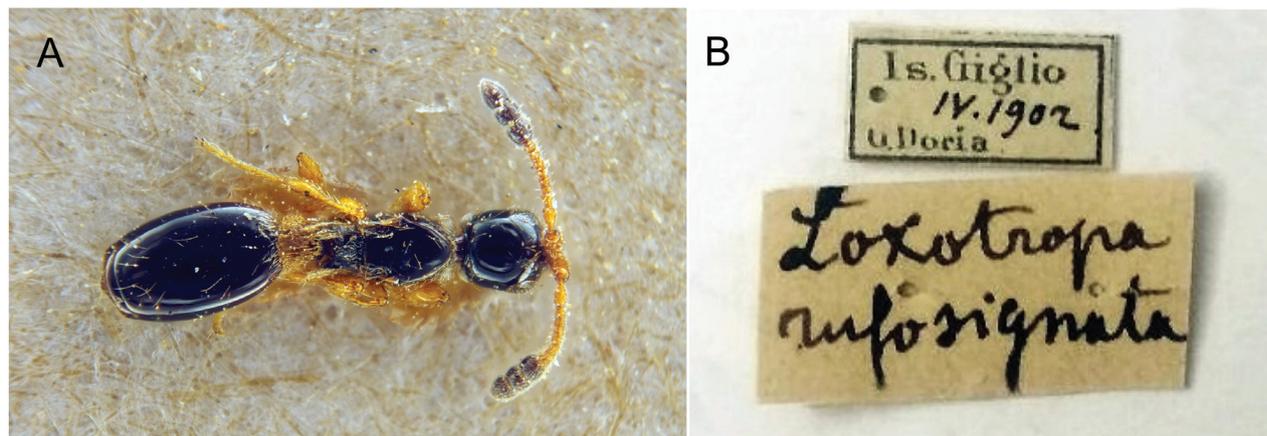


Figure 3. Holotype ♀ of *Loxotropa rufosignata* Kieffer, 1911: **A** habitus, dorsal view **B** labels.

Distribution. Czechia (Macek 1989 as *B. rufocincta* [sic]); Denmark (Buhl 1998 as *B. rufocincta* [sic]) confirmed here; France - mainland France (Kieffer 1911b as *L. rufocincta*) confirmed here; France - Corsica (new record); Germany (new record); Italy (Kieffer 1911b as *L. rufosignata*); Netherlands (Wasmann 1909 as *L. longiceps*); Norway (new record); Spain (new record); Sweden (Hedqvist 2007 as *B. rufocincta* [sic]); United Kingdom (Nixon 1980 as *B. rufocincta* [sic]) confirmed here.

Biology. Host unknown. *Basalys rufocinctus* has previously been considered to be a myrmecophile but the evidence is weak. Of all the specimens we have seen only one, Wasmann's, was found in an ant nest, in a mixed colony of *Solenopsis fugax* and *Formica sanguinea*, and may have entered the nest by accident. Wasmann provided no ethological observations to demonstrate myrmecophily and the species has no obvious morphological adaptation for myrmecophily when compared to other *Basalys*.

Remarks. From the extensive material examined we recognised only one taxon, diagnosed above, and with more variation than previously understood. Most importantly we found that the head was always elongate when seen from above, also significant variation in fore wing length, and expression of the basal vein which was present and weakly pigmented in longer winged individuals, becoming hyaline and then altogether absent in shorter winged individuals. This taxon is therefore a *Basalys* since there is no significant morphological difference: some other species of *Basalys* are known to have elongate heads, also some other *Basalys* have the basal vein absent in short-winged individuals. Based on our examination of the type specimens we consider all four nominal species above, including *Geodiapria longiceps*, belong to this taxon.

Further support for the generic placement of *B. rufocinctus* is based on genetic analyses. A representative ML tree (Appendix 1; *Idiotype maritima* (Haliday, 1833) as outgroup, 1000 generations) with 76 Diapriini specimens shows *B. rufocinctus* nested within a *Basalys* clade (Appendix 1). The obtained sequences are publicly available on the BOLDSYSTEMS platform (Ratnasingham and Hebert 2007).

Some nomenclatural notes are necessary:

1. We differ from some authors in recognising *Loxotropa longiceps* as a nominal species separate from, and not just a combination of, *Geodiapria longiceps*. *Loxotropa longiceps* is available from Wasmann's (1909) paper

where the name is first used. The name is made available by indication (ICZN 1999: Code art. 12.2.1) since Wasmann refers to his description (Wasmann, 1899) of a specimen previously misidentified as a male of *Solenopsia imitatrix* Wasmann, 1899. Although Wasmann attributes the name to Kieffer, the author of the name is actually Wasmann because he was responsible for publishing the name and writing the prior description (ICZN 1999: Code art. 50.1). The oldest available name for the taxon is thus *L. longiceps* Wasmann, 1909.

2. As *L. longiceps* is transferred to *Basalys* it becomes a secondary junior homonym of *B. longiceps* (Ashmead, 1893) so is invalid.
3. The next oldest available name is *G. longiceps* described as new by Kieffer (1911a). The date of publication is early 1911: evidence comes from the NHMUK copy which has a library stamp 25 Feb. 1911, and the page bound into the end of vol. 10 of *Species des Hyménoptères d'Europe et d'Algérie* which says 1 Mar. 1911.
4. As *G. longiceps* is transferred to *Basalys* it becomes a secondary junior homonym of *B. longiceps* (Ashmead, 1893) so is invalid.
5. The next oldest available names are *L. rufosignata* Kieffer, 1911b and *L. rufocincta* Kieffer, 1911b which were published simultaneously in mid-1911: the page bound into the end of vol. 10 of *Species des Hyménoptères d'Europe et d'Algérie* says 1 Jun. 1911.
6. Since the only two remaining potentially valid names are published simultaneously, we here make a first revisor action to determine precedence thus: *L. rufocincta* has precedence over *L. rufosignata*. We have chosen *L. rufocincta* because this is the more widely used name.
7. *L. longiceps*, *G. longiceps* and *L. rufosignata* are all new synonyms of *L. rufocincta*.
8. The valid name is thus *Basalys rufocinctus*, a combination first recognised by Nixon (1980).
9. Despite previous misspellings, when in combination with *Basalys*, the correct spelling of the species epithet is *rufocinctus*; the gender of *Basalys* is masculine (Notton (2014)).

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Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statement

No ethical statement was reported.

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Author contributions

Conceptualization and methodology, all authors; resources, all authors; writing – original draft, all authors; writing – review and editing, all authors; supervision, David Notton; funding acquisition, Jeremy Hübner and Vasilisa Chemyreva. All authors have read and agreed to the published version of the manuscript.

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Data availability

All of the data that support the findings of this study are available in the main text or Supplementary Information.

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Appendix 1

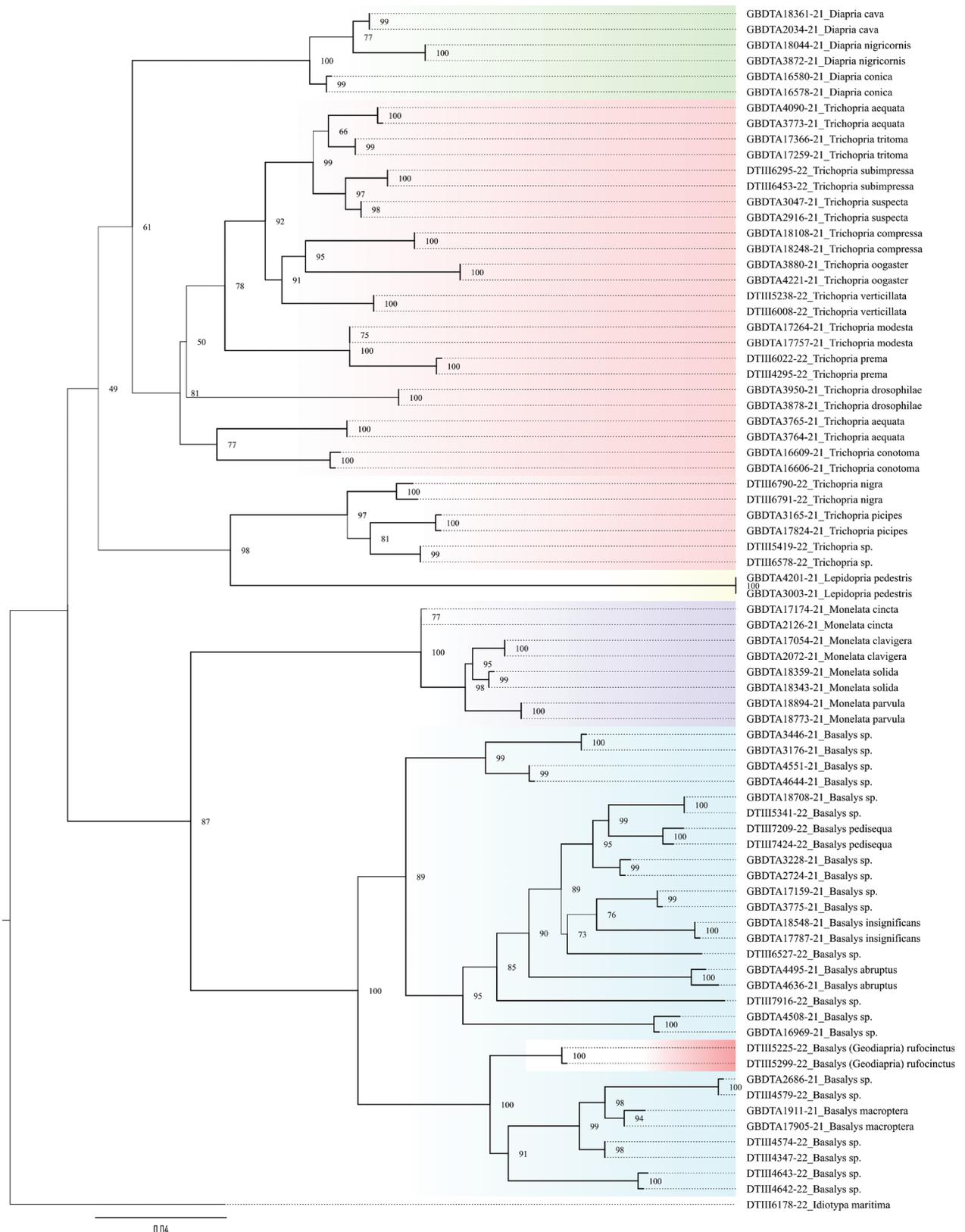


Figure A1. Maximum-likelihood tree of 76 Diapriini specimens, with *Idiotypa maritima* as outgroup. The different genera are color-coded, the numbers on the nodes represent the bootstrap values. Files are openly accessible online at TREEBASE (Piel et al. 2009; <http://purl.org/phylo/treebase/phyloWS/study/TB2:S30685>).

Supplementary material 1

Supplementary data

Authors: Jeremy Hübner, Vasilisa G. Chemyreva, David G. Notton

Data type: xlsx

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A taxonomic revision of the freshwater crab genus *Parvuspotamon* Dai & Bo, 1994 (Decapoda, Brachyura, Potamidae), with descriptions of a new genus and two new species

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Abstract

The taxonomy of the potamid crab genus *Parvuspotamon* Dai & Bo, 1994, with two species native to Yunnan province of southwest China, is revised based on morphological and molecular data. In order to stabilise the taxonomy of these species (and the genus), two separate genera are hereby designated: *Parvuspotamon* and *Songpotamon* **gen. nov.** While *Parvuspotamon* is restricted to *P. yuxiense* Dai & Bo, 1994, as a monotypic genus, *P. dixuense* Naruse, Chia & Zhou, 2018, is transferred to a new genus, *Songpotamon* **gen. nov.** In addition, two new species of *Songpotamon* **gen. nov.** are described herein: *S. funingense* **sp. nov.** and *S. malipoense* **sp. nov.** *Songpotamon* **gen. nov.** morphologically most resembles *Parvuspotamon* and *Chinapotamon* Dai & Naiyanetr, 1994, but can be distinguished by the combination of characters in the carapace, third maxilliped, thoracic sternites, and male first gonopod. The genetic data derived from the mitochondrial 16S rDNA also supports the monophyly of these new taxa.

Key words: China, Crustacea, new combination, Potamiscinae, taxonomy, Yunnan



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Introduction

The Yunnan Province of southwest China is noted for harbouring an exceptional number of freshwater species with a high level of endemism. This is widely recognised to be a direct consequence of the geological history of this mountainous region, e.g., orogenic processes and/or past climatic changes (Myers et al. 2000; Li et al. 2015; Antonelli et al. 2018; Rahbek et al. 2019; Pan et al. 2022). This diversity in landscape should have offered sufficient stability to the eco-environment, which not only supports the persistence of endemic species but also propels evolution and speciation (He and Jiang 2014; Atlas and Fu 2019; Ye et al. 2019; Wu et al. 2022).

Yunnan is a centre of diversification for Chinese freshwater crabs (Dai 1999; Cumberlidge et al. 2011). Although extensive research has been conducted on freshwater crabs in this region, the discovery of new genera and species still continues, and many new taxa have recently been revealed through morphological and molecular studies (Chu et al. 2017, 2018a, b; Naruse et al. 2018; Huang et al. 2020a, b; Wang et al. 2020; Zhang et al. 2020; Pan et al. 2021a, b,

2023; Tan et al. 2021; Shi et al. 2022). This is partly attributed to ongoing efforts focused on previously under-sampled areas.

The genus *Parvuspotamon* Dai & Bo, 1994, was erected for its type species *Parvuspotamon yuxiense* Dai & Bo, 1994, which is currently only known from Yuxi City, Yunnan Province. Naruse et al. (2018) recently described *Parvuspotamon dixuense* Naruse, Chia, & Zhou, 2018, from Yunnan, citing its morphological similarities with *Parvuspotamon*. Recent surveys in southwest China (Fig. 1) resulted in the collection of several freshwater crab specimens, which are similar to *P. dixuense*. Interestingly, these specimens are different from the type species of *Parvuspotamon*, i.e., *P. yuxiense*. After morphological comparisons and molecular phylogenetic inferences, we reveal that *Parvuspotamon* is polyphyletic and consists of two distinct clades. *Parvuspotamon* is therefore hereby revised, and a new genus, *Songpotamon* gen. nov., is established to accommodate *P. dixuense* and two new species, *Songpotamon funingense* sp. nov. and *Songpotamon malipoense* sp. nov.

Materials and methods

Crab collection

All individuals were collected from Yunnan Province. Specimens were preserved in 95% ethanol and were deposited at the Jiangsu Key Laboratory for Biodiversity and Biotechnology, College of Life Sciences, Nanjing Normal University, Nanjing, China (NNU) and the Institute of Zoology, the Chinese Academy of Sciences, Beijing, China (CB). The terminology is after Ng (1988), with changes as recommended by Dai (1999) and Davie et al. (2015). The abbreviations used are as follows: **asl.**, above sea level; **G1**, male first gonopod; **G2**, male second gonopod.

Phylogenetic analyses

DNA was extracted from gill or muscle tissues using the Trelief Animal Genomic DNA kit (Tsingke, Beijing, P.R. China) following the manufacturer's protocol.

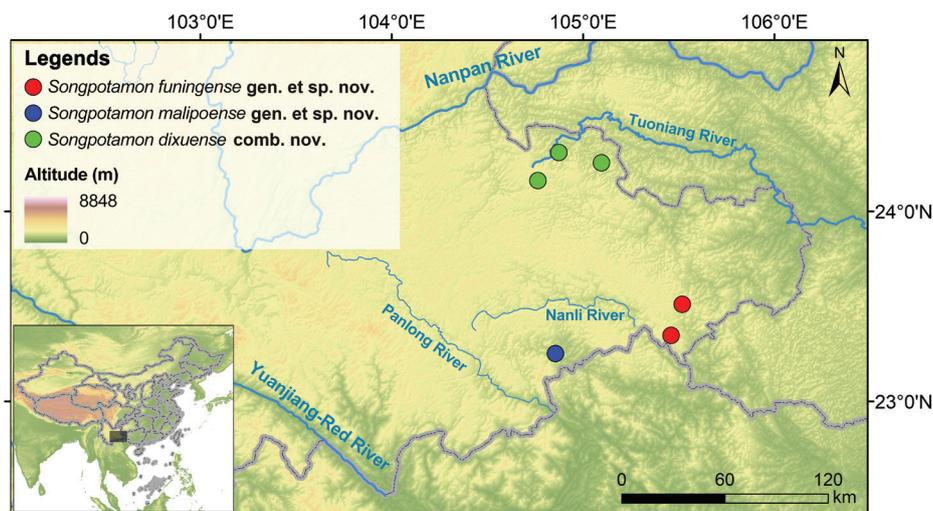


Figure 1. Map of southeast Yunnan showing the distribution of three species of *Songpotamon* gen. nov.

A region of 490 base pairs (bp) of the 16S r DNA (16S) was amplified by polymerase chain reaction (PCR) using the primers 1471 and 1472 (Crandall and Fitzpatrick 1996). The PCR conditions included: initial denaturation at 95 °C for 3 min; 35 cycles of 30 s at 95 °C, 40 s at 50 °C, and 1 min at 72 °C; and a 7-min incubation at 72 °C. The following accession numbers were obtained from the GenBank: *Songpotamon funingense* gen. et sp. nov., OR469050, OR469051, OR469054, OR469055, OR469057, and OR469058; *Songpotamon malipoense* gen. et sp. nov., OR469052 and OR469053; *Songpotamon dixuense* (Naruse, Chia & Zhou, 2018) comb. nov., OR469056 and OR544490; and *Parvuspotamon yuxiense*, OR469059 (also see type material sections).

All sequences were aligned using MAFFT v.7.215 (Katoh and Standley 2013), with the iterative refinement method G-INS-i (accurate alignment). The 16S dataset was compiled from both GenBank ($n = 18$) and newly generated data ($n = 11$). The Maximum-likelihood (ML) phylogenetic inference was performed using IQ-TREE v. 1.6.10 (Nguyen et al. 2015). The best substitution model was selected using MODELFINDER (Kalyaanamoorthy et al. 2017) as implemented in IQ-TREE v. 2. The Bayesian Inference (BI) analysis was conducted in MR-BAYES v. 3.2.7a (Ronquist et al. 2012). Four chains were run simultaneously (three heated, one cold) for 10,000,000 generations, with tree space sampled every 1,000 generations. After a graphical analysis of the evolution of the likelihood scores, the first 250,000 generations were discarded as burn-in. The remaining trees were used to calculate the consensus tree. Acceptable convergence to the stationary distribution was checked by inspecting the posterior samples using the diagnostic software TRACER v. 1.7 (Rambaut et al. 2018). Effective sample sizes were > 200 for all parameters. The pairwise genetic distance among each species were calculated using MEGA X under the pairwise Kimura two-parameter (K2P) model (Kimura 1980; Kumar et al. 2018).

Taxonomic account

Family Potamidae Ortmann, 1896

Subfamily Potamiscinae Bott, 1970 (sensu Yeo and Ng 2004)

Genus *Parvuspotamon* Dai & Bo, 1994

Figs 2–4

Type species. *Parvuspotamon yuxiense* Dai & Bo, 1994, by original designation.

Diagnosis. Medium sized (adult carapace width 16–26 mm, $n = 15$). Carapace broader than long, ovate; dorsal surface convex, smooth, regions not clear; branchial regions swollen, smooth (Figs 2A, 4A). Epigastric cristae weakly developed, oblique, separated from each other by deep inverted Y-shaped groove; postorbital cristae low, indistinct, confluent with epigastric cristae (Figs 2A, 4A). External orbital angle bluntly triangular, outer margin and anterolateral margin of carapace confluent (Figs 2A, 4A). Anterolateral margin of carapace entire convex, smooth; posterolateral margins of carapace gently converging, smooth (Figs 2A, 4A). Epibranchial tooth indistinct (Figs 2A, 4A). Sub-orbital, sub-hepatic and pterygostomial regions smooth (Figs 2B, C, 4B, C). Antennular fossae slit-like in anterior view; median lobe of epistome posterior margin narrowly triangular (Figs 2B, 4B). Exopod of third maxilliped reaching

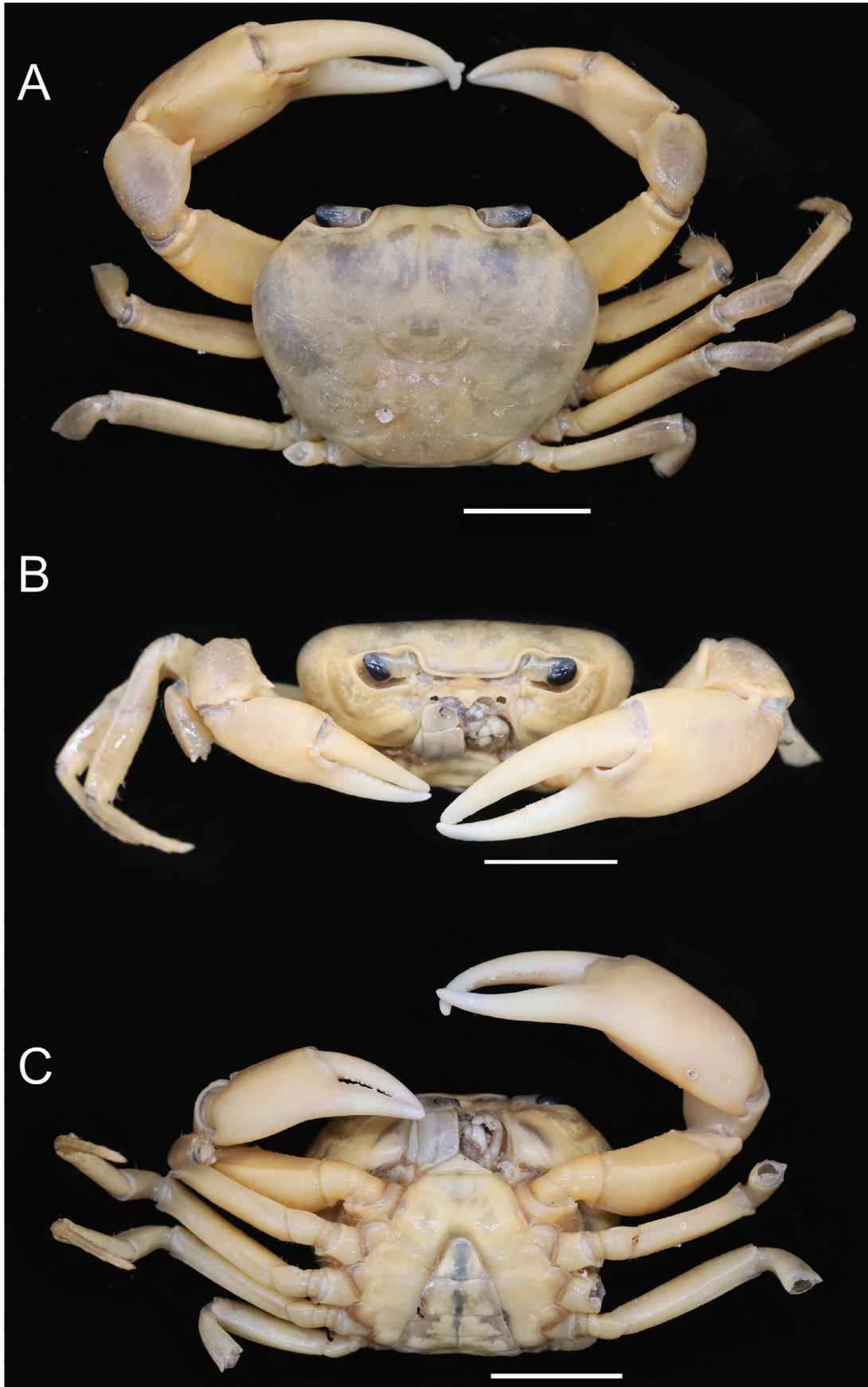


Figure 2. *Parvuspotamon yuxiense* Dai & Bo, 1994, ♂, 26.18 × 19.73 mm (NNU-3151-01) **A** overall dorsal view **B** overall frontal view **C** overall ventral view. Scale bars: 10 mm.

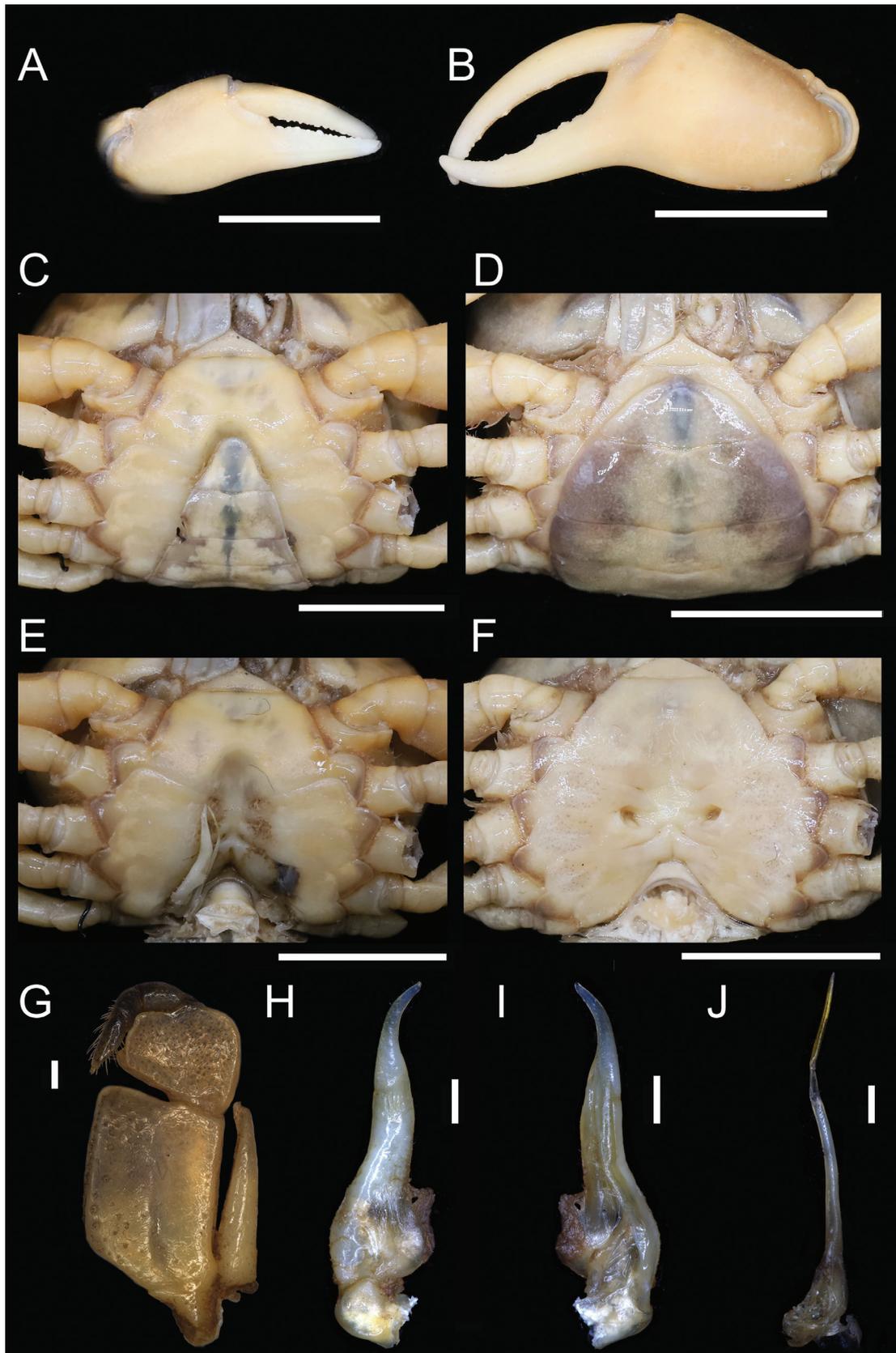


Figure 3. *Parvuspotamon yuxiense* Dai & Bo, 1994, ♂, 26.18 × 19.73 mm (NNU-3151-01) (A–C, E, G–J); ♀, 22.82 × 16.98 mm (NNU-3151-05) (D, F) **A** right chela **B** left chela **C** anterior thoracic sternum and pleon **D** pleon **E** thoracic sternum with right G1 *in situ* **F** thoracic sternum showing vulvae **G** left third maxilliped **H** dorsal view of left G1 **I** ventral view of left G1 **J** dorsal view of left G2. Scale bars: 10 mm (A–F); 1 mm (G–J).

beyond anterolateral corner of ischium, without flagellum (Fig. 3G). Thoracic sternites 3/4 in male completely fused (Figs 2C, 3C, E, 4C). Vulvae transversely ovate, widely located from each other, touching suture of sternites 5/6 (Fig. 3F). Male pleon broadly triangular (Figs 2C, 3C, 4C). G1 slender, reaching pleonal locking tubercle *in situ* (Figs 3E, H, I, 4D, E); subterminal segment stout, slightly sinuous (Figs 3H, I, 4D, E); terminal segment slender, relatively long, subconical, strongly sinuous, bent inwards, inner margin strongly concave, ~ 0.6× length of subterminal segment, without groove for G2 on ventral side, tip rounded, dorsal flap absent (Figs 3H, I, 4D–G). G2 longer than G1; terminal segment relatively long; subterminal segment ~ 1.5× length of terminal segment (Fig. 3J).

Remarks. *Parvuspotamon* was previously known by two species, *P. yuxiense* (type species) and *P. dixuense*. The latter species was recently described by Naruse et al. (2018) based on the characters in the carapace and G1 terminal segment. Based on morphological and molecular data, *P. dixuense*, however, is transferred to *Songpotamon* gen. nov. since it possesses the generic characters of the new genus (see Remarks for the new genus). The present revision thus restricts *Parvuspotamon* only to the type species, i.e., *P. yuxiense*.

The morphological similarities between *Parvuspotamon* and *Songpotamon* gen. nov. notwithstanding, *Parvuspotamon* can easily be distinguished from *Songpotamon* gen. nov. by the characters in the carapace, vulvae and G1 (see Remarks for *Songpotamon* gen. nov.). *Parvuspotamon* is immediately distinguished from most of the remaining Chinese potamid genera by the combination of its medium body size (adult carapace width 16–26 mm), the strongly sinuous G1 terminal segment, and the absence of a flagellum on the exopod of the third maxilliped (Dai and Bo 1994; Dai 1999).

Geographic distribution. *Parvuspotamon* is known only from Yunnan Province of southwest China.

***Parvuspotamon yuxiense* Dai & Bo, 1994**

Figs 2–4

Type material. Holotype. CHINA • ♂, 15.7 × 12.9 mm; Yunnan Province, Yuxi City, Xinping County, Gasa Township; Aug. 1990; CB05138 YN 9091116A.

Additional material. CHINA • 4 ♂, 26.18 × 19.73 mm (NNU-3151-01), 23.26 × 17.19 mm (NNU-3151-02), 22.68 × 17.02 mm (NNU-3151-03), 20.79 × 15.52 mm (NNU-3151-04), 3 ♀, 22.82 × 16.98 mm (NNU-3151-05), 21.13 × 16.47 mm (NNU-3151-06), 22.59 × 17.35 mm (NNU-3151-07); Yunnan Province, Yuxi City, Xinping County, Heshalak Village; 23.96°N, 101.45°E; altitude 955 m asl; 11 Apr. 2019; Boyang Shi, Xiyang Hao, Zewei Zhang, and Hongying Sun, leg. • 5 ♂, 24.94 × 18.94 mm (NNU-1513-01), 21.16 × 16.86 mm (NNU-1513-02), 22.02 × 16.06 mm (NNU-1513-03), 18.72 × 13.42 mm (NNU-1513-04), 16.58 × 11.98 mm (NNU-1513-05), 2 ♀, 22.54 × 16.63 mm (NNU-1513-06), 17.12 × 12.77 mm (NNU-1513-07); Yunnan Province, Yuxi City, Gasha Town; 24.02°N, 101.58°E; altitude 795 m asl; 15 Oct. 2015; Kelin Chu, Qiang Zhao, Pengfei Wang, and Hongying Sun leg.

Description. Medium sized (adult carapace width 16–26 mm, *n* = 15). Carapace broader than long, ovate; dorsal surface convex both transversely and longitudinally, smooth, regions not clear; branchial regions swollen, smooth

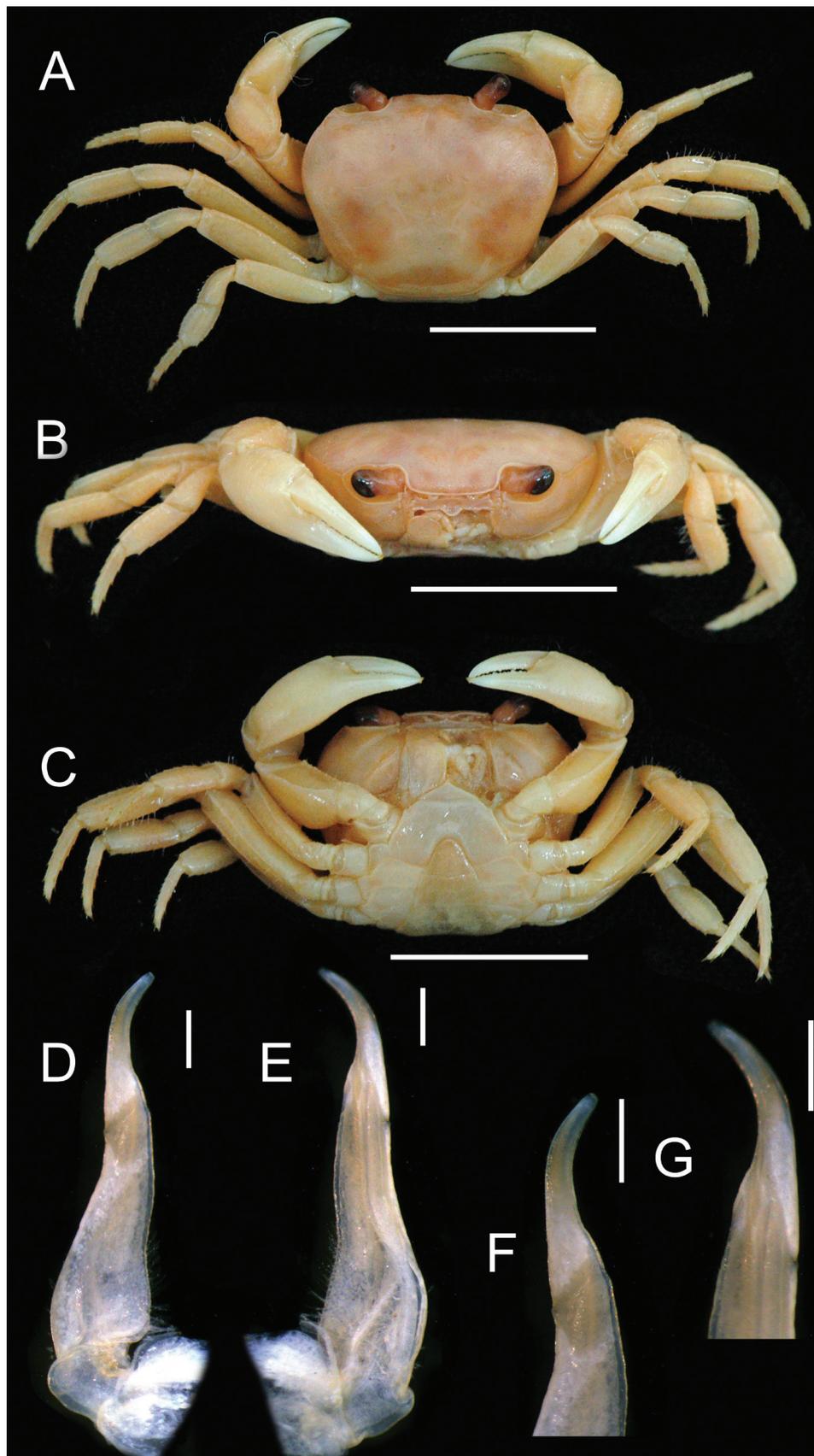


Figure 4. *Parvuspotamon yuxiense* Dai & Bo, 1994, holotype ♂, 15.7 × 12.9 mm (CB05138 YN 9091116A) **A** overall dorsal view **B** overall frontal view **C** overall ventral view **D** dorsal view of left G1 **E** ventral view of left G1 **F** dorsal view of left G1 distal portion **G** ventral view of left G1 distal portion. Scale bars: 10 mm (**A–C**); 1 mm (**D–G**).

(Figs 2A, 4A). Postorbital and epigastric cristae confluent (Figs 2A, 4A); epigastric cristae weakly developed, oblique, separated by deep inverted Y-shaped groove (Figs 2A, 4A); postorbital cristae low, indistinct (Figs 2A, 4A). External orbital angle bluntly triangular, outer margin and anterolateral margin of carapace confluent (Figs 2A, 4A). Anterolateral margin of carapace entire convex, smooth; posterolateral margin gently concave, smooth, converging towards posterior carapace margin (Figs 2A, 4A). Epibranchial tooth indistinct (Figs 2A, 4A). Orbits large; supraorbital and infraorbital margins smooth; sub-orbital, sub-hepatic, and pterygostomial regions smooth (Figs 2B, C, 4B, C). Antennular fossae slit-like in anterior view; median lobe of epistome posterior margin narrowly triangular (Figs 2B, 4B). Third maxilliped with rhombus ischium; exopod reaching beyond anterolateral corner of ischium, without flagellum (Fig. 3G).

Chelipeds unequal (Figs 2A–C, 3A, B, 4A–C). Merus trigonal in cross section; margins weakly crenulated (Figs 2A, 4A). Carpus with sharp spine at inner-distal angle (Figs 2A, 4A). Major cheliped palm length $\sim 1.3\times$ height (Fig. 3B). Occlusal margin of fingers with several small teeth; distinct gape when closed (Fig. 3A, B).

Ambulatory legs not distinctly elongated, dactyli slender (Figs 2A, C, 4A, C); second pair longest, last pair shortest (Figs 2A, C, 4A, C). Outer surface of merus weakly rugose, dorsal margin weakly serrated, without subdistal tooth, length $\sim 4.1\times$ width (Figs 2A, 4A).

Male thoracic sternum smooth, weakly pitted; sternites 1/2 fused forming triangular structure; sternites 2/3 separated by deep but incomplete groove; sternites 3/4 completely fused; median longitudinal suture of sternites 7/8 deep (Figs 2C, 3C, E, 4C). Vulvae transversely ovate, widely located from each other, touching suture of sternites 5/6, posteromesial margin with low rim, opened obliquely upwards (Fig. 3F).

Male pleon broadly triangular; male telson relatively broad, lateral margins concave, width $\sim 1.4\times$ length; male pleonal somite 6 trapezoidal, broad, width $\sim 2.3\times$ length; somites 3–5 trapezoidal, gradually decreasing in width; somite 2 trapezoidal, reaching to bases of coxae of fourth ambulatory legs, thoracic sternite 8 not visible when pleon closed (Figs 2C, 3C, 4C). Female pleon ovate, covering most of thoracic sternum (Fig. 3D).

G1 slender, reaching pleonal locking tubercle *in situ*, with terminal and sub-terminal segments clearly demarcated (Figs 3E, H, I, 4D–G); subterminal segment stout, slightly sinuous (Figs 3H, I, 4D, E); terminal segment slender, relatively long, subconical, strongly sinuous, bent inwards, inner margin strongly concave, $\sim 0.6\times$ length of subterminal segment, without groove for G2 on ventral side, tip rounded, dorsal flap absent (Figs 3H, I, 4D–G). G2 longer than G1; terminal segment relatively long; subterminal segment $\sim 1.5\times$ length of terminal segment (Fig. 3J).

Colour in life. Carapace and chelipeds are generally yellowish brown in mature individuals.

Habitat. *Parvuspotamon yuxiense* can be found under rocks in hill streams at ~ 700 – 1000 m altitude.

Remarks. *Parvuspotamon yuxiense* is the sole species of the genus and closely related to the species of *Songpotamon* gen. nov., and two species of *Tenuipotamon* Dai, 1990 (*Tenuipotamon yuxiense* Chen, 1993, and *Tenuipotamon xingpingense* Chen, 1993) that are known from Xinping County,

Yuxi City of Yunnan Province. *Parvuspotamon yuxiense* can nevertheless be differentiated from *T. yuxiense* and *T. xingpingense* by the following characters: anterolateral margins of the carapace entire and smooth (vs cristate); and G1 terminal segment relatively less strongly curved, lacking a dorsal flap (vs more strongly curved, with a distinct dorsal flap) [cf. Chen 1993: figs 3 (4–6), 4 (4–6)]. On the other hand, *P. yuxiense* can be differentiated from the species of *Songpotamon* gen. nov. by the characters in the carapace, vulvae and G1 (see Remarks for *Songpotamon* gen. nov.).

Geographic distribution. *Parvuspotamon yuxiense* is known only from the Yuxi City, Yunnan Province, southwest China.

Genus *Songpotamon* gen. nov.

<https://zoobank.org/8CCC83D0-C234-4C34-AB6B-A3580AF601CD>

Figs 5–10

Type species. *Songpotamon funingense* sp. nov., by present designation.

Species included. *Songpotamon dixuense* (Naruse, Chia & Zhou, 2018), comb. nov., *Songpotamon funingense* gen. et sp. nov., and *Songpotamon malipoense* gen. et sp. nov.

Diagnosis. Medium sized (adult carapace width 19–27 mm, $n = 16$). Carapace broader than long, ovate; dorsal surface convex, generally smooth, pitted, regions not clear; branchial regions swollen (Figs 5A, 7A). Postorbital and epigastric cristae not confluent, separated by shallow groove (Figs 5A, 7A). External orbital angle bluntly triangular, outer margin separated from anterolateral margin of carapace by shallow cleft (Figs 5A, 7A). Anterolateral margin of carapace convex (Figs 5A, 7A). Orbits large; supraorbital and infraorbital margins smooth (Figs 5B, 7B). Exopod of third maxilliped reaching beyond anterolateral corner of ischium, without flagellum (Figs 6C, 8C). Thoracic sternites 3/4 in male fused except for incomplete groove demarcating suture (Figs 5C, 6E, G, 7C, 8E, G). Vulvae transversely ovate, relatively closely located to each other, touching suture of sternites 5/6 (Figs 6H, 8H). Male pleon narrowly triangular (Figs 5C, 6E, 7C, 8E). G1 slender, almost reaching or reaching beyond pleonal locking tubercle *in situ* (Figs 6G, 8G, 9A, B, D, E, 10A–D); terminal segment slender, subconical, bent outwards, relatively short, $\sim 0.4\times$ length of subterminal segment, with distinct groove for G2 on ventral side, tip subtruncate, gently recurved upwards, dorsal flap absent (Figs 9A, B, D, E, 10A–D). G2 longer than G1; terminal segment relatively short; subterminal segment $\sim 5\times$ length of terminal segment (Fig. 9C, F).

Etymology. The genus is named after the late Prof. Daxiang Song, a senior academician in the Chinese Academy of Sciences, in the honour of his immense contributions to Chinese invertebrate systematics; in arbitrary combination with the genus name *Potamon* Savigny, 1816. Gender of genus neuter.

Remarks. *Songpotamon* gen. nov. is established for *S. dixuense* comb. nov. and two new species, *S. funingense* sp. nov. and *S. malipoense* sp. nov. *Songpotamon dixuense* comb. nov. was previously in *Parvuspotamon*, but here transferred to *Songpotamon* gen. nov. because it possesses the key generic characters of the new genus, which includes, the medium body size (adult carapace width 19–27 mm), the third maxilliped exopod lacking a flagellum, the

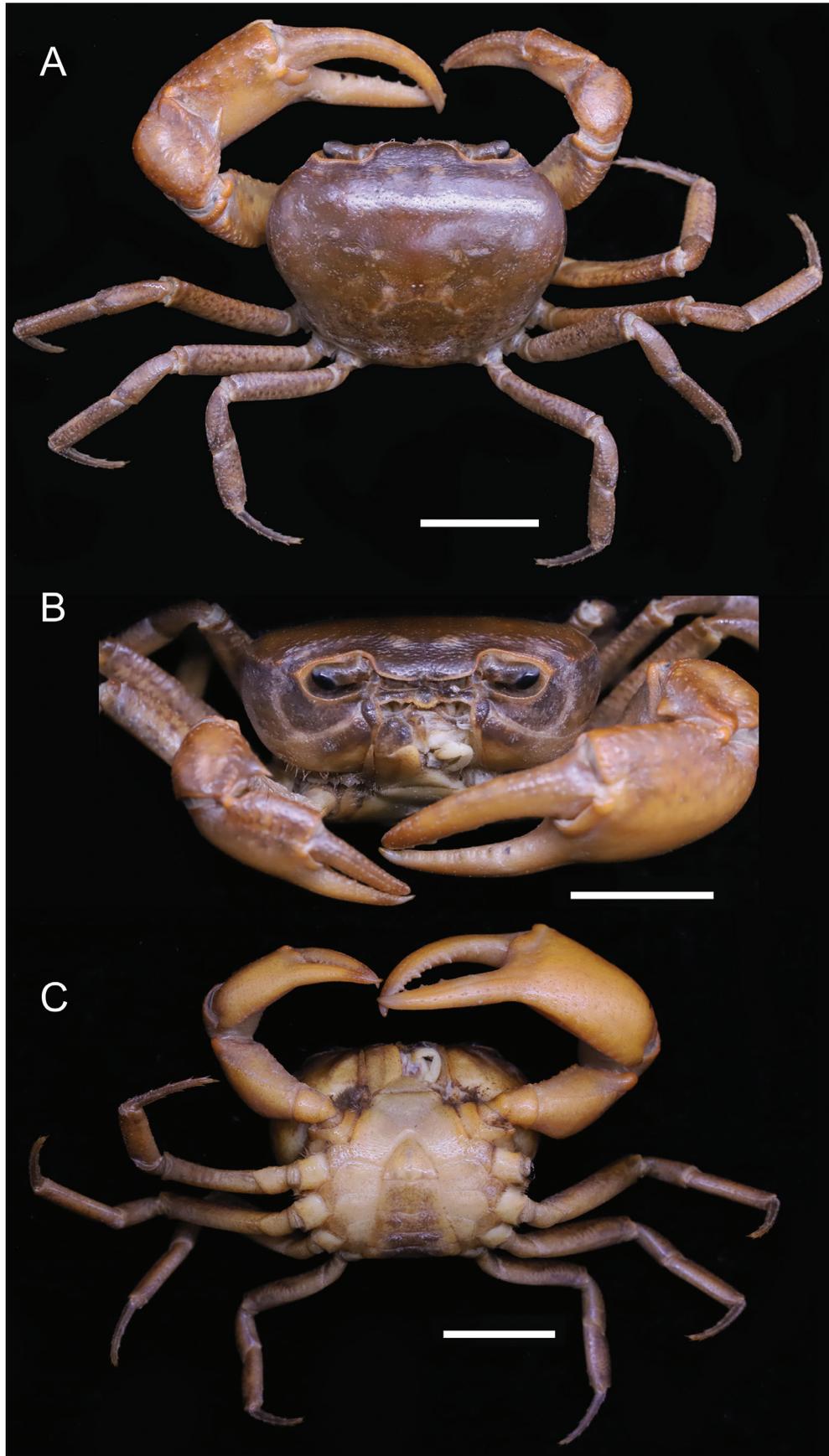


Figure 5. *Songpotamon funingense* gen. et sp. nov., holotype ♂, 27.2 × 21.9 mm (NNU-167462-01) **A** overall dorsal view **B** frontal view of cephalothorax **C** overall ventral view. Scale bars: 10 mm.

external orbital angle being bluntly triangular, the slender G1 shape, and the terminal segment being subconical and with a groove for G2 on the ventral side (cf. Naruse et al. 2018: figs 24–27).

Songpotamon gen. nov. can easily be distinguished from *Parvuspotamon* by the following characters: 1) carapace dorsal surface with scattered pits (Figs 5A, 7A; cf. Naruse et al. 2018: fig. 25A) (vs smooth; Figs 2A, 4A); 2) outer margin of the external orbital angle separated from the anterolateral margin of the carapace by the shallow cleft (Figs 5A, 7A; cf. Naruse et al. 2018: fig. 25A) (vs confluent with each other; Figs 2A, 4A); 3) vulvae relatively close located to each other (Figs 6H, 8H; cf. Naruse et al. 2018: fig. 27) (vs relatively widely located from each other; Fig. 3F); 4) G1 terminal segment relatively shorter, ~ 0.4× the length of the subterminal segment, with a truncated tip (Figs 9A, B, D, E, 10A–D; cf. Naruse et al. 2018: fig. 26A–D) (vs relatively longer, ~ 0.6× the length of the subterminal segment, with a rounded tip; Figs 3H, I, 4D–G); 5) G1 terminal segment bent outwards but with the tip gently recurved upwards, the inner margin being straight to gently curved (Figs 9A, B, D, E, 10A–D; cf. Naruse et al. 2018: fig. 26 A–D) (vs bent inwards, with the inner margin being strongly concave; Figs 3H, I, 4D–G); and 6) groove for G2 on the G1 terminal segment clearly visible in the ventral view (Figs 9 B, E, 10B, D; cf. Naruse et al. 2018: fig. 26A, B) (vs not visible; Figs 3I, 4E, G).

Furthermore, *Songpotamon* gen. nov. is most likely to be confused with *Chinapotamon* Dai & Naiyanetr, 1994, as both the genera have a very similar carapace physiognomy, and their G1 terminal segment is subconical, with the groove for G2 visible in the ventral view. The new genus, *Songpotamon* gen. nov., is nevertheless distinguished from *Chinapotamon* by the following characters: 1) carapace relatively high (Figs 5B, 7B) (vs relatively low); 2) ambulatory legs relatively stout (Figs 5A, C, 6D, 7A, C, 8D) (vs relatively slender); 3) anterolateral margin of the carapace being less convex (Figs 5A, 7A) (vs strongly convex); 4) third maxilliped exopod without flagellum (Figs 6C, 8C) (vs with well-developed flagellum); 5) thoracic sternites 3/4 with incomplete but distinct groove demarcating suture (Figs 5C, 6E, G, 7C, 8E, G) (vs groove demarcating suture absent); and 6) G1 terminal segment gently curved outwards (Figs 9A, B, D, E, 10A–D) (vs strongly bent outwards) (cf. Dai 1999: figs 42–47; Ng 2017: figs 2–4, 6–8; Zou et al. 2018: figs 2–6).

Geographic distribution. *Songpotamon* gen. nov. is known from Wenshan Prefecture, eastern Yunnan Province, southwest China.

***Songpotamon funingense* gen. et sp. nov.**

<https://zoobank.org/8C1EEA1D-F6D9-4256-B0D4-1599AA753C99>

Figs 5, 6, 9A–C, 10A, B

Type material. Holotype. CHINA • ♂, 27.2 × 21.9 mm; Yunnan Province, Wenshan Prefecture, Funing County, Tianwan Township; 23.20°N, 104.87°E; altitude 880 m asl.; 22 Oct. 2020; Boyang Shi, Ruxiao Wang, and Hongying Sun leg.; GenBank: OR469050; NNU-167462-01.

Paratype. CHINA • ♂, 25.2 × 20.9 mm; same collection data as for holotype; GenBank: OR469051; NNU-167462-02 • ♂, 26.6 × 21.0 mm; same collection data as for holotype; GenBank: OR469057; NNU-167462-03 • ♂, 23.5 × 19.1 mm;

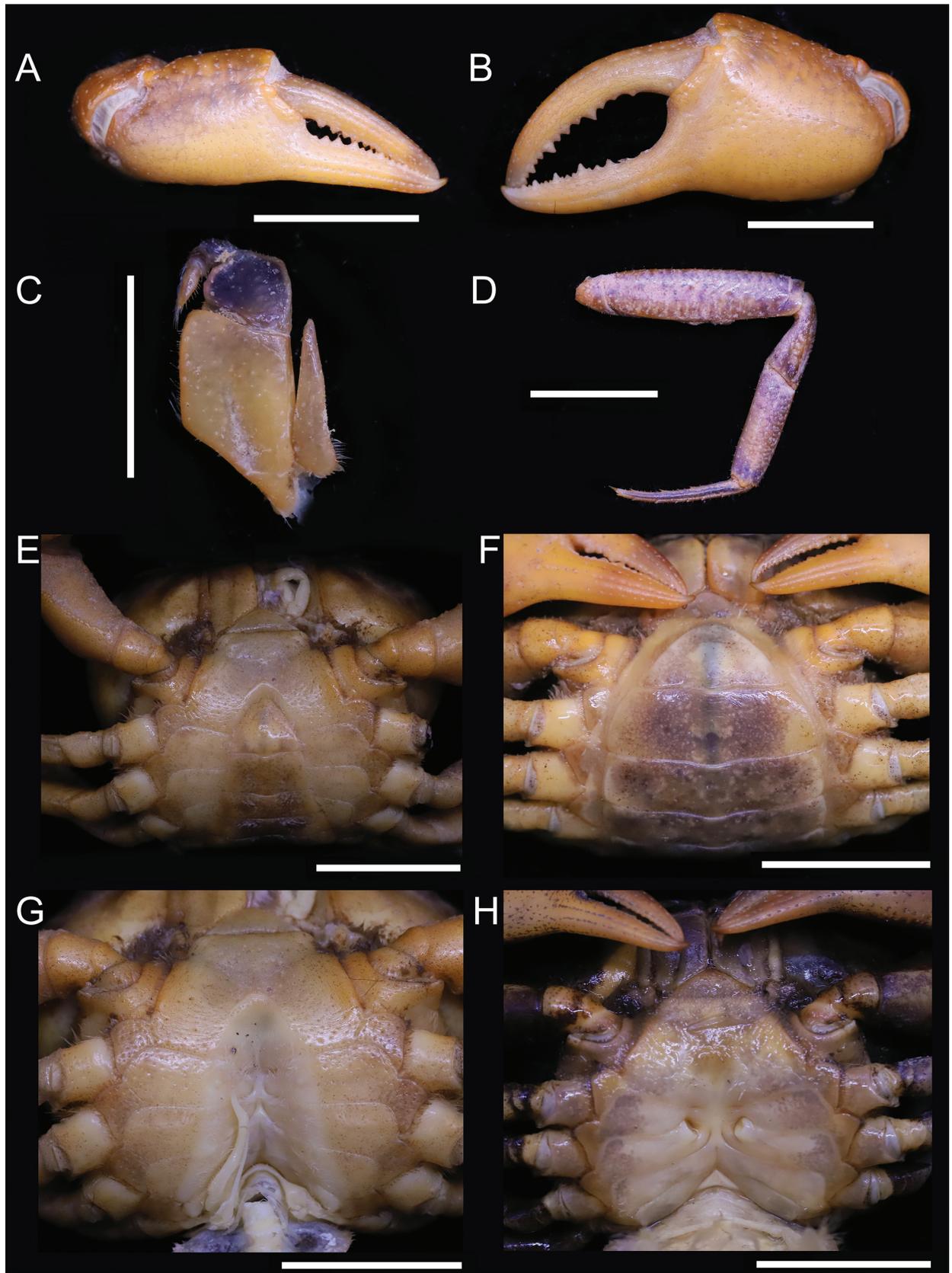


Figure 6. *Songpotamon funingense* gen. et sp. nov., holotype ♂, 26.18 × 19.73 mm (NNU-3151-01) (A–E, G); paratype ♀, 22.6 × 18.0 mm (NNU-167462-05) (F, H) **A** right chela **B** left chela **C** left third maxilliped **D** right second ambulatory leg **E** anterior thoracic sternum and pleon **F** pleon **G** thoracic sternum with right G1 *in situ* **H** thoracic sternum showing vulvae. Scale bars: 10 mm.

same collection data as for holotype; GenBank: OR469058; NNU-167462-04 • ♀, 22.6 × 18.0 mm; same collection data as for holotype; NNU-167462-05 • ♀, 24.6 × 19.7 mm; same collection data as for holotype; NNU-167462-06 • ♂, 22.2 × 17.8 mm; Yunnan Province, Wenshan Prefecture, Funing County, Longbo Township; 23.31°N, 105.46°E; altitude 1611 m asl.; 24 Oct. 2020; Boyang Shi, Ruxiao Wang, and Hongying Sun leg.; GenBank: OR469054; NNU-167533-01 • ♂, 21.5 × 17.7 mm; same collection data as for NNU-167533-01; GenBank: OR469055; NNU-167533-02 • ♀, 20.8 × 16.4 mm; same collection data as for NNU-167533-01; NNU-167533-03.

Diagnosis. Medium sized (adult carapace width 21–27 mm, $n = 9$). Carapace broader than long, ovate; dorsal surface convex, smooth, pitted, regions not clear; branchial regions swollen (Fig. 5A). Postorbital and epigastric cristae low, not confluent, separated by weak shallow groove (Fig. 5A); epigastric cristae weakly developed, straight, separated by shallow inverted Y-shaped groove; postorbital cristae low, rugose (Fig. 5A). External orbital angle bluntly triangular, outer margin convex, separated from anterolateral margin of carapace by shallow cleft (Fig. 5A). Anterolateral margin of carapace convex, generally smooth, weakly cristate; posterolateral margins gently converging, smooth (Fig. 5A). Orbits large; supraorbital and infraorbital margins smooth (Fig. 5B); sub-orbital, sub-hepatic and pterygostomial regions smooth or weakly rugose (Fig. 5B, C). Antennular fossae rectangular in anterior view; median lobe of epistome posterior margin low, rounded (Fig. 5B). Exopod of third maxilliped reaching beyond anterolateral corner of ischium, without flagellum (Fig. 6C). Thoracic sternites 3/4 in male fused except for relatively deep, incomplete groove demarcating suture (Figs 5C, 6E, G). Vulvae transversely ovate, closely located to each other, touching suture of sternites 5/6, opened obliquely ~ 45° upwards (Fig. 6H). Male pleon narrowly triangular; somite 6 relatively narrow, width ~ 2.4× as length (Fig. 5C). G1 slender, almost reaching pleonal locking tubercle *in situ* (Figs 6G, 9A, B, 10A, B); subterminal segment stout, sinuous, inner margin concave; terminal segment subconical, bent at ~ 45° outwards, relatively short, ~ 0.4× length of subterminal segment, with distinct groove for G2 on ventral side, tip subtruncate, recurved upwards (Figs 9A, B, 10A, B). G2 longer than G1; terminal segment relatively short; subterminal segment ~ 5× length of terminal segment (Fig. 9C).

Description. Medium sized (adult carapace width 21–27 mm, $n = 9$). Carapace broader than long, ovate; dorsal surface convex transversely, longitudinally, smooth, pitted, regions not clear; branchial regions swollen, smooth (Fig. 5A). Postorbital and epigastric cristae inconspicuous, not confluent, separated by weakly shallow groove (Fig. 5A); epigastric cristae weakly developed, straight, separated by shallow Y-shaped groove; postorbital cristae low, rugose, reaching epibranchial tooth (Fig. 5A). Cervical groove indistinct (Fig. 5A). External orbital angle bluntly triangular, outer margin straight, with shallow cleft demarcating it from epibranchial tooth; epibranchial tooth weakly developed (Fig. 5A). Anterolateral margin convex, smooth, weakly cristate; posterolateral margin gently concave, smooth, converging towards posterior carapace margin (Fig. 5A). Orbits large; supraorbital and infraorbital margins smooth; sub-orbital, sub-hepatic, and pterygostomial regions relatively smooth or weakly rugose (Fig. 5B, C). Antennular fossae rectangular in anterior view; median lobe of epistome posterior margin low, rounded (Fig. 5B). Third maxilliped with rhombus

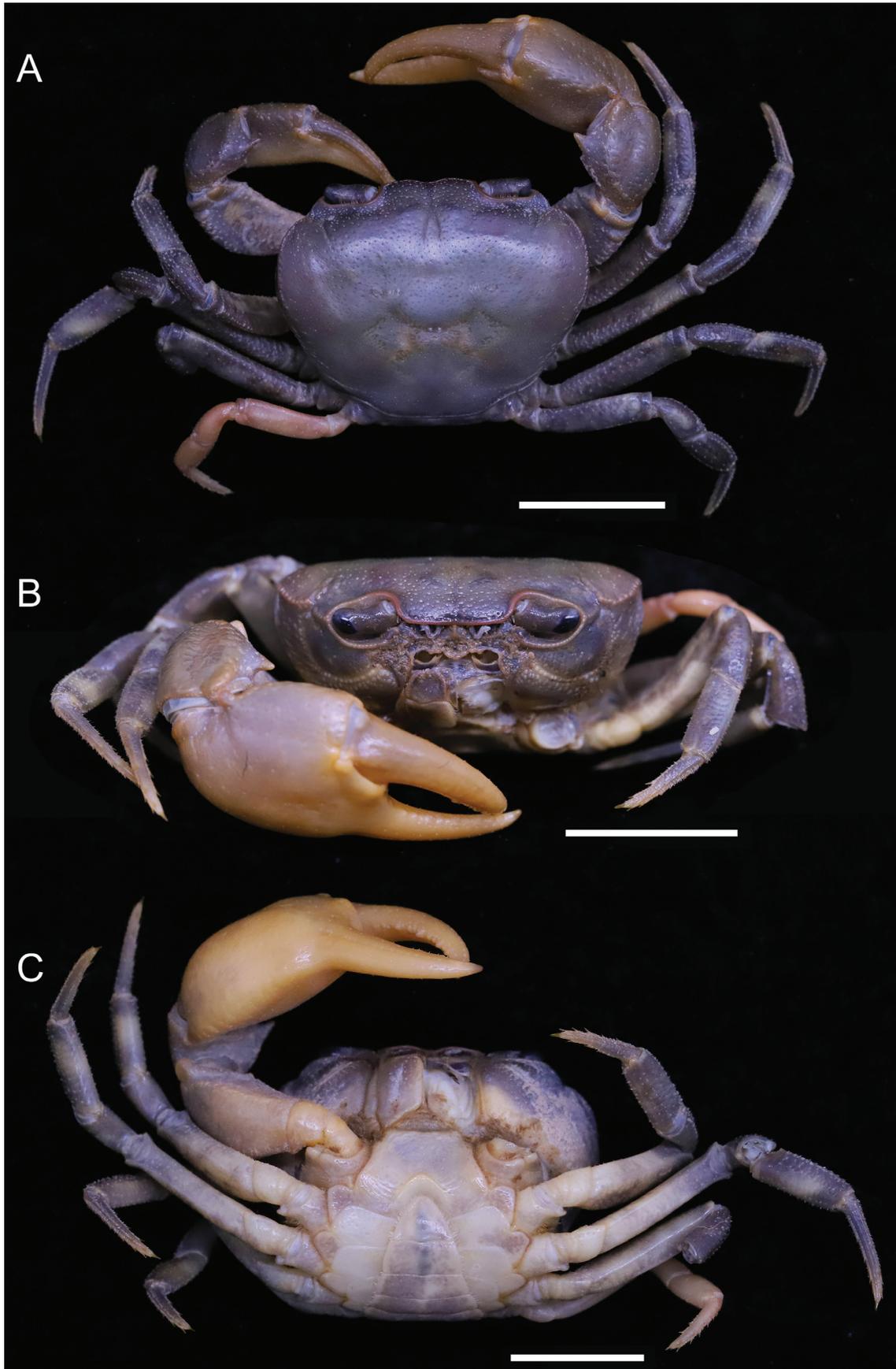


Figure 7. *Songpotamon malipoense* gen. et sp. nov., holotype ♂, 21.7 × 16.8 mm (NNU-167444-01) **A** overall dorsal view **B** overall frontal view **C** overall ventral view. Scale bars: 10 mm.

ischium; exopod of third maxilliped reaching beyond anterolateral corner of ischium, without flagellum (Fig. 6C).

Chelipeds unequal (Figs 5A, C, 6A, B). Merus trigonal in cross section; margins crenulated (Fig. 5A, C). Carpus with sharp spine at inner-distal angle (Fig. 5A, C). Major cheliped palm length $\sim 1.4\times$ as height (Fig. 6B). Occlusal margin of fingers with sharp teeth; distinct gape when closed (Fig. 6B).

Ambulatory legs not distinctly elongated, dactyli slender (Figs 5A, C, 6D); second pair longest, last pair shortest (Fig. 5A, C). Outer surface of merus slightly rugose, dorsal margin weakly serrated, without subdistal tooth, length $\sim 3.7\times$ as width (Fig. 6D).

Male thoracic sternum generally smooth, weakly pitted; sternites 1/2 fused to form a triangular structure (Figs 5C, 6E, G); sternites 2/3 demarcated by horizontal groove; sternites 3/4 fused except for relatively deep, incomplete groove demarcating suture (Figs 5C, 6E, G); median longitudinal suture of sternites 7/8 deep (Fig. 6E, G). Vulvae transversely ovate, closely located to each other, touching suture of sternites 5/6, opened obliquely $\sim 45^\circ$ upwards, posteromesial margin with low raised rim (Fig. 6H).

Male pleon narrowly triangular; telson relatively broad, lateral margins slightly convex, width $\sim 1.2\times$ as length (Figs 5C, 6E); somite 6 broadly rectangular, width $\sim 2.4\times$ as length; suture between somites 6/7 sinuous; somites 3–5 trapezoidal, gradually decreasing in width; somite 2 trapezoidal, reaching to bases of coxae of fourth ambulatory legs; thoracic sternite 8 not visible when pleon closed (Figs 5C, 6E). Female pleon ovate, covering most of thoracic sternum (Fig. 6F).

G1 slender, almost reaching pleonal locking tubercle *in situ*, with terminal and subterminal segments clearly demarcated (Figs 6G, 9A, B, 10A, B); subterminal segment stout, sinuous, distal part prominently narrow, inner margin concave (Figs 9A, B, 10A, B); terminal segment slender, subconical, bent at $\sim 45^\circ$ outwards, relatively short, $\sim 0.4\times$ length of subterminal segment, outer margin slightly convex, inner margin straight, with distinct groove for G2 on ventral side, tip subtruncate, recurved upwards (Figs 9A, B, 10A, B). G2 longer than G1, terminal segment relatively short; subterminal segment $\sim 5\times$ length of terminal segment (Fig. 9C).

Etymology. The species is named after Funing County, the type locality of the new species in the Yunnan Province of China.

Colour in life. Carapace and chelipeds are generally bright orange to red with purplish brown ambulatory legs in mature individuals. Generally purplish brown all over with bright orange tips of the chelipeds in smaller individuals.

Habitat. This new semi-terrestrial species digs and inhabits mud burrows close to small hill streams and seeps.

Remarks. The new species most closely resembles *S. malipoense* gen. et sp. nov., in general carapace morphology, especially in possessing the relatively narrower male pleonal somite 6, the recurved tip of the G1 terminal segment, and the distinct and entire groove for the G2 on the ventral side of the G1 terminal segment. *Songpotamon funingense* gen. et sp. nov., however, can be separated from *S. malipoense* gen. et sp. nov. by the following characters: 1) anterolateral margins of the carapace generally smooth (Fig. 5A) (vs with small granules; Fig. 7A); epigastric cristae straight in dorsal view and separated from each other by a shallow inverted Y-shaped groove (Fig. 5A) (vs oblique in dorsal view

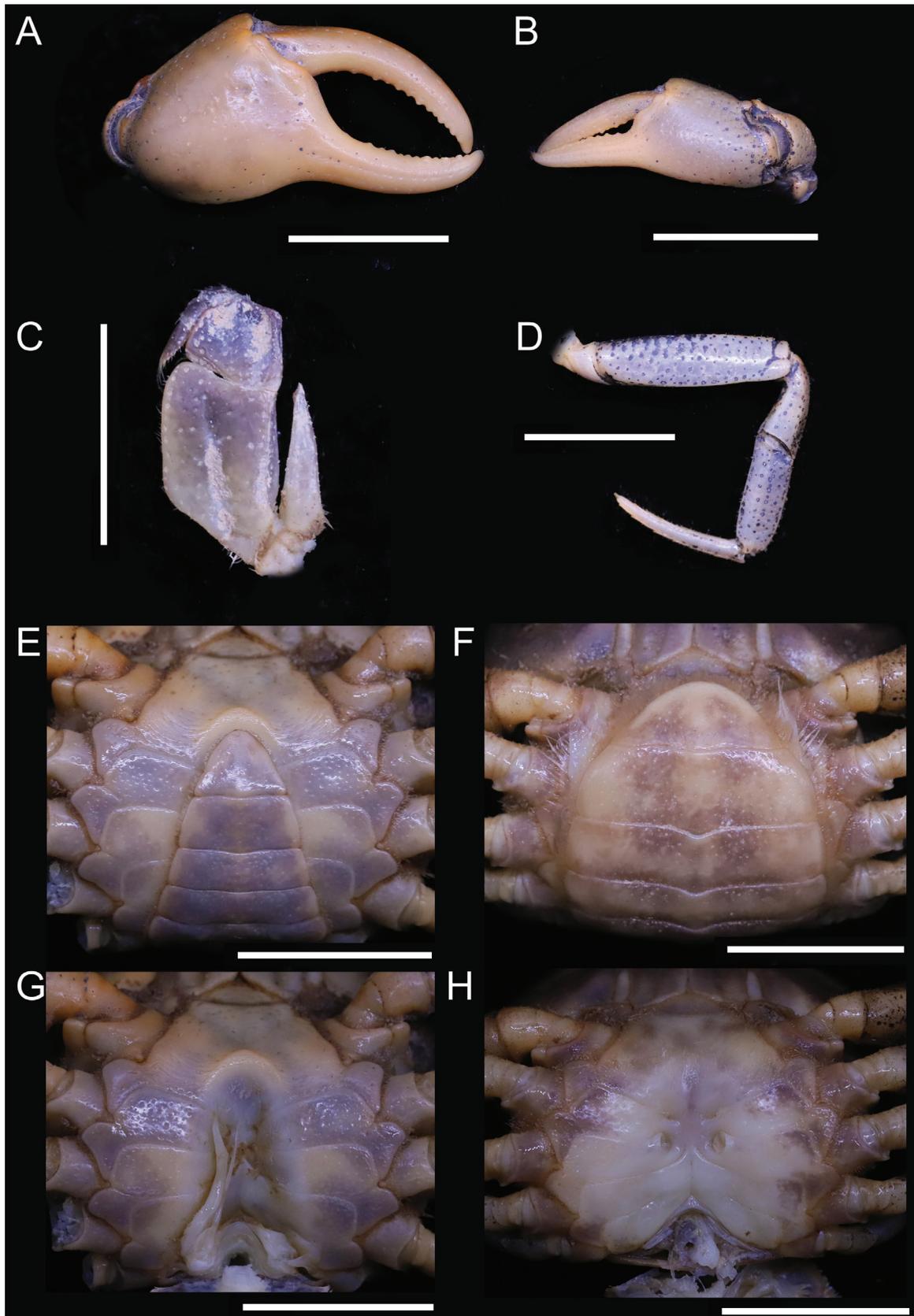


Figure 8. *Songpotamon malipoense* gen. et sp. nov., holotype ♂, 21.7 × 16.8 mm (NNU-167444-01) (A–E, G); paratype ♀, 20.7 × 16.7 mm (NNU-167444-05) (F, H) **A** right chela **B** left chela **C** left third maxilliped **D** right second ambulatory leg **E** anterior thoracic sternum and pleon **F** pleon **G** thoracic sternum with right G1 *in situ* **H** thoracic sternum showing vulvae. Scale bars: 10 mm.

and separated from each other by a relatively deep inverted Y-shaped groove; Fig. 7A); male thoracic sternites 3/4 with relatively deep groove demarcating suture (Figs 5C, 6E, G) (vs relatively shallow; Figs 7C, 8E, G); vulvae opening obliquely $\sim 45^\circ$ upwards (Fig. 6H) (vs opening inwards; Fig. 9H); G1 subterminal segment relatively stouter, with the inner margin concave (Figs 9A, B, 10A, B) (vs relatively slenderer, with the inner margin almost straight; Figs 9D, E, 10C, D); and G1 terminal segment strongly bent at $\sim 45^\circ$ outwards (Figs 9A, B, 10A, B) (vs gently curved at $\sim 30^\circ$ outwards; Figs 9D, E, 10C, D).

The new species is also morphologically similar to *S. dixuense* comb. nov. in the weakly developed epibranchial tooth, the relatively smooth sub-orbital, sub-hepatic, and pterygostomial regions, and the sinuous subterminal segment of the G1. *Songpotamon funingense* gen. et sp. nov., however, can be distinguished from *S. dixuense* comb. nov. by the following characters: antennular fossae subrectangular (Fig. 5B) (vs slit-like); male pleonal somite 6 relatively narrower (Fig. 5C) (vs relatively broader); vulvae opening distinctly oblique $\sim 45^\circ$ upwards (Fig. 6H) (vs opening slightly oblique $\sim 30^\circ$ upwards); G1 subterminal segment relatively stouter (Figs 9A, B, 10A, B) (vs relatively slenderer); and G1 terminal segment relatively strongly bent at $\sim 45^\circ$ outwards (Figs 9A, B, 10A, B) (vs gently curved at $\sim 30^\circ$ outwards) (cf. Naruse et al. 2018: figs 24B, 26, 27).

Geographic distribution. *Songpotamon funingense* gen. et sp. nov. is known from Funing County, eastern Wenshan Prefecture, Yunnan Province, southwest China.

***Songpotamon malipoense* gen. et sp. nov.**

<https://zoobank.org/6D3DB24F-9039-4DDB-A1C7-F0F46443826C>

Figs 7, 8, 9D–F, 10C, D

Type material. Holotype. CHINA • ♂, 21.7 × 16.8 mm; Yunnan Province, Wenshan Prefecture, Malipo County, Tiechang Township; 23.20°N, 104.83°E; altitude 864 m asl.; 24 Oct. 2020; Boyang Shi, Ruxiao Wang, and Hongying Sun leg.; GenBank: OR469052; NNU-167444-01.

Paratype. CHINA • ♂, 22.1 × 17.8 mm; same collection data as for holotype; GenBank: OR469053; NNU-167444-02 • ♂, 20.3 × 16.2 mm; same collection data as for holotype; NNU-167444-03 • ♂, 19.6 × 15.7 mm; same collection data as for holotype; NNU-167444-04 • ♀, 20.7 × 16.7 mm; same collection data as for holotype; NNU-167444-05 • ♀, 20.5 × 15.4 mm; same collection data as for holotype; NNU-167444-06 • ♀, 18.6 × 14.3 mm; same collection data as for holotype; NNU-167444-07.

Diagnosis. Medium sized (adult carapace width 19–22 mm, $n = 7$). Carapace broader than long, ovate; dorsal surface convex, smooth, pitted, regions not clear; branchial regions swollen, smooth (Fig. 7A). Postorbital and epigastric cristae inconspicuous, not confluent, separated by shallow groove (Fig. 7A); epigastric cristae weakly developed, oblique, separated by deep inverted Y-shaped groove; postorbital cristae low, weakly rugose (Fig. 7A). External orbital angle bluntly triangular, outer margin convex, separated from anterolateral margin of carapace by shallow cleft (Fig. 7A). Anterolateral margin of carapace convex, cristate, granular; posterolateral margin straight, with multiple weakly oblique striae (Fig. 7A). Orbits large; sub-orbital regions smooth;



Figure 9. *Songpotamon funingense* gen. et sp. nov., holotype ♂, 27.2 × 21.9 mm (NNU-167462-01) (A–C). *Songpotamon malipoense* gen. et sp. nov., holotype ♂, 21.7 × 16.8 mm (NNU-167444-01) (D–F) A, D dorsal view of left G1 B, E ventral view of left G1 C, F dorsal view of left G2. Scale bars: 1 mm.

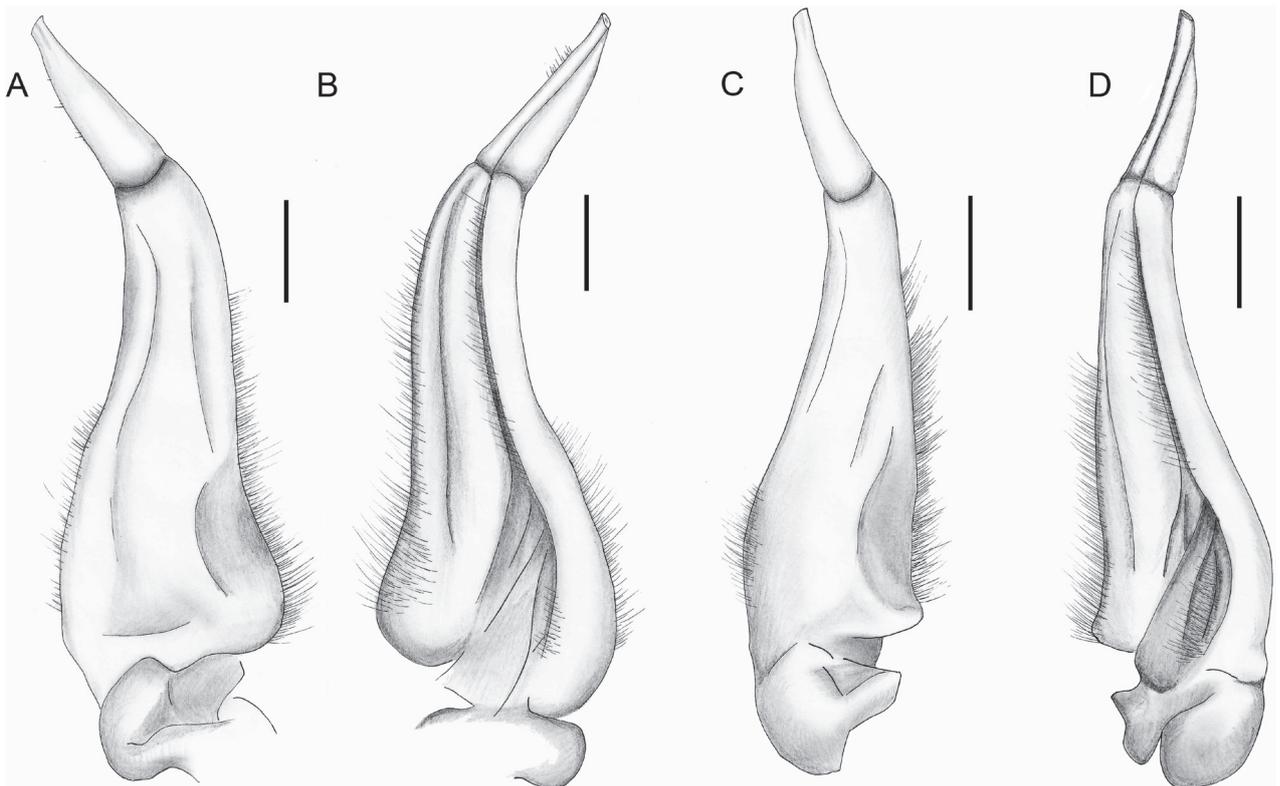


Figure 10. *Songpotamon funingense* gen. et sp. nov., holotype ♂, 27.2 × 21.9 mm (NNU-167462-01) (A, B). *Songpotamon malipoense* gen. et sp. nov., holotype ♂, 21.7 × 16.8 mm (NNU-167444-01) (C, D) A, C dorsal view of left G1 B, D ventral view of left G1. Scale bars: 1 mm.

sub-hepatic and pterygostomial regions with small, rounded granules (Fig. 7B, C). Antennular fossae semi-circular; median lobe of epistome posterior margin broadly triangular (Fig. 7B). Exopod of third maxilliped reaching beyond antero-lateral corner of ischium, without flagellum (Fig. 8C). Thoracic sternites 3/4 in

male fused except for relatively shallow, incomplete groove demarcating suture (Figs 7C, 8E, G). Vulvae transversely ovate, closely located to each other, touching suture of thoracic sternites 5/6, opened inwards (Fig. 8H). Male pleon narrowly triangular; somite 6 relatively narrow, width $\sim 2.5\times$ as length (Fig. 8E). G1 slender, reaching beyond pleonal locking tubercle up to suture between thoracic sternites 4/5 *in situ* (Figs 8G, 9D, E, 10C, D); subterminal segment relatively slender, gently sinuous, inner margin almost straight; terminal segment short, slender, subconical, relatively less strongly bent at $\sim 30^\circ$ outwards, $\sim 0.4\times$ length of subterminal segment, with distinct groove for G2 on ventral side, tip subtruncate, recurved upwards (Figs 9D, E, 10C, D). G2 longer than G1; terminal segment relatively short; subterminal segment $\sim 5\times$ length of terminal segment (Fig. 9F).

Description. Medium sized (adult carapace width 19–22 mm, $n = 7$). Carapace broader than long, ovate; dorsal surface convex transversely, longitudinally, smooth, pitted, regions not clear; branchial region swollen, smooth (Fig. 7A). Postorbital and epigastric cristae inconspicuous, not confluent, separated by shallow groove; epigastric cristae weakly developed, oblique, separated by deep inverted Y-shaped groove; postorbital cristae low, weakly rugose, reaching epibranchial tooth (Fig. 7A). Cervical groove distinct, shallow (Fig. 7A). External orbital angle bluntly triangular, outer margin convex, with shallow cleft demarcating it from epibranchial tooth; epibranchial tooth weakly developed (Fig. 7A). Anterolateral margin of carapace convex, cristate, granular; posterolateral margin straight, with multiple weakly oblique striae, converging towards posterior carapace margin (Fig. 7A). Orbits large; supraorbital and infraorbital margins smooth; sub-orbital regions smooth, sub-hepatic and pterygostomial regions with small, rounded granules (Fig. 7B, C). Antennular fossae semi-circular in anterior view; median lobe of epistome posterior margin broadly triangular (Fig. 7B). Third maxilliped with subrectangular ischium; exopod of third maxilliped reaching beyond anterolateral corner of ischium, without flagellum (Fig. 8C).

Chelipeds unequal (Figs 7A, C, 8A, B). Merus trigonal in cross section; margins crenulated (Fig. 7A, C). Carpus with bluntly stout spine at inner-distal angle (Fig. 7A, C). Major cheliped palm length $\sim 1.2\times$ as height (Fig. 8A). Occlusal margin of fingers with rounded, blunt teeth; distinct gape when closed (Fig. 8A).

Ambulatory legs not elongated, slender dactyli (Figs 7A, C, 8D); second pair longest, last pair shortest (Fig. 7A, C). Outer surface of merus slightly rugose, dorsal margin weakly serrated, without subdistal tooth, length $\sim 3.5\times$ as width (Fig. 8D).

Male thoracic sternum generally smooth, weakly pitted; sternites 1/2 fused forming triangular structure (Figs 7C, 8E, G); sternites 2/3 demarcated by horizontal groove; sternites 3/4 fused except for relatively shallow, incomplete groove demarcating suture (Figs 7C, 8E, G); median longitudinal suture of sternites 7/8 deep (Fig. 8E, G). Vulvae transversely ovate, closely located to each other, touching suture of thoracic sternites 5/6, opened inwards, posteromesial margin with low raised rim (Fig. 8H).

Male pleon narrowly triangular; telson relatively broad, lateral margins slightly convex, width $\sim 1.3\times$ as length (Figs 7C, 8E); somite 6 broadly rectangular, width $\sim 2.5\times$ as length; suture between somites 6/7 sinuous; somites 3–5 trapezoidal, gradually decreasing in width; somite 2 trapezoidal, reaching to bases of coxae of fourth ambulatory legs; thoracic sternite 8 not visible when pleon closed (Figs 7C, 8E). Female pleon ovate, covering most of thoracic sternum (Fig. 8F).

G1 slender, reaching beyond pleonal locking tubercle up to suture between thoracic sternites 4/5 *in situ*, with terminal and subterminal segments clearly demarcated (Figs 8G, 9D, E, 10C, D); subterminal segment relatively slender, gently sinuous, distal part prominently narrow, inner margin almost straight (Figs 9D, E, 10C, D); terminal segment short, slender, subconical, relatively less strongly bent at $\sim 30^\circ$ outwards, $\sim 0.4\times$ length of subterminal segment, outer margin convex, inner margin convex, with distinct groove for G2 on ventral side, tip subtruncate, recurved upwards (Figs 9D, E, 10C, D). G2 longer than G1, terminal segment relatively short; subterminal segment $\sim 5\times$ length of terminal segment (Fig. 9F).

Etymology. The species is named after Malipo County, the type locality of the new species in the Yunnan Province of China.

Colour in life. The dorsal surface of the carapace is dark brown, with brighter chelae; the ventral surface is paler.

Habitat. *Songpotamon malipoense* gen. et sp. nov. is usually found hiding under rocks in small hill streams. Some large specimens have nevertheless been collected from deep mud burrows at the bank of hill streams, suggesting a semi-terrestrial lifestyle.

Remarks. The new species superficially resembles *S. dixuense* comb. nov. in overall carapace physiognomy, especially in possessing the granular anterolateral margin of the carapace and the relatively slender G1. *Songpotamon malipoense* gen. et sp. nov., however, can immediately be distinguished from *S. dixuense* comb. nov. by the following characters: 1) carapace dorsal surface glabrous, with dense pits (Fig. 7A) (vs with few short setae and scattered pits); 2) inverted Y-shaped groove between the epigastric cristae relatively deep (Fig. 7A) (vs relatively shallow); 3) chela generally smooth on the outer surface (Fig. 8A) (vs relatively rugose); 4) pterygostomial regions with prominent rounded granules (Fig. 7B) (vs relatively smooth); 5) antennular fossae rectangular in anterior view (Fig. 7B) (vs slit-like); 6) median tooth on the epistome posterior margin broadly triangular (Fig. 7B) (vs narrowly triangular); 7) male pleonal somite 6 relatively narrower (vs relatively broader); and 8) G1 with an almost straight inner margin of the subterminal segment (Fig. 9D, E, 10C, D) (vs with a gently concave inner margin) (cf. Naruse et al. 2018: figs 24A, B, 25B, 26A, C). Biogeographically, these two species are also isolated due to their occurrence in different drainages, with the new species in the Yuanjiang-Red River Basin and *S. dixuense* comb. nov. in the Pearl River Basin (Fig. 1). *Songpotamon malipoense* gen. et sp. nov. need not be confused with *S. funingense* gen. et sp. nov. (see Remarks for the latter new species).

Geographic distribution. *Songpotamon malipoense* gen. et sp. nov. is known from Malipo County, southern Wenshan Prefecture, Yunnan Province, southwest China.

Phylogenetic analysis and discussion

A total of 18 potamid species from 10 genera, including the new genus and two new species, and *P. yuxiense*, were used in the analysis. A 490 bp 16S rDNA segment, excluding the variable regions, was aligned. ML and BI analyses resulted in congruent tree topologies with some minor differences in the terminal lineages. The phylogenetic results inferred that two new species and

S. dixuense comb. nov. formed a well-supported monophyletic lineage (Fig. 11). *Parvuspotamon yuxiense* is situated at a basal position and is far away from the new genus, *Songpotamon* gen. nov., in the phylogenetic tree. *Songpotamon* gen. nov. is phylogenetically more closely related to *Diyutamon* Huang, Shih & Ng, 2017, and *Chinapotamon* than to *Parvuspotamon*, occurring in southeast Yunnan. These genera, however, are not only morphologically distinct but also characterised by different geographic distributions and habitats, i.e., *Diyutamon* colonised subterranean karst streams (Huang et al. 2017), and *Chinapotamon* occurred in both subterranean karst streams and hill streams (Dai and Naiyanetr 1994; Ng 2017; Zou et al. 2018).

The phylogenetic trees suggested that two new species of *Songpotamon* gen. nov. cluster with their congener *S. dixuense* comb. nov. *Songpotamon malipoense* gen. et sp. nov. is close to *S. dixuense* comb. nov. (PP/BV = 0.96/89), whereas *S. funingense* gen. et sp. nov. is positioned outside (PP/BV = 1/100). The pairwise distance based on the Kimura 2 parameter model showed that most of the pairwise genetic distances between the 12 species beyond a threshold of 0.04 (Table 1). The genetic distances between *Songpotamon* gen. nov. and the other genera ranged from 0.042 to 0.178, and the minimum value

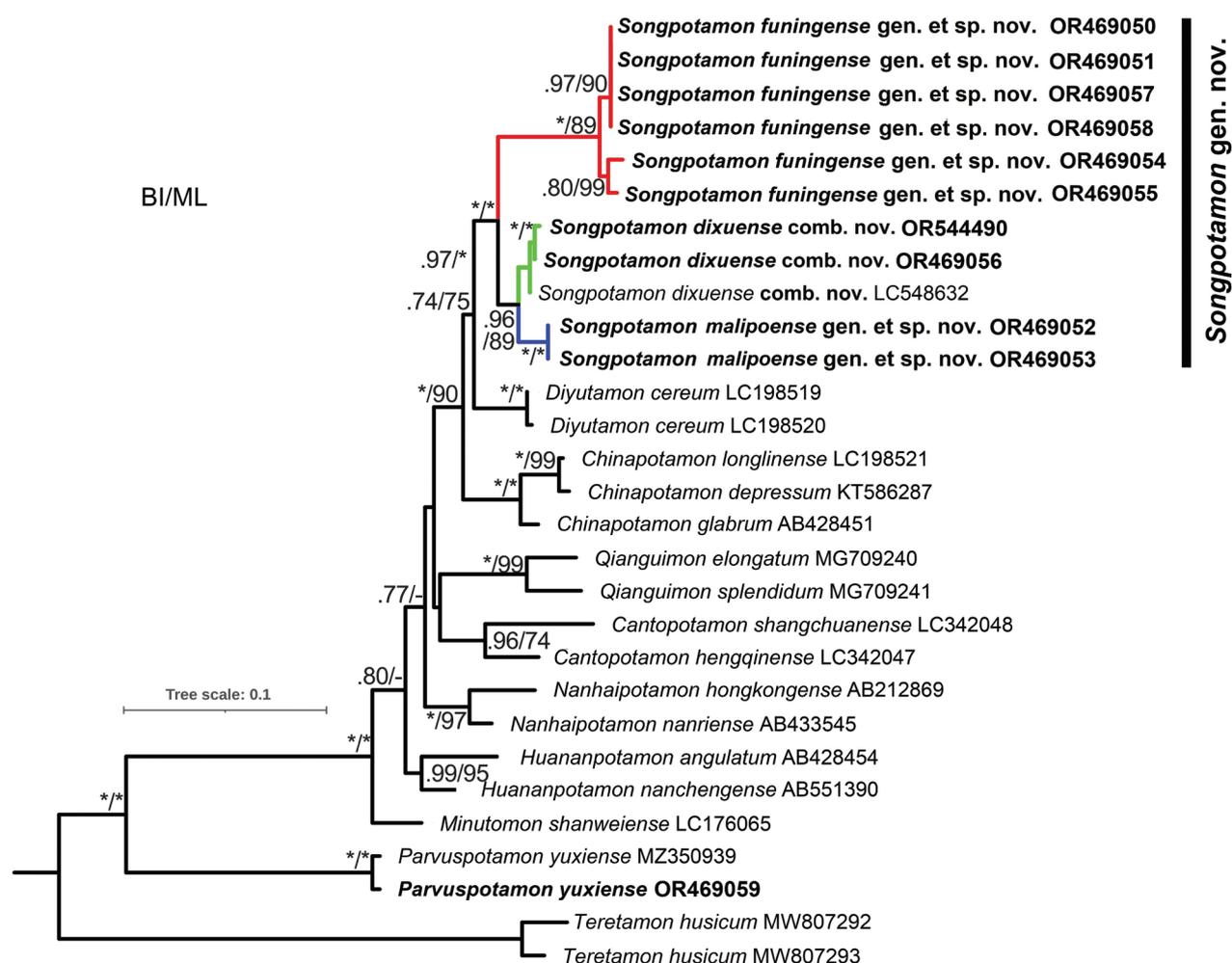


Figure 11. Maximum Likelihood phylogenetic tree based on 16S rDNA sequences. Support values at the nodes represent the > 50% posterior probabilities (PP) and bootstrap values (BV) for BI and ML (PP/BV), respectively. The new sequences are indicated in bold font. Asterisks indicate PP = 1.00 or BS = 100.

Table 1 Matrix of pairwise nucleotide divergences based on the Kimura 2 parameter model using 16S rDNA sequences between the species of *Songpotamon* gen. nov., *Parvuspotamon*, *Cantopotamon*, *Chinapotamon*, *Diyutamon*, and *Qianguiimon*.

	1	2	3	4	5	6	7	8	9	10	11
1. <i>Parvuspotamon yuxiense</i>											
2. <i>Cantopotamon hengqinense</i>	0.135										
3. <i>Cantopotamon shangchuanense</i>	0.148	0.059									
4. <i>Chinapotamon longlinense</i>	0.162	0.073	0.080								
5. <i>Chinapotamon depressum</i>	0.159	0.073	0.088	0.006							
6. <i>Chinapotamon glabrum</i>	0.165	0.064	0.083	0.026	0.028						
7. <i>Diyutamon cereum</i>	0.148	0.062	0.074	0.053	0.055	0.046					
8. <i>Qianguiimon elongatum</i>	0.156	0.068	0.075	0.080	0.082	0.080	0.069				
9. <i>Qianguiimon splendidum</i>	0.154	0.080	0.085	0.090	0.092	0.085	0.067	0.041			
10. <i>Songpotamon dixuense</i> comb. nov.	0.163	0.067	0.088	0.062	0.065	0.044	0.042	0.078	0.081		
11. <i>Songpotamon malipoense</i> gen. et sp. nov.	0.160	0.068	0.090	0.066	0.068	0.052	0.044	0.084	0.084	0.042	
12. <i>Songpotamon funingense</i> gen. et sp. nov.	0.178	0.083	0.097	0.084	0.087	0.068	0.074	0.098	0.104	0.054	0.060

within *Songpotamon* gen. nov. was 0.042. Considering the profound morphological differences and the genus/species level genetic divergence among these genera and species, we revealed that *Songpotamon* gen. nov. and the two new species of this new genus, indeed represent distinct taxa of Potamidae.

Geographically, the three species of *Songpotamon* gen. nov. occur in two different drainages, with *S. dixuense* comb. nov. occurring in the Tuoniang River (tributaries of the Pearl River), and the two new species in the Panlong River and Nanli River, respectively (tributaries of Yuanjiang-Red River) (Fig. 1). Previous studies of stream-associated freshwater crabs have shown that drainage systems can drive species divergence and biogeographical patterns (Daniels et al. 2015; Fang et al. 2015; Shi et al. 2021). In the present study, we inferred the two hydrologic systems may contributed the genetic divergence between *S. dixuense* comb. nov. and the two new species of *Songpotamon* gen. nov. Meanwhile, the species divergence between two new species may be attributed to local adaptive evolution in different tributaries.

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Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statement

No ethical statement was reported.

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Author contributions

B.Y. Shi, D. Pan, and H.Y. Sun conceived the study; B.Y. Shi and H.Y. Sun collected the samples; B.Y. Shi prepared them for DNA sequencing and carried out the analyses; B.Y. Shi, D. Pan, and H.Y. Sun wrote and approved the final manuscript.

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Data availability

All of the data that support the findings of this study are available in the main text.

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Checklist, distribution, diversity, and rarity of mayflies (Ephemeroptera) in Slovakia

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Abstract

Despite the essential role of mayflies (Ephemeroptera) in freshwater ecosystems and their long-term use in research and routine biomonitoring in the Carpathian and Pannonian ecoregions, their distribution data are fragmentary and outdated. All published and unpublished data on mayflies from Slovakia was gathered and a database of > 15,000 species records from 2206 localities built with the aims (i) to critically revise available data and assess the completeness of the species inventory, (ii) to identify hotspots of species diversity, and (iii) to provide a benchmark for assessment of species rarity and conservation status in the region. After the critical revision of the data covering more than 100 years, the occurrence of 109 mayfly species in Slovakia was confirmed. The species inventory appears to be nearly complete, as evidenced by the rarefaction curve and a nonparametric species richness estimator. The highest mayfly gamma diversity was recorded below 500 m a.s.l. and in streams of the fifth order, which can be considered hotspots of mayfly diversity in the region. Six species were last recorded before 1990 and thus can be considered extinct in Slovakia. Twenty-nine species could be classified as very rare, with their occurrence frequency decreasing with increasing altitude and most of them being restricted to large lowland rivers and stagnant water habitats in their floodplains. In conclusion, our study provides comprehensive data on key freshwater bioindicators and suggests increasing conservation priorities, especially in lowland river floodplains occupied by several very rare mayfly species.

Key words: Freshwater bioindicators, lowland rivers, rare taxa, species frequency, species richness

Introduction

Mayflies (Ephemeroptera) represent one of the oldest insect orders, whose origin dates back to the late Carboniferous (Sartori and Brittain 2015), and together with dragonflies and damselflies (Odonata), they are considered the sister lineage to all other winged orders of insects (Thomas et al. 2013). Their long evolutionary history has resulted in extraordinary morphological and ecological diversity, especially in nymphs, reflected in the diverse types of feeding,



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locomotion, occupied microhabitats, life cycles or overall requirements for abiotic and biotic environmental conditions (Sartori and Brittain 2015; Jacobus et al. 2019). Mayflies colonise a broad spectrum of freshwater habitats on almost all continents except Antarctica and some remote islands (Sartori and Brittain 2015). However, among the eight major aquatic insect lineages, mayflies are among the least species rich (Dijkstra et al. 2014), but their nymphs constitute a significant part of the macroinvertebrate biomass and production in lotic habitats (Brittain and Sartori 2009). Mayfly nymphs are essential consumers of periphyton and detritus and serve as prey for predators such as fish, amphibians, or predaceous invertebrates (Wallace and Webster 1996; Baptista et al. 2006). They participate in maintaining important ecosystem functions, such as bioturbation, bio-irrigation, decomposition, and self-cleaning processes, which support the natural balance of the whole system (Jacobus et al. 2019). The cosmopolitan distribution of mayflies and their high-water quality requirements make them essential bioindicators of water and habitat quality (Baptista et al. 2001; Medina and Vallania 2001; Arimoro and Muller 2010) and an integral part of biomonitoring protocols (Menetrey et al. 2008; Makovinská et al. 2015) and metrics (e.g., EPT richness; Lewin et al. 2013; Wright and Ryan 2016).

The extant global Ephemeroptera fauna encompasses almost 3800 species in 478 genera and 42 families (Sartori and Brittain 2015; Jacobus et al. 2021), with the highest generic diversity occurring in the Neotropics and the lowest in the Palearctic (but with the highest number of recorded species, Barber-James et al. 2008). From a taxonomic perspective, North America and Europe are the best-explored parts of the world (Sartori and Brittain 2015). The last checklist of mayfly fauna covering most of the Western Palearctic reported 369 species in 48 genera and 19 families (Bauernfeind and Soldán 2012). In general, the diversity of mayflies is low in alpine habitats, while meta- and hyporhithral sections in the coline or lower mountain zones are inhabited by many species (Landolt and Sartori 2001; Bauernfeind and Soldán 2012). Some studies also indicate a high diversity of mayflies in pristine lowland rivers (Bauernfeind and Moog 2000), which are currently known to be the most affected by the reduction of potamal specialists (Zedková et al. 2015). However, more extensive data summarising the diversity of mayflies depending on basic characteristics such as hypsometric distribution, stream order or the habitat classification of running waters (according to Illies 1953 and Illies and Botosaneanu 1963) are largely absent in many European regions, and the current knowledge is thus based on only a few studies (e.g., Landa and Soldán 1989; Bauernfeind and Moog 2000; Landolt and Sartori 2001).

The first faunistic records of mayflies from today's territory of Slovakia extended to the Austro-Hungarian Empire (Mocsáry 1875, 1878; Petricskó 1892), and the first "checklist" was presented by Mocsáry (1899), who reported 11 species. This list was later expanded to 33 species (Pongrácz 1914). Later, most of the research on mayflies was local and faunistic in nature, often associated with the first records of several species (for a synopsis, see Derka 2006). Previous knowledge was summarised by Landa (1969), who processed data on the distribution, ecology, and taxonomy of 78 mayfly species reported from Czechoslovakia, 68 of which were recorded in today's territory of Slovakia. Subsequent decades have seen significant progress in mayfly taxonomic knowledge in Central Europe, with revisions of several groups and descriptions of many new species (e.g., Landa 1970; Sowa 1971; Sowa 1981; Sowa and

Soldán 1986; Klonowska et al. 1987). Extensive faunistic-ecological investigations consequently characterised the turn of the 1970s and 1980s, and new data on the distribution and ecology of mayflies were obtained as part of broadly focused hydrobiological studies in Slovakia (for a synopsis, see Derka 2006). Landa and Soldán (1989) summarised the long-term research on mayflies in Czechoslovakia concerning water quality, and the number of species reported from Slovakia rose to 94. Finally, the latest catalogue contains as many as 123 species from 37 genera and 16 families, unfortunately without a closer specification of the respective species findings (Derka 2003a) but with a relatively detailed overview of their autecological characteristics (Derka 2003b).

Despite the long tradition of European mayfly faunistic research, checklists are missing in several European countries, including Slovakia, and only a few of them can be considered reliable [e.g., Czech Republic – Zahrádková et al. (2009); Germany, Austria, and Switzerland – Haybach (2010); Austria – Weichselbaumer et al. (2015); Serbia – Petrović et al. (2015); Kosovo – Xërxa et al. (2019); Croatia – Vilenica et al. (2021)]. Our first aim was (i) to critically revise the species list and assess the completeness of the species inventory in Slovakia. Hydro-morphological modifications of rivers, construction of hydropower plants, water pollution, the spread of invasive species and the effects of climate change have recently caused excessive degradation and loss of natural freshwater habitats (Dudgeon et al. 2006; Carpenter et al. 2011), leading to a significant change in communities and a decrease in freshwater biodiversity (Zedková et al. 2015; Sánchez-Bayo and Wyckhuys 2019; Rumschlag et al. 2023). Therefore, we also aimed (ii) to identify regional hotspots of mayfly species diversity and (iii) to provide a benchmark for assessing species rarity and conservation status in the region.

Materials and methods

Study area

Although the majority of the area of Slovakia (49,035 km²; 16°50–22°34'E, 47°44–49°37'N) belongs to the Carpathian Mountains system (Mráz and Ronikier 2016), the territory belongs to the Carpathian and Pannonian ecoregions (Illies 1978; Hók et al. 2019). Substantial landscape diversity (from lowlands to mountains) results in high variability of annual temperature (~ 0.3–11.4 °C), precipitation (500–1400 mm) and elevation (94–2654 m a.s.l.). Most of the largest rivers originate in the central arch of the Western Carpathians and drain to the Danube River basin. Up to 47,056 km² of the country belongs to the Black Sea drainage area, whereas the minority (1953 km²) drains into the Baltic Sea (Vistula River Basin; Miklós 2002).

Dataset

The data in this study are compiled from two primary sources:

1. Published data. Records of mayflies in Slovakia were gathered from 91 publications and six monographic studies covering the period from 1905 to 2021 (see Suppl. material 1 for publication references). Only one work was published in 1905, 66 between 1950 and 1999, and 33 since 2000.

2. Field survey. Qualitative and quantitative sampling of mayflies was performed at 317 localities during 2003–2021, with more than 1/3 occurring during 2019–2021. Various lotic and lentic habitats were sampled, from springs to potamal sections of the largest rivers and from the lowlands to the high alpine lakes and ponds. Most of the material processed was represented by nymphs, mainly sampled by the kick netting (Frost et al. 1971) or resulting from individual collections from specific types of microhabitats (e.g., clay banks). A negligible part of the material was represented by adults obtained by sweep netting. The material was preserved in situ with 96% ethanol or 4% formaldehyde. Subsequently, individuals were examined under a stereomicroscope for assignment to higher taxonomic groups. Finally, most of the individuals were identified to the species level using the identification keys of Bauernfeind and Humpesch (2001), Eiseler (2005) and Krno and Derka (2011). Voucher material is stored in the collection of the Department of Ecology, Comenius University, Bratislava, Slovakia, and the Department of Biology and General Ecology, Technical University, Zvolen, Slovakia.

Data handling and analysis

Overall, we processed data on mayfly occurrence from 2206 localities (Fig. 1, see Suppl. material 1 for details on collection data) located within the altitudinal range 94–2091 m a.s.l., with a majority situated between 192 and 587 m a.s.l. Lotic ecosystems represented more than 93% of all localities, covering a broad spectrum of aquatic environments from springs and small creeks to large lowland rivers. Alpine lakes and ponds, reservoirs, gravel pits, wetlands or temporary ponds in inundated areas represented lentic ecosystems.

For taxonomic consistency, we used the nomenclature according to Bauernfeind and Soldán (2012), even though several subgenera listed in this study are now commonly considered as genera (e.g., Waltz et al. 1994; Cruz et al. 2021). The final dataset includes only records identified at the species level, except for five taxa with insufficient taxonomical characters in the nymphal stage (refer to Results). Taxa classified by Bauernfeind and Soldán (2012) as “*species inquirenda*” in the latest checklist of mayflies in Europe were excluded from the dataset. This category includes species whose taxonomic position is unclear, and it is impossible to decide whether they represent valid species or should be regarded as subspecies or conspecifics of another species. Another category of excluded taxa includes dubious species, whose findings in Slovakia were based on misidentification as determined in our morphological revision or literature review, demonstrating their highly improbable distribution in the territory (Bauernfeind and Soldán 2012). To evaluate the last record of the species in our territory, we used four time periods (\leq 1990, 1991–2000, 2001–2010, and 2011–2021), which correspond to the period when the collection of the species was published, since in several publications it is not possible to determine the exact time of collection, or it is a longer period.

Geographical coordinates of sampling localities were directly measured in the field, extracted from publications, or determined by the most accurate estimate using the online software Mapy.cz (<https://mapy.cz>) based on the description of the investigated site in the source publication. Elevation data were determined using Google Earth Pro 7.3.6.9345 or extracted from publications. Repeated samples from the same localities were pooled, and species data were presented only once.

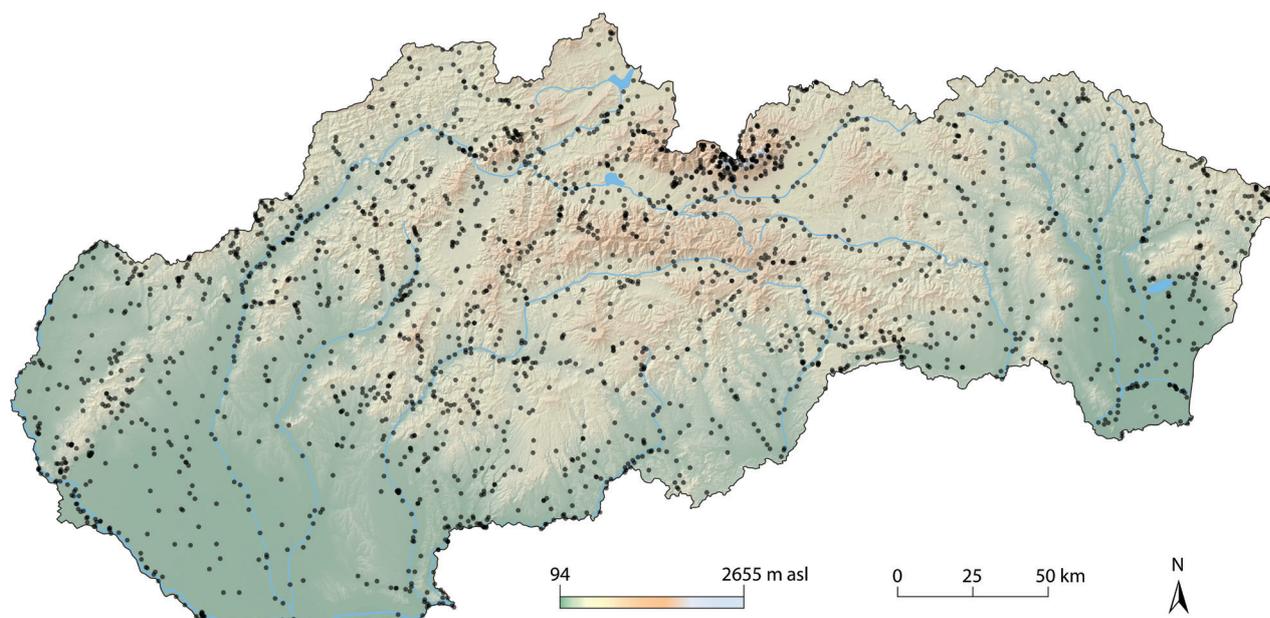


Figure 1. Spatial distribution of localities sampled for mayflies in Slovakia from 1905 to 2021.

We constructed an analytical sample-based rarefaction curve with unconditional confidence intervals (Colwell et al. 2004) to assess the completeness of the mayfly species inventory. In addition, we used the asymptotic richness estimator Chao2 (Chao 1987) to estimate the total number of mayfly species, including unobserved species. Since the detection probabilities of the species were relatively homogeneous (coefficient of variation of infrequent species = 0.35), we used the bias-corrected form of the estimator (Chao 2005).

To explore the species hypsometric distribution, we created a series of box-plots showing altitudinal optima (median) and variation in species occurrence along a 2000 m elevation gradient. The same approach has been employed to investigate species distributions based on rarity level. To evaluate species rarity based on the frequency of occurrence (i.e., the number of localities with the positive occurrence of the species), we used a five-degree scale developed by Sartori and Landolt (1999): F1 – very rare (up to 10 localities of occurrence), F2 – rare (11–25 localities), F3 – uncommon (26–50 localities), F4 – common (51–100 localities), and F5 – widespread (over 100 localities). This scale was designed for mayflies concerning the order's chorological specificity and has already been applied in other European countries with similar species compositions (e.g., Switzerland – Landolt and Sartori 2001; Czech Republic – Zahradková et al. 2009), which enables comparison.

Since sampling frequency and collection methods changed considerably among sampling localities, we decided not to compare site-level mayfly diversity. However, we divided the studied altitudinal gradient into four 500 m-wide altitudinal belts (< 500 m, 501–1000 m, 1001–1500 m, and > 1501 m) and estimated the total number of mayfly species (the concept of gamma diversity according to Whittaker 1960) expected in each belt, which diminished the potential bias introduced by different sampling strategies. Since the number of localities varied widely among the belts (80–1528 localities), we standardised the sampling effort and estimated the expected total number of species at 80 localities in each belt using sample-based interpolation (Colwell et al. 2004).

Since mayflies are predominantly stream-dwelling insects, we also explored diversity patterns among streams of different orders. Each lotic site was classified according to Strahler's system using the EU-Hydro River-Net dataset, a high-resolution pan-European hydrographic database (Gallaun et al. 2019). Again, sample-based interpolation was used to estimate the total number of species in each stream order, standardising the sampling effort to 100 streams. We restricted the analysis to localities with stream orders ranging from 1 to 6 because higher-order streams were sampled rarely.

The analysis was performed in R (R Development Core Team 2022) using the packages *ggplot2* (Wickham 2016) and *iNEXT* (Chao et al. 2014).

Results

Checklist

Our extensive field survey resulted in the identification of 91 mayfly species. A literature review of all available publications related to mayflies revealed additional 40 taxa. Finally, the total number of species ever reported from the territory of Slovakia is 131. However, the detection of 15 species was evaluated as dubious, and seven observations were assigned "*species inquirenda*". Hence, the current checklist of mayflies includes 109 species (Table 1). The delimitation of four species from the genus *Rhithrogena* is unclear, and therefore, we treated them as *Rhithrogena iridina* + *R. picteti* and *R. carpatoalpina* + *R. puytoraci*. *Ecdyonurus nigrescens* is reported with cf. (confer) due to ambiguous determining characters, which requires future comparison with the type material. More than 55% of the species belong to families Heptageniidae and Baetidae, nine families are monogeneric, and seven are monospecific. Finally, we report the following species richness for the detected families: Heptageniidae – 35, Baetidae – 27, Caenidae – 12, Leptophlebiidae – 9, Ephemerellidae – 5, Oligoneuridae, Ephemeridae and Siphonuridae – 4, Ameletidae – 2, and Ametropodidae, Isonychiidae, Arhthropleidae, Behningiidae, Palingeniidae, Polymitarciidae and Potamanthidae – 1. The mayfly species inventory of Slovakia seems to be nearly complete as the accumulation curve reached an asymptote (Fig. 2). The expected total number of species calculated by the bias-corrected Chao2 estimator was 111, meaning that only two species are expected to remain undetected.

Species distribution and diversity

Baetis rhodani was the most frequently occurring species, whereas *Behningia ulmeri*, *Oligoneuriella polonica*, *O. pallida*, and *Oligoneurisca borysthenica* were found at only a single location. Most of the mayfly species had optimal altitudinal distributions below 500 m, and only a few species were typical of the mountain areas (e.g., *Ameletus inopinatus*, *Rhithrogena loyolaea*, *Rhithrogena hercynia*, and *Rhithrogena circumtatrica*) (Suppl. material 2). The broadest amplitudes were recorded for *Baetis alpinus* (elevation range of 1982 m), *B. vernus* (1877 m), and *B. rhodani* (1871 m). Mayfly preferences for lower altitudes were also apparent in the gamma diversity patterns. The highest number of species was found at elevations below 500 m a.s.l. (72 spp.), while the gamma diversity decreases steeply towards higher altitudes (Fig. 3A). Considering the lotic

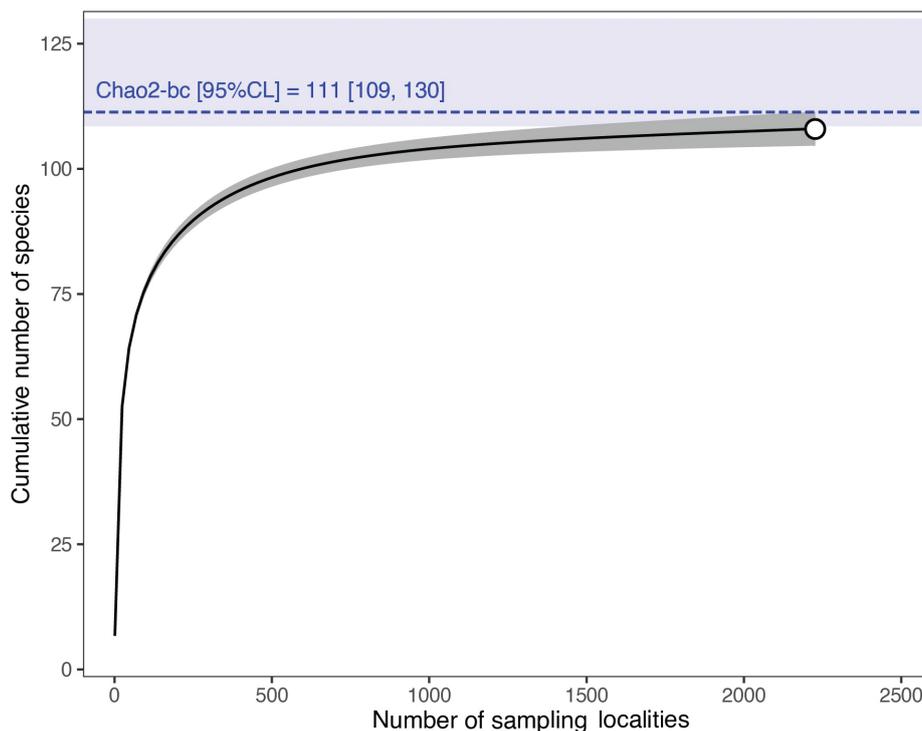


Figure 2. Sample-based rarefaction curve of mayfly species richness in Slovakia. The shaded area around the curve indicates the 95% confidence interval. The dashed line (\pm 95% confidence interval in blue) represents an estimate of the total number of species based on the bias-corrected Chao2 estimator (Chao2-bc).

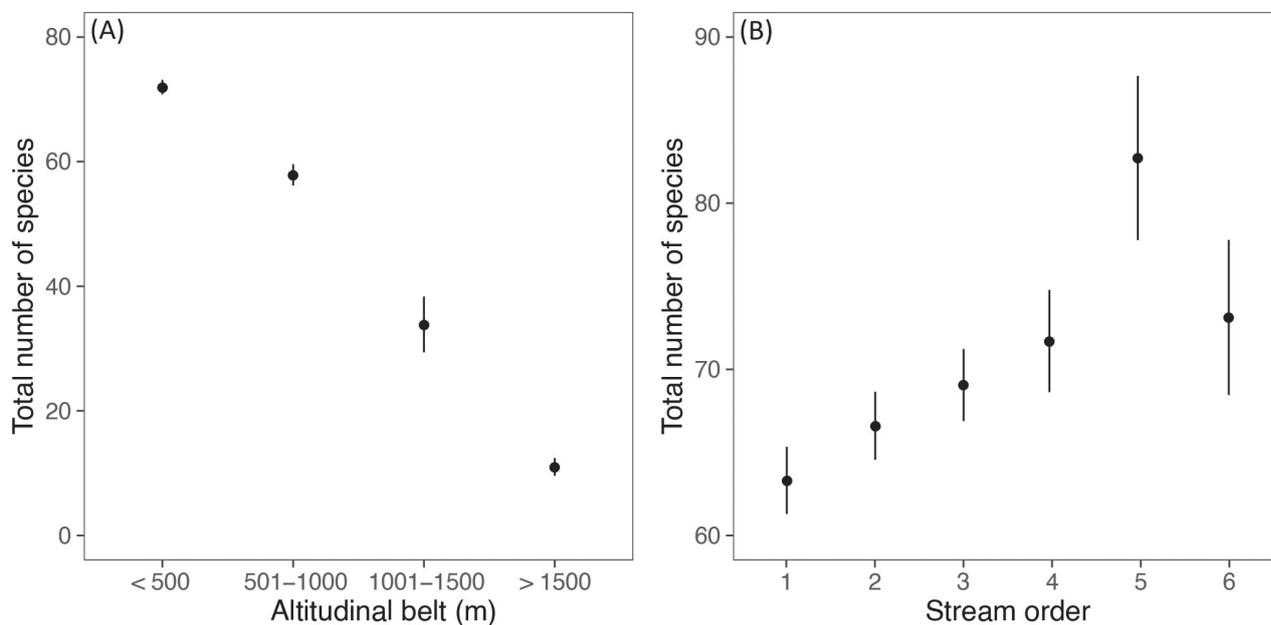


Figure 3. Total number of mayfly species (gamma diversity) according to **A** altitudinal belts and **B** stream orders. The estimated total number of species (black circle) is displayed with 95% confidence intervals (error bars).

species, mayfly gamma diversity showed a unimodal pattern along stream orders, with the highest number of species expected in streams of the fifth order (83 spp.) (Fig. 3B).

Table 1. Checklist of mayflies occurring in Slovakia and their species rarity (F1 to F5, see Material and Methods) according to Sartori and Landolt (1999), with the number of findings in brackets and the period of the last record according to the year of publication (++++ = ≤1990; +++ = 1991–2000; ++ = 2001–2010; + = 2011–2021). Excluded species are presented at the end of the checklist (*species inquirenda* and dubious findings). The species list is arranged by family, genus (subgenus), and species according to taxonomic nomenclature of Bauernfeind and Soldán (2012).

Taxa	Species rarity	Last record
AMELETIDAE Mc Cafferty, 1991		
Ameletus Eaton, 1885		
<i>Ameletus inopinatus</i> Eaton, 1887	F4 (92)	+
Metreletus Demoulin, 1951		
<i>Metreletus balcanicus</i> (Ulmer, 1920)	F1 (8)	+
SIPHONURIDAE Ulmer, 1920 (1888)		
Siphonurus (Siphonurus) Eaton, 1868		
<i>Siphonurus (Siphonurus) aestivalis</i> Eaton, 1903	F3 (43)	+
<i>Siphonurus (Siphonurus) armatus</i> Eaton, 1870	F2 (17)	+
<i>Siphonurus (Siphonurus) lacustris</i> Eaton, 1870	F2 (19)	+
Siphonurus (Siphurella) Say, 1824		
<i>Siphonurus (Siphurella) alternatus</i> (Say, 1824)	F1 (5)	++
AMETROPODIDAE Bengtsson, 1913		
Ametropus Albarda, 1878		
<i>Ametropus fragilis</i> Albarda, 1878	F1 (4)	+
BAETIDAE Leach, 1815		
Baetis (Acentrella) Bengtsson, 1912		
<i>Baetis (Acentrella) inexpectatus</i> (Tshernova, 1928)	F1 (7)	++++
<i>Baetis (Acentrella) sinaicus</i> Bogoescu, 1931	F2 (12)	+
Baetis (Baetis) Leach, 1815		
<i>Baetis (Baetis) alpinus</i> (Pictet, 1843)	F5 (621)	+
<i>Baetis (Baetis) buceratus</i> Eaton, 1870	F5 (288)	+
<i>Baetis (Baetis) fuscatus</i> (Linnaeus, 1761)	F5 (453)	+
<i>Baetis (Baetis) liebenauae</i> Keffermüller, 1974	F3 (26)	+
<i>Baetis (Baetis) lutheri</i> Müller-Liebenau, 1960	F5 (349)	+
<i>Baetis (Baetis) melanonyx</i> (Pictet, 1843)	F5 (153)	+
<i>Baetis (Baetis) pentaplebodes</i> Ujhelyi, 1966	F5 (136)	+
<i>Baetis (Baetis) scambus</i> Eeaton, 1870	F5 (287)	+
<i>Baetis (Baetis) tracheatus</i> Keffermüller & Machel, 1967	F1 (8)	+
<i>Baetis (Baetis) vardarensis</i> Ikononov, 1962	F5 (221)	+
<i>Baetis (Baetis) vernus</i> Curtis, 1834	F5 (529)	+
Baetis (Labiobaetis) Novikova & Kluge, 1987		
<i>Baetis (Labiobaetis) tricolor</i> Tshernova, 1928	F2 (24)	+
Baetis (Nigrobaetis) Novikova & Kluge, 1987		
<i>Baetis (Nigrobaetis) gracilis</i> Bogoescu & Tabacaru, 1957	F1 (6)	++
<i>Baetis (Nigrobaetis) muticus</i> (Linnaeus, 1758)	F5 (506)	+
<i>Baetis (Nigrobaetis) niger</i> (Linnaeus, 1761)	F4 (54)	+
Baetis (Rhodobaetis) Jacob, 2003		
<i>Baetis (Rhodobaetis) rhodani</i> (Pictet, 1843)	F5 (1322)	+
Baetopus (Raptobaetopus) Müller-Liebenau, 1978		
<i>Baetopus (Raptobaetopus) tenellus</i> (Albarda, 1878)	F1 (5)	+

Taxa	Species rarity	Last record
Centroptilum Eaton, 1869		
<i>Centroptilum luteolum</i> (O. F. Müller, 1776)	F5 (135)	+
Cloeon (Cloeon) Leach, 1815		
<i>Cloeon (Cloeon) dipterum</i> (Linnaeus, 1761)	F5 (282)	+
Cloeon (Similicloeon) Kluge & Novikova, 1992		
<i>Cloeon (Similicloeon) simile</i> Eaton, 1870	F3 (32)	+
Procloeon (Procloeon) Bengtsson, 1915		
<i>Procloeon (Procloeon) bifidum</i> (Bengtsson, 1912)	F4 (78)	+
<i>Procloeon (Procloeon) ornatum</i> Tshernova, 1928	F1 (9)	++
Procloeon (Pseudocentroptilum) Bengtsson, 1915		
<i>Procloeon (Pseudocentroptilum) macronyx</i> Kluge & Novikova, 1992	F1 (7)	+
<i>Procloeon (Pseudocentroptilum) pennulatum</i> (Eaton, 1870)	F3 (49)	+
<i>Procloeon (Pseudocentroptilum) pulchrum</i> (Eaton, 1885)	F1 (1)	+
ISONYCHIIDAE Ulmer, 1914		
Isonychia (Isonychia) Eaton, 1871		
<i>Isonychia (Isonychia) ignota</i> (Walker, 1853)	F1 (8)	+
OLIGONEURIDAE Ulmer, 1914		
Oligoneuriella Ulmer, 1924		
<i>Oligoneuriella pallida</i> (Hagen, 1855)	F1 (1)	++++
<i>Oligoneuriella polonica</i> Mol, 1984	F1 (1)	++++
<i>Oligoneuriella rhenana</i> (Imhoff, 1852)	F4 (90)	+
Oligoneurisca Lestage, 1938		
<i>Oligoneurisca borysthenica</i> (Tshernova 1937)	F1 (1)	++++
ARTHROPLEIDAE Balthasar, 1937		
Arthroplea Bengtsson, 1908		
<i>Arthroplea congener</i> Bengtsson, 1908	F1 (6)	+
HEPTAGENIIDAE Needham, 1901		
Ecdyonurus (Ecdyonurus) Eaton, 1871		
<i>Ecdyonurus (Ecdyonurus) aurantiacus</i> (Burmeister, 1839)	F4 (87)	+
<i>Ecdyonurus (Ecdyonurus) dispar</i> (Curtis, 1834)	F5 (132)	+
<i>Ecdyonurus (Ecdyonurus) insignis</i> (Eaton, 1870)	F3 (32)	+
<i>Ecdyonurus (Ecdyonurus) macani</i> Thomas & Sowa, 1970	F5 (138)	+
<i>Ecdyonurus (Ecdyonurus) starmachi</i> Sowa, 1971	F5 (249)	+
<i>Ecdyonurus (Ecdyonurus) submontanus</i> Landa, 1969	F5 (146)	+
<i>Ecdyonurus (Ecdyonurus) torrentis</i> Kimmins, 1942	F5 (212)	+
<i>Ecdyonurus (Ecdyonurus) venosus</i> (Fabricius, 1775)	F5 (263)	+
Ecdyonurus (Helvetoraeticus) Bauernfeind & Soldán, 2012		
<i>Ecdyonurus (Helvetoraeticus) carpathicus</i> Sowa, 1973	F4 (55)	+
<i>Ecdyonurus (Helvetoraeticus) cf. nigrescens</i> Klapálek, 1908	F1 (4)	+
<i>Ecdyonurus (Helvetoraeticus) picteti</i> (Meyer-Dür, 1864)	F2 (15)	+
<i>Ecdyonurus (Helvetoraeticus) subalpinus</i> Klapálek, 1907	F5 (168)	+
Electrogena Zurwerra & Tomka, 1985		
<i>Electrogena affinis</i> (Eaton, 1883)	F2 (21)	+
<i>Electrogena lateralis</i> (Curtis, 1834)	F5 (129)	+
<i>Electrogena quadrilineata</i> (Landa, 1969)	F2 (25)	+

Taxa	Species rarity	Last record
<i>Electrogena ujhelyii</i> (Sowa, 1981)	F5 (158)	+
Heptagenia (Dacnogenia) Kluge, 1987		
<i>Heptagenia (Dacnogenia) coeruleans</i> Rostock, 1878	F3 (31)	+
Heptagenia (Heptagenia) Walsh, 1863		
<i>Heptagenia (Heptagenia) flava</i> Rostock, 1878	F3 (141)	+
<i>Heptagenia (Heptagenia) longicauda</i> (Stephens, 1836)	F2 (15)	+
<i>Heptagenia (Heptagenia) sulphurea</i> (Müller, 1776)	F5 (166)	+
Heptagenia (Kageronia) Matsumura, 1931		
<i>Heptagenia (Kageronia) fuscogrisea</i> (Retzius, 1783)	F1 (6)	+
Epeorus (Epeorus) Eaton, 1881		
<i>Epeorus (Epeorus) assimilis</i> Eaton, 1885	F5 (504)	+
Rhithrogena Eaton, 1881		
<i>Rhithrogena beskidensis</i> Alba-Tercedor & Sowa, 1987	F5 (119)	+
<i>Rhithrogena carpatoalpina</i> Klonowska et al. 1987 + <i>Rhithrogena puytoraci</i> Sowa & Degrange, 1987	F5 (491)	+
<i>Rhithrogena circumtatica</i> Sowa & Soldán, 1986	F3 (34)	+
<i>Rhithrogena germanica</i> Eaton, 1885	F4 (59)	+
<i>Rhithrogena gorganica</i> Klapálek, 1907	F1 (9)	++
<i>Rhithrogena hercynia</i> Landa, 1969	F3 (36)	+
<i>Rhithrogena iridina</i> (Kolenati, 1839) + <i>Rhithrogena picteti</i> Sowa, 1971	F5 (463)	+
<i>Rhithrogena loyolaea</i> Navás, 1922	F5 (107)	+
<i>Rhithrogena podhalensis</i> Sowa & Soldán, 1986	F1 (5)	+
<i>Rhithrogena savoienensis</i> Alba-Tercedor & Sowa, 1987	F3 (44)	+
<i>Rhithrogena semicolorata</i> (Curtis, 1834)	F5 (608)	+
LEPTOPHLEBIIDAE Banks, 1900		
Choroerpes (Choroerpes) Eaton, 1881		
<i>Choroerpes (Choroerpes) picteti</i> (Eaton, 1871)	F1 (10)	+
Habroleptoides Schönemund, 1929		
<i>Habroleptoides confusa</i> Sartori & Jacob, 1986	F5 (542)	+
Habrophlebia Eaton, 1881		
<i>Habrophlebia fusca</i> (Curtis, 1834)	F4 (99)	+
<i>Habrophlebia lauta</i> Eaton, 1884	F5 (306)	+
Leptophlebia Westwood, 1840		
<i>Leptophlebia marginata</i> (Linnaeus, 1767)	F1 (7)	+
<i>Leptophlebia vespertina</i> (Linnaeus, 1758)	F1 (8)	+
Paraleptophlebia Lestage, 1917		
<i>Paraleptophlebia cincta</i> (Retzius, 1783)	F1 (10)	++
<i>Paraleptophlebia submarginata</i> (Stephens, 1836)	F5 (114)	+
<i>Paraleptophlebia wernerii</i> Ulmer, 1920	F2 (15)	+
BEHNINGIIDAE Motaş & Băcesco, 1937		
Behningia Lestage, 1929		
<i>Behningia ulmeri</i> Lestage, 1929	F1 (1)	++++
EPHEMERIDAE Latreille, 1810		
Ephemera (Ephemera) Linnaeus, 1758		
<i>Ephemera (Ephemera) danica</i> Müller, 1764	F5 (481)	+
<i>Ephemera (Ephemera) lineata</i> Eaton, 1870	F4 (65)	+

Taxa	Species rarity	Last record
<i>Ephemera (Ephemera) vulgata</i> Linnaeus, 1758	F4 (74)	+
<i>Ephemera (Sinephemera)</i> Kluge, 2004		
<i>Ephemera (Sinephemera) glaucops</i> Pictet, 1843	F1 (7)	++++
PALINGENIIDAE Albarda, 1888		
<i>Palingenia</i> Burmeister, 1839		
<i>Palingenia longicauda</i> (Olivier, 1791)	F2 (13)	+
POLYMITARCYIDAE Banks, 1900		
<i>Ephoron</i> Williamson, 1802		
<i>Ephoron virgo</i> (Olivier, 1791)	F3 (43)	+
POTAMANTHIDAE Albarda, 1888		
<i>Potamanthus</i> Pictet, 1843		
<i>Potamanthus luteus</i> (Linnaeus, 1767)	F5 (215)	+
EPHEMERELLIDAE Klapálek, 1909		
<i>Ephemerella</i> Walsh, 1862		
<i>Ephemerella ignita</i> (Poda, 1761)	F5 (576)	+
<i>Ephemerella mesoleuca</i> (Brauer, 1857)	F2 (16)	++
<i>Ephemerella mucronata</i> (Bengtsson, 1909)	F5 (468)	+
<i>Ephemerella notata</i> Eaton, 1887	F4 (72)	+
<i>Torleya</i> Lestage, 1917		
<i>Torleya major</i> (Klapálek, 1905)	F5 (211)	+
CAENIDAE Newman, 1853		
<i>Brachycercus</i> Curtis, 1834		
<i>Brachycercus europaeus</i> Kluge, 1991	F1 (4)	++
<i>Brachycercus harrisellus</i> Curtis, 1834	F2 (14)	+
<i>Cercobrachys</i> Soldán, 1986		
<i>Cercobrachys minutus</i> (Tshernova, 1952)	F1 (2)	+
<i>Caenis</i> Stephens, 1835		
<i>Caenis beskidensis</i> Sowa, 1973	F4 (92)	+
<i>Caenis horaria</i> (Linnaeus, 1758)	F5 (118)	+
<i>Caenis lactea</i> (Burmeister, 1839)	F1 (8)	+
<i>Caenis luctuosa</i> (Burmeister, 1839)	F5 (301)	+
<i>Caenis macrura</i> Stephens, 1836	F5 (288)	+
<i>Caenis pseudorivulorum</i> Keffermüller, 1960	F5 (119)	+
<i>Caenis pusilla</i> Navás, 1913	F1 (2)	++
<i>Caenis rivulorum</i> Eaton, 1884	F3 (48)	+
<i>Caenis robusta</i> Eaton, 1884	F4 (91)	+
SPECIES INQUIRENDA		
<i>Baetis (Baetis) beskidensis</i> Sowa, 1972	F1 (9)	+
<i>Baetis (Rhodobaetis) gemellus</i> Eaton, 1885	F2 (14)	+++
<i>Cloeon (Cloeon) cognatum</i> Stephens, 1836	F2 (21)	++
<i>Cloeon (Cloeon) inscriptum</i> Bengtsson, 1914	F2 (11)	+
<i>Cloeon (Similicloeon) praetextum</i> Bengtsson, 1914	F1 (6)	++
<i>Procloeon (Pseudocentropilum) nana</i> (Bogoescu, 1951)	F1 (3)	+
<i>Rhithrogena zelinkai</i> Sowa & Soldán, 1984	F1 (4)	++
DUBIOUS FINDINGS		
<i>Baetis (Baetis) macani</i> Kimmins, 1957	F1 (1)	+

Taxa	Species rarity	Last record
<i>Baetis (Baetis) subalpinus</i> Bengtsson, 1917	F2 (17)	++
<i>Baetis (Nigrobaetis) digitatus</i> Bengtsson, 1912	F1 (4)	++
<i>Oligoneuriella keffermuelleriae</i> Sowa, 1973	F1 (1)	+
<i>Ecdyonurus (Helvetoraeticus) austriacus</i> Kimmins, 1958	F1 (1)	+++
<i>Ecdyonurus (Helvetoraeticus) epeorides</i> Demoulin, 1955	F1 (2)	+++
<i>Ecdyonurus (Helvetoraeticus) helveticus</i> (Eaton, 1885)	F4 (70)	++
<i>Ecdyonurus (Helvetoraeticus) zelleri</i> (Eaton, 1885)	F2 (19)	++
<i>Ecdyonurus forcipula</i> (Pictet, 1843)	F4 (69)	+++
<i>Rhithrogena alpestris</i> Eaton, 1885	F1 (1)	++++
<i>Rhithrogena dorieri</i> Sowa, 1971	F1 (2)	+++
<i>Rhithrogena hybrida</i> Eaton, 1885	F4 (65)	+
<i>Rhithrogena landai</i> Sowa & Soldán, 1984	F1 (1)	++++
<i>Rhithrogena wolosatkae</i> Klonowska, 1987	F1 (3)	+++
<i>Palingenia fuliginosa</i> (Georgi, 1802)	F1 (8)	+

Species rarity

Six species, which we considered extinct (refer to Discussion), are dated to a period before 1990, none between 1991 and 2000 and eight between 2001 and 2010. Only 95 species have been recorded since 2011. At the same time, we tried to confirm all species found before 2010 with our field research but without a positive result (Table 1). Applying the five-degree frequency scale to our data, we can classify 29 species as very rare (F1), 12 as rare (F2), 11 as uncommon (F3), 13 as common (F4) and 42 as widespread (F5) (Table 1, Suppl. material 3A). Moreover, species with very rare and rare frequencies usually occupy localities at lower altitudes (according to the median value) and in the lower altitudinal range, in contrast to those with very frequent distributions (Suppl. material 3B, C).

Discussion

Checklist

This study presents the first critically revised checklist of mayflies in Slovakia after two decades (Derka 2003a), listing 109 species from 33 genera and 16 families. This species list can be considered almost complete, as evidenced by the rarefaction analysis and nonparametric estimation.

In our list, six species from the family Baetidae and one from the Heptageniidae are marked as “*species inquirenda*”. Among those, the most frequently reported is *Baetis gemellus*. The first taxonomic ambiguities occurred when Steinmann (1907) described nymphs of *B. alpinus* as *B. gemellus*, and several authors followed this interpretation (e.g., Lestage 1918). However, the description of the nymphs does not exist, and male imagoes are very similar to *Baetis gadeai* (Thomas, 1999) or *B. rhodani* (Bauernfeind and Soldán 2012). Kimmins (1960) regarded *B. gemellus* sensu Steinman as a junior synonym of *B. alpinus* and *B. gemellus* sensu Eaton as identical to the closely related *B. rhodani*. Several authors followed this interpretation, including in reports from Slovakia (e.g., Landa 1969; Landa and Soldán 1989; Deván 1994). Therefore, all these findings

of *B. gemellus* probably represent *B. rhodani*. Another species excluded from the checklist is *B. beskidensis* Sowa, 1972, reported by Deván (1992, 1993) and Mišíková-Elexová et al. (2010, 2015) from nine localities in our territory. The morphological separation, especially in the nymphal stage, from *B. fuscatus* or *B. scambus* is probably doubtful due to the minute details, mainly in the right mandible and labial palp (for a synopsis, see Bauernfeind and Soldán 2012).

Three species from the genus *Cloeon* (*C. cognatum*, *C. inscriptum*, *C. praetextum*) and one from *Procloeon* (*P. nana*) are also considered “*species inquirenda*”. Nymphs of *C. cognatum* and *C. inscriptum* cannot be reliably separated from *C. dipterum*, and the differences in the imagoes are probably based on misidentification (Bauernfeind and Soldán 2012). Therefore, records of these species in Slovakia probably belong to *C. dipterum*. *Cloeon praetextum* is very similar to *C. simile* in all stages, except for minor differences in egg chorion sculpture (Sowa 1980). However, such morphological features change considerably during development and have only weak diagnostic value (Bauernfeind and Soldán 2012). Accordingly, records of *C. praetextum* reported by Deván (1999, 2005) are considered conspecific with *C. simile*.

Procloeon nana, described initially as *Centroptilum nana* by Bogoescu (1951), was in the past placed in several genera (e.g., *Cloeon*; *Pseudocentroptiloides* Jacob, 1986) and probably represented the most problematic species in the category “*species inquirenda*”. The original description was elementary and based only on male and female imagoes. Subsequently, several authors published data on the occurrence of *Centroptilum nana* and a description of the nymph from different parts of Europe, which only led to other ambiguities in the description of this species (for a synopsis, see Głazaczow and Kłównowska-Olejnik 2009). However, Bauernfeind and Soldán (2012) suggest that *P. nana* might represent a senior subjective synonym of *Procloeon macronyx*. In our checklist, three findings of *P. nana* were therefore considered synonymous with *P. macronyx*.

Rhithrogena zelinkai is the last species in the “*species inquirenda*” category. Descriptions of the subimago and imago of this species do not exist, and nymphs are closely related to *R. loyolaea* and *R. gorganica*. Finally, nymphs are not always identifiable without a doubt and are therefore considered “*species inquirenda*” (Bauernfeind and Soldán 2012).

The second taxon category excluded from the checklist represents 15 dubious species from four families (Baetidae, Heptageniidae, Oligoneuriidae, and Palingeniidae). Several species were identified in our territory by only one author, and most of them were identified in a single location (*Baetis macani*, *Ecdyonurus austriacus*, *Rhithrogena alpestris*, and *R. landai*) or the same stream/river (*R. dorieri* and *R. wolosatkae*), but subsequent investigations never confirmed their occurrence. Moreover, their distribution in Slovakia is very unlikely for several reasons. For example, the distribution of *Baetis macani* is restricted to northern Europe, with the southernmost limit in northern Germany and northeast Poland, where it is a typical lowland species (Bauernfeind and Soldán 2012). In our territory, its identification by Mišíková-Elexová et al. (2015) is therefore doubtful, and it was probably confused with the closely related and superficially similar *B. vernus*. The distribution of *Rhithrogena alpestris* is mainly restricted to the Pyrenees and Alps, including mountain ranges in Slovenia (Bauernfeind and Soldán 2012). Nymphs prefer hypocrenal to epirhithral

sections of brooks and small rivers at higher elevations, and their occurrence in the Danube River near Bratislava, as reported by Landa (1969), is highly improbable. *Rhithrogena landai* is another species with a primary distribution in the Alps, including Slovenia and farther north in the Czech Republic and mostly in meta- and hyporhithral sections of streams (Bauernfeind and Soldán 2012). Accordingly, the record from a typical lowland river in our territory (Little Danube near Bratislava) reported by Landa and Soldán (1989) is doubtful. *R. drieri* represents a West Alpine faunistic element, and the distribution of *R. wolos-atkae* is probably restricted to the Pyrenees (Bauernfeind and Soldán 2012); therefore, we considered their findings at single localities (Deván 1995a; Krno et al. 1996) as dubious. *Ecdyonurus epeorides* was reported by Deván (1993, 1999) from two localities, but the occurrence of this species is also improbable since the species is likely restricted to the southeastern Balkans (Bauernfeind and Soldán 2012). *Oligoneuriella pallida* was reported by Mišíková-Elexová et al. (2015) in a tributary of the Slaná River with a typical occurrence of *O. rhenana* (Mišíková-Elexová et al. 2015) and according to Bauernfeind and Soldán (2012), nymphs of *O. pallida* never coexist with *O. rhenana*. In contrast, they prefer the metapotamal sections of larger rivers at lower altitudes and never occur in streams. Therefore, we consider its records dubious and probably based on misidentification. Finally, *O. pallida* was recorded from Slovakia only once and in a single location by Soldán (1978). We examined the material of *Baetis digitatus* and *Oligoneuriella keffermuelleriae* recorded by Mišíková-Elexová et al. (2010, 2021) from all known localities in Slovakia and stored at the Department of Ecology, Comenius University, Bratislava, Slovakia. After the taxonomic revision, we considered these findings to be dubious due to misidentifications. Finally, the nymphs of *O. keffermuelleriae* corresponded to *O. rhenana* and *Baetis digitatus* to *B. niger*. Moreover, Mišíková-Elexová et al. (2021) reported *Oligoneuriella keffermuelleriae* in the Poprad River and its very close tributary, both typical of the occurrence of *O. rhenana*, which was also confirmed by our records. Furthermore, *O. keffermuelleriae* never co-occurs with *O. rhenana* (Bauernfeind and Soldán 2012).

The most frequently reported dubious species were *Ecdyonurus forcipula*, *E. helveticus*, *E. zelleri*, *Rhithrogena hybrida*, and *Baetis subalpinus*. The occurrence of *Ecdyonurus forcipula* sensu Pictet (1843–1845) in our territory corresponds to several taxa from the *E. venosus* species group. Therefore, we consider the records of this species dubious. The records of *E. helveticus* and *E. zelleri* were reported mostly by Deván (e.g., 1993; 1995a, b; 1996a, b; 1999), Derka (1995), Krno et al. (1996), and Krno (1997a, b). However, these records are probably based on misidentification since the distribution of these species is primarily limited to the Alps (Bauernfeind and Soldán 2012). Moreover, nymphs of *E. helveticus* are very similar to *E. picteti*, and findings in Slovakia may thus correspond to the latter species. Another erroneously determined species is *Rhithrogena hybrida*, whose distribution is probably restricted to the Alps (Black Forest, Germany, Bauernfeind and Soldán 2012). Records from Slovakia probably correspond to other representatives of the *R. hybrida* species group, e.g., *R. podhalensis* or *R. circumtrica* (Bauernfeind & Soldán, 2012). The last species relatively often reported as dubious was *Baetis subalpinus* (e.g., Krno 1991, 1997a; Derka 1995, 2003c; Deván 1999, 2000). However, findings from central and southern Europe are questionable and probably also based on misidentification because nymphs

are superficially similar to *B. vernus* in all stages (Bauernfeind and Soldán 2012). Finally, the latest morphological and molecular analyses confirmed the dubious taxonomical status of *Palingenia fuliginosa* in southeastern Europe (Manko et al. 2023), including in reports from Slovakia (Landa 1969; Soldán 1981a; Landa and Soldán 1989; Mišíková-Elexová et al. 2015).

Species distribution and diversity

We have shown that most mayfly species occurring in Slovakia prefer habitats at lower elevations (< 500 m), and overall mayfly diversity continually decreases from lowland to mountain areas. This agrees with the general observations that high mountain habitats are relatively poor in mayfly species richness (e.g., Landolt and Sartori 2001), and the number of mayfly species decreases with increasing altitude (Brittain and Sartori 2009). According to the habitat classification of running waters (Illies 1953; Illies and Botosaneanu 1963), the highest aquatic species richness occurs in lotic-erosional habitats or rhithral sections. The taxa richness of mayflies in Europe is particularly high in meta- and hyporhithral sections in the colline or lower mountain zones (Landolt and Sartori 2001; Bauernfeind and Soldán 2012). These sections correspond to most habitats of fifth-order streams in Slovakia, the stream order with the highest recorded mayfly gamma diversity. Regarding mayflies, the potamal sections or lotic-depositional habitats are less species-rich (Bauernfeind and Soldán 2012). Such habitats correspond to higher stream orders ($\geq 6^{\text{th}}$ stream order in Slovakia), with low species richness, but are usually occupied by several ecological specialists with a very low frequency of occurrence (see below) and being mostly restricted to these river sections (Landolt and Sartori 2001). In contrast, Bauernfeind and Moog (2000) showed the highest species and family richness within ecologically intact to moderately disturbed sampling localities in the potamal sections due to the high diversity of microhabitats. However, lowland rivers are typically exposed to extensive chemical pollution and suffer from the loss of habitat heterogeneity, current variability, and various substrate types needed for mayfly specialists (Zedková et al. 2015; Vilenica et al. 2020, 2022). Such negative impacts significantly affect the biodiversity of entire communities and cause the decline of many rare specialists, which are replaced by more tolerant species (Bauernfeind and Moog 2000; Rumschlag et al. 2023).

Species rarity

According to their occurrence frequency, 29 species (26%) were evaluated as very rare. These species usually occupied localities at lower altitudes. According to the generally accepted classification of Baillie and Groombridge (1996), a species is considered extinct if its latest record is older than 30 years. Here, we list six species that meet this criterion: *Behningia ulmeri*, *Oligoneuriella polonica*, *O. pallida*, *Oligoneurisca borysthenica*, *Baetis inexpectatus*, and *Ephemerella glaucops*. *Behningia ulmeri*, *Oligoneuriella polonica*, *O. pallida*, and *Oligoneurisca borysthenica* were last reported by Landa and Soldán (1989) and Soldán (1978) from two sampling localities in the southeast part of Slovakia. These species prefer epi- and metapotamal sections of large rivers, where their nymphs inhabit coarse shifting sand (*Behningia ulmeri*, *Oligoneuriella polonica*,

Oligoneurisca borysthenica) or stony bottom (*Oligoneuriella pallida*), which probably determines their occurrence (Bauernfeind and Moog 2000; Bauernfeind and Soldán 2012). *Baetis inexpectatus* and *Ephemera glaucops* were reported from seven localities having thus scarce distributions. In Slovakia, *E. glaucops* was recorded in large lowland rivers (Landa and Soldán 1989) and one natural lake of volcanic origin with oligotrophic to mesotrophic conditions (Gajdúšek and Kubíček 1970). Nymphs were also found in different artificial waterbodies in central Europe (Jacob et al. 1975; Studemann et al. 1992; Sroka et al. 2022). The biology of *Baetis inexpectatus* is poorly known (Bauernfeind and Soldán 2012). In Slovakia, nymphs were recorded in medium-sized lowland rivers and always in habitats with maximum current velocity and stony substrata (Soldán 1981b; Landa and Soldán 1989). The fauna of the large lowland rivers and their floodplains has undergone the most significant changes in species composition caused mainly by human activities (Deván 2001; Soldán et al. 2017), which probably led to the extinction of the five species mentioned above in Slovakia. Recent reports from Ukraine confirmed the importance of lowland rivers for rare mayfly species (Martynov 2018, 2020). In some cases, it is plausible to expect the rediscovery of some rare species, as evidenced by our finding of *Cercobrachys minutus* in 2021, more than 40 years after the last record (Soldán 1978).

Among other very rare species, we found species that inhabit lentic habitats often overlooked during hydrobiological research and routine biomonitoring in Slovakia (Mišíková-Elexová et al. 2010, 2015, 2021) or that occur at the edge of their geographic distribution (Soldán et al. 1998). For example, *Leptophlebia vespertina* and *L. marginata* inhabit slow-flowing and slightly acidic streams, rivers, and, more frequently, lakes (Bauernfeind and Soldán 2012). In Slovakia, these species were found mainly in lentic habitats such as subalpine dystrophic lakes in the High Tatras (e.g., Landa and Soldán 1989; Krno 1991) and water reservoirs (Mišíková-Elexová et al. 2015). Species preferring stagnant waters include *Siphonurus alternatus*, *Procloeon pulchrum*, and *Caenis lactea* (Bauernfeind and Soldán 2012). *Siphonurus alternatus* predominantly inhabits pools with submerged vegetation, isolated backwaters in the inundation areas of larger lowland rivers, oligotrophic ponds, artificial impoundments, and montane glacial lakes in Central Europe (Landa and Soldán 1989; Soldán et al. 1998; Bauernfeind and Soldán 2012).

Metreletus balcanicus and *Arthroplea congener* are among taxa inhabiting rather specific and probably overlooked habitat type. *Metreletus balcanicus* usually occurs in periodic slow-flowing streams with muddy and clay bottoms with or without aquatic vegetation (Russev and Vidinova 1994; Bauernfeind and Soldán 2012; Martynov 2018). *Arthroplea congener* was recently confirmed in two neighbouring localities in southwest Slovakia, while a relatively large population was recorded only in the shallow temporally inundated wetland in an alder forest (Macko and Derka 2021). *Ametropus fragilis*, *Brachycercus europaeus*, and *Heptagenia fuscogrisea* are other “very rare” species that currently occur in only a few relatively preserved lowland rivers of southeastern Slovakia (e.g., Mišíková-Elexová et al. 2010, 2015, 2021) and/or the Ipeľ (Ipoly) River (Kovács et al. 2002; Macko and Derka 2021).

In contrast, the frequency of *Rhithrogena gorganica* was also evaluated as “very rare”, but this species is widely distributed in the Ukrainian Carpathians

(e.g., Godunko 2000). Localities mostly represented by hypocrenal brooks in the beech forest situated in the northeastern part of Slovakia, the Nízke Beskydy Mountains (e.g., Novikmec et al. 2007) probably represent the westernmost limit of the distribution of this species endemic to the eastern Carpathians (Bauernfeind and Soldán 2012). *Caenis pusilla* represents a Mediterranean faunistic element with a northern area extension (Malzacher 1986) or holomediterranean distribution (Haybach and Jacob 2010). Nymphs predominantly inhabit hyporhithral and epipotamal sections of rivers, especially with stony bottoms in Central Europe (Bauernfeind and Soldán 2012), as was confirmed in two known localities in Slovakia (Mišíková-Elexová et al. 2010). At the same time, they also probably represent the easternmost and only known localities in the western Carpathians (Derka 2005a). *Baetopus tenellus* is a Transpalaeartic species with usually very low densities at sampling localities (Derka 2005b), predominantly in the epi- and metapotamal sections of large lowland rivers (Bauernfeind and Soldán 2012). In the 20th century, *B. tenellus* was recorded in our territory at only a single locality, exceptionally representing the hyporhithral section of River Ulička (Landa and Soldán 1989), and at the beginning of the 21st century, it was also discovered in the metapotamal section of the Morava River (Derka 2005b, Mišíková-Elexová et al. 2010). Our current findings represent three additional occurrence localities of this species and typical epi- and metapotamal sections of our large lowland rivers. The occurrence of *Isonychia ignota* in Slovakia remains rare and findings are irregular. This species was recently confirmed at four hyporhithral localities (Mišíková-Elexová et al. 2010, 2015). However, despite our repeated locality visits since 2019, we have not recorded this species.

Conclusions

We present the first comprehensive checklist of mayflies in Slovakia based on century-long research, containing 109 species. Due to the high spatial heterogeneity of the region and the robustness of our dataset covering more than 2200 sampling localities, we believe that fundamental aspects of mayfly diversity revealed in our study can be generalised beyond the western Carpathians and Pannonia. The highest number of species was found at elevations below 500 m a.s.l. and decreases towards higher altitudes. Regarding stream longitudinal zonation, gamma diversity showed a unimodal pattern, with the highest number of species occurring in streams of the fifth order. Rare species mostly occurred in lower altitudes. Moreover, all six species are considered extinct in Slovakia, dwelling in lowland rivers. Owing to the high mayfly diversity and the occurrence of many rare species, lowland rivers and their floodplains deserve high priority for the conservation of mayflies in Central Europe.

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Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statement

No ethical statement was reported.

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Author contributions

Conceptualization: TD, PM, MS. Data curation: MN, MŠ, MS, PM, TD. Formal analysis: PM, MS. Funding acquisition: MS, TD. Investigation: MS, TD, PM, MŠ. Methodology: PM, MŠ, MS. Project administration: TD, PM, MS. Resources: MN, TD, MS, PM. Software: MS. Supervision: TD, MS, MN. Validation: MN, PM, TD, MS. Visualization: MS, PM, MŠ. Writing - original draft: PM, MŠ. Writing - review and editing: MŠ, MS, PM, TD, MN.

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Data availability

All of the data that support the findings of this study are available in the main text or Supplementary Information.

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Supplementary material 1

Details of the collection data of mayflies in Slovakia from 1905 to 2021

Authors: Patrik Macko, Tomáš Derka, Michaela Šamulková, Milan Novikmec, Marek Svitok
Data type: xlsx

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Link: <https://doi.org/10.3897/zookeys.1183.109819.suppl1>

Supplementary material 2

Altitudinal distribution of mayfly species in Slovakia

Authors: Patrik Macko, Tomáš Derka, Michaela Šamulková, Milan Novikmec, Marek Svitok

Data type: jpg

Explanation note: Species are ordered according to the position of their altitudinal optima (median of the distribution). The number of occurrence localities is given in italics for each species. Note that *R. iridina* and *R. carpatoalpina* also represent *R. picteti* and *R. puytoraci*, respectively.

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Supplementary material 3

Number of mayfly species in five frequency classes, and their altitudinal and geographical distributions

Authors: Patrik Macko, Tomáš Derka, Michaela Šamulková, Milan Novikmec, Marek Svitok

Data type: xlsx

Explanation note: **A** Number of mayfly species in five frequency classes (F1 to F5, see Materials and methods) defined by Sartori and Landolt (1999) and their **B** altitudinal and **C** geographical distributions.

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Invalid lectotypification for *Synodontis victoriae* Boulenger, 1906 (Siluriformes, Mochokidae) by Poll (1971), and the designation of a new lectotype

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Abstract

The lectotype and paralectotype of *Synodontis victoriae* Boulenger, 1906, designated by Poll (1971), were examined. Inconsistencies between data presented for the designated lectotype and the illustrated individual raise the question of whether lectotypification by Poll is valid. This case is not formally regulated by the International Code of Zoological Nomenclature, but based on Article 74.5, the lectotypification for *S. victoriae* should be considered invalid because it cannot unambiguously indicate a single name-bearing specimen. Thus, we designate a new lectotype for *S. victoriae* (BMNH 1906.5.30.191, Entebbe, standard length 188.2 mm) out of two syntypes and provide illustrations and new morphometric and meristic data for both specimens.

Key words: Catfish, East Africa, freshwater fish, ICZN, taxonomy



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Introduction

Based on an extensive collection of fishes from Lake Victoria made by Edward J.E. Degen in 1905, Boulenger (1906) described 26 new species, including *Synodontis victoriae* Boulenger, 1906. The original description of this species was based on two syntypes from the north-western part of Lake Victoria: one from Entebbe (collected on 1 October 1905; standard length (SL) 192 mm) and a second from Buganga (collected on 15 November 1905; SL 225 mm) (Boulenger 1907). Additional descriptive data were provided in Boulenger's "*The Fishes of the Nile*", where the first illustration of *S. victoriae* appeared (Boulenger 1907: pl. LXVII) (Fig. 1). In a comprehensive revision of the genus, Poll (1971) designated the larger of the two syntypes as the lectotype (BMNH 1906.5.30.190, from Buganga).

After careful examination of the two type specimens, we found inconsistencies in both the information presented by Poll (1971) and the labels on and in the jars containing the specimens. This ambiguity regarding the identity of the name-bearing specimen questions the validity of the lectotype designation for *S. victoriae* by Poll (1971). Here, we discuss this case in light of Article 74 of the International Code

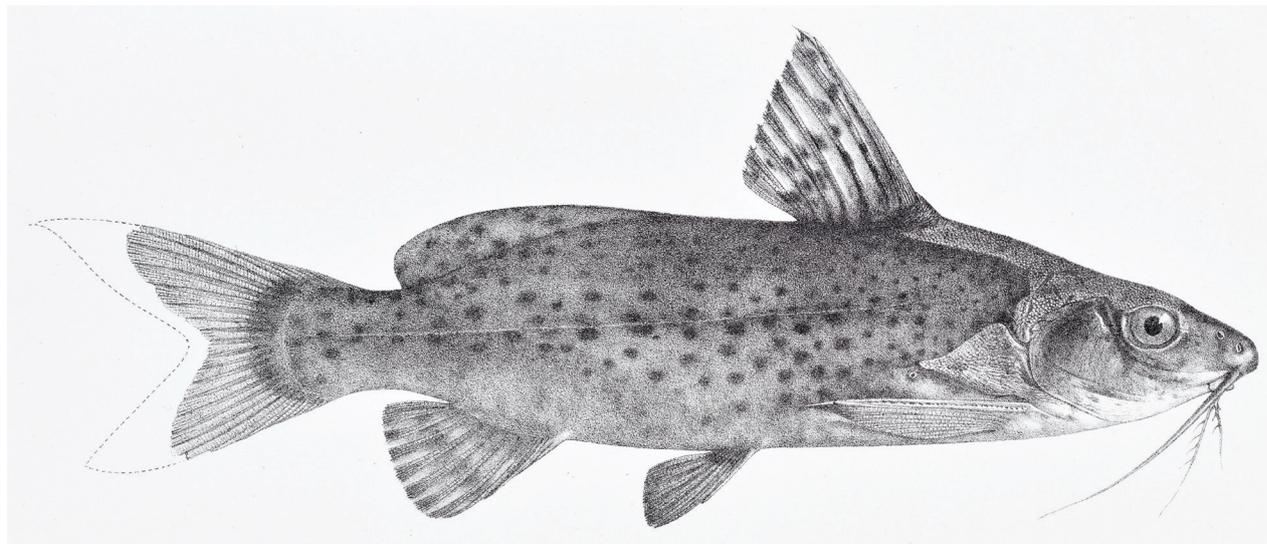


Figure 1. First illustration of *Synodontis victoriae* published in "The Fishes of the Nile" (modified from Boulenger 1907: pl. LXVII) representing the specimen from Entebbe (BMNH 1906.5.30.191) and not from Buganga (BMNH 1906.5.30.190) as stated by Boulenger (1907: xiii). A reproduction of this right lateral view was used by Poll (1971: 121, fig. 50).

of Zoological Nomenclature (ICZN 1999), designate a new lectotype, and provide illustrations and new morphometric and meristic data for both type specimens.

Material and methods

The types of *Synodontis victoriae* were examined, and 36 morphometric measurements and 20 meristic characters, including four axial skeleton counts (from radiographs), were taken. Measurements were made point-to-point using callipers to the nearest 0.1 mm. Most measurements (21) follow Skelton and White (1990), seven are summarised in Englmaier et al. (2020) (body depth at dorsal fin origin, pectoral–pelvic distance, pelvic–anal distance, anal-fin depth, pectoral-fin length, pelvic-fin length, and minimum caudal-peduncle depth). Eight additional measurements were conducted as follows: body depth at anal fin refers to the greatest vertical distance (including the height of the adipose fin) at origin and insertion of the anal fin; dorsal fin to caudal peduncle was measured from the insertion of the dorsal fin to the posterior margin of the last complex centrum at midline; head depth and head width at posterior eye margin were measured as greatest vertical and lateral distances; maximum cranium width was measured between lateral margins of pterotics; head length was measured from the tip of snout to the posterior margin of the soft gill cover; and width of mandibular teeth row refers to a maximum distance between the outermost visible replacement teeth. Counts of external meristic traits and axial skeleton elements follow Skelton and White (1990); caudal-fin ray counts as described in McDowall (2001). The posterior two branched rays in the anal fin, located on the last complex proximal pterygiophore of the fin, were counted as two. Vertebral counts were made from radiographs and include six Weberian vertebrae (the 6th centrum already with ribs) and a single count for the last complex centrum (Skelton and White 1990). The first true caudal vertebra is considered as a vertebra with "fully developed haemal spine" being similar in length as the haemal spine of the vertebra behind it.

Taxonomic remarks

The two types of *Synodontis victoriae* differ considerably in state of preservation and can therefore be easily distinguished (Figs 2, 3). The smaller specimen from Entebbe has distinct body markings, and the dorsal and pectoral fin spines are entirely preserved, whereas in the larger specimen from Buganga, the body markings are indistinct and the spines in the dorsal and pectoral fins are broken. This must have already been the case when Boulenger examined the material, because data for the dorsal and pectoral spines are missing for the specimen from Buganga (Boulenger 1907: 363).

Inconsistencies regarding the lectotype designation by Poll (1971), as well as with the internal and external jar labels, were noted as follows:

1. While Poll (1971) indicated the syntype from Buganga as lectotype by collection number, locality, and morphology, the illustration (Poll 1971: 121, fig. 50) with the legend that reads “*Synodontis victoriae* BOULENGER, lectotype, 290 mm, Buganga, lake Victoria (BRIT. MUS. no 1906.5.30.190). Partim G. A. BOULENGER, 1907, Fishes of the Nile, pl. LXVII” actually represents the syntype from Entebbe (BMNH 1906.5.30.191) (Fig. 1). This reproduction from Boulenger (1907) is the right lateral view of the specimen. In both publications, Boulenger (1907: xiii) and Poll (1971: 121), the illustrated syntype is erroneously referred to as originating from Buganga. The two additional illustrations provided by Poll (Poll 1971: 121, fig. 50; dorsal and ventral view) show a specimen with entire pectoral spines and thus cannot refer to BMNH 1906.5.30.190, a specimen where pectoral spines are broken.
2. The labels, on and in both jars and signed by Poll, however, identify the specimen from Entebbe as the lectotype and the specimen from Buganga as the paralectotype (Figs 2, 3), in contrast to (1).

This situation does not allow to unequivocally identify a unique name-bearing type in *S. victoriae*, presenting a nomenclatural problem when lectotype designation cannot be unambiguously traced back to a single specimen. Article 74.5 of the ICZN (1999) states that “In a lectotype designation made before 2000, either the term ‘lectotype’, or an exact translation or equivalent expression (e.g. ‘the type’), must have been used or the author must have unambiguously selected a particular syntype to act as the unique name-bearing type of the taxon”. This implies that a single specimen is chosen “... to become the unique bearer of the name of a nominal species-group taxon ...”. (Article 74.1, ICZN 1999), and that this specimen can be unambiguously traced back from the context of the original work. Although Poll (1971) assigned the term “lectotype” to a specific syntype, recognised by collection number, locality, and morphology, the illustration of the lectotype refers to a different specimen, resulting in a composite description of two syntypes. Additional ambiguity is introduced by the jar labels added by Poll, which would identify a different lectotype than designated by description. Articles 72 and 74 of the ICZN (1999) provide specific recommendations regarding labelling of type specimens: Recommendation 72D “... Holotypes, syntypes, lectotypes and neotypes should be labelled in a way that will unmistakably denote their status” and Recommendation 74E “... An author who designates a lectotype should clearly label other former syntypes as ‘paralectotypes’ ...”. These recommenda-



Figure 2. *Synodontis victoriae* BMNH 1906.5.30.191, lectotype, 188.2 mm SL, Entebbe, Lake Victoria, Uganda. The Trustees of the Natural History Museum, London.



Figure 3. *Synodontis victoriae* BMNH 1906.5.30.190, paralectotype, 225.0 mm SL, Buganga, Lake Victoria, Uganda. The Trustees of the Natural History Museum, London.

tions are also stated in the 2nd edition of the ICZN (1964), valid at the time Poll designated the lectotype of *S. victoriae*, in 72B and 74E, respectively. The ICZN also provides a recommendation regarding the selection of a lectotype if a syntype has previously been illustrated, stating that: "... A zoologist should choose as lectotype a syntype of which a figure has been published, if such exists" (Recommendation 74B, ICZN 1964; see also Recommendation 74B, ICZN 1999). This could probably explain the original intention of Poll to designate the smaller syntype from Enteb-

be as the lectotype during his visit to (and loans from) the British Museum (Natural History) in 1969–1970, as this specimen was illustrated by Boulenger (1907).

From the discussion above, we conclude that the lectotypification for *S. victoriae* by Poll (1971) should be considered invalid because it cannot be unambiguously traced back to a single name-bearing specimen. We herewith designate a new lectotype, out of the two syntypes, as follows.

***Synodontis victoriae* Boulenger, 1906: 438**

Type materials. Lectotype (hereby designated): BMNH 1906.5.30.191, Entebbe, 188.2 mm SL, coll. E. Degen.

Paralectotype: BMNH 1906.5.30.190, Buganga, 225.0 mm SL, coll. E. Degen.

Notes. In Figs 2–4 we provide illustrations and radiographs (axial skeletons) of both the lectotype and paralectotype of *S. victoriae*; new morphometric and meristic data of the two specimens are given in Table 1.

Table 1. Morphometric measurements and meristic counts for type specimens of *Synodontis victoriae*. Vertebral counts indicate numbers of total vertebrae: abdominal vertebrae + caudal vertebrae / postanal vertebrae.

Character states	<i>S. victoriae</i> BMNH 1906.5.30.191 lectotype	<i>S. victoriae</i> BMNH 1906.5.30.190 paralectotype
Standard length (mm)	188.2	225.0
MORPHOMETRIC DATA		
Percent of standard length		
Body depth at dorsal fin origin	23.1	25.8
Body depth at anal fin origin	24.1	26.1
Body depth at anal fin insertion	19.0	19.4
Predorsal length	37.3	37.4
Prepectoral length	26.0	25.3
Prepelvic length	54.0	54.4
Preanal length	72.8	77.0
Pectoral–pelvic distance	32.0	32.5
Pelvic–anal distance	20.8	22.9
Caudal-peduncle length	14.7	13.8
Dorsal fin to caudal peduncle	52.4	48.7
Adipose basal length	27.7	31.6
Dorsal-fin depth	25.5	23.9
Anal-fin depth	19.9	18.6
Pectoral-fin length	24.2	24.2
Pelvic-fin length	14.8	15.8
Head length	27.1	27.6
Percent of head length		
Head depth at posterior eye margin	57.3	59.0
Head width at posterior eye margin	70.6	68.8
Maximum cranium width	53.7	56.6
Snout length	43.3	48.4
Interorbital width	42.0	43.6
Maxillary-barbel length	97.6	100.3
Outer mandibular-barbel length	50.4	49.8
Inner mandibular-barbel length	32.7	28.8
Humeral-process length	53.1	52.6

Character states	<i>S. victoriae</i> BMNH 1906.5.30.191 lectotype	<i>S. victoriae</i> BMNH 1906.5.30.190 paralectotype
Pectoral spine length (unsegmented)	82.2	absent
Dorsal spine length (unsegmented)	81.2	absent
Percent of snout length		
Orbit diameter	45.2	37.9
Mouth width	64.3	64.8
Premaxillae width	44.3	32.6
Width of mandibular teeth row	20.8	19.9
Percent of caudal peduncle length		
Minimum caudal-peduncle depth	71.7	68.2
Adipose to caudal peduncle	68.5	68.8
Percent of Dorsal fin to caudal peduncle		
Dorsal-adipose length	29.3	17.3
MERISTIC DATA		
Dorsal fin rays	II-7	II-8
Anal fin rays	V-9	V-9
Pelvic fin rays	I-6	I-6
Pectoral fin rays	I-9	I-9
Caudal-fin principal rays (upper lobe + lower lobe)	7+8	8+8
Caudal-fin procurrent rays (upper + lower)	12+14	13+13
Mandibular teeth + Primary premaxillary teeth	18+27	20+26
Branches on outer mandibular barbels	4	5
Branches on inner mandibular barbels	5	8
Vertebral counts	39:18+21/19	40:17+23/19

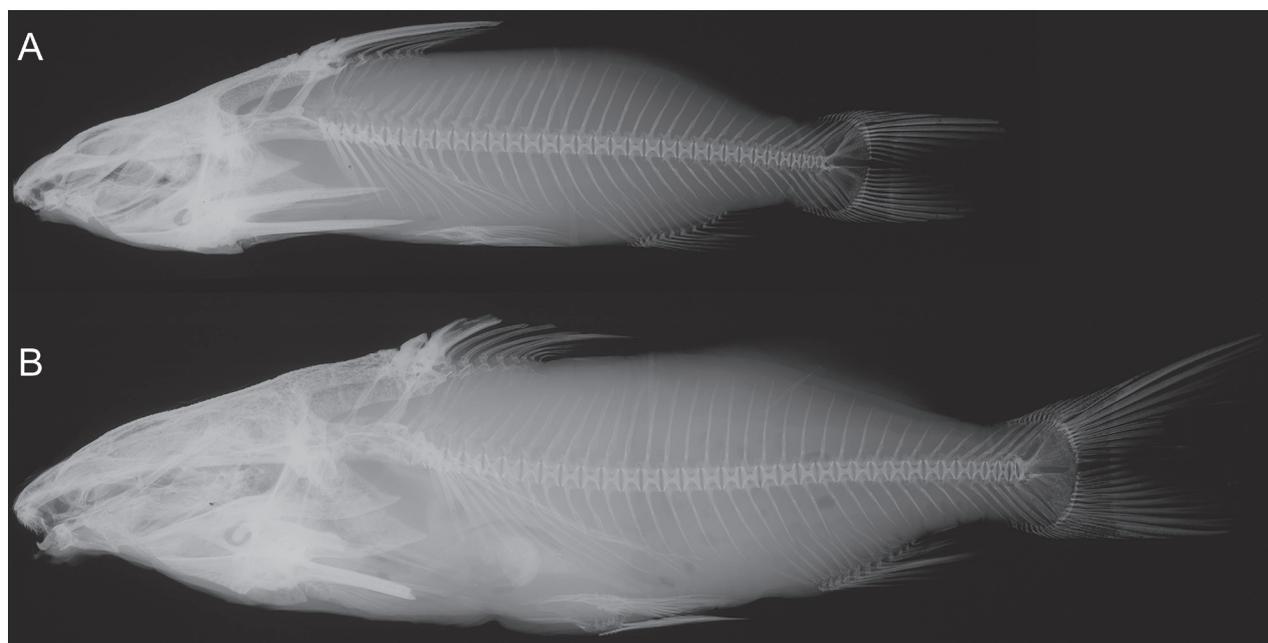


Figure 4. Axial skeletons in *Synodontis victoriae* **A** BMNH 1906.5.30.191, lectotype **B** BMNH 1906.5.30.190, paralectotype.

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Additional information

Conflict of interest

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Author contributions

Conceived and coordinated the study: GKE. Morphological examination: GKE, RAC. Coordinated photographs and specimen preparation: RAC. Wrote the first draft of the paper: GKE. Both authors contributed equally to the improvement of the manuscript.

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Data availability

All of the data that support the findings of this study are available in the main text.

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Epitomapta aumakua sp. nov., a new species of apodous sea cucumber from Hawai`i (Echinodermata, Holothuroidea, Apodida)

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Abstract

Epitomapta aumakua sp. nov. occurs at a depth of 2.5 m in Kualoa, O`ahu, Hawai`i, living in coarse sand. It is distinctive in having 12 pinnate tentacles, each tentacle with three pairs of digits and 6–8 sensory cups. The body wall bears papillae or oval bumps, and the length of body reaches a maximum length of 18.4 mm after relaxation.

Key words: Leptosynaptinae, Synaptidae, taxonomy



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Introduction

The apodous sea cucumbers of the subfamily Leptosynaptinae Smirnov, 1989 (Apodida Brandt, 1835; Synaptidae Burmeister, 1837) are interstitial organisms that inhabit intertidal and shallow waters. They have a vermiform, translucent integument (Hendler et al. 1995; Woo et al. 2021). Heding (1928) placed the genus *Epitomapta* Heding, 1928 in the subfamily Synaptinae and included *Epitomapta roseola* (Verrill, 1873) from Connecticut and Massachusetts, USA, and *E. tabogae* Heding, 1928 from Taboga and Taboguilla, Panama. Heding based the new genus on the presence of notched rather than perforated radial pieces of the calcareous ring. Later, Solís-Marín et al. (2019) described a new species from the Tropical East Pacific in Mexico, *E. simentalae* Solís-Marín, Conejeros-Vargas, Caballero-Ochoa & Arriaga-Ochoa, 2019, based on having 12 tentacles, with each tentacle with two or three pairs of digits and 4–6 sensory cups, and a body lacking papillae or oval bumps. *Epitomapta* is, thus, currently represented by four nominal species, including the new one described here. Smirnov (1989) placed the genus in the subfamily Leptosynaptinae.

Materials and methods

Specimens are preserved in the Marine Invertebrate Collection of the Beaty Biodiversity Museum, University of British Columbia, Canada (MI). Ossicles were extracted from the body wall (anterior, medium, and posterior region), longitudinal muscles and one whole tentacle. The tissue was dissolved in household bleach (5.0–6.5%). Bleach was washed off from the ossicles by rinsing them twice with distilled water. Hereafter the distilled water was replaced by rinsing the ossicles with 70, 80, and 95% ethanol. Finally, absolute ethanol was added to the ossicles, whereafter a small aliquot was taken and placed to dry on a scanning electron microscope (SEM) stub. The dry sample was sputter coated with 5 nm gold/palladium (80/20) using a Leica EM ACE600 and imaged with a Zeiss Crossbeam 350 SEM.

Taxonomy

Order Apodida Brandt, 1835

Family Synaptidae Burmeister, 1837

Subfamily Leptosynaptinae Smirnov, 1989

Diagnosis. Pinnate tentacles 10, 11 or 12, with 1–9 digits on each side. Digits increase in size from base to tip of tentacle. Anchor plate develops from a rod which lies at a right angle to stock of developing anchor. Anchor plates with small number of holes, usually seven (6+1) in main part of the plate: six holes form a circle around a central hole. Articular end of plate usually has a “ledge” for contact with anchor keel. Anchor arms regularly serrated, rarely smooth, and without minute knobs on the vertex (Heding 1928; Smirnov 1989).

Genus *Epitomapta* Heding, 1928

Diagnosis. Tentacles pinnate, usually 12. Digits in 2–5 pairs on each side (rarely two or none). Sense organs never in form of pigment-eyes, but as minute cups on inner face of stalk of tentacles. Calcareous ring well developed. Radial pieces not perforated for passage of nerves, but with an anterior notch. Cartilaginous ring absent. Polian vesicle usually single. Stone canal single, unbranched. Ciliated funnels of different shapes and attached to body wall, not to mesenteries. Calcareous deposits in body wall are anchors, anchor plates and miliary granules; tentacles with rods only. Stock of anchors finely toothed, but not branched; arms usually with teeth on outer edge; vertex smooth. Anchor plates oval, with large central hole, surrounded by six large holes, usually more or less dentate, and two large and several small smooth holes at narrow posterior end, but without an arched bow crossing outer surface; broad end often with additional dentate holes (Solís-Marín et al. 2019).

Type species. *Epitomapta tabogae* Heding, 1928 by original designation.

***Epitomapta aumakua* sp. nov.**

<https://zoobank.org/01CD60ED-A303-4C39-A4B7-CD0616E5FF08>

Figs 1–3

Type materials. Holotype. MI 4942, 18.4 mm total length (TL), off Kualoa, O`ahu, Hawai`i, Pacific Ocean 21°30'N, 157°50'W, 2.5 m depth, July 1975. **Paratypes.** MI 4944, 2 specimens, 1 extensively dissected, same data as the holotype.

Type locality. Off Kualoa, O`ahu, Hawai`i, Pacific Ocean 21°30'N, 157°50'W.

Diagnosis. Body wall smooth, covered with small, oval-circular bumps, especially on anterior part of body. Tentacles 12, each with three pairs of lateral digits and a terminal digit; 6–8 sensory cups on each tentacle. Polian vesicle, 1/10 of body length; stone canal single, unbranched. Anchor and anchor plates of one kind: anchors usually exceeding 170 µm in length, plates exceeding 110 µm in length. Miliary granules scarce, only present in longitudinal muscles, relatively coarse, usually in form of simple flat, often faintly undulating, stout, straight rods with enlarged ends, slightly bent but never C-shaped, usually exceeding 20 µm in length. Tentacle ossicles shaped like smooth, flattened rods, not exceeding 50 µm in length, curved, with perforated ends; some rods broad (ca 14 µm in width) with few circular peripheral holes.

Holotype description. 18.4 mm long. Specimen uniformly whitish, body wall translucent when expanded. Anchors (Fig. 1A) not projecting through body wall. Tentacles 12, each with three pairs of digits and a terminal digit; digits increase in length distally, and terminal digit longest. Inner (oral) surfaces of tentacles with double row of well-developed sensory cups; up to eight sensory cups on each tentacle. Ciliated funnels of various shapes (Fig. 2) occur on body wall, not on mesenteries. Two longitudinal rows of round-lipped, ciliated funnels present, each row attached to one side of one longitudinal muscle; a single V-shaped notch splits round lips of funnels and extends about 1/2 length of funnel. Polian vesicle single. Stone canal single, unbranched. Calcareous ring simple, stout, well developed (Fig. 3); radial pieces notched anteriorly, more conspicuous than that in interradiial pieces; not pierced.

Ossicles. Body-wall deposits comprise anchors and anchor plates (Fig. 1A, B). Anchors and plates at anterior, middle, and posterior body wall essentially similar. Anchors average 170 µm in length and 55 µm in largest width (width of the arms). Arms carry up to five conspicuous teeth; vertex smooth. Stock unbranched, but equipped with numerous small, sharp projections (Fig. 1A). Anchor plates elongate, approximately oval, with numerous toothed perforations. Anchor plates average 110 µm in length and 90 µm in greatest width (Fig. 1B). Miliary granules scarce, present only in epithelium covering longitudinal muscles, variable in shape but generally flat and tending to have enlarged endings. Granules up to ca 20 µm in length (Fig. 1D). Tentacle ossicles small (40–50 µm in length), smooth, shaped like flattened, curved rods, with perforated ends (Fig. 1C). Some rods flat and broad (ca 14–16 µm in width) having 6–10 circular peripheral holes.

Paratype variations. Specimens range from 16–17 mm in length.

Etymology. The specific epithet *aumakua* refers, in Hawaiian mythology, to a person or family god that originated as a deified ancestor, who takes on physical forms as spirit vehicles. Here it is used as a non-Latin noun in apposition.

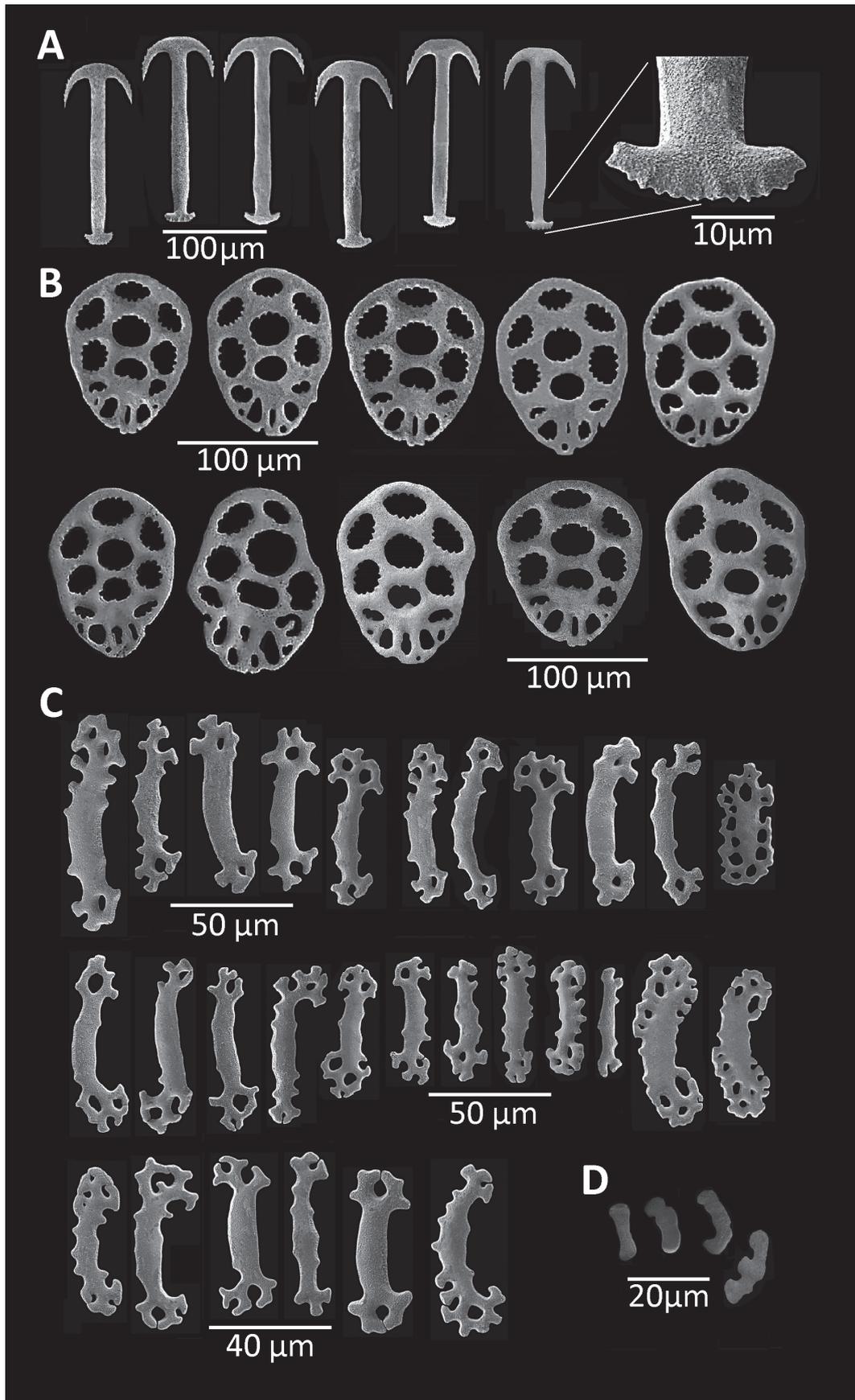


Figure 1. *Epitomapta aumakua* sp. nov. Holotype MI 4942 **A** anchors from mid-body, showing the detail of the posterior part **B** anchor plates from mid-body **C** rods from tentacles **D** military granules from the body wall.

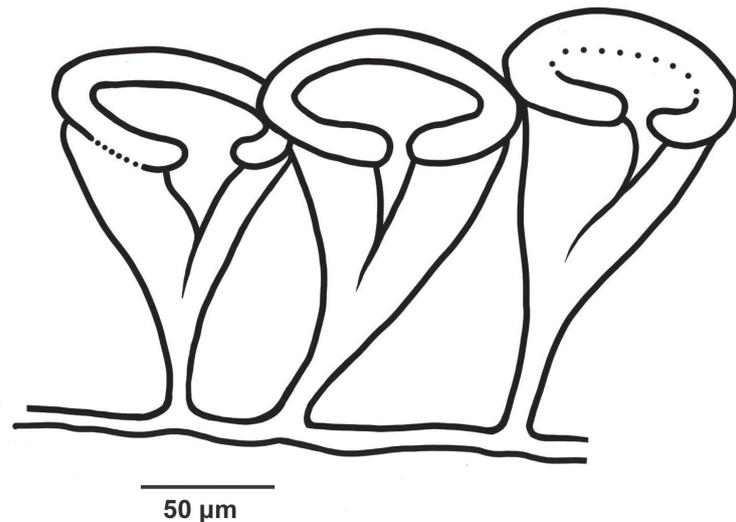


Figure 2. *Epitomapta aumakua* sp. nov. Paratype MI 4944. Ciliated funnels showing their differing sizes and shapes.

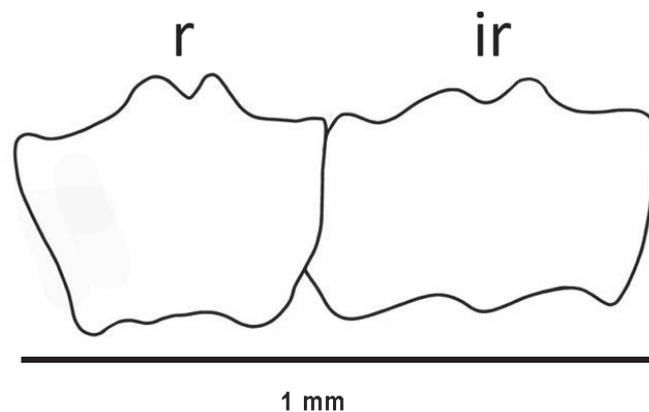


Figure 3. *Epitomapta aumakua* sp. nov. Holotype MI 4942, calcareous ring. Abbreviations: r = radial piece, ir = interradial piece.

Ecology. *Epitomapta aumakua* sp. nov. occurs at 2.5 m depth, buried in coarse sand.

Geographical distribution. Known only from its type locality.

Discussion

Epitomapta aumakua sp. nov. is very similar to its central Eastern Pacific congener *E. simentalae* but differing in the number of sensory cups per tentacle (4–6 in *E. simentalae*, 6–8 in *E. aumakua* sp. nov.). In addition to the geographical distribution, *E. aumakua* sp. nov. is smaller (<20 mm) than *E. simentalae* (<50 mm) (Solís-Marín et al. 2019). *Epitomapta aumakua* sp. nov. clearly differs from *E. tabogae* and *E. roseola* in the number of sensory cups per tentacle (8–14 in *E. tabogae*, 2–5 in *E. roseola*), and in the number of pairs of digits present on the tentacles (5–6 in *E. tabogae*, 7 in *E. roseola*, and 2–3 in *E. aumakua* sp. nov.). *Epitomapta tabogae* was originally recorded from Taboga and Taboguilla, Panama, by Heding (1928) and is distributed throughout the Gulf of California (Solís-Marín et al. 2009), whereas *E. aumakua* sp. nov. currently is known only

from Hawai`i. In its original description (Verrill 1873), *E. roseola* was recorded from Long Island Sound, Connecticut, and Vineyard Sound, Massachusetts; it was subsequently described from Bermuda (Heding 1928) and later recorded from Connecticut and Massachusetts to Florida (USA) (Hendler et al. 1995). Most recently, *E. roseola* has been reported from the South American coast (Brazil) (Miranda et al. 2015). It has never been reported from Hawai`i.

The anchors of the body wall in *E. aumakua* sp. nov. are similar in shape to those of *E. roseola*, but they differ in size, being approximately 160–170 µm long and 76–80 µm wide in *E. aumakua* sp. nov. (Fig. 1A) versus 120–150 µm long and 70–75 µm wide in *E. roseola* (Heding 1928). The anchors of the posterior region of the body wall in both these species are similar and can reach up to 150 µm long and 70 µm wide; anchors from the anterior end of the body wall in *E. roseola* measure almost 120 µm long and 70 µm wide (Heding 1928), while in *E. aumakua* sp. nov. they are 90–150 µm long and 70 µm wide. On the other hand, the anchors of the Pacific *E. tabogae* are 200 µm in length and 100 µm in width in the posterior region of the body, and 170 µm length and 100 µm width in the anterior region of the body (Heding 1928). Today *E. tabogae* and *E. aumakua* sp. nov. possess the largest known anchors of any species in this genus.

Epitomapta aumakua sp. nov. is clearly distinguished from other species of the genus in having extremely large anchors, a character that has been used to differentiate species of the genus by various authors (see Heding 1928 and Hendler et al. 1995).

Key to species of the genus *Epitomapta*

- 1 Papillae or oval bumps present all over the body wall.....**2**
 - Papillae or oval bumps absent. With 2–3 pairs of tentacle digits, each tentacle with 4–6 sensory cups. Miliary granules in the shape of small, C- and O-shaped bodies; no papillae or oval bumps present on the body wall.....
..... ***E. simentalae***
- 2 Atlantic Ocean. With 7 pairs of tentacle digits, each tentacle with 2–5 sensory cups. Anchors of body wall exceed 120 µm in length (up to 150 µm). Miliary granules in the shape of small, oval rings and very few C-shaped bodies..... ***E. roseola***
- Pacific Ocean.....**3**
- 3 Central America (Panama). With 5–6 pairs of tentacle digits, each tentacle with 8–14 sensory cups. Anchors of body wall exceed 120 µm in length (up to 200 µm). Miliary granules in the shape of oval rings and very few C-shaped bodies..... ***E. tabogae***
- Eastern Indo Pacific (Hawai`i). With 3 pairs of tentacle digits, each tentacle with 6–8 sensory cups. Anchors of body wall exceed 150 µm in length. Scarce miliary granules in the shape of stout, flat rods.... ***E. aumakua* sp. nov.**

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Data availability

All of the data that support the findings of this study are available in the main text.

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Complete mitochondrial genome of the abyssal coral *Abyssoprímnoa gemina* Cairns, 2015 (Octocorallia, Primnoidae) from the Clarion-Clipperton Zone, Pacific Ocean

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Abstract

The Clarion-Clipperton Zone (CCZ) in the tropical East Pacific is a region of interest for deep-sea mining due to its underwater deposits of polymetallic nodules containing economically important metals such as nickel, copper, and cobalt. It is also a region of extensive baseline studies aiming to describe the state of the environment, including the biodiversity of the benthic fauna. An abundant component of the abyssal plain ecosystem consists of sessile fauna which encrusts polymetallic nodules and are vulnerable to potential impacts arising from exploitation activities, particularly removal of substrate. Therefore, this fauna is often considered to have key species whose genetic connectivity should be studied to assess their ecological resilience. One such species is *Abyssoprímnoa gemina* Cairns, 2015, a deep-sea coral from the CCZ whose presence in the Interoceanmetal Joint Organization (IOM) claim area has been confirmed during samplings. In this study, we used next-generation sequencing (NGS) to obtain the 18S nuclear rRNA gene and the complete mitochondrial genome of *A. gemina* from IOM exploration area. The mitogenome is 18,825 bp long and encodes for 14 protein coding genes, 2 rRNAs, and a single tRNA. The two phylogeny reconstructions derived from these data confirm previous studies and display *A. gemina* within a highly supported cluster of seven species whose mitogenomes are all colinear and of comparable size. This study also demonstrates the suitability of NGS for DNA barcoding of the benthic megafauna of the CCZ, which could become part of the IOM protocol for the assessment of population diversity and genetic connectivity in its claim area.

Key words: Deep sea, environmental baseline studies, IOM, ISA, key species

Introduction

The Clarion-Clipperton Zone (CCZ) is a large abyssal area beyond the national jurisdiction in the northern tropical part of the Pacific Ocean, west of Mexico and California and south-east of Hawaii, and governed by the International Seabed Authority (the ISA). This zone has been the area of scientific and industrial interest since the 1950s and is famous for the largest known deposits of



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polymetallic nodules—concretions containing various metals, including manganese, iron, copper, nickel, and cobalt (Van Nijen et al. 2018)—covering the seafloor (ISA 2010; Kuhn and Rühlemann 2021). It is also the largest region of exploration activities undertaken by ISA contractors and the scientific community and, as of now, the best recognized region for abyssal plain exploration in terms of environmental conditions (Amon et al. 2022).

Due to the growing interest in exploitation for nodules, an increasing number of sampling campaigns have been taking place in this area, all conducted under the legal framework of UNCLOS, the 1994 Agreement, and a set of Exploration Regulations of the ISA (in place since 2000; ISA 2015). Efforts are underway to develop regulations and establish a legal framework for deep-sea mining to ensure best environmental practices and to prevent, reduce, and control pollution and other hazards, which can potentially interfere with the ecological balance of the marine environment. Research expeditions are ongoing to study the biodiversity and ecological significance of the CCZ to better understand the potential impacts of mining activities and inform environmental management and conservation efforts.

The seafloor is inhabited by endemic species, with an increasing number being discovered and taxonomically described as exploration continues. A large majority of them represent invertebrates such as amphipods, annelids, or ophiuroids (e.g. Amon et al. 2016; Riehl and De Smet 2020; Bonifácio et al. 2021; Bribiesca-Contreras et al. 2021, 2022; Durden et al. 2021; Jones et al. 2021; Laming et al. 2021; Lejzerowicz et al. 2021; Neal et al. 2022; Stewart et al. 2023; Uhlenkott et al. 2023). The CCZ also hosts large benthic foraminifera, including sessile Xenophyophores attached to the nodules (Kamenskaya et al. 2012, 2015, 2017; Gooday et al. 2018, 2020, 2021; Goineau and Gooday 2019; Stachowska-Kamińska et al. 2022; Gooday and Wawrzyniak-Wydrowska 2023).

The CCZ seafloor is also home to an endemic species of deep-water coral, *Abyssoprímnoa gemina* Cairns, 2015 (Cairns 2016), which lives attached to the nodules. The genus *Abyssoprímnoa* is for now known to be monospecific. A major morphological feature of this taxon is the presence of polyps that always occur in pairs, hence its species name *gemina* (Eng. “twins”). Its type locality lies within the German exploration area (BGR claim area), but specimens have also been documented in the neighbouring UK claim area (UKSRL I), all situated in the eastern part of the CCZ.

The eastern part of the CCZ is also where the Interoceanmetal Joint Organization exploration area (IOM claim area) is located (Fig. 1). The IOM claim area is ca 75,000 km², at depths of 2,450–4,750 m, and has been explored by IOM since 1987 (Baláž 2022). Among the various topics of environmental baseline research (e.g. Skowronek et al. 2021; Hikov et al. 2022; Milakovska et al. 2022; Štyriaková et al. 2022), benthic megafauna and nodule-fauna studies are of crucial importance. The main sampling methods applied include photo profiling (video and still imagery documentation) and box-coring of the seafloor. Photo profiling documents the occurrence of benthic organisms living on and just above the seafloor.

Based on this method, the presence of *A. gemina* in the IOM claim area was suggested as early as in 2014 (Figs 2, 3) (IOM Megafauna Atlas, published online in 2021, <https://iom.gov.pl/environmental-research/megafauna-atlas/>) and confirmed later on in the same year by box-coring (Figs 4, 5), before its formal description by Cairns (2016).

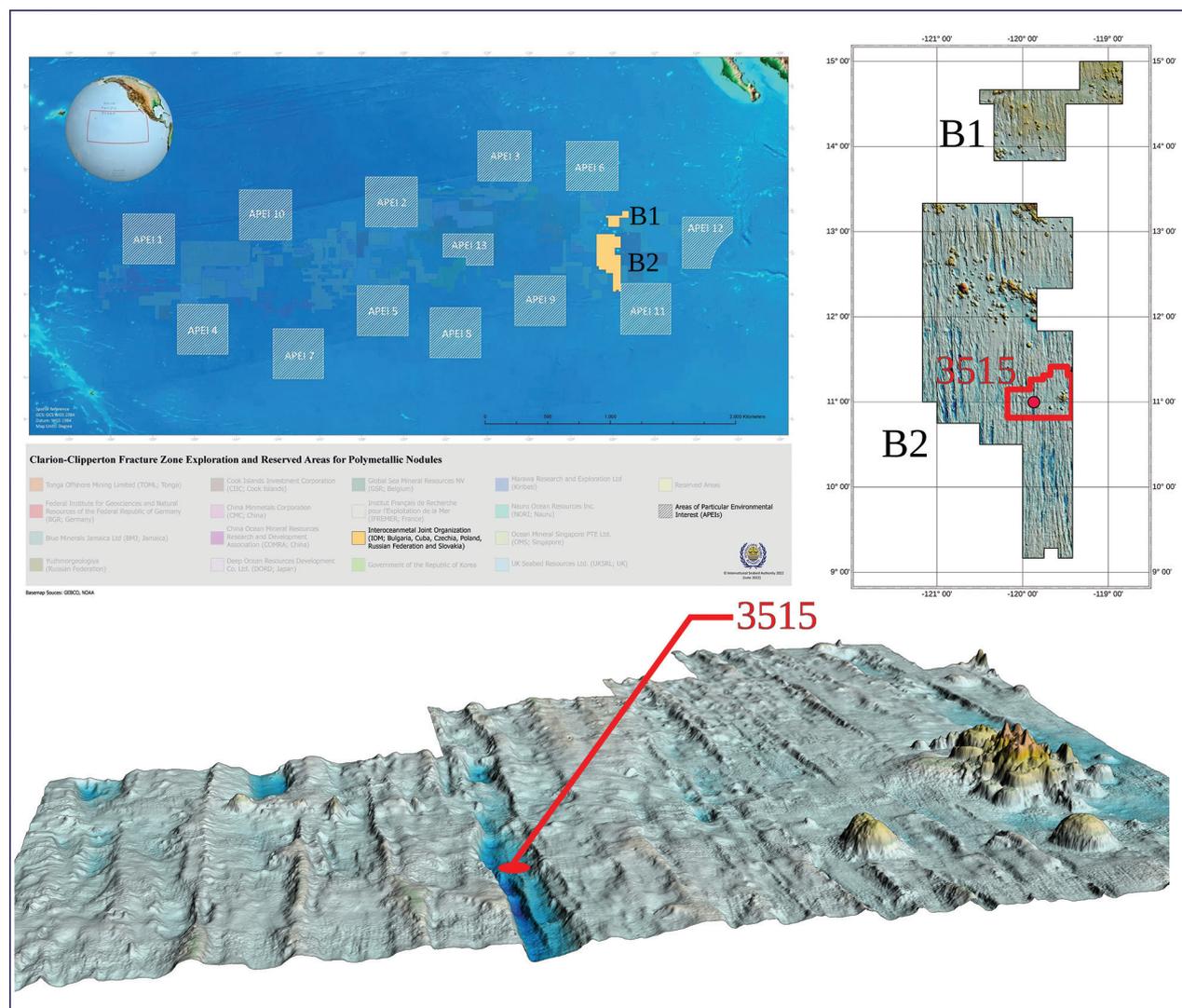


Figure 1. Upper left: location of the IOM claim area in the Clarion-Clipperton Zone, the Pacific Ocean (in orange) (<https://www.isa.org.jm/maps/interoceanmetal-joint-organization/>); upper right: bathymetric map of the IOM claim area B1 and B2, with the location of the exploration block H22 in the B2 claimed area (delimited by red lines) and the location of 3515 sampling station (red dot with the number); bottom: a block diagram of seafloor relief in the exploration block H22 (red dot – location of 3515 sampling station).

During box-corer sampling, undisturbed seafloor sediment, and nodules were retrieved on board of the research vessel and all specimens of benthic mega-, macro-, and nodule fauna were sorted, photographed, registered, and then conserved in ethanol. Attempts were made to taxonomically identify each collected specimen on the basis of its morphology to the lowest level possible. This preliminary identification was planned to be complemented using molecular barcodes (one or more), such as the commonly used genes 18S (of the nuclear small subunit of the ribosomal RNA) or *cox 1* (the mitochondrial cytochrome c oxidase subunit 1 gene).

Although initially not mandatory (ISBA/19/LTC/8), DNA barcoding of specimens from the key taxonomic group (i.e. in the recommendations limited to the representatives of megafauna size class) is currently included in the 2019 “Recommendations for the guidance of contractors for the assessment of the possible environmental impacts arising from exploration for marine minerals in

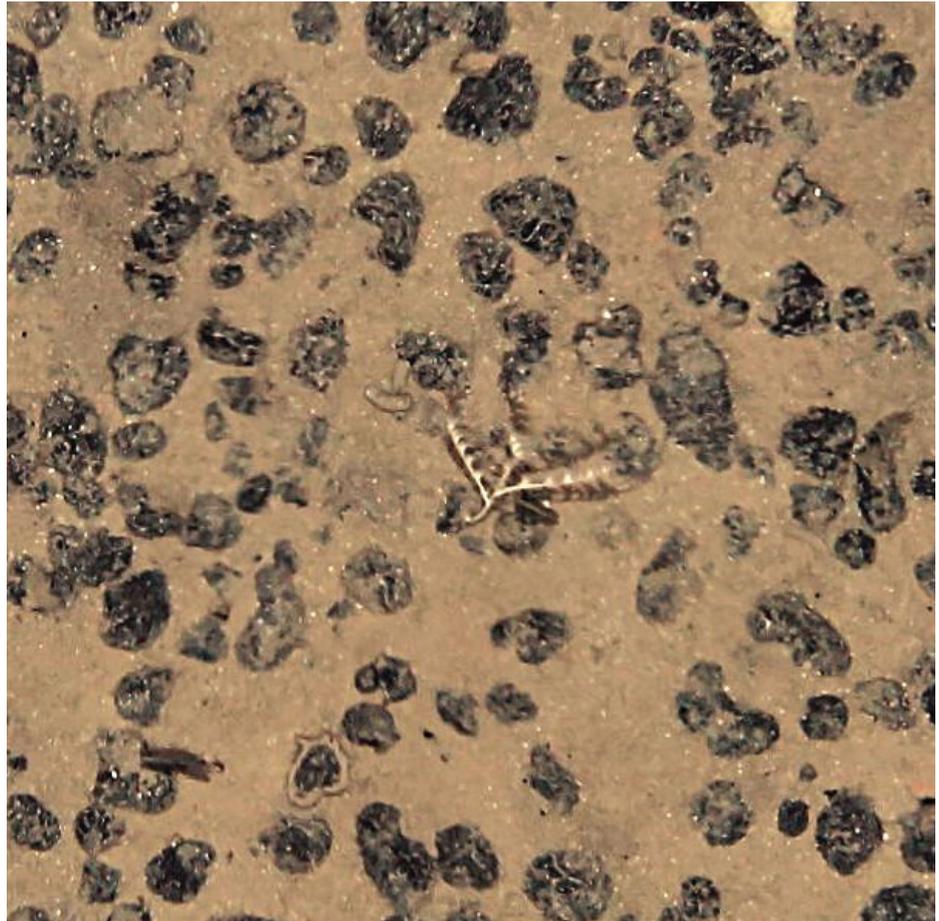
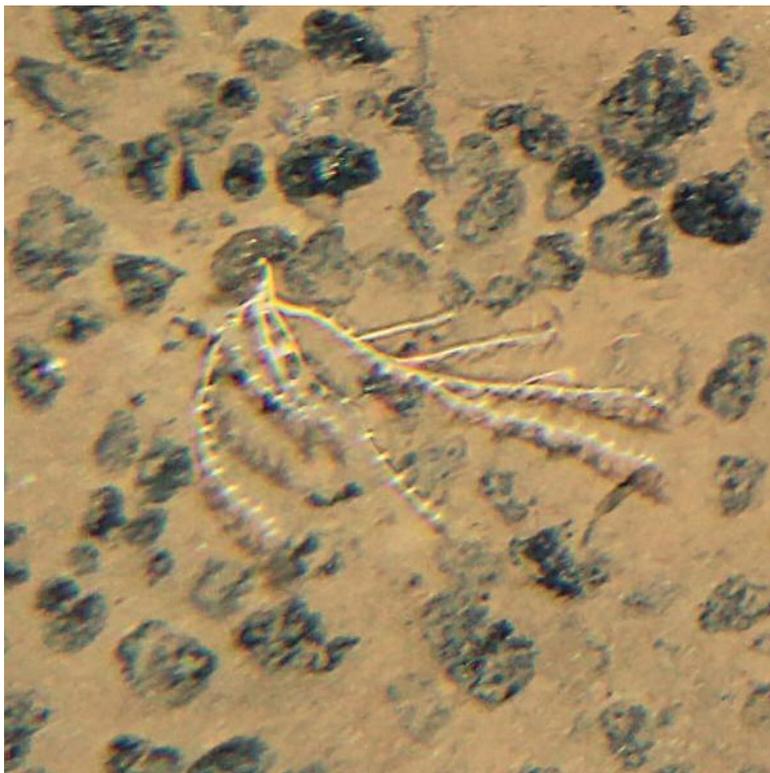


Figure 2. *Abyssoprímnoa gemina* in-situ, as encountered in the IOM exploration zone at ca 4000 m depth (2014).

the Area” (ISBA/25/LTC/6/Rev.2 2022), which are considered obligatory for ISA contractors. Contractors are obliged to “assess regional distribution of species and communities/assemblages as well as genetic connectivity of key and representative species” (section III(b)(15)(d)). Furthermore, it is underlined that: “it is important that molecular studies be undertaken in conjunction with morphological taxonomic analyses” (Annex, 32(a)). However, no specific recommendation is given regarding which molecular marker should be used.

Following these recommendations, IOM recently developed and implemented a DNA-barcoding protocol, which was first applied to the samples obtained during the two exploration campaigns in 2014 and 2019. Principally based on the amplification and sequencing of the two genes mentioned above (*18S* and *cox1*) on all specimens except large Foraminifera, the protocol also tries to use, whenever possible, next-generation sequencing (NGS).

Prior to the current study, there were six sequences of *A. gemina* in GenBank, all of them being partial genes. These sequences originated from two studies. The first one exemplifies the use of DNA barcoding on the CCZ benthic fauna with a focus on Cnidaria (Dahlgren et al. 2016) and is based on two molecular markers, one nuclear (*18S*), and one mitochondrial (*16S*). The second study (Cairns and Wirshing 2018), which was aimed at a large scale multigene phylogeny of Primnoidae, compared with their classification based on morphological characters and relied on four markers, two nuclear (*18S* and *28S*) and two mitochondrial (*cox1* and *mutS*).



Figures 3. *Abyssoprímnoa gemina* in-situ, as encountered in the IOM exploration zone at ca 4000 m depth (2014).



Figure 4. A specimen of *Abyssoprímnoa gemina* collected from the CCZ on a nodule.

A specimen of *A. gemina* was sampled in the IOM area in 2014 and identified under a stereomicroscope a few years later based on the formal description by Cairns (2016). In the frame of the development of a DNA barcoding protocol for the IOM, it was subjected to NGS in 2021. Although it was uncertain if the analysis would be successful due to the time spent by the sample in ethanol, the complete mitogenome and 18S gene of *A. gemina* were obtained.



Figure 5. Same specimen of *Abyssoprímnoa gemina* with outstretched branches.

The present article describes these findings and their comparison with existing references. The two phylogeny reconstructions derived from the mitogenome confirm the previous placement. The belonging of *A. gemina* to key species is introduced, and the interest of the intergenic regions of the mitogenome for population genetic studies on this species is discussed.

Materials and methods

Exploration and sampling

The specimen used in this study was sampled during the 2014 IOM cruise on 04/24/2014 at station 3515 (–119.7990, –11.1258), at 4241 m depth (Fig. 1). Specimens were acquired by a double shovel box-corer with a surface area of 0.25 m² and penetration depth of 50 cm. The habitat type at the sampling station was described as sediments and polymetallic nodules (according to the ISA habitat type classification, ISBA/21/LTC/15/Corr.1 2021). The specimen was photographed, removed from the nodule it was attached to, moved to a 2.0 mL eppendorf tube with 96% ethanol for storage at 4 °C before being registered under the accession number 2014_28 in the benthic fauna collection of the IOM.

Photography

Photographs of the sea bottom (Figs 2, 3) were taken using a Neptune TS-M1 towed on 8000 m long coaxial wireline. The camera set consists of pressure hull with the CANON EOS 60D camera inside (effective matrix resolution of 18 megapixel). The photo frame (automatic mode) was taken at pre-set time interval (20–30 s) when the current sonar data coincided with a given distance of 4 m above the sea floor, enabling to get photographs of the bottom surface with areal size of about 5 m². Photographs of the specimen brought on board (Figs 4, 5) were taken with a Nikon D700 camera equipped with an AF-S MICRO Nikkor 105mm 1:2.8G ED lens.

Sequencing and bioinformatic analyses

DNA was extracted using a DNeasy Blood & Tissue extraction kit from Qiagen from a 0.8 cm fragment of *A. gemina*. DNA was then sent to the Beijing Genomics Institute (BGI) in Shenzhen (China) where it was sequenced on a DNBSEQ platform. The 60 million 150-bp paired-end reads were assembled using SPAdes v. 3.15.5 (Bankevich et al. 2012) with a k-mer of 125. The mitochondrial genome and the *18S* gene were extracted from the contigs file by blastn command line analyses (Camacho et al. 2009). Annotation of the mitogenome was made with the help of MITOS (Bernt et al. 2013) with the genetic code 4 (mold, protozoan, and coelenterate mitochondrial code). The map of the mitogenome was generated using OGDRAW (Lohse et al. 2013).

Phylogeny

Two phylogenetic analyses were conducted based on two recent works on octocorals (Muthye and Lavrov 2021; Muthye et al. 2022). The first one was based on the concatenated sequences of all the mitochondrial protein coding genes (PCG), and the second one on the amino-acid sequence of the DNA repair protein encoded by the *MutS* gene. Datasets from Muthye et al. (2022) were downloaded from OSF and appended with the corresponding sequences of *A. gemina*. All alignments were performed with MAFFT v. 7 (Katoh and Standley 2013) and the -auto option before being trimmed by trimAl v. 1.4.rev15 (Capella-Gutiérrez et al. 2009) and the -automated1 option. For the PCG, the genes were aligned separately, trimmed, and then concatenated using Phyutility v. 2.7.1 (Smith and Dunn 2008). The best model of evolution was chosen with ModelTest-NG (Darriba et al. 2020) on the protein alignment and the concatenated alignment. All maximum-likelihood phylogenies were conducted using IQ-TREE v. 2.2.0 (Minh et al. 2020) with 1000 ultra-fast bootstrap replications in each case.

Data resources

The mitochondrial genome and the *18S* gene were submitted to GenBank with accession numbers OR197546 and OR192930, respectively. The raw fasta sequence of the mitogenome and *18S* gene, the annotated gbk file for the mitogenome, the alignments used for phylogeny and the complete trees in Newick format were deposited on Zenodo (<https://doi.org/10.5281/zenodo.8100227>).

Results

Sequencing, assembly, and phylogeny reconstructions

It was possible to retrieve the complete mitochondrial genome with redundant endings from the contigs file. However, for unknown reasons, the operon of nuclear rRNA appeared in several pieces that failed to merge. Thus, only the complete *18S* gene (1,833 bp) was extracted from the contigs file and later deposited in GenBank (Accession number: OR192930).

The complete mitogenome is 18,825-bp long (GenBank: OR197546). It encodes for 14 protein coding genes, 2 rRNAs, and a single tRNA (Fig. 6), which

is congruent with other octocorals. The best models of evolution returned by ModelTest-NG were TVM+I+G4 for the concatenated PCG and HIVW+I+G4+F for the *MutS* encoded protein. The complete trees, which were too large for publication, are available as indicated in the data resources statement. The figures represent instead highly supported subtrees containing five families. *Abyssoprимnoa gemina* is displayed in both phylogeny reconstructions in a highly supported clade (100%) with all the six other species of the Primnoidae family (Figs 7, 8). It is noteworthy that the mitogenome of *A. gemina* is also colinear with these Primnoidae. There are discrepancies in the rest of the subtrees for what concerns the position of the family Ifalukellidae, represented here by *Trichogorgia capensis* (Hickson, 1904) (Hickson 1904). It is also noteworthy that the support at the nodes for the *MutS*-inferred tree is in general lower when compared to the multigene tree. It especially concerns two nodes, one associating Primnoidae and Ifalukellidae (66%), and the other associating Chrysogorgiidae to Keratoisididae + Isidoidae.

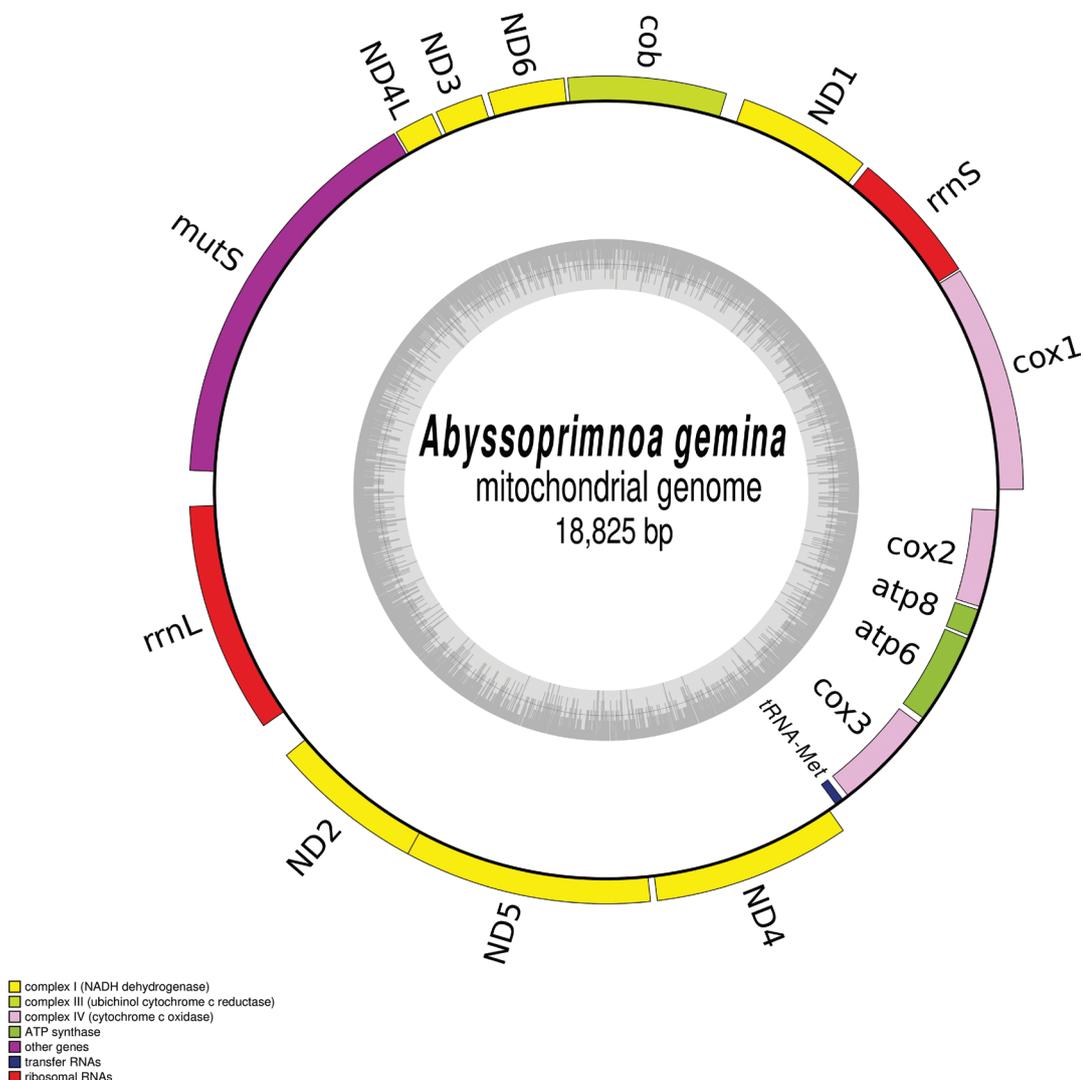


Figure 6. Map of the mitochondrial genome of *Abyssoprимnoa gemina*. The type of genes (e.g. complex I–IV genes, rRNA genes) is represented by different colours whose meaning is explained on the bottom left part. The grey circle represents the GC content.

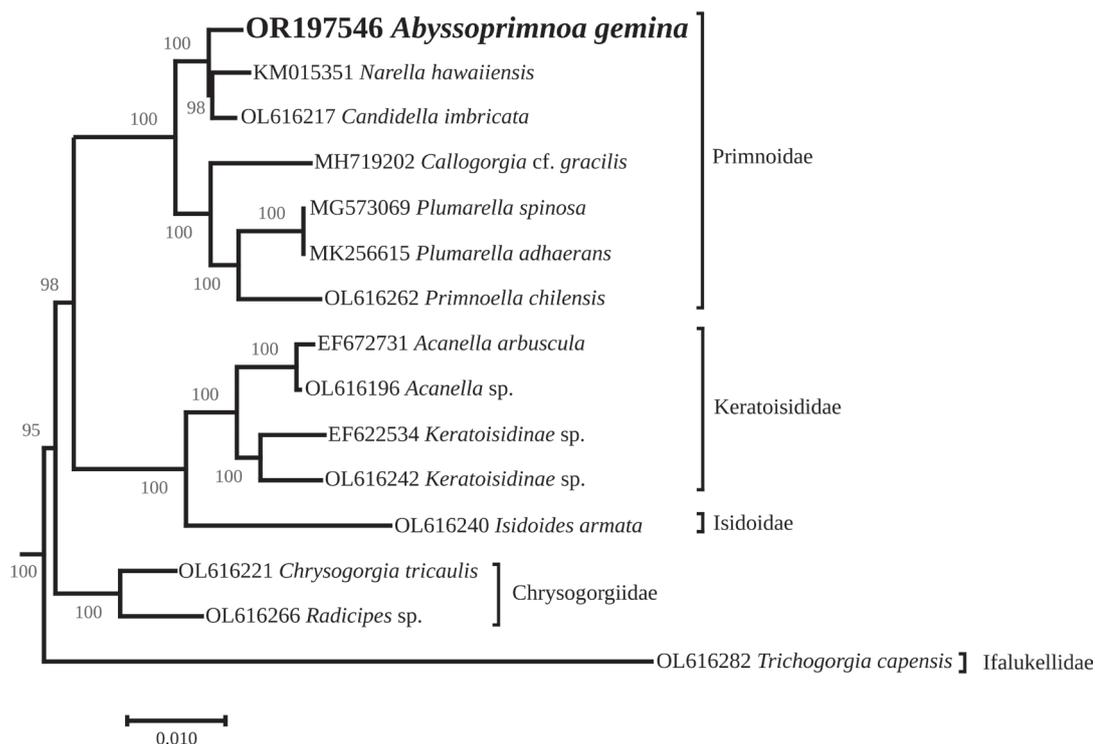


Figure 7. Maximum-likelihood phylogenetic tree obtained from an alignment of concatenated mitochondrial protein-coding genes of 185 taxa of octocorals. The subtree corresponds to a highly supported clade containing among other the family Primnoidae. The name of the families is indicated next to the brackets. The bootstrap values are indicated at the nodes, and the GenBank accession number of the sequence is indicated before the species name. The scale represents the number of substitutions per site.

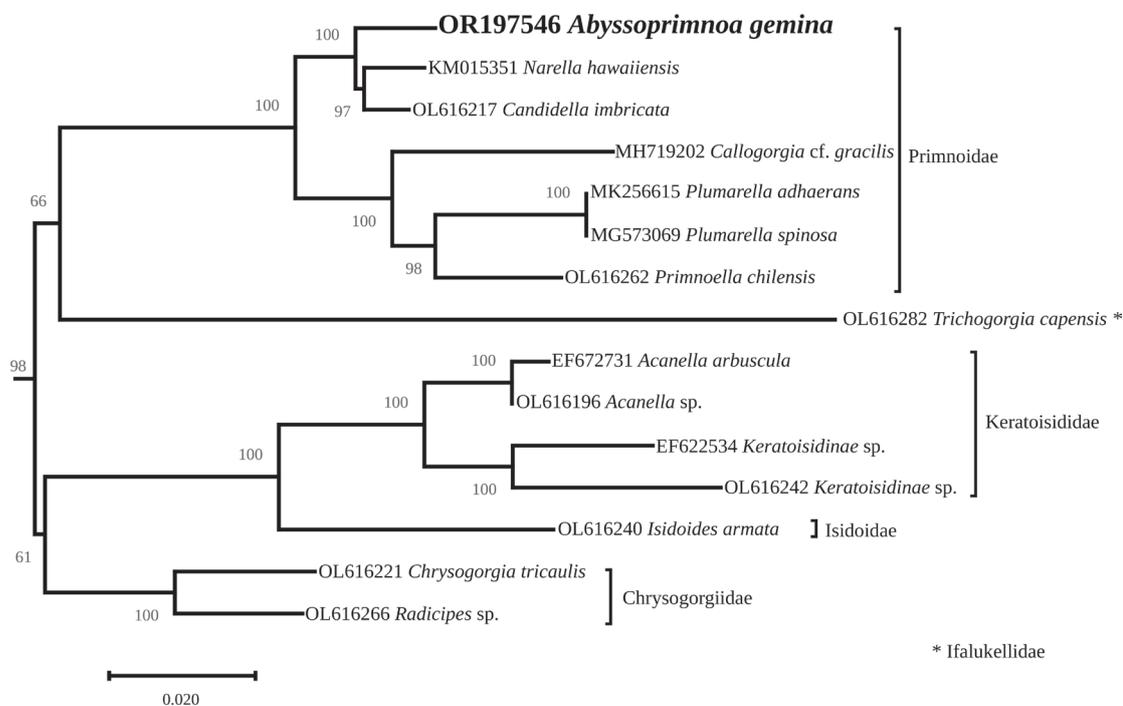


Figure 8. Maximum-likelihood phylogenetic tree obtained from an alignment of 183 *MutS* encoded protein. The subtree corresponds to the highly supported clade containing among other the family Primnoidae. The name of the families is indicated next to the brackets. The bootstrap values are indicated at the nodes, and the GenBank accession number of the sequence is indicated before the species name. The scale represents the number of substitutions per site.

Comparison with available sequences: DNA barcoding

Comparison of the sequences of the mitochondrial PCG with the references from GenBank showed a complete identity. The sequences concerned were the partial *cox1* (MG986971) and *MutS* (MG986922) genes. For what regards the partial mitochondrial 16S gene (KX384626), there were two polymorphisms found at the nine last base pairs of the 3' ending. There was a single indel in the 5' ending of sequence KX384618, differentiating it from the 18S complete gene obtained in the course of this study. Both sequences, however, differed from MG980108 by the presence of a 9-bp deletion at the 3' ending of the sequence.

Discussion

As stated above, the mitogenomes of *A. gemina* and the other six Primnoidae species are colinear, clustering together in both phylogeny reconstructions. The size of the *A. gemina* mitogenome (18,825 bp) is slightly smaller compared to the other ones, which range between 18,838 bp for *Narella hawaiiensis* Cairns & Bayer, 2008 (Cairns and Bayer 2008; Figueroa and Baco 2015) to 19,037 bp for *Plumarella spinosa* Kinoshita, 1907 (Kinoshita 1907; Choi et al. 2020).

To our knowledge, *A. gemina* is so far only the second representative of the CCZ benthic fauna to have its mitochondrial genome sequenced. This can be easily accounted for by the scarcity and small sample sizes, as well as the difficulty to accurately identify them taxonomically. Due to the small size of most benthic macrofauna specimens, obtaining a sufficiently large amount of DNA might result in the destruction of large fragments of their colonies, which may be a problem when depositing voucher specimens. In addition, in the case of the IOM samples, it must be remembered that they had been kept in ethanol for seven years prior to DNA extraction, which could have jeopardized the outcome of the sequencing by lowering the quantity and quality of DNA to be used as a template for the preparation of the library.

During this study, we noticed that an NGS-based approach could be considered when the size of the specimen is large enough and belongs to a known species, even if the biological material is not fresh. In addition to the original aim of performing DNA barcoding on the CCZ samples for comparison with databases, we also obtained the complete mitogenome and obtained phylogeny reconstructions, which provide more evidence for the proximity between *A. gemina* and the genus *Narella* Gray, 1870, as already demonstrated by Cairns and Wirshing (2018).

As mentioned above, *A. gemina* was not the first organism from the CCZ benthos to be studied using NGS, as five years earlier the mitochondrial genome of the demosponge *Plenaster craigi* Lim & Wiklund, 2017 (Lim et al. 2017) had been obtained by Taboada et al. (2018a). Contrary to our study, which is based on a single individual, the subsequent article from Taboada et al. (2018b) was based on 75 Porifera specimens. Their aim was to find nuclear microsatellite loci among the contigs obtained after assembly for studies at the population level, and to test their distribution among other specimens by PCR.

Taboada et al. (2018b) justified their approach on the grounds of the small numbers of polymorphic sites in the mitochondrial genome of Porifera. A similar problem is likely to occur in octocorals, such as with *A. gemina*. The high conservation level of octocoral mitogenomes has already been noted by

several authors (Muthye and Lavrov 2021; Muthye et al. 2022; Ramos et al. 2023), which can be a problem in population genetics. There is an absolute conservation observed among mitochondrial PCG of our sample and others in the databases. Even if polymorphisms were spotted between the rRNA genes, they were always located at the endings of the reference sequences, all obtained by Sanger sequencing. Although not rejecting the possibility that these polymorphisms do exist, more samples need to be sequenced to confirm this.

An additional interest of sequencing a complete mitogenome is that it also includes the non-coding parts. As stated above, the conservation of mitochondrial genes among Anthozoa is reputedly high, leading authors to deem them as less efficient for studies at the population level than the nuclear gene (Shearer et al. 2002). This is exemplified by *Balanophyllia elegans* Verrill, 1864 (Verrill 1864) for which partial *cox1* gene has been found invariable among 18 populations distributed along 3,000 km (Hellberg 2006). However, studies on mitochondrial intergenic regions were used to define haplotypes among Anthozoa (Smith et al. 2004). For example, up to eight haplotypes were found for *Galaxea fascicularis* (Linnaeus, 1767) (Watanabe et al. 2005). Smith et al. (2004) studied a non-coding region between *cox1* and *cox2*, while Watanabe et al. (2005) used the intergenic spacer between *cob* (or *cytb*, coding for cytochrome b) and *ND2* (coding for the second subunit of the NADH dehydrogenase). In *A. gemina*, there is also a 155 bp intergenic spacer between *cox1* and *cox2* (both genes located on different strands), but *cob* and *ND2* are not contiguous in this species. Instead, we found other intergenic sequences of potential interest, for example between *ND1 - cob* (131 bp) and *rrnL - ND2* (265 bp). Although shorter than the regions sequenced by the aforementioned authors, they could still present polymorphisms of interest.

In addition, reads such as those obtained in the course of this study can also be processed through pipelines such as HybPiper (Johnson et al. 2016) supplemented with a proper database (e.g. Quek et al. 2020) to directly extract from them orthologous loci putatively polymorphic. The data gathered can be later employed in phylogenomic studies as recently exemplified by Quek et al. (2023), but they might also be used for studies at the population level.

During the exploration phase of the CCZ, the contractors are obliged to gather environmental data (describing the state of environment) to inform the baseline against which possible environmental impacts arising from exploration for marine minerals will be assessed (ISBA/25/LTC/6/Rev.2). Collecting information on “regional distribution of species and communities/assemblages as well as genetic connectivity of key and representative species” is one of the requirements imposed on the contractors by the regulator; however, there is no recommendation with respect to the criteria for identifying key species. Rabone et al. (2023) proposed a list of key taxonomic groups of macrofauna (tanaids, isopods, and polychaetes), as well as megafauna (asteroids and ophiuroids). The term “key” as used here means most abundant and dominant (“major”) groups of benthic fauna (Simon-Lledó et al. 2020). To our knowledge, there is limited information on connectivity of benthic fauna in the CCZ, whether it refers to key species or not (Taboada et al. 2018b; Kersten et al. 2019; Janssen et al. 2019; Patel et al. 2020; Bribiesca-Contreras et al. 2021). It represents one of the knowledge gaps presently identified (Amon et al. 2022), which must be addressed in order to inform evidence-based environmental management. The point of the current study also belongs to IOM's strategy to deal with this issue in the eastern part of the CCZ.

If we refer to existing works, *P. craigi*, the aforementioned species of demosponge found on polymetallic nodules, was proposed by Taboada et al. (2018a, 2018b) as a key species and a model organism to study biogeographic patterns at varying spatial scales, with the help of molecular and genomic tools. The three reasons behind this choice (Taboada et al. 2018b) were: (1) a high dependence on polymetallic nodules which provide the substrate for adults, (2) a filter-feeding mechanism of obtaining nutrients from particles suspended in water, and thus high vulnerability to increased turbidity, also resulting from collector plumes (Weaver et al. 2022), and (3) presumed (analogous to other sponges) short pelagic larval durations (lecithotrophic larvae) with relatively limited dispersal ability. Combination of these three traits of *P. craigi* can, in turn, result in high vulnerability of this species to temporal (increased turbidity) and permanent (substrate removal) changes in environmental conditions caused by deep-sea mining.

Abyssoprímnoa gemina shares at least two (or three if lecithotrophic larvae are confirmed) of these traits (in general coral larvae are considered lecithotrophic (Rodd et al. 2022)), and therefore we propose that it can be considered a key species. In general, cold-water corals, including deep-sea corals, are regarded vulnerable to anthropogenic impacts (e.g. Cordes et al. 2016). In addition to the traits already mentioned, these corals are also characterized by slow growth and recovery rates (Roark et al. 2009).

If *A. gemina* is to be later considered a key species, it will imply that further genetic investigations will have to be conducted on it, building on the current work. Depending on the results of the next IOM cruises, perhaps additional specimens of *A. gemina* will become available for sequencing. The other ISA contractors and members of the scientific community working on the CCZ could also participate to improve our knowledge on *A. gemina* from their own exploration area following the protocol described here.

Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statement

No ethical statement was reported.

Funding

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Author contributions

Conceptualization: RG. Funding acquisition: TA. Investigation: RG, TA, PD, KM, VS. Methodology: PD, RG. Project administration: TA, KM. Visualization: AK. Writing - original draft: RG. Writing - review and editing: VS, KM, PD, TA, AK.

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Data availability

All of the data that support the findings of this study are available in the main text.

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Surprising discovery of an enigmatic geometrid in Croatia: *Mirlatia arcuata*, gen. nov., sp. nov. (Lepidoptera, Geometridae)

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Abstract

A new monotypic genus of Geometridae, *Mirlatia* **gen. nov.**, and a new species, *M. arcuata* **sp. nov.**, are described from Croatia. Based on external and genitalia characters, the new genus is tentatively placed in the subfamily Larentiinae. However, the new genus takes a highly isolated position by having unique characters of the tympanum and showing an unusually long pectination of female antennae. Genetic analysis of a fragmented DNA barcode (mtDNA; cytochrome c oxidase 1) did not result in a clear assignment to any geometrid subfamily or tribe. Adults, male and female genitalia, and habitat photos of the type locality of the new species are illustrated.

Key words: Cold-adapted, DNA barcoding, geometer moths, Mediterranean, tympanum



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Introduction

In January 2014, the third author of this paper acquired the Lepidoptera collection of Robert Hentscholek, an amateur entomologist from Linz (Austria). In the course of inspecting the collection, a male specimen of a peculiar geometrid moth collected in 1983 in Podgora, Croatia (then Yugoslavia) was detected. The moth clearly differed from every known European geometrid species and could not even be assigned to a known genus. The collector was contacted for further information about the unusual moth, and it became evident that a male and a female specimen of the same species had been donated to the late Kurt Huber (1941–2002) who had allegedly passed the two specimens on to a geometrid specialist at the Insect Fair in Weiden, the identity of whom could not be clarified. Later in the same year, two Geometridae specialists, Peder Skou and the first author of this paper, were contacted by TM for help in identifying the unknown species; however, both failed to find out more about the identity and potential relationships of the Croatian moth.

In 2015, the second author independently and unexpectedly had located a female specimen of the same species collected in 1982 in Podgora by R. Hentscholek in the Rudolf Pinker (1905–1987) collection during a survey in the Natural History Museum, Vienna. This specimen is likely the female mentioned by

the collector to have been obtained by Huber and seemingly had ended up in the Pinker collection. As the second author also failed to identify the species, he contacted the first author hoping to get the species identified and, thus, the two parallel discoveries of the same problematic geometrid had been linked together. However, as no Geometridae specialist who had been contacted for advice could even attribute the species to a genus, the moth remained unidentified and the whereabouts of one of the three specimens remained unknown. In 2022, with the aim to revive the identification efforts and attempt to trace the missing second male, the third author contacted the fourth author for an opinion about the taxon. As a result, a team was formed to work on identifying the enigmatic geometrid moth. Although the authors could not trace the second male specimen, both sexes of the taxon were available for detailed examination.

After ruling out the possibility of an accidental introduction of the species (see Discussion) we regarded it as a resident species new to science. Venation and shape of hindwing suggest the placement of the species in the subfamily Larentiinae. However, many unique characters (e.g. the peculiar morphology of the ansa of the tympanum) make this attribution rather tentative. A set of largely distinctive morphological characters and the highly isolated position of the taxon based on a DNA barcode analysis suggest that the species belongs to a new monotypic genus, which is together with its type species described in this present paper: *Mirlatia arcuata* gen. et sp. nov.

Materials and methods

Morphological studies

The genitalia were dissected, stained with Chlorazol black (holotype) or Eosin red (paratype) and embedded in Euparal on microscope slides applying standard methods of preparation (Lafontaine and Mikkola 1987). Photos of adults were taken using an Olympus Tough TG-5 camera (holotype) and a Nikon D90 SLR camera equipped with Nikkor AF Macro 60 mm lens (paratype). Genitalia were photographed using an Olympus E-M1 camera on a Leica DM2700M stereomicroscope (holotype) and a Nikon DS-Fi1 digital camera mounted on a Nikon Eclipse 80i compound microscope (paratype).

Wing venation was examined under a Wild M3Z stereomicroscope equipped with a Wild drawing tube type 308700.

Genetic studies

DNA barcodes were obtained by removing one mid-leg from the dry holotype specimen. DNA extraction, amplification and sequencing of the “barcode” region of the mitochondrial cytochrome c oxidase I (COI-5P) gene region (658 base pairs) were carried out for the outgroup specimens at the Canadian Centre for DNA Barcoding, Ontario, Canada (CCDB), using standard high through-put protocols (Ivanova et al. 2006). For the holotype of the new species a special NGS protocol for ancient DNA in museum specimens was used at the CCDB (Prosser et al. 2016; D’Ercole et al. 2021).

Analysis of DNA barcodes: sequence divergences within and between species were calculated using the Kimura 2-parameter model (Kimura 1980), using

the analytical tools provided by BOLD Systems v. 4 platform (Ratnasingham and Hebert 2007; <http://www.boldsystems.org/>). Phylogenetic and molecular evolutionary analyses were conducted using MEGA v. 11 (Tamura et al. 2021). All sequences and metadata are accessible in the public dataset DS-MIRLATIA (<https://doi.org/10.5883/DS-MIRLATIA>).

Type label data

Information provided in quotation marks is transcribed verbatim. A new line on the label is denoted with “/”, and a different label with “//”; any additional information is provided in square brackets.

Abbreviations

BOLD	Barcode of Life Data System;
CBG	Centre for Biodiversity Genomics, Guelph, Canada;
CCDB	Canadian Centre of DNA Barcoding, Guelph, Canada;
coll.	collection;
gen.prp.	genitalia preparation;
NHMV	The Natural History Museum, Vienna, Austria;
TLMF	Tiroler Landesmuseum Ferdinandeum, Innsbruck, Austria;
ZSM	SNSB-Bavarian State Collection of Zoology (Zoologische Staatssammlung München), Munich, Germany.

Results

Genus *Mirlatia* gen. nov.

<https://zoobank.org/D12B5E0C-3088-47A3-8949-77EF9BFB0A84>

Type species. *Mirlatia arcuata* sp. nov. (by monotypy).

Description (Figs 1–6). External morphology. **Head.** Head medium-sized, compound eye relatively large, labial palp narrow, length 1.1× the diameter of eye in male, 1.5× in female. Proboscis well developed. Male antenna distinctly bipectinate, length of longest branches 1.6 mm, approximately 10× the diameter of flagellum, branches checkered black and white; female antenna distinctly bipectinate, longest branches 4–5× the diameter of flagellum. **Thorax** (wings, legs). Forewing costa and dorsum slightly, termen markedly convex, apex pointed; hindwing termen distinctly arcuate in both sexes. Transverse lines diffuse, hardly discernible. **Venation:** forewing with double areole; R2–4 and R5 arising connate from tip of second areole, M1 and R5 shortly stalked laterally on second areole; hindwing with long fusion of Sc+R1 and Rs, distal parts of Rs and M1 completely fused, M2 arising shortly below cell apex (caudad); discocellular cross vein of hindwing distinctly incurved. Male frenulum well developed as a single bristle. Legs long and narrow, spur formula 0-2-4 in male, 0-2-x in female (hindlegs of the examined specimen are missing). Male foreleg with long, black, narrow epiphysis arising from middle of tibia.

Abdomen. Tympanal organ (Fig. 4). Ansa of tympanal organ very broad at base, gradually tapered, neither dilated medially, nor at apex with hammer-shaped dilation, tip truncate, with a few micro-spinules in the male.

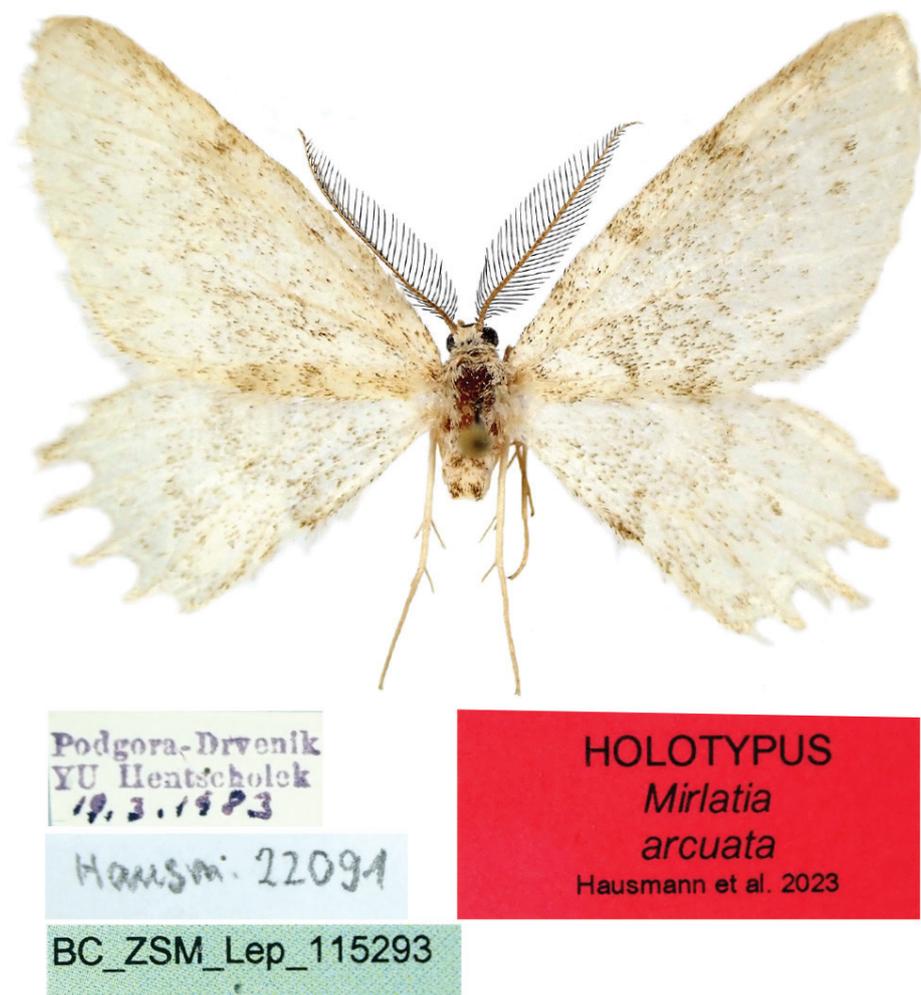


Figure 1. Adult. *Mirlatia arcuata* sp. nov., holotype, male (coll. TLMF).

Genitalia. Descriptions of the male and female genitalia are provided under the description of the type species of the new genus.

Differential diagnosis. Presence of paired tympanal caves with ansa at the base of the abdomen clearly proves the assignation of the new genus to the family Geometridae. *Mirlatia* is distinguished from the vast majority of members of the subfamily Ennominae by the tubular M2 vein of the hindwing and the long fusion of hindwing veins Sc+R1 and Rs. It differs from the genera of the subfamilies Ennominae, Geometrinae, Larentiinae, and Sterrhinae by the very broad base and in the lacking apical dilatation of the tympanal ansa. So far, no other geometrid is known to display a similarly shaped ansa, although a broad ansa basis is found in Archiearinae, Desmobathrinae, and Alsophilini, but these groups have an ansa with a pointed tip. The new genus differs from the vast majority of geometrid genera also by the long pectination of the female antenna.

Genetic data, phylogeny. The genetic data are summarised under the species description. The COI barcode suggests a largely isolated position within Geometridae. The new genus is tentatively placed in the subfamily Larentiinae, supported by the double forewing areole and the hindwing venation with pres-

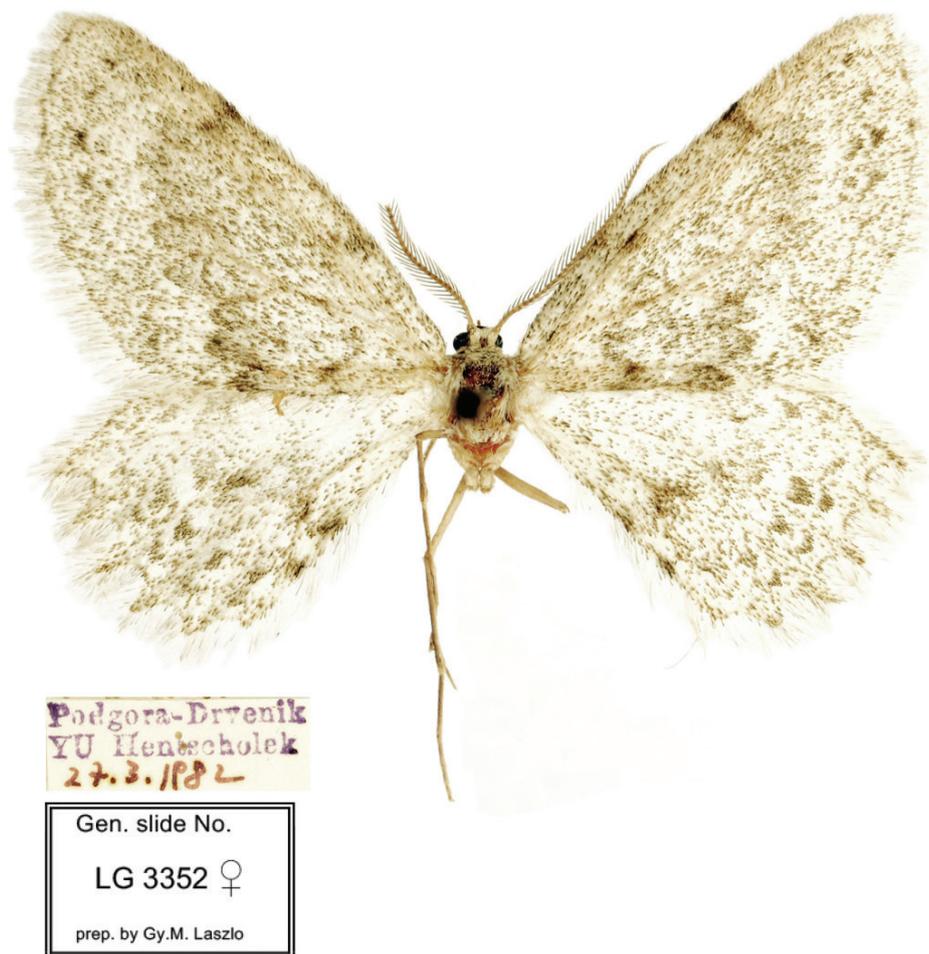


Figure 2. Adult. *Mirlatia arcuata* sp. nov., paratype, female (coll. NHMV).

ence of the M2 vein and long fusion of Sc+R1 and Rs. Further aspects of the phylogeny are discussed later in this paper.

Etymology. The new generic name *Mirlatia* is introduced as a feminine noun. It is an aggregate of the stems of two latin words, i.e. *mir-* (stem of the noun *mirum*, *mira* meaning surprise(s)) and *lat-* (*latum*, the perfect participle form of the verb *ferre* meaning to bring, referring to the rather surprising discovery of this curious new geometrid moth.

***Mirlatia arcuata* sp. nov.**

<https://zoobank.org/A451B800-0C1C-47F6-A326-46640D6B7E79>

Type materials. Holotype: male, “Podgora – Drvenik / YU [southern Croatia, 25 km SE Makarska] [leg. Robert] Hentscholek / [handwritten] 18.3.1983” // DNA barcode sample ID BC_ZSM_Lep_115293 // gen. prp. Hausm. G 22091 // coll. TLMF.

Paratype: 1 female, “Podgora – Drvenik / YU [southern Croatia, 25 km SE Makarska] [leg. Robert] Hentscholek / [hand written] 27.3.1982” // [gen. prp. nr. László] 3352 ♀ // coll. NHMV.



Figure 3. Male genitalia. *Mirlatia arcuata* sp. nov., holotype, slide No.: G 22091 (prep. A. Hausmann, coll. TLMF). Scale bar: 1 mm.

Description. For structural external morphology of adults, see the genus description.

Male (Fig. 1). **Wingspan:** 27 mm. **Colouration.** Frons brown, vertex whitish. Ground colour of wings whitish, slightly irrorated by brown scales (holotype apparently in a slightly worn state); wing pattern very diffuse, undulate antemedial line and postmedial line marked by brown scales, hardly visible. Ante- and postmedial lines more sharply marked at forewing costa and at inner termen of fore- and hindwing. Discal spots absent on all wings. Fringe concolorous with ground colour.

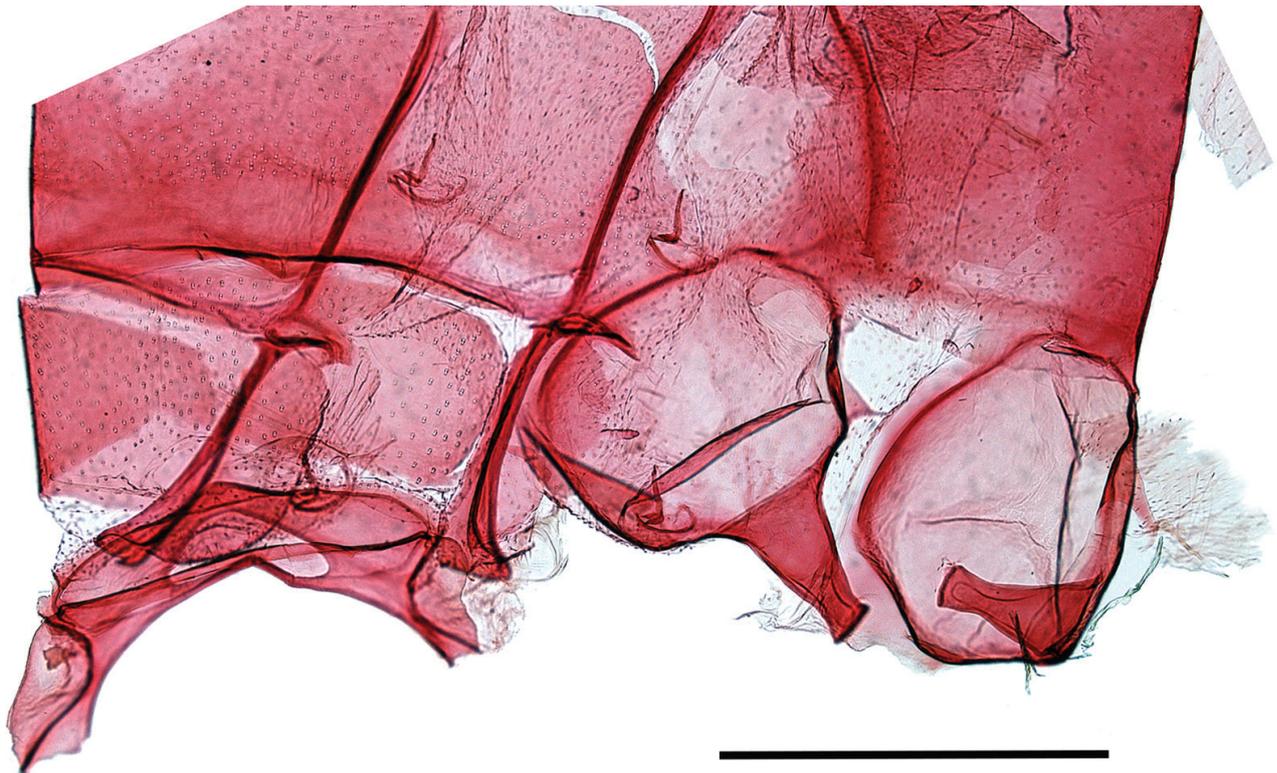


Figure 4. Tympanal organ. *Mirlatia arcuata* sp. nov., female paratype, slide No.: LG 3352 (prep. G. László, coll. NHMV). Scale bar: 1 mm.

Male genitalia (Fig. 3). Uncus broadly dilated, spoon-shaped, covered by sparse, long hairs; gnathos absent; juxta with rugose and posteriorly spinulose membrane; saccus short, angular with rounded corners; valva broad, dorsal margin gently concave, ventral margin convex with a short rounded subbasal projection, apex broadly rounded, valva plate largely membranous with narrow costal sclerotization without appendages. Aedeagus stalked in the basal half, abruptly broadened in the distal half; unverted vesica with fine spinules anteriorly and a large field of aciculate cornuti posteriorly. Sternum A8 and tergum A8 membranous, simple, without appendages.

Female (Fig. 2). **Wingspan:** 29 mm. **Colouration.** Frons brown, vertex whitish. Ground colour of wings whitish, heavily irrorated by brown scales; wing pattern diffuse, undulate antemedial line, dentate postmedial line and a few dark brown dots in terminal area vaguely visible on forewing; ante- and postmedial lines more strongly marked at costa and inner termen. On hindwing, dentate medial and postmedial lines more contrasting towards inner termen. Discal spots absent on all wings. Terminal line brown, indistinct. Fringe concolorous with ground colour.

Female genitalia (Fig. 5). Papilla analis broad, evenly rounded, finely setose. Posterior apophysis twice as long as anterior apophysis, the latter ones interconnected by a narrow, strongly sclerotized, evenly arched band. Ostium bursae membranous, corrugated, rather broad. Ductus bursae strongly sclerotized, very short and broad, twice as wide as long. Corpus bursae oval, strongly sclerotized in posterior third, with longitudinal striation towards ductus bursae. One strongly contrasting, elongate structure in the corpus bursae likely referring to remnant of a spermatophore.



Figure 5. Female genitalia. *Mirlatia arcuata* sp. nov., paratype slide No.: LG 3352 (prep. G. László, coll. NHMV). Scale bar: 1 mm.

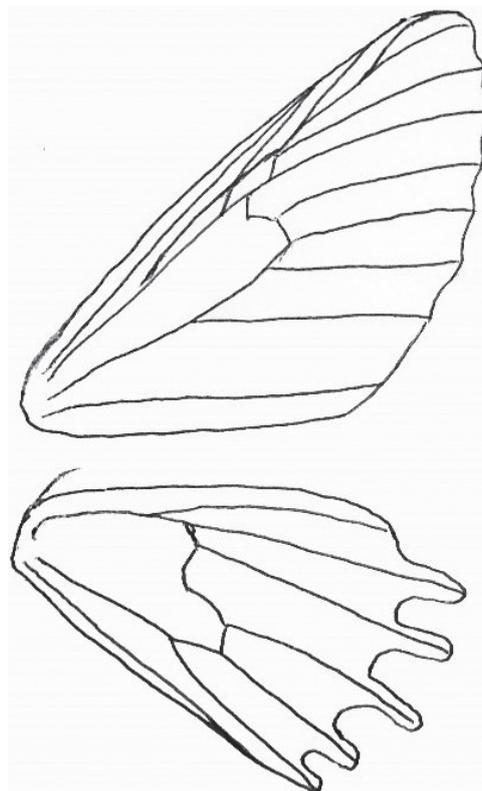


Figure 6. *Mirlatia arcuata* sp. nov., male, wing venation.

Genetic data. The male holotype has been successfully sequenced to a 658-bp fragment containing an internal 200-bp gap. Nearest neighbor: *Idaea muricata* at a distance of 7.8% in the BOLD barcode-gap analysis, with several next-nearest species at distances of 7.8–8.0% from various families such as Gelechiidae, Blastobasidae, Erebidae, and Euteliidae. Chimera status excluded by examination of both subfragments: Subfragment 1 (3') with nearest neighbor from genus *Adoxophyes* (Tortricidae: 6.37%) and several geometrids (all subfamilies) at distances of 6.8–7.0%. Subfragment 2 (5') with nearest neighbor from genus *Ergavia* (Sterrhinae: 5.95%) and several Lepidoptera from other families (e.g. Erebidae) at distances of ~6.2%. Hence, there is no evidence for contamination in both fragments and, therefore, no evidence for a chimera sequence. Nevertheless, from a genetic point of view, our fragmented COI sequence does not allow for a clear assignment of the new genus to any geometrid subfamily, tribe, or genus.

Differential diagnosis. The distinctive features of the new species are discussed under the differential diagnosis of the genus.

Etymology. The species name refers to the arcuate hindwing termen.

Ecology, phenology. The type series was collected in southern Croatia at Drvenik (25 km SE of Makarska) from mid- to late March, close to the Mediterranean shoreline, in a habitat dominated by steep limestone rocks and scree (Fig. 7). The worn stage of the holotype indicates that the main flight period might be earlier, i.e. in late winter, and even a hibernation in the adult stage cannot be ruled out. The whitish ground colour of the adults may indicate a possible camouflaging and resting habit among light rocks characteristic at the type locality.



Figure 7. Habitat of *Mirlatia arcuata* sp. nov., Croatia, Podgora (photograph S. Gomboc).

Discussion

The phylogenetic position of this new taxon is still unclear and requires further study. Its assignment to Larentiinae is tentative and is mainly based on venation; no larentiine moth is known with a similarly shaped tympanal ansa. The double forewing areole and the long fusion of Sc+R1 and Rs in the hindwing are characteristic for Larentiinae (the latter also present in Alsophilini) (Fig. 6). The distinctly incurved discocellular cross vein is reminiscent of that in Alsophilini (Ennominae), which also possesses a broad-based tympanal ansa. An arcuate hindwing termen occurs in a few species of Larentiinae, e.g. *Triphosa dubitata* (Linnaeus, 1758).

The COI barcode data suggests a highly distinct position of *Mirlatia arcuata* within Geometridae, with the closest species at a large p -distance in Sterrhinae (*Idaea muricata*; in the BOLD barcode-gap analysis). No phylogenetic conclusions can be drawn from p -distances of this amplitude; thus, the available data likely point to an isolated phylogenetic position of *M. arcuata*, which is in full agreement with its unique morphological characters. Multi-gene molecular analyses would probably shed more light on the potential relationships of this peculiar taxon and allow to its attribution to one of the described subfamilies and tribes (cf. Murillo-Ramos et al. 2021, 2023), or to recognize it as a member of a distinct new tribe or even subfamily. Nevertheless, these molecular studies could much better be carried out on samples with less degraded DNA. Obtaining fresh samples, however, appears to be a difficult task due to the early flight period and the insufficient knowledge of the habitat preference of the species. Recently, the type locality was investigated for the species during 17–20 March 2022 by Stanislav Gomboc deploying 21 light sources over the course of three nights, but despite this intensive sampling, the species was not captured.

Male and female genitalia of *M. arcuata* sp. nov. do not exhibit any unique characters that would help establish any closer relationships with other geometrid lineages.

As the discovery of a new geometrid in Europe is rather unusual in the third decade of the 21st century, the possibilities of introduction of the species from other continents had to be scrutinised. A possible introduction of this species from other parts of the world can be ruled out from the following reasons:

1. The three specimens collected in March in two consecutive years points to a (at least temporary) reproduction of the species at the site and also suggests that the species is cold-adapted. Furthermore, the species seems to be established in the area, as it was collected in two consecutive years.
2. As no Holarctic species with even similar morphology could be traced by the authors, the only possible region of origin of the species could be in the least known tropics. It is quite unlikely, however, that a cold-adapted species was transported from a tropical country. Nevertheless, the authors thoroughly screened the known geometrids having southernmost distribution in the southern hemisphere (i.e. Chile, Argentina, southern Africa, and southern Australia including Tasmania), where cold-adapted species occur and could not identify any similar species from these regions.
3. The collecting locality at Podgora is not in a direct vicinity of a port, and, additionally, the traffic at Dalmatian harbours during Yugoslavian times was rather limited. Both large ports of Split and Dubrovnik are some 70–80 km away from the locality, a distance that is rather large for a delicately winged early-spring moth with likely limited flying abilities to travel. Additionally, the probability of a tropical species establishing a population and gradually expanding its range in northern Mediterranean areas, where the winter is often cold, is highly unlikely, especially considering the early-spring flying period of this moth. In the early 1980s, under the communist era of the former Yugoslavia, Split or other Croatian ports were rarely visited by ships from other continents.
4. The collector had not been collecting outside of Europe during the time when the specimens were collected, and he had never collected in the tropics at all. Thus, an error in labelling can be excluded.

It may seem peculiar that such a remarkable species has remained undiscovered for so long. However, Dalmatia has not been a highly popular research area for lepidopterists, especially early in the year, in March. It is worth noting that recently there have been other surprising discoveries from the Balkan Peninsula, for example, *Kresnaia beshkovi* (Ganev, 1987) which belongs to a separate, hitherto unknown genus, and *Idaea millesima* Hausmann & Prochazka, 2020 (in Hausmann 2020), which is the first *Idaea* species with bipectinate antennae.

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Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statement

No ethical statement was reported.

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Data availability

All of the data that support the findings of this study are available in the main text.

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Two new bamboo-feeding species of the planthopper genus *Bambusicaliscelis* Chen & Zhang, 2011 (Hemiptera, Fulgoromorpha, Caliscelidae) from China

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Abstract

Two new species of the Chinese caliscelid planthopper genus *Bambusicaliscelis* Chen & Zhang, 2011, *B. bibulbus* **sp. nov.** from Fujian Province and *B. clavatus* **sp. nov.** from Jiangxi Province, are described and illustrated. The genus now known to include six described species. A checklist and identification key to *Bambusicaliscelis* species are provided.

Key words: Bamboo, Caliscelini, distribution, Fulgoroidea, morphology, Oriental region, taxonomy



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Introduction

The caliscelid genus *Bambusicaliscelis* was erected by Chen and Zhang (2011) based on two species, *B. dentis* Chen & Zhang, 2011, and *B. fanjingensis* Chen & Zhang, 2011, from Guizhou Province, southern China. It belongs to the tribe Caliscelini of the subfamily Caliscelinae (Hemiptera, Fulgoroidea, Caliscelidae) (Chen and Zhang 2011). Two species, *B. flavus* Chen & Gong, 2018, and *B. guttatus* Chen & Gong, 2018, were later described from Yunnan and Guangxi Provinces of southern China (Gong et al. 2018). *Bambusicaliscelis* species are similar to one another, but they can be easily distinguished by their male genitalia. All species of the genus are small-bodied (body length ca 3.1–5.1 mm), flightless, and feed on bamboo according to Chen and Zhang (2011) and Gong et al. (2018).

Here, we describe and illustrate two new species, *B. bibulbus* **sp. nov.** and *B. clavatus* **sp. nov.**, from Fujian and Jiangxi Provinces of southern China and collected on bamboo. Thus, six species are now known in the genus. A checklist and a key based on male genitalia to all known *Bambusicaliscelis* species are provided.

Materials and methods

Terminology used for the external morphology and the male genitalia mainly follows Chan and Yang (1994) and Chen and Zhang (2011). The description of the female genitalia mainly follows Bourgoin (1993). Dry specimens were used for the descriptions and illustrations. External morphology was observed under a stereoscopic microscope and characters were measured with an ocular micrometer. All measurements are given in millimeters (mm); body length was measured from the apex of the head to tip of the abdomen in repose. The genital segments of the examined specimens were macerated in 10% NaOH and examined in glycerin jelly using a Leica MZ 12.5 stereomicroscope. Photographs were taken with a KEYENCE VHX-1000 system. Illustrations were scanned with CanoScan LiDE 200 and imported into Adobe Photoshop CS6 for labelling and composition of the figures. The dissected male genitalia are preserved in glycerine in small plastic tubes pinned together with the specimens.

The type specimens and material examined are deposited in the Institute of Entomology, Guizhou University, Guiyang, China (IEGU).

Taxonomy

Order Hemiptera Linnaeus, 1758

Suborder Fulgoromorpha Evans, 1946

Family Caliscelidae Amyot & Audinet-Serville, 1843

Subfamily Caliscelinae Amyot & Serville, 1843

Tribe Caliscelini Amyot & Serville, 1843

***Bambusicaliscelis* Chen & Zhang, 2011**

Type species. *Bambusicaliscelis fanjingensis* Chen & Zhang, 2011, by original designation. *Bambusicaliscelis* Chen & Zhang, 2011: 95; Chen et al. 2014: 157; Gong et al. 2018: 81.

Diagnosis. For the diagnosis of *Bambusicaliscelis*, see Gong et al. (2018: 82). In addition, the hind tibiae has one spine at middle. Spinal formula of hind leg 6 (7)-3-2.

Host plant. Bamboo.

Distribution. Southern China (Guizhou, Yunnan, Guangxi, Jiangxi, Fujian provinces) (Fig. 5).

Checklist of species of *Bambusicaliscelis* Chen & Zhang, 2011

B. dentis Chen & Zhang, 2011; China (Guizhou).

B. fanjingensis Chen & Zhang, 2011; China (Guizhou).

B. flavus Chen & Gong, 2018; China (Yunnan).

B. guttatus Chen & Gong, 2018; China (Guangxi).

B. bibulbus Gong & Yang, sp. nov.; China (Fujian).

B. clavatus Gong & Yang, sp. nov.; China (Jiangxi).

Key to species of genus *Bambusicaliscelis* (modified from Gong et al. 2018) (males)

- 1 The ratio of vertex base width to median length is less than 2; phallus without any teeth-like processes.....**2**
- The ratio of vertex base width to median length is more than 2; phallus with 2–3 teeth-like processes (Chen and Zhang 2011: figs 19, 20) ***B. dentis***
- 2 Forewing yellow; pygofer in lateral view (Gong et al. 2018: fig. 8) with posterior margin sinuate..... ***B. flavus***
- Forewing brown; pygofer in lateral view with posterior margin concave in the middle **3**
- 3 Forewing with one large marking near apical margin.....***B. guttatus***
- Forewing without marking near apical margin **4**
- 4 Forewing with one pale yellow marking near base ***B. bibulbus* sp. nov.**
- Forewing without any marking near base..... **5**
- 5 Spinal formula of hind leg 6-3-2; pygofer in posterior view (Chen and Zhang 2011: fig. 7) ventral margin with short, broad medioventral process, lobe-like ***B. fanjingensis***
- Spinal formula of hind leg 7-3-2; pygofer in posterior view (Fig. 4(H)) ventral margin with claviform medioventral process..... ***B. clavatus* sp. nov.**

***Bambusicaliscelis bibulbus* sp. nov.**

<https://zoobank.org/BE41F1DA-FB57-437A-B1C3-CD629F64FA39>

Figs 1–3

Description. Measurements. Body length (from apex of vertex to tip of abdomen): male 3.9–4.1 mm ($N = 3$), female 4.9–5.1 mm ($N = 4$); forewing length: male 1.7–1.8 mm ($N = 3$), female 1.9–2.1 mm ($N = 4$).

Colouration. Male: body mainly brown; longitudinal stripe from apex of vertex to tip of abdomen pale yellow. Frons dark brown, with small, yellowish-white tubercles between lateral and sublateral carinae. Clypeus dark brown. Eyes yellowish brown. Forewing brown, with one pale yellow marking

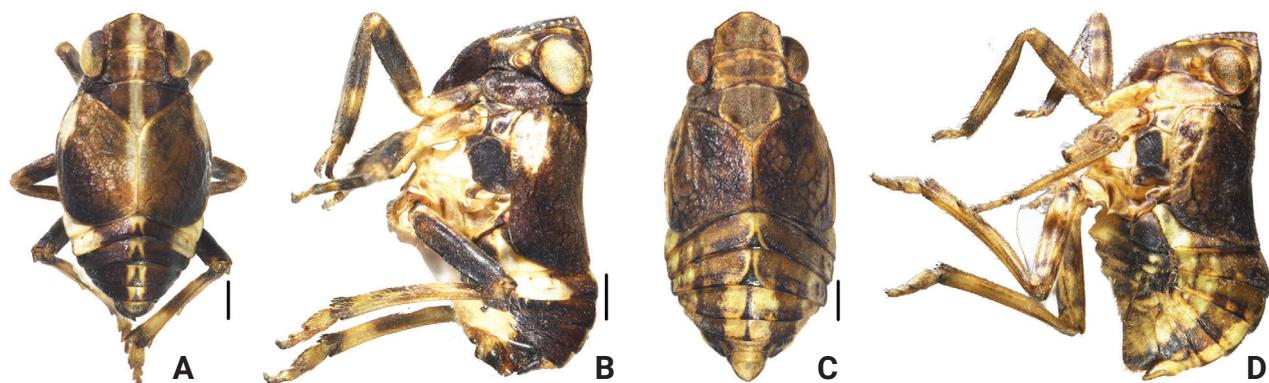


Figure 1. *Bambusicaliscelis bibulbus* sp. nov. **A** male habitus, dorsal view **B** male habitus, lateral view **C** female habitus, dorsal view **D** female habitus, lateral view. Scale bars: 0.5 mm (A–D).

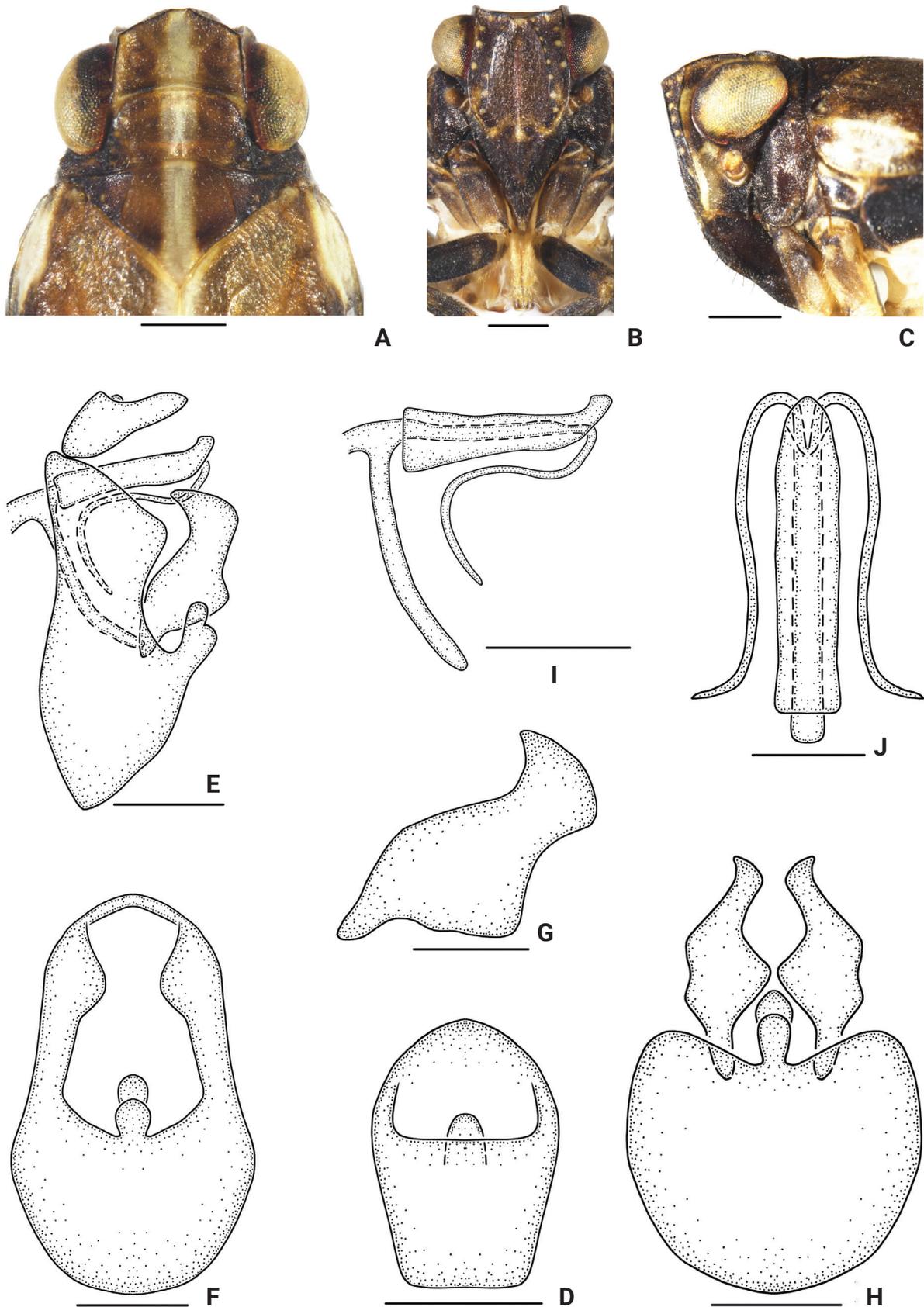


Figure 2. *Bambusicalscelis bibulbus* sp. nov., male **A** head and thorax, dorsal view **B** face **C** head and thorax, lateral view **D** anal segment, dorsal view **E** genitalia, lateral view **F** pygofer, posterior view **G** genital styles, lateral view **H** pygofer and genital styles, ventral view **I** aedeagus, lateral view **J** aedeagus, dorsal view. Scale bars: 0.5 mm (**A–C**, **E**, **F**, **H**); 0.3 mm (**D**, **G**, **I**, **J**).

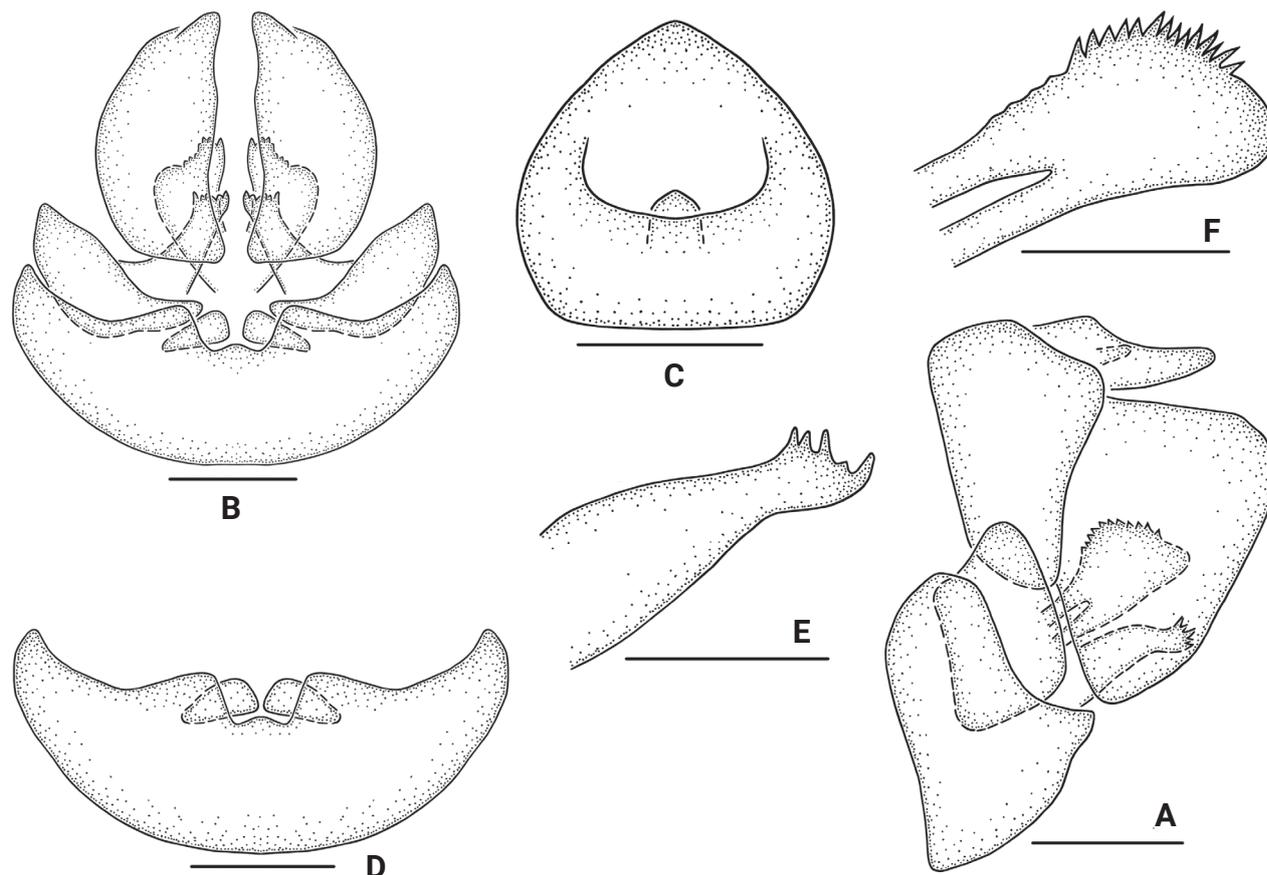


Figure 3. *Bambusicaliscelis bibulbus* sp. nov., female **A** genitalia, lateral view **B** genitalia, ventral view **C** anal segment, dorsal view **D** abdominal sternite VII, ventral view **E** gonapophysis VIII, lateral view **F** gonapophysis IX, lateral view. Scale bars: 0.5 mm (**A, B, D**); 0.3 mm (**C, E, F**).

near base. Abdominal 4th and 5th pleuron pale yellow. Female: body mainly brown but some green; longitudinal stripe from apex of vertex to tip of abdomen inconspicuous and pale yellow. Eyes and forewing brown.

Head and thorax. Vertex with anterior margin subtruncate; width of vertex, including eyes, as long as pronotum. Vertex at middle 0.6 times wider than width at base. Frons 1.1 times longer in middle than at widest part; sublateral carinae slightly keeled; median carina distinct; areas between sublateral carinae and lateral carinae slightly depressed. Pronotum as long as vertex. Mesonotum at middle 0.8 times as long as vertex and pronotum together, 3-carinate, median carina weak. Spinal formula of hind leg 7-3-2.

Male genitalia. Anal segment in dorsal view 1.5 times longer at middle than at widest part; apical margin roundly convex, broadening apically, and broadest at apical third; dorsal margin in lateral view slightly convex, widest at apical half, thence constricted, ventral margin slightly concave in the middle. Pygofer in lateral view with posterior margin with upper half roundly convex, lower half heart-shaped, convex, and ventral margin strongly oblique; in posterior view 1.7 times as long as widest part; in ventral view, posterior margin with a double-droplet-shaped medioventral process. Genital style in lateral view with basal half broad, apical third narrowest; apical margin slightly convex; a finger-like process apically arises from dorsal margin, slightly dorsally curved; genital style in ventral view long, median portion broad. Phallobase tubular, with broad

base, narrowing apically, apex ventrally divided into double petals. Aedeagus double-tubular, much more slender and longer, encircled in phallobase, reflexed basad at level of apex of phallobase, tapering apically.

Female genitalia. Anal segment in dorsal view 0.9 times longer at middle than at widest part; apex narrowed; apical margins convex; anal pore located in the middle, in lateral view small, narrowing apically. Abdominal sternite VII in ventral view with width 3.6 times as long as length; posterior margin strongly trapezoidal concave, behind the posterior margin with two small, triangular ossification flakes. Gonapophysis VIII (first valvula) elongate, with five spines at apical margin. Gonapophysis IX (second valvula) with two symmetrical lobes; each lobe with many spines at dorsal margin. Gonoplac (third valvula) with outer surface shagreened; in lateral view broad, nearly triangular.

Host plant. Bamboo.

Distribution. China (Fujian Province) (Fig. 5).

Type materials. **Holotype:** ♂, CHINA: Fujian Province, Jianan County, Nanping Park, 2019-VIII-10, Zhicheng Zhou. **Paratypes,** 5♂♂, 7♀♀: data same as holotype, Xiaoya Wang and Yongjin Sui.

Etymology. The specific name is derived from a combination of the Latin “bi-” (two) and “bulbus” (bulb), referring to the shape of the medioventral processes on the posterior margin of the pygofer.

Remarks. This new species is closely related to *B. fanjingensis* Chen & Zhang, 2011, but differs in the following: 1) forewing with one pale-yellow mark near base (without any mark in *B. fanjingensis*); 2) posterior margin of pygofer with a strongly medioventral process which is double-droplet-shaped (with only a slightly medioventral process in *B. fanjingensis*); 3) genital style in lateral view long and narrow, and ventral margin roundly concave in the middle (genital style with median portion broad and large, and ventral margin roundly convex in *B. fanjingensis*).

***Bambusicaliscelis clavatus* sp. nov.**

<https://zoobank.org/D9F25415-6E02-4120-A4E4-D00F533FA077>

Fig. 4

Description. Measurements. Body length (from apex of vertex to tip of abdomen): male 4.3 mm; forewing length: male 1.8 mm.

Coloration. Body mainly brown; longitudinal stripe from apex of vertex to tip of abdomen pale yellow. Frons brown with small, yellowish-white tubercles between lateral and sublateral carinae. Clypeus dark brown. Eyes yellowish brown. Pronotum and mesonotum lateral areas with several yellowish-brown sensory pits. Forewing brown to dark brown. Abdominal 4th and 5th pleuron pale yellow.

Head and thorax. Vertex with anterior margin subtruncated, width of vertex including eyes as long as pronotum. Vertex at middle 0.6 times wider than width at base. Frons 0.9 times wider at middle than widest part; sublateral carinae slightly keeled; median carina distinct; areas between sublateral carinae and lateral carinae slightly depressed. Pronotum as long as vertex. Mesonotum 0.8 times as long as vertex and pronotum together in middle line, 3-carinate; median carina weak. Spinal formula of hind leg 7-3-2.

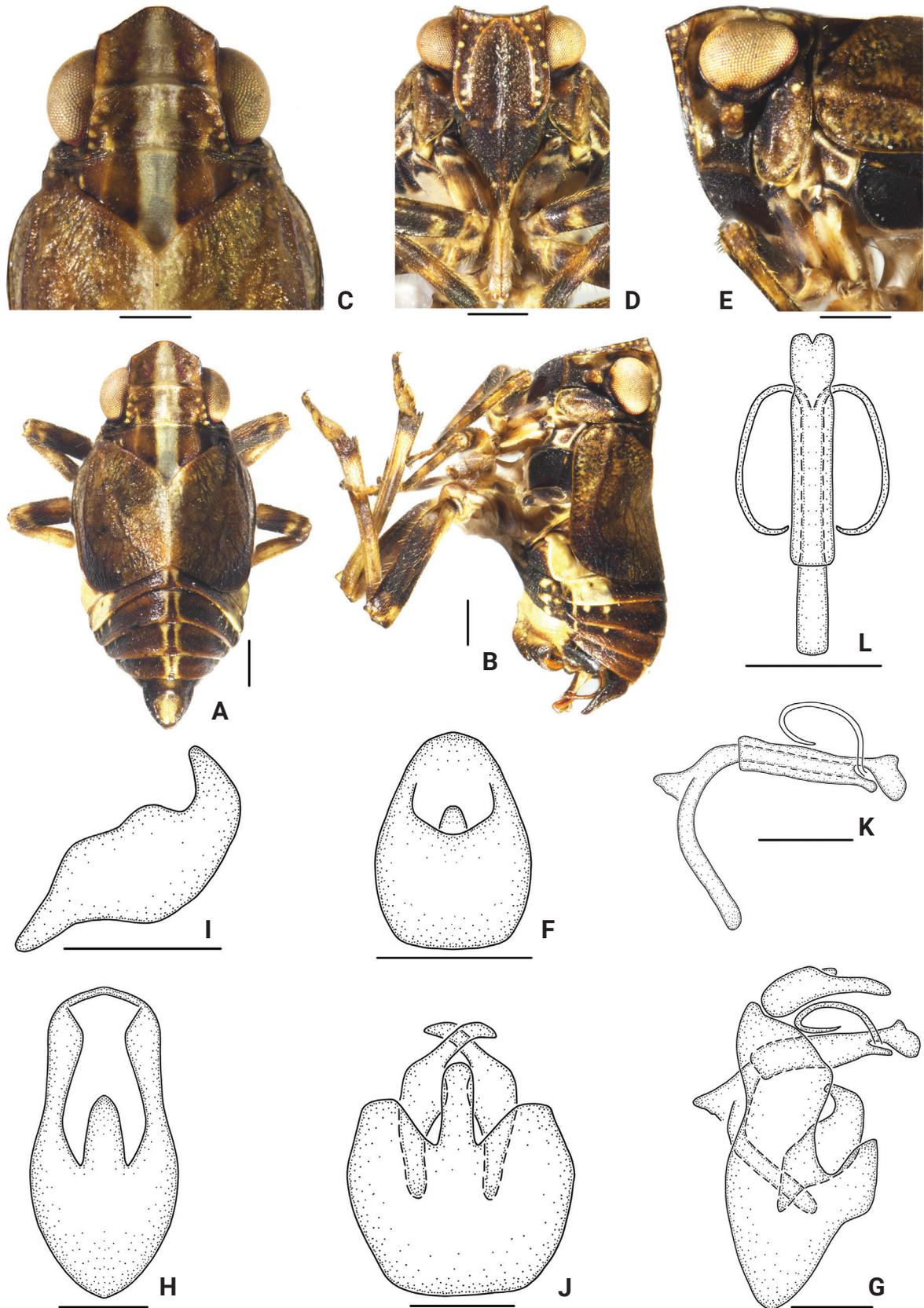


Figure 4. *Bambusicalscelis clavatus* sp. nov., male **A** habitus, dorsal view **B** habitus, lateral view **C** head and thorax, dorsal view **D** face **E** head and thorax, lateral view **F** anal segment, dorsal view **G** male genitalia, lateral view **H** pygofer, posterior view **I** genital styles, lateral view **J** pygofer and genital styles, ventral view **K** aedeagus, lateral view **L** aedeagus, dorsal view. Scale bars: 0.5 mm (**A–E, G, H, J**); 0.3 mm (**F, I, K, L**).

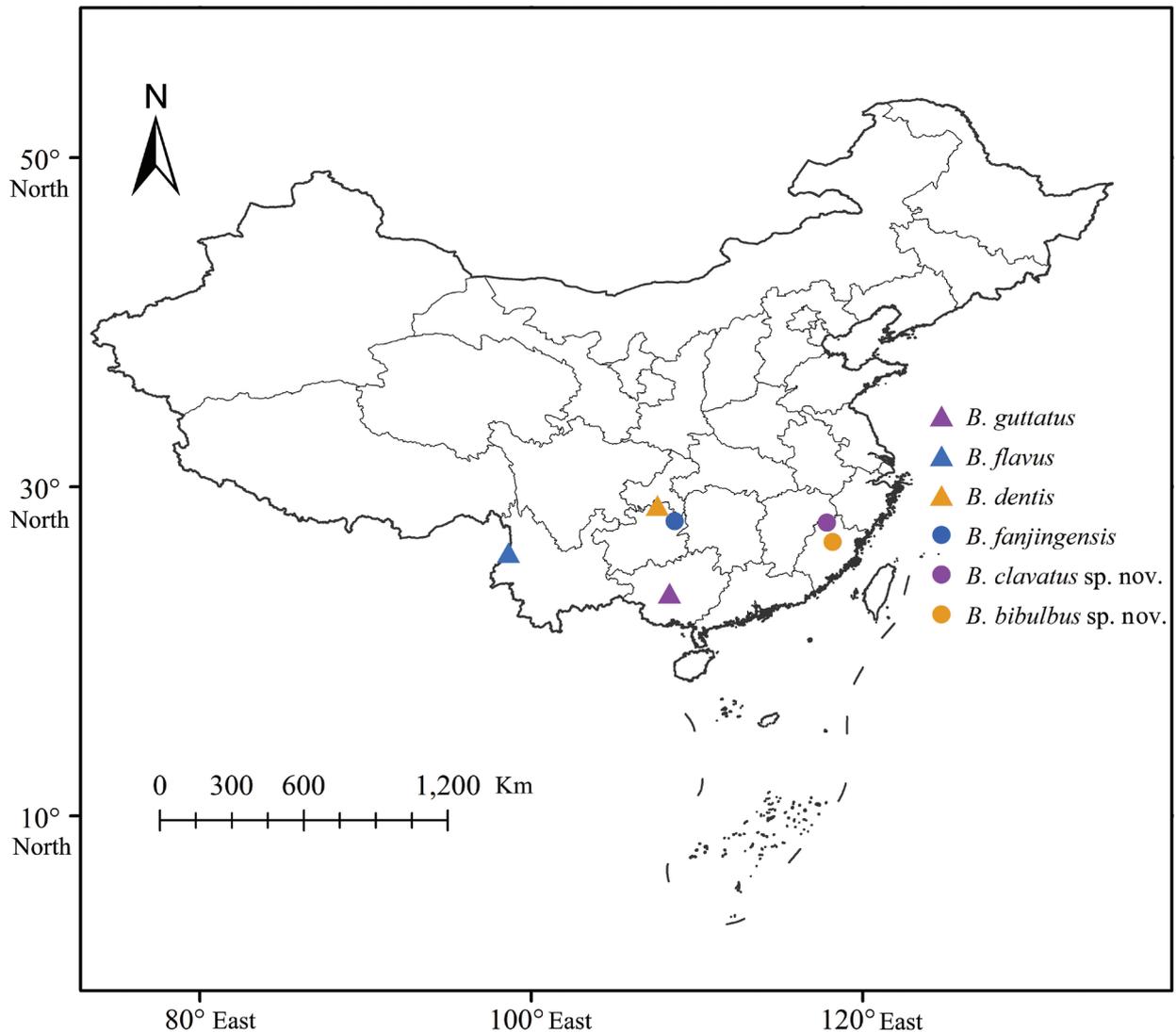


Figure 5. Geographic distributions of species of *Bambusicaliscelis* Chen & Zhang, 2011.

Male genitalia. Anal segment in dorsal view 1.4 times longer at middle than at widest part, narrowing apically, with apical margin roundly convex; in lateral view dorsal margin slightly convex; ventral margin slightly concave in middle, base half as broad, apex half as narrow. Pygofer in lateral view with posterior margin with upper half roundly convex, lower half strongly quadrangular convex, ventral margin strongly oblique; in posterior view 2.1 times longer than at its widest part; in ventral view, posterior margin with a claviform medioventral process. Genital style in lateral view large and broad, ventral margin convex, dorsal margin sinuate, apical margin slightly convex; finger-like process apically arising from dorsal margin, slightly dorsally curved, narrowing apically; in ventral view long, median portion broad. Phallobase tubular; apex ventrally divided into double petals; ventral margin of distal third resembles a finger process. Aedeagus double-tubular, much more slender and longer, encircled in phallobase, reflexed dorsad at level of apical third of phallobase, proximal ventrally curved toward apex, tapering apically.

Host plant. Bamboo.

Distribution. China (Jiangxi Province) (Fig. 5).

Type materials. *Holotype*: ♂, CHINA: Jiangxi Province, Qianshan County, Wuyi Mountains, 2018-VIII-19, Xiangsheng Chen. *Paratype*, 1♂: data same as holotype, 2013-VIII-3, Jiankun Long.

Etymology. The specific name is derived from the Latin words “*clava*” (a staff or club), referring to the shape of the claviform medioventral process.

Remarks. This new species is closely related to *B. fanjingensis* Chen & Zhang, 2011, but differs by the following: 1) spinal formula of hind leg 7-3-2 (spinal formula of hind leg 6-3-2 in *B. fanjingensis*); 2) posterior margin of pygofer with a strongly claviform medioventral process (with a slightly medioventral process in *B. fanjingensis*); 3) aedeagus reflexed dorsad (reflexed ventrad in *B. fanjingensis*).

Discussion

Based on published information as well as available specimens, we have found that the phallobase in all species of is of the “closed-tube” type. Thus, by this character, *Bambusicaliscelis* may be considered one of the most primitive members of Caliscelini. Compared to the “open-tube” type found in other Peltonotellini (Emeljanov 2008: figs 2, 3) and Caliscelini (Gnezdilov and Bourgoïn 2009: figs 63–65), this may suggest a primitive (ancestral) condition.

According to characters of their genitalia, *B. fanjingensis*, *B. guttatus*, *B. flavus*, and *B. dentis* are similar in having the genital style with a narrow capitulum. *Bambusicaliscelis fanjingensis*, *B. guttatus*, *B. dentis*, and *B. bibulbus* sp. nov. all share a ventrally reflexed aedeagus. *Bambusicaliscelis fanjingensis*, *B. guttatus*, *B. bibulbus* sp. nov., and *B. clavatus* sp. nov. have the ventral margin of the pygofer in posterior view with a medioventral process. In *B. dentis*, *B. fanjingensis*, *B. guttatus*, *B. bibulbus* sp. nov., and *B. clavatus* sp. nov. the pygofer in lateral view has the medio-posterior margin concave.

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Author contributions

Nian Gong conceived and designed the experiments, performed the experiments, analyzed the data, prepared figures, authored or reviewed drafts of the paper, and approved the final draft. Xiang-Sheng Chen analyzed the data, prepared figures and tables, and approved the final draft. Lin Yang conceived and designed the experiments, authored or reviewed drafts of the paper, and approved the final draft.

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Data availability

All of the data that support the findings of this study are available in the main text.

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Taxonomic clarification and lectotype designation for *Cryphalus striatulus* Mannerheim, 1853 (non Browne, 1978, nec Browne, 1981) (Coleoptera, Curculionidae, Scolytinae), and notes on pervasive homonymy

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The bark beetle *Cryphalus striatulus* Mannerheim, 1853 was described on the basis of two specimens from Alaska, one under the bark of unknown tree and one caught in flight (Mannerheim 1853). Schwarz (1895) listed *C. striatulus* as feeding on the spruce tree *Picea englemanni* Engelm. [sic!] (Pinaceae) based on specimens collected while on vacation near Alta, Cottonwood Canyon, Utah, in June 1891. These specimens share the approximate collection data (with year and host omitted) as the specimen which became the type of *Cryphalus ruficollis* Hopkins, 1915. It is unclear why Hopkins treated them as such, but all subsequent publications before 2021 refer to Mannerheim's species as *Procryphalus* Hopkins, 1915 then as *Trypophloeus* Fairmaire, 1864. Schwarz also collected specimens of *Trypophloeus* from the same locality, eventually becoming the holotype of *Trypophloeus punctipennis* Hopkins, 1915, now a synonym of *Trypophloeus nitidus* Swaine, 1912.

Later reviews of North American Cryphalini (sensu Wood, 1954) found that there was a proliferation of described names, many of which represent synonymous taxa (Wood 1954). For *Cryphalus striatulus* Mannerheim, 1853, the identity was uncertain because the types could not be found in Mannerheim's collection. Despite this, Wood proposed that *Trypophloeus nitidus* Swaine, 1912 was junior synonym of *Cryphalus striatulus*, thus providing the *Trypophloeus striatulus* [sic!] combination (Wood 1969, 1973). This change was probably based on two major features: (1) Mannerheim's statement that the specimen was similar to *Trypophloeus granulatus* (Ratzeburg, 1837) (Mannerheim 1853), and (2) *Trypophloeus nitidus* was the only North American Cryphalini described as being north of British Columbia in literature at that time (Wood 1969, 1973). This taxonomic combination remained unchanged until Kvamme et al. (2021) in which the authors, while looking for *Trypophloeus* types, discovered a single specimen of *Cryphalus striatulus* Mannerheim, 1853 in the type material pres-

ent in the Zoological Institute (St. Petersburg, Russia) (Fig. 1A). Kvamme et al. found that the species described by Mannerheim was a species of *Cryphalus* Erichson, 1836 and re-established the original combination (Kvamme et al. 2021), putting *Cryphalus ruficollis* Hopkins, 1915 as a junior synonym.

Mannerheim (1853) explicitly described two ‘forms’ in the description, with differences that are neither diagnostic of *Cryphalus* nor *Trypophloeus*. However, given the multiple specimens with different morphologies in the original description, there remains an unlikely but possible chance that the source of historical confusion was that two species were present in the type series. To maintain taxonomic stability, we designate the only known co-type as the lectotype of *Cryphalus striatulus*. This specimen bears the labels: (1) golden circle used to mark type specimens; (2) “*Cryphalus striatulus* Mnrhm. Kenai J[unio]. [?] Russam [?Russian America]” (unclear); and (3) “Lectotype



Figure 1. Habitus and original labels of primary types of species sharing the combination “*Cryphalus striatulus*”. Specimen photographs are resized to a common scale, black bars represent 1.0 mm **A** *Cryphalus striatulus* Mannerheim, 1853; designated lectotype, Zoological Institute (St. Petersburg, Russia) **B** *Cryphalus brownei* (Beaver, 1991) (= *Cryphalomorphus striatulus* Browne, 1978) holotype, NHMUK 010805928 **C** *Cryphalus punctistriatulus* Johnson, 2020 (= *Cryphalus striatulus* Browne, 1981) holotype, NHMUK 010805993.

Cryphalus striatulus Mnrhm. Marchioro et al. des. 2023". This designation promotes stability in case the second specimen is found and represents a different species.

Additionally, the taxonomic change following the discovery of the type creates a new homonym. *Cryphalus striatulus* (Browne, 1978) was originally described as *Cryphalomorphus striatulus* Browne, 1978 on the basis of a single specimen from Penang, Malaysia (Fig. 1B), collected in the gut of a swiftlet (Beaver and Browne 1978). Subsequently, the species was moved to *Hypothenemus* Westwood, 1834 and given the replacement name *Hypothenemus brownei* Beaver, 1991 since this taxonomic combination was already pre-occupied by *Hypothenemus striatulus* Schedl, 1942 (Schedl 1942; Beaver 1991). In 2020, Johnson et al. removed the species from *Hypothenemus* and placed it in *Cryphalus*, rendering the replacement name no longer necessary, using *Cryphalus striatulus* (Browne, 1978) as the valid combination (Johnson et al. 2020). Since the combination *Cryphalus striatulus* is now occupied by *Cryphalus striatulus* Mannerheim, 1853 (sensu Kvamme et al. 2021), we treat the name *Cryphalus striatulus* (Browne, 1978) as a junior homonym, and the novel combination, *Cryphalus brownei* (Beaver, 1991), as the valid name. This is an unusual nomenclatural situation, for using a replacement name as a valid name when in a different genus.

An additional potential source of confusion is *Cryphalus striatulus* Browne, 1981 (Fig. 1C), which was already replaced with *Cryphalus punctistriatulus* Johnson, 2020 due to homonymy with *Cryphalus striatulus* (Browne, 1978) (Johnson et al. 2020). Furthermore, *Cryphalus brownei* Wood, 1992, already exists as an unnecessary replacement name for *Cryphalus artocarpus* Schedl, 1958, (now a synonym of *Cryphalus artocarpus* (Schedl, 1939)) (Johnson et al. 2020). Given such a high degree of homonymy within *Cryphalus*, we suggest correctly citing the authority with the year to avoid future confusion.

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Data availability

All of the data that support the findings of this study are available in the main text.

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New and little-known stonefly species of the *Rhopalopsole vietnamica* ‘western assemblage’ group (Plecoptera, Leuctridae) from China

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Abstract

We examined Chinese stonefly specimens of the *Rhopalopsole vietnamica* ‘western assemblage’ group. A new species from Hainan Province, *R. bawanglinga* Li, Li & Yang, **sp. nov.** is described and illustrated from male and female adults, and it is compared to closely related taxa. The hitherto unknown female of *R. hainana* Li & Yang, 2010 is described. Morphological evidence is presented for the identity of *R. dentiloba* Wu, 1973, on the basis of topotypes from Yunnan Province, southwestern China.

Key words: female description, new species, redescription, *Rhopalopsole bawanglinga*, *Rhopalopsole dentiloba*, *Rhopalopsole hainana*, taxonomy



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Introduction

The stonefly genus *Rhopalopsole* Klapálek, 1912 is one of the largest leuctrid genera, with about one hundred valid species, distributed in the Oriental and East Palaearctic regions (DeWalt et al. 2023). Over sixty species have been recorded from China by Chen et al. (2022), Chen and Du (2017), Klapálek (1912), Li et al. (2010a, 2010b, 2011, 2017, 2022), Li and Yang (2010, 2011, 2012), Mo et al. (2018), Qian et al. (2014), Qian and Du (2011, 2012a, 2012b, 2013, 2017), Sivec et al. (2008), Wu (1949, 1973), Yang and Du (2021a, 2021b, 2022), Yang et al. (2021, 2022), Yang et al. (2004, 2009), Yang and Li (2006) and Yang and Yang (1991a, 1991b, 1993, 1994, 1995a, 1995b). The ‘western assemblage’ of the *R. vietnamica* group was recognized by Sivec et al. (2008), and currently, thirteen species belong to this group (Wu 1973; Yang and Yang 1993; Sivec et al. 2008; Li and Yang 2010; Li et al. 2017, 2010b, 2022; Qian and Du 2017; Yang et al. 2022; Yang and Du 2022). In this contribution, two species of this species group were described or supplemented, including a new species, *R. bawanglinga* Li, Li & Yang, sp. nov. from Hainan Province in southern China, and the hitherto unknown female of *R. hainana* Li & Yang, 2010. Additionally, we provide a redescription and new images for *R. dentiloba* Wu, 1973, a newly included species of this group, based on topotypes.

Table 1. World list of species belonging to the *Rhopalopsale vietnamica* ‘western assemblage’ group. Abbreviation: M, male; F, female.

Species	Known life stages	Distribution
<i>R. amamiensis</i> Kawai, 1967	M, F	Japan: Kagoshima Prefecture, Okinawa
<i>R. assamensis</i> Sivec & Harper, 2008	M, F	India: Assam
<i>R. bawanglinga</i> sp. nov.	M, F	China: Hainan
<i>R. brevidigitata</i> Qian & Du, 2017	M	China: Yunnan
<i>R. dentiloba</i> (Wu, 1973)	M, F	China: Yunnan
<i>R. fengyangshanensis</i> Yang, Shi & Li, 2009	M	China: Fujian, Zhejiang
<i>R. furcospina</i> (Wu, 1973)	M, F	China: Guangxi, Shaanxi, Sichuan, Zhejiang
<i>R. hainana</i> Li & Yang, 2010	M	China: Hainan
<i>R. nanlinga</i> Yang & Du, 2022	M	China: Guangdong
<i>R. sinensis</i> Yang & Yang, 1993	M	China: Chongqing, Fujian, Gansu, Guangxi, Guizhou, Hubei, Ningxia, Shaanxi, Zhejiang; Vietnam: Laocai
<i>R. singiplatta</i> Yang & Du, 2022	M, F	China: Sichuan
<i>R. sipirokana</i> Sivec & Harper, 2008	M, F	Sipirok: Sumatra
<i>R. vietnamica</i> Sivec & Harper, 2008	M, F	Vietnam: Thinhua
<i>R. yajunae</i> Li & Yang, 2010	M	China: Zhejiang
<i>R. yunnana</i> Sivec & Harper, 2008	M, F	China: Yunnan

Material and methods

The specimens were collected by hand and preserved in 75% ethanol. Most of the studied materials are deposited in the Entomological Museum of China Agricultural University, Beijing, China (**CAU**). Additional specimens are deposited in the Insect Collection of Henan Institute of Science and Technology, Xinxiang, Henan Province, China (**HIST**), as indicated in the text. The color illustrations were made using an Imaging Source CCD attached to a Leica M205FA dissecting microscope. The morphological terminology follows that of Sivec et al. (2008). The association of sexes of *Rhopalopsale hainana* is based on the type locality and barcoding data.

The maps were downloaded from Standard Map Service (<http://bzdt.ch.mnr.gov.cn/>) and edited by Photoshop 2020, map number is GS (2019)1823.

Total genomic DNA was extracted from thorax muscle using the TIANamp Genomic DNA kit (Tiangen Biotechnology, Beijing, China) following the manufacturer’s protocol. The universal primers LCO1490 and HCO2198 (Folmer et al. 1994) were used to amplify the target COI gene region. Polymerase chain reaction (PCR) program was as follows: initial denaturation at 95 °C for 60 s, followed by 40 cycles of 30 s at 95 °C, 50 s at 40–60 °C, and 60 s at 65 °C, and a final extension phase of 65 °C for 10 min. The PCR products were confirmed by 1% agarose gel electrophoresis and then sent to Sangon Biotechnology Co. Ltd. (Shanghai, China) for DNA sequencing. The primary sequences were assembled using Contigexpress software (Vector NTI Informax). Genetic distances between sequences were calculated in MEGA v.5.2 and bootstrap analysis was conducted using 1000 replicates. The GenBank accession numbers for the three specimens are in Table 2.

Table 2. China, Hainan Province specimens used for COI based identification, genetic differentiation, and circumscription analyses of three *Rhopalopsole* species.

Species	Sex	Catalog number	GenBank accessions	Geographic coordinates
<i>R. hainana</i>	1♀	J61	OR435219	19°4'52.32"N, 109°31'10.92"E
<i>R. hainana</i>	1♀	J64	OR435220	19°4'52.32"N, 109°31'10.92"E
<i>R. hainana</i>	1♂	J66	OR435221	19°4'52.32"N, 109°31'10.92"E

Results and discussion

Family Nemouridae Billberg, 1820

Genus *Rhopalopsole* Klapálek, 1912

Rhopalopsole bawanglinga Li, Li & Yang, sp. nov.

<https://zoobank.org/F26FAD81-D6AA-44BA-99B7-88067CD05AB1>

Figs 1, 2

Type material. Holotype: male (CAU), CHINA: Hainan Province, Changjiang County, Bawangling National Forest Park, Dong'er Station, 22.X.2007, 19°15'1.44"N, 109°2'2.4"E, 1000 m, leg. D. Yang. **Paratypes:** 1 female (CAU): same data as holotype; 2 females (HIST), CHINA: Hainan Province, Ledong County, Jianfengling, Tianchi–Mingfenggu, 3.VIII.2016, 18°44'49.2"N, 108°50'57.12"E, 890 m, leg. Weihai Li, Rongfeng Wang.

Diagnosis. Male adult of this species is characterized by the lateral projections of the tergum 10 being bifurcate with the upper spine longer than the lower one in lateral view. The cercus bears a stout dorsoapical spine, and the epiproct is subtrapezoid with deep, circularly incised anterior margin in dorsal view. Females are diagnosed by the posterior margin of sternum 7 forming a narrowly produced pregenital plate, posteromedial portion slightly bilobed.

Description. Adult habitus. Forewing length is 6.8 mm in the male, 7.0–7.4 mm in the females. Head brown to dark brown, slightly wider than pronotum; compound eyes black; antennae and mouthparts brownish to brown. Pronotum brown with dark rugosities; wings subhyaline with darker veins; legs brown. Abdomen brown.

Male (Figs 1, 3). Tergum 9 (Figs 1A, 3A) weakly sclerotized except anterior margin and lateral portions, medial 1/3 with a large trapezoidal membranous area surrounded by lateral sclerotized portion and ornamented posteromedial margin which terminates in a thin, produced sclerite with tiny granules. Sternum 9 (Figs 1B, 3B) longer than wide, distal portion with distinct trapezoidal subgenital plate, the plate about as long as wide, with a subapical constriction; vesicle dark brown, ovum-shaped in ventral view, tongue-like in lateral view, covered with dense hairs. Tergum 10 (Figs 1A, C, 3A, C) with well sclerotized, bifurcate lateral projections, terminating in two acute, parallel-sided points in dorsal aspect, the upper spine is longer than lower spine in lateral view. Central plate (Figs 1A, D, 3A, D) sclerotized and trilobed, lateral lobes subtriangular, together with a circular anteromedial incision of the medial lobe resemble flying wings; medial lobe darkly pigmented, with a small knob-like projection. Transverse bars slightly elevated medially, triangular, posterior margin and inner portion sclerotized. Cercus barely 3× longer than wide, curved dorsally, with a stout subapical spine. Epiproct (Figs 1A, E, 3A, E) strongly sclerotized and darkly

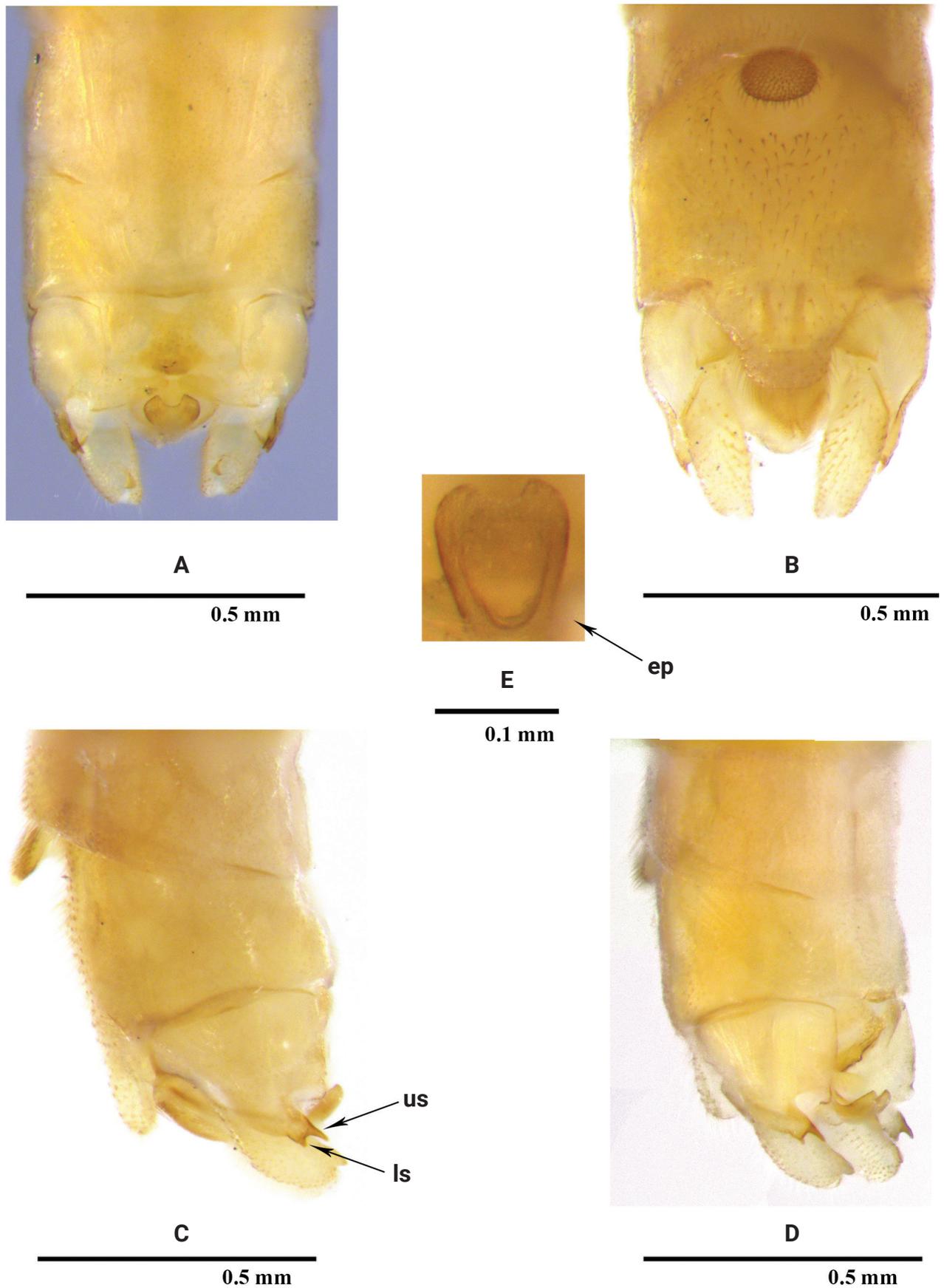


Figure 1. *Rhopalopsole bawanglinga* Li, Li & Yang, sp. nov. (male) **A** terminalia, dorsal view **B** terminalia, ventral view **C** terminalia, lateral view **D** terminalia, dorsolateral view **E** epiproct dorsal view. **ep**: epiproct; **ls**: lower spine; **us**: upper spine.

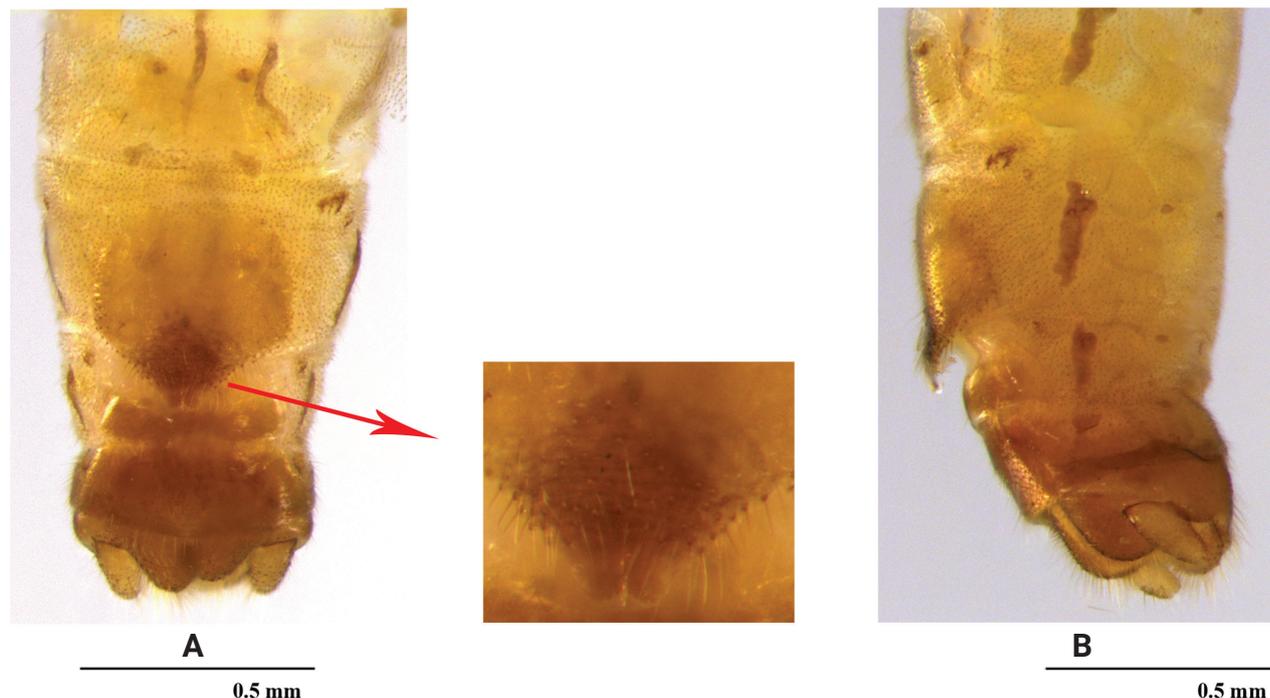


Figure 2. *Rhopalopsale bawanglinga* Li, Li & Yang, sp. n. (female) **A** terminalia, ventral view (apex of pregenital plate enlarged) **B** terminalia, lateral view.

sclerotized laterally, subtrapezoid with deep, circularly incised anterior margin in dorsal view, longer than wide. Subanal lobe (Figs 1B, 3B) distinctly sclerotized basally, lateral margins and apex membranous, ventral furrows vague.

Female (Fig. 2A, B). Posterior margin of sternum 7 forming a triangularly produced pregenital plate; plate with sclerotized bilobed distal tip. Sternum 8 membranous except a slender, transverse posterior strip.

Etymology. The specific name refers to the Bawangling National Forest Park.

Distribution. China (Hainan).

Remarks. The new species is a typical member of the *R. vietnamica* group, western assemblage sensu Sivec et al. (2008). The male of the new species seems closely related to *R. hainana* from Hainan and *R. cestroidea* Li & Yang, 2017 (in: Li et al. 2017) from Guangxi, as they share a similar wide epiproct. However, it can be differentiated from both by bifurcate lateral projections on tergum 10, with the upper spine being longer than the lower one in lateral view, and the presence of a concave anterior margin of the epiproct. In *R. hainana* and *R. cestroidea*, the terminal bifurcation of lateral projections on tergum 10 is of equal length in lateral view, and the epiproct has a truncate or convex anterior margin. Additionally, the cercus of *R. cestroidea* lacks a spine, and that of *R. hainana* has a sharp subapical spine, whereas the cercal spine in the new species is stout. The female is distinctive due to the bilobed distal tip of the pregenital plate.

***Rhopalopsale hainana* Li & Yang, 2010**

Fig. 4

Rhopalopsale hainana Li & Yang, 2010: 59 (original description).

Material examined. 11 males, 5 females (CAU), CHINA: Hainan Province, Baisha, Yinggeling, Hongxin Village, 23–24.V.2007, 19°12'22.32"N, 109°33'14.4"E, 250 m, leg. J.X. Liu; 1 female (CAU), CHINA: Hainan Province, Lingshui County, Diaoluo Mountain, 1.VII.2011, 18°43'31.08"N, 109°52'8.4"E, 294 m, leg. W.H.

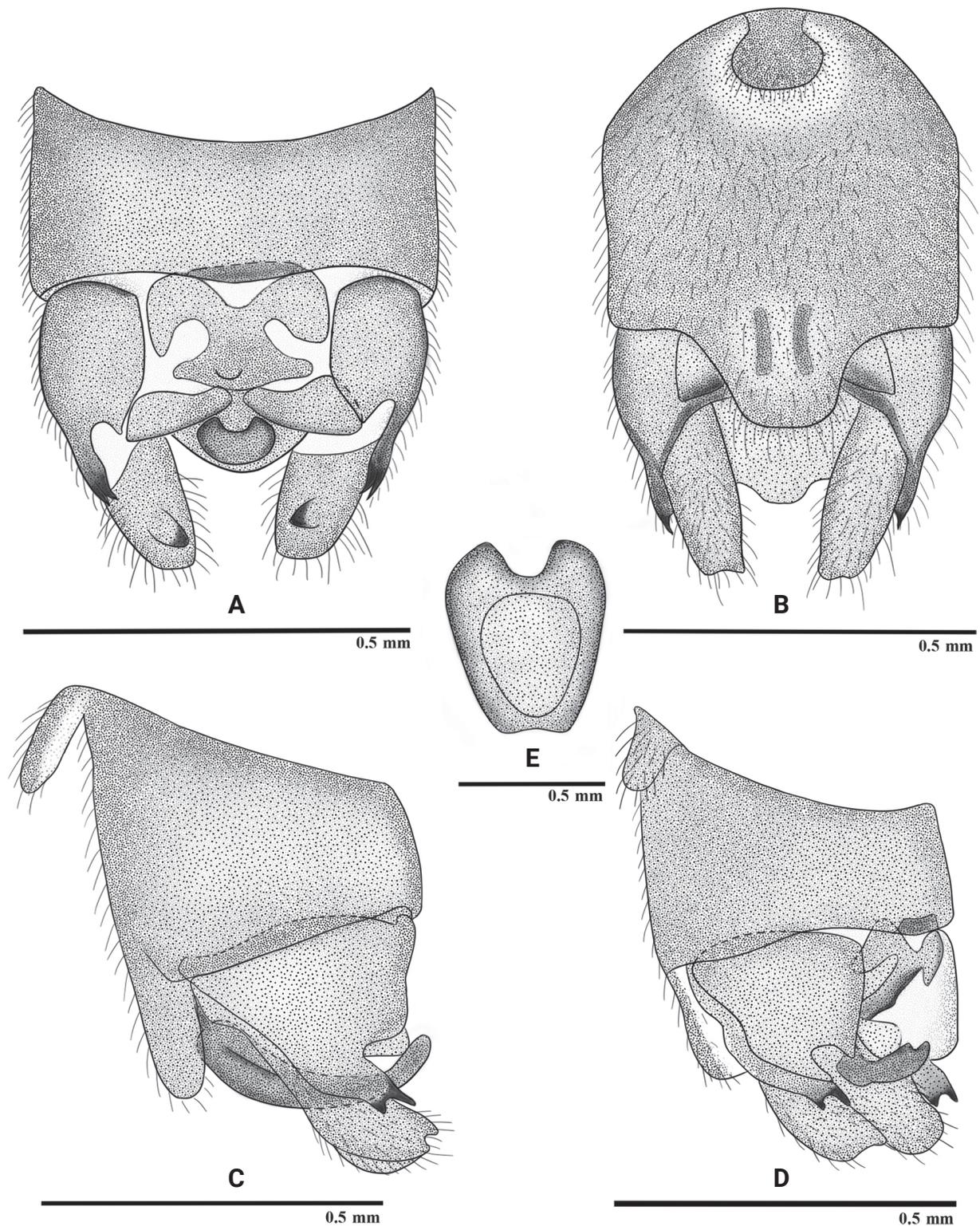


Figure 3. *Rhopalopsole bawanglinga* Li, Li & Yang, sp. n. (male) **A** terminalia, dorsal view **B** terminalia, ventral view **C** terminalia, lateral view **D** terminalia, dorsolateral view **E** epiproct dorsal view. **ep**: epiproct; **ls**: lower spine; **us**: upper spine.

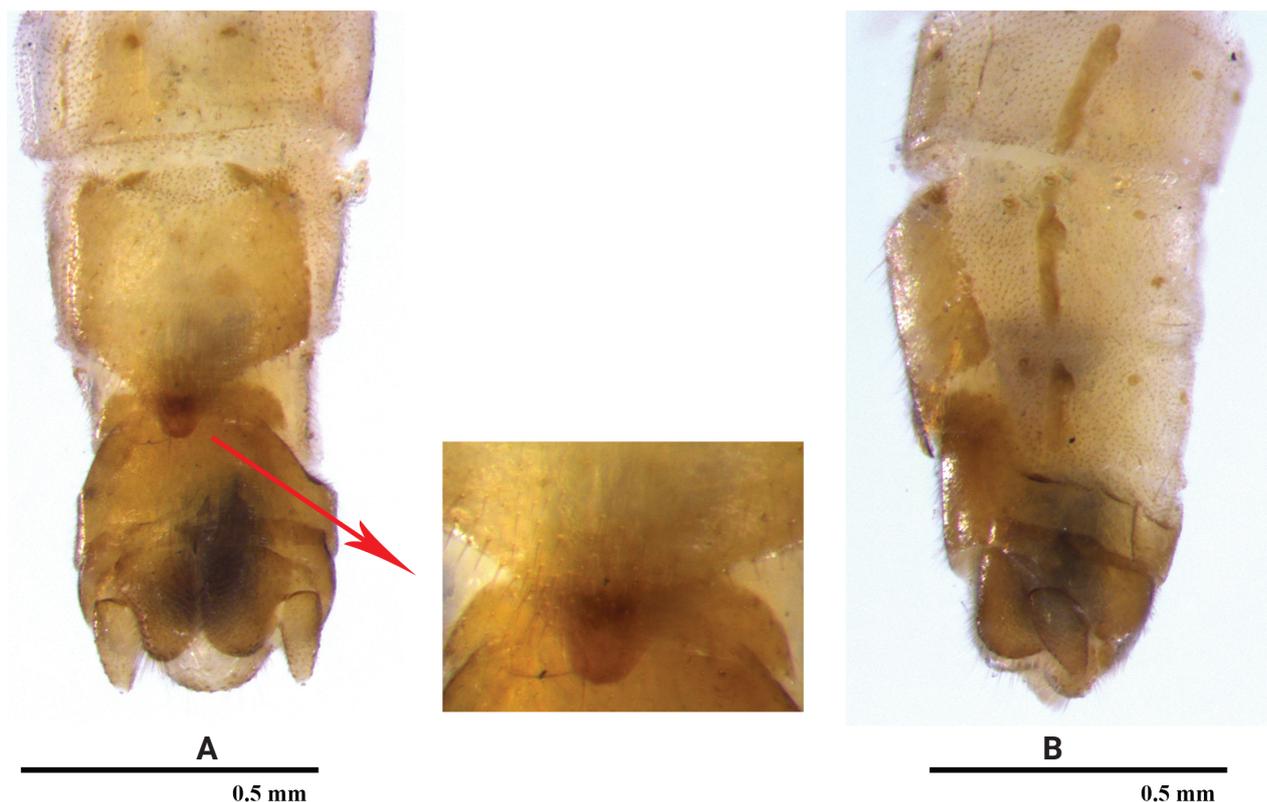


Figure 4. *Rhopalopsole hainana* Li & Yang, 2010 (female) **A** terminalia, ventral view (apex of pregenital plate enlarged) **B** terminalia, lateral view.

Li; 2 females (CAU), CHINA: Hainan Province, Baisha, Yinggeling, 29.X.2011, 19°4'52.32"N, 109°31'10.92"E, 1191 m, leg. W.H. Li.

Description. Female. (Fig. 4A, B) Pregenital plate on sternum 7 sclerotized, distally produced into strongly sclerotized triangular lobe with sinuous lateral margins, covered with long hairs; dorsoventrally flattened in lateral view. Sternum 8 with a trapezoid, transverse band across the posterior half of the segment.

Remarks. Genetic distance refers to the genetic divergence between species and can be used to compare the genetic similarity between difference species (Wang et al. 2013); generally, more than 98% of congeneric species or sister species pairs have greater than 0.02 sequence divergence (Johns and Avise 1998; Hebert et al. 2003; Park et al. 2011). In our study, pairwise distances of the *Rhopalopsole* species were 0–0.9%; lower than the 2% threshold considered for a rough differentiation between intraspecific and interspecific distances (Zhou et al. 2009). The genetic distance of COI between J66 and J61 is 0 and between J66 and J64 is 0.9% (Table 3). The combination of morphology and molecular data suggest the female is *R. hainana*.

Table 3. Genetic distances among sequenced specimens. Upper (right) triangular matrix: standard deviation; lower (left) triangular matrix: genetic distances.

	J61 F <i>R. hainana</i>	J64 F <i>R. hainana</i>	J66 M <i>R. hainana</i>
J61 F <i>R. hainana</i>		0.006	0.0
J64 F <i>R. hainana</i>	0.009		0.006
J66 M <i>R. hainana</i>	0.0	0.009	

We compared the holotype with the specimens from Baisha County, which originated from near the type locality. The hitherto unknown female resembles the female of *R. bawanglinga*, but the tip of the pregenital plate is not bilobed, and the transverse band on sternum 8 is more pronounced.

***Rhopalopsale dentiloba* Wu, 1973**

Figs 5, 6

Rhopalopsale dentiloba Wu, 1973: 105 (original description).

Material examined. 4 males, 1 female (CAU), CHINA: Yunnan Province, Xishuangbanna, Meng shimron botanical garden, 22.IV.2007, 21°55'9.12"N, 101°16'6.96"E, 550 m, leg. D. Hui. 1 male (HIST), CHINA: Yunnan Province,

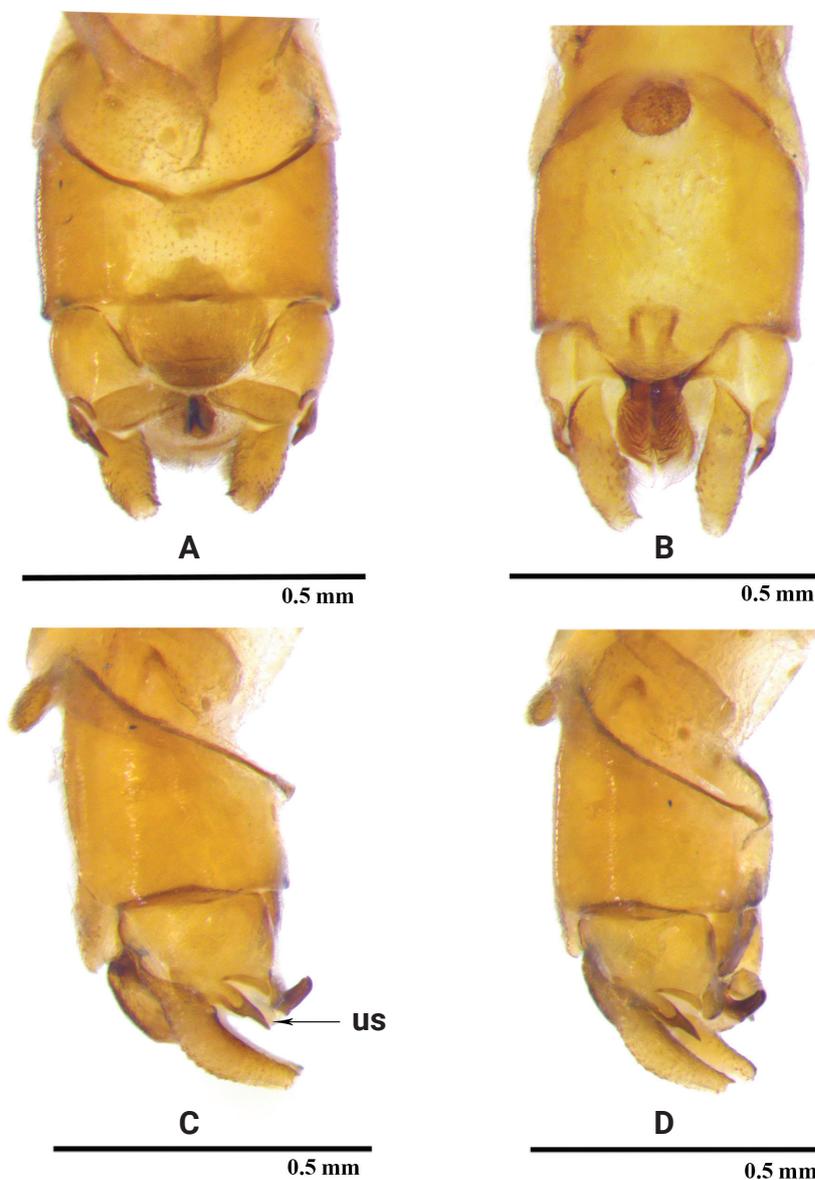


Figure 5. *Rhopalopsale dentiloba* Wu, 1973 (male) **A** terminalia, dorsal view **B** terminalia, ventral view **C** terminalia, lateral view **D** terminalia, dorsolateral view. **us**: upper spine.

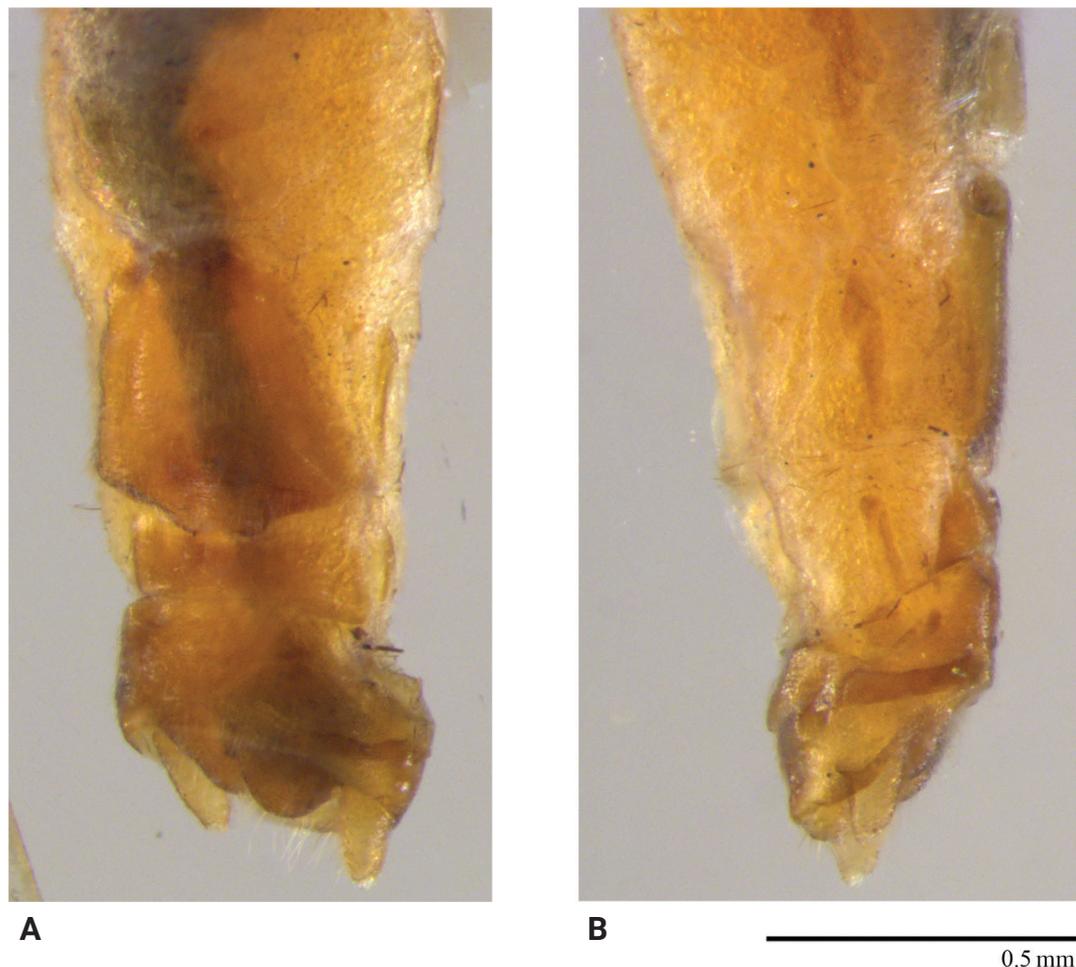


Figure 6. *Rhopalopsole dentiloba* Wu, 1973 (female) **A** terminalia, ventral view **B** terminalia, lateral view.

Xishuangbanna, Mengla, Wangtianshu scenic spot, 9.V.2009, 22°1'53.76"N, 100°52'32.88"E, 840 m, leg. X.S. Yang.

Remarks. We examined several specimens from Xishuangbanna, Yunnan Province, which is the same location where *R. dentiloba* was described. The original description and illustrations did not provide sufficient details for identification. Therefore, we discuss herein the distinctive morphological characters of our specimens. This species is a typical member of the *R. vietnamica* group, western assemblage sensu Sivec et al. (2008). The male tergum 9 (Fig. 5A, C, D) has a small triangular, upraised sclerotized process on hind margin. Tergum 10 (Fig. 5A, B) bears a small bifurcate spine at each posterolateral corner in dorsal and lateral aspects, but the inner/lower spine is not easily observed. In lateral view (Fig. 5C, D), unbranched, sclerotized lateral projections are seen. The epiproct is small, hook-like. The minute teeth of the subanal lobe described for the holotype are possibly the distinct furrows seen in the males observed in this study. The identity of these specimens is primarily based on a similar female and their proximity to the type locality (Mengsong town or Mengsong village in this town). The female (Fig. 6A, B) is identical to the original illustration. However, doubts may arise about association of the original female and the male holotype, as tropical Yunnan is well known for its high biodiversity, where more *Rhopalopsole* species may co-occur.

Conclusion

Thirteen species were previously recorded in the *R. vietnamica* ‘western assemblage’ group, as specified in Table 1. *Rhopalopsole dentiloba* was included in the *R. shaanxiensis* species group but is now transferred to the *R. vietnamica* ‘western assemblage’ group due to its great similarities to *R. sinensis* Yang & Yang, 1993. Considering the geographical (Fig. 7) differences between populations of *R. sinensis*, molecular methods should be applied to confirm the status of *R. dentiloba* in the future. With the description of the new taxon and the inclusion of *R. dentiloba*, the number of species in this group in China is now up to eleven, and more new species may await discovery.

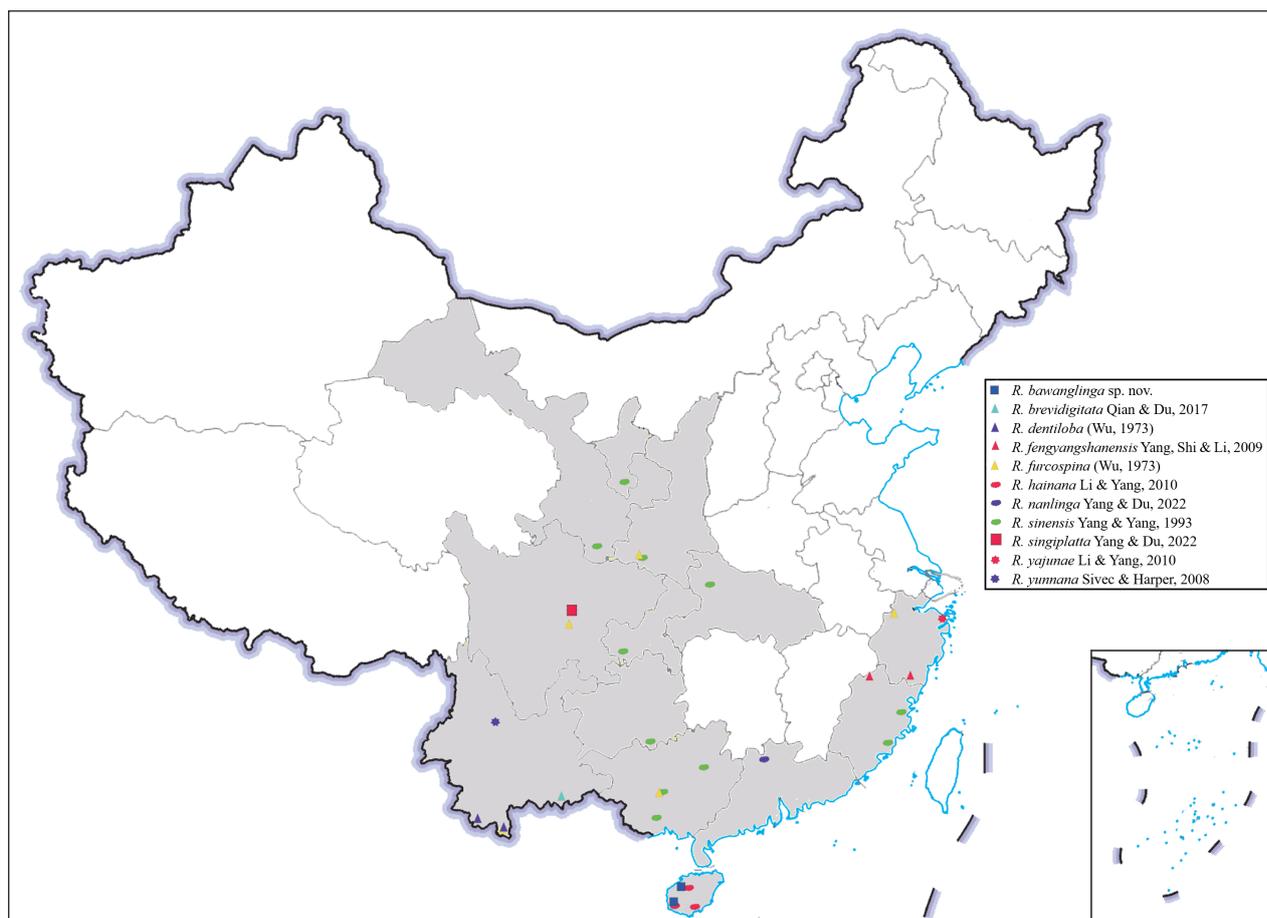


Figure 7. Distribution of species of the *Rhopalopsole vietnamica* ‘western assemblage’ group of China. City records shaded in grey.

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Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statement

No ethical statement was reported.

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Author contributions

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Data availability

All of the data that support the findings of this study are available in the main text.

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Name game conundrum: identical specific epithets in Microgastrinae (Hymenoptera, Braconidae)

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Abstract

It is a privilege to recognize a new species and immortalize it with a name. Taxonomists may use etymologies recalling the sampling locality, habitat, species morphology, people (actor, writer, singer, politician, scientist), culture (customs, beliefs), fictional characters (gods, demons, cartoons), brands, ancient names, and others. Naming a species is a creative act that allows scientists to express their love for nature. By drawing on personal and cultural associations, species names are often imbued with far greater meaning than one might initially assume. Unconventional names for species can be an effective way to capture the imagination of the public and make the species memorable. In other words, species names can be both meaningful and whimsical. The central focus of this study was to pinpoint species in the subfamily Microgastrinae that share the same specific epithet that often creates confusion regarding which species is being referred to. The findings showed that 153 specific epithets were repeated representing 340 species in 52 genera, while the remaining 2,823 species have unique epithets. Three of the five categories proposed accommodate the majority of the etymologies: people (42%), morphology (27%), and geography (15%) whereas the categories of other (9%) and biology (7%) achieve the least representation. Approximately 95% of the same specific epithets had a single clear meaning, while for the remaining 5%, it was not possible to trace etymology. The study revealed that the average length of specific epithets was 9.01 letters, the longest contains 18 (*eliethcantillanoae*) while the shortest four (*eros* and *erro*). Additionally, most identical specific epithets were repeated two times (85.25% of the occurrences), although three (12.82%), five, six, and even nine (each one with 0.64%) repetitions were also found. Finally, a list of recommendations for taxonomists when faced with the task of naming a new species is provided.

Key words: Binomial nomenclature, etymology, ICZN, scientific names, systematics

Introduction

The process of categorization is fundamental to the human experience, as it allows us to make sense of a chaotic, unpredictable environment, and to create order out of what may otherwise seem to be a random jumble of events

(e.g., Mervis and Rosch 1981; Ashby and Maddox 2005; Pothos and Wills 2011). By classifying objects and phenomena, humans can elaborate predictions about how the world works, using this knowledge to make decisions and take action (McGarty et al. 2015). Humankind tends to group things into categories based on what they perceive to be the most convenient way of organizing them (i.e., categorization of animals, plants, programming languages, books, vehicles, clothing, food, musical instruments, etc.). This means that, even if the demarcations are not always logical, they are still deeply rooted in the way of looking at the world.

Linnaean nomenclature is the system of naming organisms developed by the Swedish scientist Carl Linnaeus, and the system uses a two-part Latin name for each species of living and fossil organism. The first part is termed the generic name and indicates the genus and the second one, the specific epithet, the species within the genus (Linnaeus 1751, 1758). Thus, the juxtaposition of these two names creates a unique combination that unambiguously identifies a species from any other similar species. This system has been in use for centuries (since 1751), and it is still the most widely accepted taxonomic nomenclature system by scientists today. Aside from the theoretical and practical advantages of unambiguous species names (Vink et al. 2012; Zeppelini et al. 2021), the Linnaean nomenclature provides the opportunity to use species names to honor the scientists who discovered them, the geographical locations they were found in, or even their interests. Scientific names also are chosen based on the morphological traits of the species, its environment, or the researcher's creative ideas (Jozwiak et al. 2015; Ohl 2018). This is a way to make the work of classifying species more meaningful. As long as taxonomists adhere to a few basic grammatical rules regulating the derivation of etymologies, they can come up with a unique name for any species (Vendetti and Garland 2019). The creative potential of ascribing names is virtually boundless, presenting a wide range of possibilities and avenues for imaginative expression for the descriptor (Ohl 2018).

A small sampling of specific epithets used in parasitoid wasps is given below. Some epithets allude to species traits [e.g., *Wilkinsonellus corpustriacolor* Arias-Penna, Zhang & Whitfield (Microgastrinae); it refers to the three colorations on the body; in Arias-Penna et al. 2014]; the locality of a species [e.g., *Ophiclypeus Chiangmaiensis* Kang (Cardiochilinae); only known from Chiang Mai Province in Thailand; in Kang et al. 2023]; and biological aspects such as one of the levels of the tritrophic interactions, food plant-herbivore-parasitoid [e.g., *Cotesia typhae* Fernández-Triana (Microgastrinae); *Typha* L. (Poales: Typhaceae) is the genus plant on which the herbivore lepidopteran host feeds on; in Kaiser et al. 2017]. More creatively, epithets may refer to renowned people [e.g., *Aleiodes gaga* Quicke & Butcher (Rogadinae); Stefani Joanne Angelina Germanotta (Lady Gaga) is an American singer, songwriter, and actress; in Butcher et al. 2012. *Conobregma bradpitti* Quicke & Butcher (Rogadinae); William Bradley (Brad) Pitt is an American actor and film producer; in Butcher et al. 2016. *Foenatopus nimaarkanii* Ghafouri Moghaddam & Rakhshani (Stephanidae); Nima Arkani-Hamed is an American-Canadian theoretical physicist of Iranian descent; in Ghafouri Moghaddam et al. 2019], a fictional cartoon character [e.g., *Masona popeye* Quicke & Chaul (Masoninae); Popeye the Sailor Man cartoon; in Quicke et al. 2019], or simply represents a wordplay [e.g.,

Hypomicrogaster zan Valerio (Microgastrinae); the name is a random combination of letters without any meaning; in Valerio and Whitfield 2015].

The use of Latin and Latinized Greek words has been accepted and mandated by the International Code of Zoological Nomenclature (ICZN), which sets out the rules for naming organisms (ICZN 1999). This means that even though taxonomy is evolving and modernizing, Latin, an ancient language, is still the language of choice for naming organisms. The modern classification system has not changed significantly since its introduction centuries ago and is still valid today. Consequently, the Linnaean system is reliable with rules consistent over time.

Taxonomy is a field of science that fosters lively and sometimes contentious discussions. Notable among these is the emergence of novel methods for species classification, including photography-based (e.g., Ceriaco et al. 2016; Chaladze 2017; Faundez 2017), and COI sequence-based taxonomy (e.g., Meierotto et al. 2019; Sharkey et al. 2021; Chua et al. 2023). Furthermore, a plethora of heated debates have surfaced regarding the ICZN regulations (e.g., Dubois 2011; DuBay et al. 2020; Guedes et al. 2023; Pethiyagoda 2023; Roksandic et al. 2023; Slabin 2023; amongst many others), accompanied by a multitude of criticisms and recommendations voiced by researchers through social media platforms such as Taxacom, as well as in the form of published articles encompassing cases, declarations, opinions, comments, and correspondences.

Etymology refers to the study of the origin of words and their meanings (Jozwiak et al. 2015). This process involves tracking down the original description of the word by using dictionaries (Latin or Greek), employing the author's prior knowledge of classical languages such as Greek and Latin, referring to previous works on the subject, or consulting webpages (e.g., Wikipedia, <https://www.wikipedia.org/> and Wikispecies, <https://species.wikimedia.org/>) (Nilsson 2010).

The pivotal purpose of nomenclature is to establish a unique name for each taxon in the classification system. Maintaining consistency in the usage of organism names holds particular importance currently within digital environments. Binomial scientific names are unique identifiers within databases. In the context of online collaborative environments like the Global Biodiversity Information Facility (GBIF, <https://www.gbif.org/>), it becomes imperative to adhere to standardized criteria during the construction of these databases to ensure seamless utilization (see Welter-Schultes 2012). The ICZN does not impose any restrictions on using identical epithets for naming new species. Frequently, researchers should explore multiple sources to make sure they are looking at the correct species. At first glance, this task can be especially difficult and confusing when two species have identical epithets. To address this confusion, the ICZN (Articles 11, 23, 24, 32, 58, Recommendations 11A, 58A) encourages researchers to use similar names with slightly different spellings, or pairs of scientific and vernacular names to differentiate related species (ICZN 1999).

Etymologies are the stories behind words and their origins. By studying them, one can learn about the history of words and how their meanings have changed over time. This study aimed to delve into the choices made by authors for identical epithets when using etymologies for naming species, with a specific focus on Microgastrinae, a subfamily within the Braconidae that encompasses a total of 3,163 extant species distributed globally (Ghafouri Moghaddam et al. 2023).

Materials and methods

Microgastrinae species names follow Fernández-Triana et al. (2020) which is the most comprehensive and up-to-date list of valid species for the subfamily. Taxonomic changes proposed in the publication were also adopted here. Additionally, all newly discovered species until August 2023 were included. The number of currently known microgastrine species was retrieved from the website Microgastrinae Wasps of the World (Ghafouri Moghaddam et al. 2023). Detailed information from the original description of Microgastrinae species can be found in Fernández-Triana et al. (2020).

This research is laser-focused on a specific subset—species that share identical specific epithets in their names. This subset represents part of the whole diversity of microgastrine names, making the data manageable and easier to compare and analyze. It is worth pointing out that there are instances of partial matches observed in specific epithets. This is attributed to their variations in the spelling, and using the surname or full name, which subsequently these examples were excluded from the analysis (e.g., *andybenneti*; *brasiliensis* and *braziliensis*; *brevicarinata* and *brevicarinis*; *gavinbroadi*; *cameronae*, *sydneyae*, and *sydneycameronae*; and *mikesharkeyi*).

Species etymologies were classified into five broad categories (in alphabetical order): those referring to (1) biology (host associations, habitat, or some behavioral adaptation), (2) geography (distribution of the species), (3) morphology (morphological traits including size, color, or shape), (4) other (epithets that are puns, arbitrary combinations of letters, names that refer to a legend, names of gods or deities, and many others), and (5) people (fictional characters, scientists, actors, singers, political officials, beloved ones, other people).

The category to which each of the epithets belongs was determined by consulting the original descriptions under the section Etymology. In cases where this section was missing, the text was scrutinized for any clues that provided insight into the meaning of the species epithet.

Results

In total, 153 identical specific epithets were found in Microgastrinae which represent 340 species in 52 genera. The remaining 2,823 species displayed unique epithets. The level of repetition of epithets was low (10.7%) which could potentially lead to inaccurate results when analyzing the specific epithet distributions within the subfamily. The categories of people (42%, corresponding to 142 spp.), morphology (27%, 92 spp.), and geography (15%, 50 spp.) are the ones with the most repeated specific epithets whereas other (9%, 30 spp.) and biology (7%, 26 spp.) obtained the least number of repetitions (Fig. 1). The vast majority (95%) of repeated specific epithets have an unambiguous meaning and only a small fraction (5%) have an uncertain definition and probably multiple meanings.

The vast majority of specific epithets were repeated two times (85.25% of the occurrences) followed by three times (12.82% of the occurrences). In contrast, a small number of specific epithets were repeated five, six, and even nine times but each one accounted for less than 1% of the occurrences (Fig. 2). The specific epithets with the highest number of repetitions were *masoni* (in nine genera), *orientalis* (in six genera), and *nixonii* (in five genera).

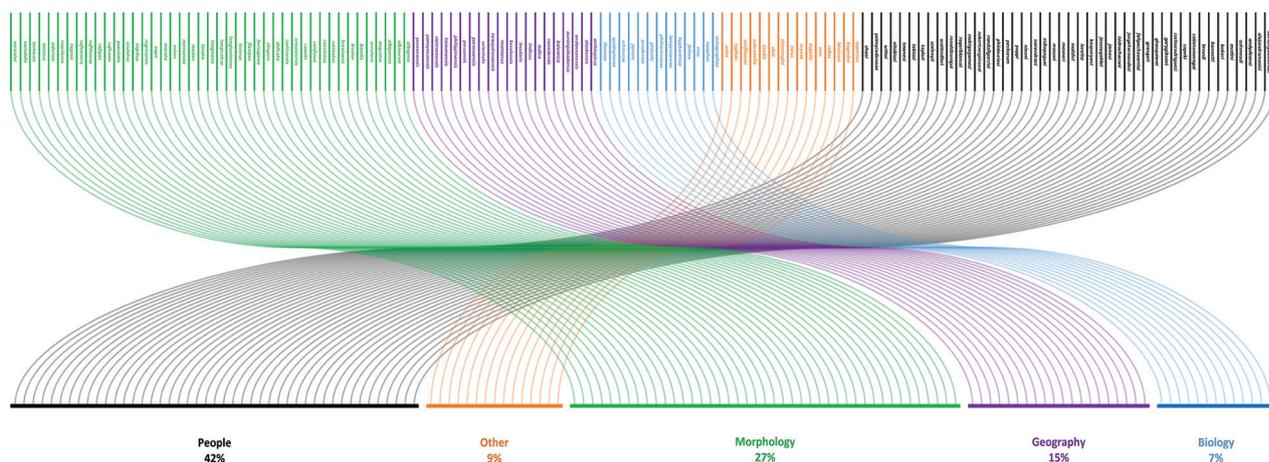


Figure 1. The five categories used for the classification of the identical specific epithets in the subfamily Microgastrinae (Hymenoptera, Braconidae) display their respective frequency of use. Colored bars represent categories, blue = biology, purple = geography, green = morphology, orange = others, and black = people.

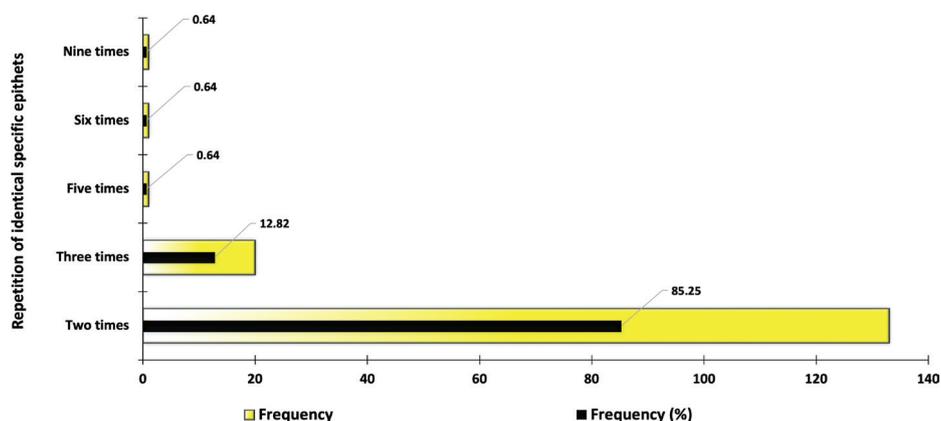


Figure 2. Frequency and percentage frequency distribution of identical and repeated specific epithets within the subfamily Microgastrinae (Hymenoptera, Braconidae).

As to the length of the specific epithet (number of alphabetic characters), the average length was nine. The longest epithet, *eliethcantillanoae*, contained 18 alphabetic characters and belonged to the people category. The shortest epithets, *eros* (in the biology category) and *erro* (in the other category), each contained only four letters. By analyzing each category, the highest number of specific epithets repeated with the same number of letters was located in morphology (eight letters in 12 species) followed by the people category (seven letters in eight species), and the geography category (eleven letters in four species) (Fig. 3).

When analyzed by category, the same pattern was observed, a large number of specific epithets was repeated twice, meaning assigned to only two genera (Table 1). Thus, the highest percentage of occurrences was in the biology and the other categories, where all of the specific epithets (100%) were repeated twice. In contrast, the category of people had the lowest percentage (15%). Identical specific epithets were also repeated three times but to a lesser extent and only in three categories, geography (25%), morphology (14%), and people (13%). People is the only category with specific epithets replicated two, three, five, and nine times.

The identical specific epithets in the Microgastrinae species are listed alphabetically as follows.

Table 1. The five categories into which identical specific epithets were classified within the subfamily Microgastrinae (Hymenoptera, Braconidae) with their respective frequency percentages.

Category	Two times	Three times	Five times	Six times	Nine times
Biology	100%	–	–	–	–
Geography	70%	25%	–	5%	–
Morphology	86%	14%	–	–	–
Other	100%	–	–	–	–
People	82%	13%	2%	–	2%

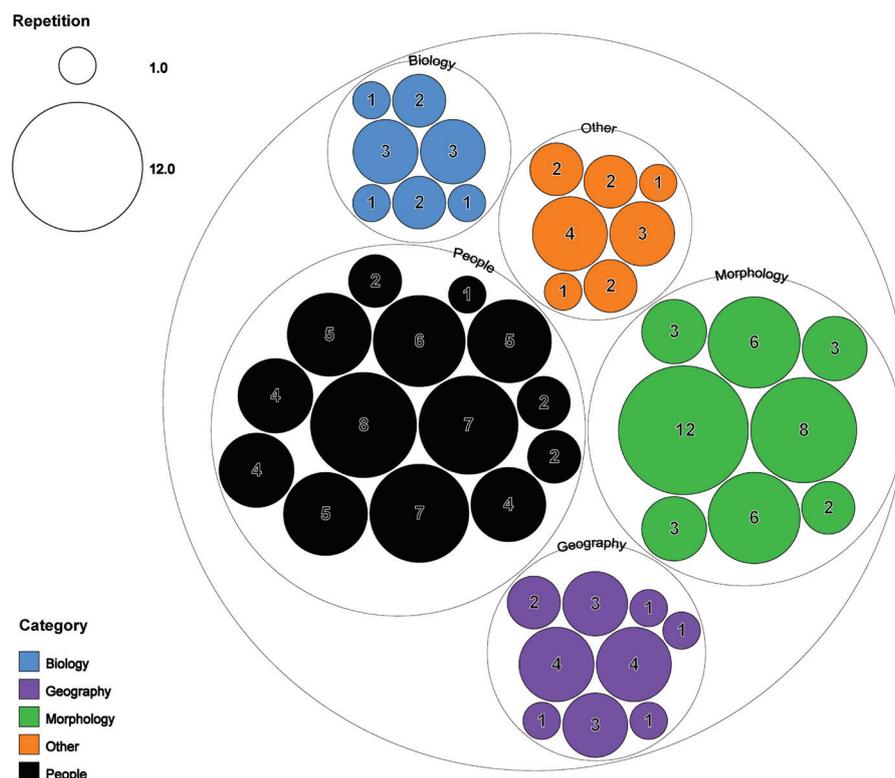


Figure 3. Occurrences of identical specific epithets with the same number of alphabetic characters across the five categories within the subfamily Microgastrinae (Hymenoptera, Braconidae). In each circle, the number indicates the number of letters that compose the specific epithet and the relative size of the circle represents the number of species in each group.

List of identical specific epithets within the subfamily Microgastrinae

achterbergi

Etymology. The epithet honors the Dutch braconidologist, Cornelis (Kees) van Achterberg, whose work contributes to the knowledge of Braconidae of the world, as well as other Hymenoptera groups. He is a world-renowned hymenopterologist and his work is exemplary and truly remarkable. The suffix *-i* added to the term is a masculine Latin genitive.

Taxa. The epithet has been used in three genera: *Buluka achterbergi* Austin, 1989; *Choeras achterbergi* Narendran, 1998; and *Fornicia achterbergi* Yang & Chen, 2006.

Category. People.

adrianguadamuzi

Etymology. The epithet refers to Adrian Guadamuz for his contributions to the Área de Conservación Guanacaste (ACG) both in the Programa de Parataxónomos and the plant inventory of ACG in Costa Rica (Central America). The suffix *-i* added to the term is a masculine Latin genitive.

Taxa. The epithet has been used in three genera: *Alphomelon adrianguadamuzi* Fernández-Triana & Shimbóri, 2023; *Apanteles adrianguadamuzi* Fernández-Triana, 2014; and *Microplitis adrianguadamuzi* Fernández-Triana & Whitfield, 2015.

Category. People.

aethiopicus

Etymology. The word *aethiopicus* contains two parts, *Aethiopia* the Latin spelling of Ethiopia, an east African country located in the Somali peninsula, and the Latin suffix *-icus* which means belonging to. In taxonomy, the term *aethiopicus* describes a species that is native to or has characteristics associated with Ethiopia.

Taxa. The epithet has been used in two genera: *Jenopappius aethiopicus* (de Saeger, 1944); and *Parapanteles aethiopicus* (Wilkinson, 1931).

Category. Geography.

alaskensis

Etymology. The term *alaskensis* contains two parts, Alaska, one of the states in the United States, and the Latin suffix *-ensis* which means belonging to or inhabiting. In taxonomy, the term *alaskensis* literally means belonging to Alaska or inhabiting Alaska.

Taxa. The epithet has been used in two genera: *Microplitis alaskensis* Ashmead, 1902; and *Protapanteles alaskensis* Ashmead, 1902.

Category. Geography.

albigena

Etymology. The term *albigena* comes from two Latin words, *albus* meaning white and *gena* meaning cheek. In taxonomy, *albigena* describes a wasp with white cheeks.

Taxa. The epithet has been used in two genera: *Glyptapanteles albigena* Fagan-Jeffries, Bird & Austin, 2022; and *Protapanteles albigena* Abdoli, Fernández-Triana & Talebi, 2021.

Category. Morphology.

albinervis

Etymology. The term *albinervis* is made up of two Latin words, *albi* meaning white and *nervis* meaning veins. In taxonomy, *albinervis* indicates the white veins of the species.

Taxa. The epithet has been used in two genera: *Apanteles albinervis* (Cameron, 1904); and *Iconella albinervis* (Tobias, 1964).

Category. Morphology.

albipennis

Etymology. The term *albipennis* comes from two Latin words, *albi* meaning white and *pennis* which means feather or wing. In taxonomy, the term *albipennis* describes a species with white wings.

Taxa. The epithet has been used in two genera: *Dolichogenidea albipennis* (Nees, 1834); and *Microplitis albipennis* Abdinbekova, 1969.

Category. Morphology.

alejandromasisi

Etymology. The name refers to Alejandro Masis for his relentless efforts to administrate and protect the Área de Conservación Guanacaste (ACG) in Costa Rica (Central America). The suffix *-i* added to the term is a masculine Latin genitive.

Taxa. The epithet has been used in two genera: *Apanteles alejandromasisi* Fernández-Triana, 2014; and *Dolichogenidea alejandromasisi* Fernández-Triana & Boudreault, 2019.

Category. People.

andamanensis

Etymology. The term *andamanensis* contains two parts, Andaman, the Andaman Islands, an archipelago in the Bay of Bengal between India and Myanmar, and the Latin suffix *-ensis* which means belonging to or of the place of. In taxonomy, *andamanensis* indicates that the species is native to the Andaman Islands.

Taxa. The epithet has been used in two genera: *Diolcogaster andamanensis* Gupta & Fernández-Triana, 2015; and *Fornicia andamanensis* Sharma, 1984.

Category. Geography.

andydeansi

Etymology. The name honors Andrew (Andy) Robert Deans, an American entomologist, who has made exceptional contributions to the knowledge of Evaniidae (Hymenoptera) on a global scale. The suffix *-i* added to the term is a masculine Latin genitive.

Taxa. The epithet has been used in three genera: *Alphomelon andydeansi* Fernández-Triana & Shimbori, 2023; *Glyptapanteles andydeansi* Arias-Penna, 2019; and *Iconella andydeansi* Fernández-Triana, 2013.

Category. People.

angustus

Etymology. The term *angustus* derives from the Latin verb *ango* which means to narrow, to constrict, or to tighten. In taxonomy, *angustus* refers to the narrow length of a particular morphological trait. Thus, the narrow areolation on the propodeum (in *Apanteles* Foerster) or a very narrow mesosoma and metasoma (in *Choeras* Mason).

Taxa. The epithet has been used in two genera: *Apanteles angustus* Liu & Chen, 2020; and *Choeras angustus* Song & Chen, 2014.

Category. Morphology.

areolaris

Etymology. The term *areolaris* comes from the Latin word *areola* which means small open space or little courtyard. In taxonomy, *areolaris* refers to a species that has a body part covered with areolate, a type of surface sculpturing.

Taxa. The epithet has been used in two genera: *Hypomicrogaster areolaris* (Blanchard, 1947); and *Microgaster areolaris* Thomson, 1895.

Category. Morphology.

ashmeadi

Etymology. The name is a tribute to the American entomologist William Harris Ashmead (1855–1908), one of the most important hymenopterologist authorities from the 19th century. The suffix *-i* added to the term is a masculine Latin genitive.

Taxa. The epithet has been used in two genera: *Diolcogaster ashmeadi* Saeed, Austin & Dangerfield, 1999; and *Glyptapanteles ashmeadi* (Wilkinson, 1928).

Category. People.

aspersus

Etymology. The term *aspersus* is a Latin adjective that means sprinkled or sprayed with. In taxonomy, *aspersus* reflects the idea of something being sprinkled or scattered over a surface. In *Apanteles*, *aspersus* refers to the spines on the outer side of the third tibia as rather sparse while in *Glyptapanteles* Ashmead, refers to the widely dispersed distribution of the species.

Taxa. The epithet has been used in two genera: *Apanteles aspersus* Liu & Chen, 2020; and *Glyptapanteles aspersus* Fagan-Jeffries, Bird & Austin, 2022.

Category. Other.

aurangabadensis

Etymology. The term *aurangabadensis* contains two parts, Aurangabad, an Indian city belonging to the Maharashtra state, and the Latin suffix *-ensis* which means belonging to or of the place of. In taxonomy, *aurangabadensis* indicates that the species was first discovered or described in the area around Aurangabad.

Taxa. The epithet has been used in two genera: *Apanteles aurangabadensis* Rao & Chalikwar, 1970; and *Diolcogaster aurangabadensis* Fernández-Triana, 2019.

Category. Geography.

austini

Etymology. The name honors Andrew (Andy) Donald Austin, an Australian hymenopterologist for his outstanding contributions to the knowledge of Microgastrinae of Australia. The suffix *-i* added to the term is a masculine Latin genitive.

Taxa. The epithet has been used in two genera: *Glyptapanteles austini* Fagan-Jeffries & Bird, 2022; and *Miropotes austini* Fernández-Triana & Whitfield, 2014.

Category. People.

autographae

Etymology. The epithet *autographae* refers to the looper moth genus, *Autographa* Hübner (Noctuidae: Plusiinae), which is the herbivore host used by these microgastrine wasps.

Taxa. The epithet has been used in two genera: *Cotesia autographae* (Muesebeck, 1921); and *Microplitis autographae* Muesebeck, 1922.

Category. Biology.

bageshri

Etymology. The term *bageshri* is likely a reference to the Indian classical music raga called Bageshri. The exact reason for this name choice is unclear, but it may be a nod to the Indian origins of the wasp species or to the sweet and soothing nature of the raga, which may reflect the behavior or appearance of the wasp.

Taxa. The epithet has been used in two genera: *Dolichogenidea bageshri* Sathe, Inamdar & Dawale, 2003; and *Microplitis bageshri* Sathe, Inamdar & Dawale, 2003.

Category. Other.

Note. Both species are under the status of unavailable names (see more detail in Fernández-Triana et al. 2020).

bakeri

Etymology. The name is dedicated to Charles Fuller Baker (1872–1927), an American entomologist, botanist, and agronomist who contributed greatly to natural science knowledge in the late 19th and early 20th centuries. The suffix *-i* added to the term is a masculine Latin genitive.

Taxa. The epithet has been used in two genera: *Diolcogaster bakeri* (Muesebeck, 1922); and *Dolichogenidea bakeri* (Wilkinson, 1932).

Category. People.

balearica

Etymology. The word *balearica* refers to the Balearic Islands, a group of islands located in the western Mediterranean Sea.

Taxa. The epithet has been used in two genera: *Cotesia balearica* Shaw & Colom, 2022; and *Microgaster balearica* Marshall, 1898.

Category. Geography.

basalis

Etymology. The word *basalis* derives from two Latin words, *basis* meaning foundation or base, and the suffix *-alis* which indicates related to or pertaining to. In taxonomy, *basalis* describes a species with a basal or fundamental form, structure, or behavior. In *Microplitis*, probably refers to the medial longitudinal groove in the basal of the first tergite while in *Snellenius* refers to white metasoma in lateral views toward the base.

Taxa. The epithet has been used in two genera: *Microplitis basalis* (Bingham, 1906); and *Snellenius basalis* (Walker, 1874).

Category. Morphology.

bennetti

Etymology. The name refers to Andrew (Andy) Michael Reeve Bennett, a Canadian entomologist and one of the world's authorities on ichneumonid wasps. The suffix *-i* added to the term is a masculine Latin genitive.

Taxa. The epithet has been used in two genera: *Deuterixys bennetti* Whitfield, 1985; and *Sendaphne bennetti* Fernández-Triana & Whitfield, 2014.

Category. People.

bhairavi

Etymology. The term *bhairavi* comes from Bhairavi, a Hindu goddess whose name means terror or awe-inspiring. The term Bhairavi can also refer to the Hindustani classical music from the northern regions of India. It is a type of raga, a melodic framework for improvisation in Indian classical music. The exact reason for this name choice is unclear, but it may be a nod to the Indian origins of the wasp species (e.g., *Cotesia bhairavi* (Sathe & Inamdar, 1991)) that was collected in Sikkim, a state in northeastern India although the species is deposited in the collection of Shivaji University, Kolhapur (India). Another interpretation is that the term refers to the intense and powerful nature of the raga, which may reflect the behavior or appearance of the wasp.

Taxa. The epithet has been used in two genera: *Cotesia bhairavi* (Sathe & Inamdar, 1991); and *Parenion bhairavi* Sathe, Inamdar & Dawale, 2003.

Category. Other.

Note. *Parenion bhairavi* Sathe, Inamdar & Dawale, 2003 is under the status of unavailable names (see more detail in Fernández-Triana et al. 2020).

bicolor

Etymology. The term *bicolor* contains two Latin words, the prefix *-bi* which means two and the noun *color* which is a cognate of the English word. In taxonomy, *bicolor* is often used as an adjective to describe a species that has two distinct colors or color patterns on the body or specific body parts.

Taxa. The epithet has been used in three genera: *Dolichogenidea bicolor* Song & Chen, 2004; *Pholetesor bicolor* (Nees, 1834); and *Snellenius bicolor* Shenefelt, 1968.

Category. Morphology.

brevivena

Etymology. The term *brevivena* contains two Latin words, *brevi* which means short and *vena* which means vein. In taxonomy, *brevivena* refers to a species with short veins.

Taxa. The epithet has been used in two genera: *Apanteles brevivena* Liu & Chen, 2015; and *Diolcogaster brevivena* Zeng & Chen, 2011.

Category. Morphology.

broadi

Etymology. The name honors the British Gavin R. Broad, one of the world's leading authorities of our time on the study of Ichneumonidae. The suffix *-i* added to the term is a masculine Latin genitive.

Taxa. The epithet has been used in two genera: *Dolichogenidea broadi* Rousse, 2013; and *Sendaphne broadi* Fernández-Triana & Whitfield, 2014.

Category. People.

calixtomoragai

Etymology. The epithet refers to Calixto Moraga for his contributions to the Área de Conservación Guanacaste (ACG) in the Programa de Parataxónomos in Costa Rica (Central America). The suffix *-i* added to the term is a masculine Latin genitive.

Taxa. The epithet has been used in two genera: *Alphomelon calixtomoragai* Fernández-Triana & Shimbori, 2023; and *Apanteles calixtomoragai* Fernández-Triana, 2014.

Category. People.

canadensis

Etymology. The term *canadensis* consists of two words, Canada, a country in North America, and the Latin suffix *-ensis* which means belonging to or inhabiting. In taxonomy, *canadensis* refers to a species that is native to or found in Canada.

Taxa. The epithet has been used in three genera: *Clarkinella canadensis* Mason, 1981; *Iconella canadensis* Fernández-Triana, 2013; and *Microgaster canadensis* Muesebeck, 1922.

Category. Geography.

capeki

Etymology. The name honors Miroslav Čapek (1927–2008), a Czech braco-nidologist from the 20th century in appreciation of his relevant entomological contributions. The suffix *-i* added to the term is a masculine Latin genitive.

Taxa. The epithet has been used in two genera: *Glyptapanteles capeki* (Györfi, 1955); and *Microplitis capeki* Nixon, 1970.

Category. People.

carinatus

Etymology. The term *carinatus* derives from the Latin word *carina* which means keel or ridge. In taxonomy, *carinatus* describes a species that has a distinct ridge or keel on a specific body part such as mesosoma or metasoma.

Taxa. The epithet has been used in two genera: *Glyptapanteles carinatus* (Szépligeti, 1913); and *Microplitis carinatus* Song & Chen, 2008.

Category. Morphology.

carlosrodriguezi

Etymology. The name refers to Carlos Rodríguez in recognition of his tireless efforts with the Programa de Ecoturismo in the Área de Conservación Guanacaste (ACG) in Costa Rica (Central America). The suffix *-i* added to the term is a masculine Latin genitive.

Taxa. The epithet has been used in two genera: *Apanteles carlosrodriguezi* Fernández-Triana, 2014; and *Pseudapanteles carlosrodriguezi* Fernández-Triana & Whitfield, 2014.

Category. People.

carolinacanoae

Etymology. The epithet refers to Carolina Cano for her contributions to the Área de Conservación Guanacaste (ACG) in the Programa de Parataxónomos in Costa Rica (Central America). The suffix *-ae* added to the term is a feminine Latin genitive.

Taxa. The epithet has been used in two genera: *Alphomelon carolinacanoae* Fernández-Triana & Shimbori, 2023; and *Apanteles carolinacanoae* Fernández-Triana, 2014.

Category. People.

cebes

Etymology. The epithet is probably dedicated to Cebes, an Ancient Greek philosopher from Thebes who was a disciple of Socrates.

Taxa. The epithet has been used in two genera: *Apanteles cebes* Nixon, 1965; and *Microplitis cebes* Nixon, 1970.

Category. Other.

christerhanssoni

Etymology. The epithet honors the Swedish chalcidologist, Christer Hansson, whose work contributes to the knowledge of Eulophidae of the world. The suffix *-i* added to the term is a masculine Latin genitive.

Taxa. The epithet has been used in two genera: *Alphomelon christerhanssoni* Fernández-Triana & Shimbori, 2023; and *Glyptapanteles christerhanssoni* Arias-Penna, 2019.

Category. People.

concinnus

Etymology. The term *concinnus* derives from the Latin verb *concinnare* which means to make ready or to put in order. In taxonomy, *concinnus* describes a species that has a well-ordered or harmonious appearance, often about a morphological trait or coloration.

Taxa. The epithet has been used in two genera: *Apanteles concinnus* Statz, 1938; and *Glyptapanteles concinnus* (Muesebeck, 1958).

Category. Morphology.

Note. *Apanteles concinnus* Statz, 1938 is a species only known from fossils (see more detail in Fernández-Triana et al. 2020).

confusus

Etymology. The Latin word *confusus* means confused or mixed up. In taxonomy, *confusus* likely refers that initially, the species was unclear or confusing (referring to more or less merged second + third tergites), as is the case with many newly discovered Microgastrinae species.

Taxa. The epithet has been used in two genera: *Microplitis confusus* Muesebeck, 1922; and *Pholetesor confusus* Liu & Chen, 2016.

Category. Morphology.

coxalis

Etymology. The term *coxalis* derives from two Latin words, *coxa* which means hip and the suffix *-alis* which means related to or pertaining to. In taxonomy, *coxalis* refers to a species whose coxa has a particularity either in size, color, or sculpturing.

Taxa. The epithet has been used in two genera: *Apanteles coxalis* Szépligeti, 1911; and *Diolcogaster coxalis* (de Saeger, 1944).

Category. Morphology.

crassicornis

Etymology. The word *crassicornis* is made up of two Latin words, *crassus* which means thick or fat and *cornis* which means horn. In taxonomy, *crassicornis* describes a species whose antennae are thick or club-shaped that resemble horns.

Taxa. The epithet has been used in two genera: *Apanteles crassicornis* (Provancher, 1886); and *Microgaster crassicornis* Ruthe, 1860.

Category. Morphology.

curticornis

Etymology. The term *curticornis* is composed of two Latin words, *curtus* which means short or truncated and *cornis* which means horn. In taxonomy, *curticornis* describes a species with short or truncated antennae that resemble horns.

Taxa. The epithet has been used in two genera: *Diolcogaster curticornis* (Granger, 1949); and *Venanides curticornis* (Granger, 1949).

Category. Morphology.

delicata

Etymology. The Latin word *delicata* means pleasing, delightful, dainty, or fine. In taxonomy, *delicata* refers to the general appearance of the body which is delicate and slender.

Taxa. The epithet has been used in two genera: *Austrocotesia delicata* Austin & Dangerfield, 1992; and *Cotesia delicata* (Howard, 1897).

Category. Morphology.

diniamartinezae

Etymology. The epithet refers to Dinia Martínez for her contributions to the Área de Conservación Guanacaste (ACG) in the Programa de Parataxónomos in Costa Rica (Central America). The suffix *-ae* added to the term is a feminine Latin genitive.

Taxa. The epithet has been used in two genera: *Alphomelon diniamartinezae* Fernández-Triana & Shimbóri, 2023; and *Apanteles diniamartinezae* Fernández-Triana, 2014.

Category. People.

duvalierbricenoi

Etymology. The epithet refers to Duvalier Briceño for his contributions to the Área de Conservación Guanacaste (ACG) in the Programa de Parataxónomos in Costa Rica (Central America). The suffix *-i* added to the term is a masculine Latin genitive.

Taxa. The epithet has been used in two genera: *Alphomelon duvalierbricenoi* Fernández-Triana & Shimbóri, 2023; and *Apanteles duvalierbricenoi* Fernández-Triana, 2014.

Category. People.

elegans

Etymology. The Latin word *elegans* means elegant or distinguished. In taxonomy, *elegans* describes a species whose general appearance is elegant, graceful, or refined.

Taxa. The epithet has been used in two genera: *Microgaster elegans* Herrich-Schäffer, 1838; and *Microplitis elegans* Timon-David, 1944.

Category. Morphology.

Note. *Microplitis elegans* Timon-David, 1944 is a species only known from fossils (see more detail in Fernández-Triana et al. 2020).

eliethcantillanoae

Etymology. The epithet refers to Elieth Cantillano for her contributions to the Área de Conservación Guanacaste (ACG) in the Programa de Parataxónomos in Costa Rica (Central America). The suffix *-ae* added to the term is a feminine Latin genitive.

Taxa. The epithet has been used in two genera: *Alphomelon eliethcantillanoae* Fernández-Triana & Shimbóri, 2023; and *Apanteles eliethcantillanoae* Fernández-Triana, 2014.

Category. People.

epaphus

Etymology. There is no clear explanation of the species name, but it is assumed that corresponds to the butterfly *Siproeta epaphus* Latreille (Nymphalidae), the herbivore host used by these parasitoid wasps.

Taxa. The epithet has been used in two genera: *Choeras epaphus* (Nixon, 1965); and *Nyereria epaphus* (de Saeger, 1944).

Category. Biology.

eros

Etymology. The Greek word *eros* refers to the god of love in Greek mythology. Its Roman counterpart is *Cupido*. In taxonomy, *eros* refers to the lepidopteran host, *Luthrodes pandava* Horsfield (Lycaenidae) commonly known as Plain's cupid.

Taxa. The epithet has been used in two genera: *Dolichogenidea eros* (Wilkinson, 1932); and *Parapanteles eros* Gupta, 2014.

Category. Biology.

erro

Etymology. The Latin word *erro* probably means to make a mistake, to err, or go astray. However, there is not a clear meaning or association in the etymology.

Taxa. The epithet has been used in two genera: *Diolcogaster erro* (Nixon, 1965); and *Microgaster erro* Nixon, 1968.

Category. Other.

eupolis

Etymology. The Greek name *eupolis* likely means good city or well-city. The epithet may intend to refer to a specific location or city, but it is difficult to say for certain.

Taxa. The epithet has been used in two genera: *Apanteles eupolis* Nixon, 1965; and *Microgaster eupolis* Nixon, 1968.

Category. Other.

felipechavarriai

Etymology. The name refers to Felipe Chavarría in recognition of his diligent efforts to understand the plant biology of the Área de Conservación Guanacaste (ACG) in Costa Rica (Central America). The suffix *-i* added to the term is a masculine Latin genitive.

Taxa. The epithet has been used in two genera: *Apanteles felipechavarriai* Fernández-Triana, 2014; and *Snellenius felipechavarriai* Fernández-Triana & Whitfield, 2015.

Category. People.

feltiae

Etymology. The term *feltiae* refers to the moth genus, *Feltia* Walker (Noctuidae: Noctuinae) which is used as an herbivore host by these parasitoid wasps. The suffix *-ae* added to the term is a Latin feminine genitive.

Taxa. The epithet has been used in two genera: *Apanteles feltiae* Viereck, 1912; and *Microplitis feltiae* Muesebeck, 1922.

Category. Biology.

ferruginea

Etymology. The Latin word *ferruginea* derives from *ferrugo* which means rust. In taxonomy, *ferruginea* describes a species that has a reddish brown or rust-colored appearance or a particular morphological trait that resembles rust.

Taxa. The epithet has been used in two genera: *Cotesia ferruginea* (Marshall, 1885); and *Microgaster ferruginea* Xu & He, 2000.

Category. Morphology.

flavipes

Etymology. The term *flavipes* derives from two Latin words, *flavus* which means yellow and *pes* which means foot. In taxonomy, *flavipes* describes a species with yellow-colored legs. In some cases, the name may refer to the entire organism having a yellow coloration, but it is most commonly used to describe a specific body part.

Taxa. The epithet has been used in three genera: *Chaoa flavipes* Luo, You & Xiao, 2004; *Cotesia flavipes* Cameron, 1891; and *Diolcogaster flavipes* (Haliday, 1834).

Category. Morphology.

garygibsoni

Etymology. The name refers to Gary Alfred Peter Gibson, a Canadian expert in the systematics of chalcid parasitoid wasps (Chalcidoidea), especially the families Eupelmidae and Pteromalidae and functional and comparative morphology of Chalcidoidea and Hymenoptera. The suffix *-i* added to the term is a masculine Latin genitive.

Taxa. The epithet has been used in two genera: *Apanteles garygibsoni* Fernández-Triana, 2014; and *Glyptapanteles garygibsoni* Arias-Penna, 2019.

Category. People.

ghesquierei

Etymology. The epithet honors Fernand Ghesquière (1879–1924), a Belgian braconidologist and naturalist who made significant contributions to the study of African insects at the end of the 19th and beginning of the 20th century. The suffix *-i* added to the term is a masculine Latin genitive.

Taxa. The epithet has been used in two genera: *Apanteles ghesquierei* de Saeger, 1941; and *Fornicia ghesquierei* de Saeger, 1942.

Category. People.

gloriasihezarae

Etymology. The epithet refers to Gloria Sihezar for her contributions to the Área de Conservación Guanacaste (ACG) in the Programa de Parataxónomos in Costa Rica (Central America). The suffix *-ae* added to the term is a feminine Latin genitive.

Taxa. The epithet has been used in two genera: *Alphomelon gloriasihezarae* Fernández-Triana & Shimbori, 2023; and *Apanteles gloriasihezarae* Fernández-Triana, 2014.

Category. People.

grangeri

Etymology. The epithet is dedicated to Charles Granger, a French entomologist who started the laborious revision of braconid wasps of the Malagasy subregion. The suffix *-i* added to the term is a masculine Latin genitive.

Taxa. The epithet has been used in two genera: *Diolcogaster grangeri* (Shenefelt, 1973); and *Dodogaster grangeri* Rouse, 2013.

Category. People.

guillermopereirai

Etymology. The epithet refers to Guillermo Pereira for his contributions to the Área de Conservación Guanacaste (ACG) in the Programa de Parataxónomos in Costa Rica (Central America). The suffix *-i* added to the term is a feminine Latin genitive.

Taxa. The epithet has been used in two genera: *Alphomelon guillermopereirai* Fernández-Triana & Shimbori, 2023; and *Apanteles guillermopereirai* Fernández-Triana, 2014.

Category. People.

hazelcambreroae

Etymology. The epithet refers to Hazel Cambrero for her contributions to the Área de Conservación Guanacaste (ACG) in the Programa de Parataxónomos in Costa Rica (Central America). The suffix *-ae* added to the term is a feminine Latin genitive.

Taxa. The epithet has been used in two genera: *Alphomelon hazelcambreroae* Fernández-Triana & Shimbori, 2023; and *Apanteles hazelcambreroae* Fernández-Triana, 2014.

Category. People.

hyphantriae

Etymology. The term *hyphantriae* is derived from the Greek words *hyphantes* which means weaver and *tria* which means three. The suffix *-ae* added to the term is a Latin feminine genitive. In taxonomy, *hyphantriae* refers to a moth genus, *Hyphantria* Harris (Erebidae), which is an herbivore host used by these parasitoid wasps.

Taxa. The epithet has been used in two genera: *Cotesia hyphantriae* (Riley, 1887); and *Microplitis hyphantriae* Ashmead, 1898.

Category. Biology.

indica

Etymology. The Latin word *indica* derives from *indicus* which means of India. In taxonomy, *indica* refers to a species that is native to or has a significant presence in the Indian subcontinent. The name has been also used to describe morphological traits that are commonly found in organisms from India or the surrounding areas.

Taxa. The epithet has been used in three genera: *Apanteles indica* Chougale, 2016; *Cotesia indica* Sathe & Rokade, 2005; and *Diolcogaster indica* (Wilkinson, 1927).

Category. Geography.

Note. *Apanteles indica* Chougale, 2016 is under the status of unavailable names (see more detail in Fernández-Triana et al. 2020).

indicus

Etymology. The Latin word *indicus* means of India or belonging to India. In taxonomy, *indicus* refers to a species that is native to or has a significant presence in the Indian subcontinent.

Taxa. The epithet has been used in three genera: *Microplitis indicus* Marsh, 1978; *Parapanteles indicus* (Bhatnagar, 1950); and *Pholetesor indicus* Ahmad, Ghramh & Pandey, 2020.

Category. Geography.

insularis

Etymology. The Latin word *insularis* derives from *insula*, which means island or of or belonging to an island. In taxonomy, *insularis* describes a species that is found exclusively or predominantly on islands. The epithet also associates the physical or ecological traits of islands themselves, such as insular climates or insular vegetation.

Taxa. The epithet has been used in two genera: *Apanteles insularis* Muesebeck, 1921; and *Diolcogaster insularis* (Hedqvist, 1965).

Category. Geography.

isidrochaconi

Etymology. The epithet refers to Isidro Villegas in recognition of his diligent efforts on the Programa de Sectores for the Área de Conservación Guanacaste (ACG) in Costa Rica (Central America). The suffix *-i* added to the term is a masculine Latin genitive.

Taxa. The epithet has been used in two genera: *Apanteles isidrochaconi* Fernández-Triana, 2014; and *Snellenius isidrochaconi* Fernández-Triana & Whitfield, 2015.

Category. People.

jamesi

Etymology. The epithet is dedicated to James Bryan Whitfield, an American brachonidologist. He is one of the prestigious authorities on the taxonomy and phylogenomics of microgastrine parasitoid wasps and their coevolution with symbiotic polydnaviruses. The suffix *-i* added to the term is a masculine Latin genitive.

Taxa. The epithet has been used in two genera: *Jimwhitfieldius jamesi* Fernández-Triana & Boudreault, 2018; and *Microplitis jamesi* Austin & Dangerfield, 1993.

Category. People.

jesusgaldei

Etymology. The epithet refers to Jesús Ugalde in recognition of his diligent efforts in the administration of the Instituto Nacional de Biodiversidad (INBio) in Costa Rica (Central America). The suffix *-i* added to the term is a masculine Latin genitive.

Taxa. The epithet has been used in two genera: *Apanteles jesusgaldei* Fernández-Triana, 2014; and *Glyptapanteles jesusgaldei* Arias-Penna, 2019.

Category. People.

jorgehernandezi

Etymology. The epithet is dedicated to Jorge Hernández in recognition of his diligent efforts to understand the plant biology of the Área de Conservación Guanacaste (ACG), Costa Rica (Central America). The suffix *-i* added to the term is a masculine Latin genitive.

Taxa. The epithet has been used in two genera: *Apanteles jorgehernandezi* Fernández-Triana, 2014; and *Microplitis jorgehernandezi* Fernández-Triana & Whitfield, 2015.

Category. People.

kasparyani

Etymology. The epithet honors the Russian entomologist Dmitri Rafaelievich Kasparyan, for his contributions to ichneumonid taxonomy. The suffix *-i* added to the term is a masculine Latin genitive.

Taxa. The epithet has been used in two genera: *Cotesia kasparyani* (Tobias, 1976); and *Diolcogaster kasparyani* Kotenko, 2007.

Category. People.

keineraragoni

Etymology. The epithet refers to Keiner Aragón for his contributions to the Área de Conservación Guanacaste (ACG) in the Programa de Parataxónomos in Costa Rica (Central America). The suffix *-i* added to the term is a feminine Latin genitive.

Taxa. The epithet has been used in two genera: *Alphomelon keineraragoni* Fernández-Triana & Shimbori, 2023; and *Apanteles keineraragoni* Fernández-Triana, 2014.

Category. People.

keralensis

Etymology. The term *keralensis* consists of two words, Kerala, a state on the Malabar coast of India, and the Latin suffix *-ensis* which means belonging to or inhabiting. Kerala comes from the Malayalam word Keralam which means land of coconuts, the place is known for its rich biodiversity and is home to a large number of native plants and animals. In taxonomy, *keralensis* describes a species that is native to or has a significant presence in Kerala.

Taxa. The epithet has been used in two genera: *Illidops keralensis* (Narendran & Sumodan, 1992); and *Philoplitis keralensis* Ranjith & Fernández-Triana, 2019.

Category. Geography.

lacteus

Etymology. The Latin word *lacteus* means milky or white as milk. In taxonomy, *lacteus* describes a species that has a milky or white coloration or appearance.

Taxa. The epithet has been used in two genera: *Apanteles lacteus* (Nees, 1834); and *Microplitis lacteus* Austin & Dangerfield, 1993.

Category. Morphology.

lamprosemae

Etymology. The epithet refers to the moth genus, *Lamprosema* Hübner (Crambidae), which is the herbivore host used by these parasitoid wasps. The suffix -ae added to the term is a Latin feminine genitive.

Taxa. The epithet has been used in two genera: *Glyptapanteles lamprosemae* (Wilkinson, 1928); and *Illidops lamprosemae* (Ahmad, 2005).

Category. Biology.

longiantenna

Etymology. The term *longiantenna* contains two Latin words, *longus* which means long and *antenna* which means yard, sailyard, or pole. In taxonomy, *longiantenna* describes a species with relatively long antennae compared to other members of the same taxonomic rank.

Taxa. The epithet has been used in two genera: *Apanteles longiantenna* Chen & Song, 2004; and *Fornicia longiantenna* Luo & You, 2008.

Category. Morphology.

longicalcar

Etymology. The term *longicalcar* integrates two Latin words, *longus* which means long and *calcar* which means spur. In taxonomy, *longicalcar* is often used to describe a species with elongated hind leg spurs or tarsal claws which are used for various purposes (e.g., defense, mating, or gripping surfaces).

Taxa. The epithet has been used in two genera: *Dolichogenidea longicalcar* (Thomson, 1895); and *Microgaster longicalcar* Xu & He, 2003.

Category. Morphology.

longivena

Etymology. The term *longivena* contains two Latin words, *longus* which means long and *vena* which means vein. In taxonomy, *longivena* describes a species with elongated veins, structures that help to support the delicate wing during flight.

Taxa. The epithet has been used in three genera: *Dolichogenidea longivena* Liu & Chen, 2018; *Glyptapanteles longivena* Chen & Song, 2004; and *Rasivalva longivena* Song & Chen, 2004.

Category. Morphology.

loretta

Etymology. The term *loretta* is a female given name of Italian origin. The name derives from the Latin word *laurus* which means laurel. The laurel plant was a symbol of victory, honor, or fame. In taxonomy, *loretta* is used to honor loved ones.

Taxa. The epithet has been used in two genera: *Choeras loretta* (Nixon, 1965); and *Distatrix loretta* Grinter, 2009.

Category. People.

lunata

Etymology. The Latin word *lunata* derives from *luna* which means moon, the celestial body that has a crescent shape during certain phases of its cycle. In taxonomy, *lunata* describes morphological traits that have a curved or crescent shape, such as wings or antennae.

Taxa. The epithet has been used in three genera: *Apanteles lunata* Song & Chen, 2004; *Cotesia lunata* (Packard, 1881); and *Dolichogenidea lunata* Liu & Chen, 2019.

Category. Morphology.

malshri

Etymology. The term *malshri* could be a reference to a person's name based on the suffix *-i*, which is a masculine Latin genitive. It could also refer to a Hindu name for a woman. Malshri in Sanskrit means wonderful garland. The information is incomplete, so it is difficult to determine the exact origin.

Taxa. The epithet has been used in two genera: *Cotesia malshri* (Sathe & Inamdar, 1991); and *Glyptapanteles malshri* Sathe, Inamdar & Dawale, 2003.

Category. People.

Note. *Glyptapanteles malshri* Sathe, Inamdar & Dawale, 2003 is under the status of unavailable names (see more detail in Fernández-Triana et al. 2020).

manuelriosi

Etymology. The epithet refers to Manuel Ríos for his contributions to the Área de Conservación Guanacaste (ACG) in the Programa de Parataxónomos in Costa Rica (Central America). The suffix *-i* added to the term is a masculine Latin genitive.

Taxa. The epithet has been used in two genera: *Alphomelon manuelriosi* Fernández-Triana & Shimbori, 2023; and *Apanteles manuelriosi* Fernández-Triana, 2014.

Category. People.

masneri

Etymology. The epithet honours Lubomír (Lubo) Masner, a prominent Canadian entomologist, whose work contributes to the understanding of the taxonomy and systematics of the order Hymenoptera. The suffix *-i* added to the term is a masculine Latin genitive.

Taxa. The epithet has been used in three genera: *Microplitis masneri* Austin & Dangerfield, 1993; *Philoplitis masneri* Fernández-Triana & Goulet, 2009; and *Pholetesor masneri* (Mason, 1981).

Category. People.

masoni

Etymology. The epithet honors the Canadian William Richardson Miles Mason (1921–1991), one of the greatest pioneers in the study of the Microgastrinae

of the 20th century. His legacy is immense. The suffix *-i* added to the term is a masculine Latin genitive.

Taxa. The epithet has been used in nine genera: *Apanteles masoni* Chen & Song, 2004; *Diolcogaster masoni* Saeed, Austin & Dangerfield, 1999; *Dolichogenidea masoni* Pandey, Ahmad, Haider & Shujaiddin, 2005; *Hypomicrogaster masoni* Valerio, 2015; *Parapanteles masoni* Austin & Dangerfield, 1992; *Pholetesor masoni* Whitfield, 2006; *Prasmodon masoni* Fernández-Triana & Whitfield, 2014; *Sathon masoni* Williams, 1988; and *Wilkinsonellus masoni* Long & van Achterberg, 2011.

Category. People.

medon

Etymology. The Greek word *medon* means ruler or lord. In taxonomy, *medon* denotes a dominant, superior, or distinctive morphological trait such as larger size.

Taxa. The epithet has been used in two genera: *Apanteles medon* Nixon, 1965; and *Diolcogaster medon* (Nixon, 1965).

Category. Morphology.

memorata

Etymology. The term *memorata* derives from the Latin word *memoratus* which means remembered or noted. In taxonomy, *memorata* likely emphasizes a notable or remarkable morphological trait present in the species.

Taxa. The epithet has been used in two genera: *Iconella memorata* Kotenko, 2007; and *Microgaster memorata* Papp, 1971.

Category. Morphology.

merata

Etymology. The word Latin adjective *merata* likely means earned or deserved. However, *merate*, *meratus* is also an Australian aboriginal word that means naked. In *Diolcogaster*, *merata* refers to the tergite 3 which does not form a carapace with tergites 1 and 2.

Taxa. The epithet has been used in two genera: *Diolcogaster merata* Saeed, Austin & Dangerfield, 1999; and *Iconella merata* (Kotenko, 1981).

Category. Morphology.

mikepoguei

Etymology. The epithet honors Michael (Mike) G. Pogue, an American lepidopterist. His work has been widely recognized and respected within the lepidopterist community, making his name synonymous with excellence. The suffix *-i* added to the term is a masculine Latin genitive.

Taxa. The epithet has been used in two genera: *Glyptapanteles mikepoguei* Arias-Penna, 2019; and *Prasmodon mikepoguei* Fernández-Triana & Whitfield, 2014.

Category. People.

mikesharkeyi

Etymology. The epithet honors the American braconidologist, Michael (Mike) Joseph Sharkey, whose work contributes to the knowledge of Braconidae of the world. He is a distinguished hymenopterologist and his work is truly remarkable. The suffix *-i* added to the term is a masculine Latin genitive.

Taxa. The epithet has been used in two genera: *Alphomelon mikesharkeyi* Fernández-Triana & Shimbori, 2023; and *Glyptapanteles mikesharkeyi* Arias-Penna, 2019.

Category. People.

minor

Etymology. The Latin adjective *minor* means smaller or lesser. In taxonomy, *minor* describes a species with a small body size.

Taxa. The epithet has been used in two genera: *Apanteles minor* Fahringer, 1938; and *Glyptapanteles minor* Ashmead, 1906.

Category. Morphology.

montanus

Etymology. The Latin adjective *montanus* derives from the noun *mons*, *montis* which means mountain. In taxonomy, *montanus* indicates that the species is of the mountains or has been reported at high altitudes.

Taxa. The epithet has been used in two genera: *Apanteles montanus* de Saeger, 1944; and *Microplitis montanus* Muesebeck, 1922.

Category. Geography.

Note. *Apanteles montanus* de Saeger, 1944 is under the status of species inquirendae (see more detail in Fernández-Triana et al. 2020).

narendrani

Etymology. The epithet honors Thekke Curupathe Narendran (1944–2013), an Indian entomologist, in recognition of his immense contributions to parasitic Hymenoptera. The suffix *-i* added to the term is a masculine Latin genitive.

Taxa. The epithet has been used in three genera: *Diolcogaster narendrani* Rema & Sheeba, 2004; *Microplitis narendrani* Ranjith & Nasser, 2015; and *Neoclarkinella narendrani* Veena, 2014.

Category. People.

newguineaensis

Etymology. The term *newguineaensis* contains two words, New Guinea, the world's second-largest island located in the southwestern Pacific Ocean, and the Latin suffix *-ensis* which means belonging to or inhabiting. In taxonomy, *newguineaensis* refers to a species that is native to or was first discovered in New Guinea.

Taxa. The epithet has been used in two genera: *Diolcogaster newguineaensis* Saeed, Austin & Dangerfield, 1999; and *Microplitis newguineaensis* Austin & Dangerfield, 1993.

Category. Geography.

niger

Etymology. The Latin word *niger* means black. In taxonomy, *niger*, *nigra*, *nigrum* are used to describe a species with black or dark coloration on the whole body or in a specific morphological trait.

Taxa. The epithet has been used in two genera: *Dolichogenidea niger* (Muesebeck, 1921); and *Jenopappius niger* (de Saeger, 1944).

Category. Morphology.

Note. The original species name *Apanteles niger* Muesebeck, 1921, was transferred to *Dolichogenidea* by Fernández-Triana et al. (2020). The specific epithet, *niger*, was changed to *nigra* to comply with gender agreement as the gender of *Dolichogenidea* is feminine (Fernández-Triana et al. 2020).

nigricornis

Etymology. The term *nigricornis* contains two Latin words, *niger* which translates to black and *cornu* which means horn. In taxonomy, *nigricornis* refers to the black coloration of the antennae or other horn-like structures.

Taxa. The epithet has been used in two genera: *Glyptapanteles nigricornis* (Muesebeck, 1921); and *Microgaster nigricornis* Motschoulsky, 1863.

Category. Morphology.

Note. *Microgaster nigricornis* Motschoulsky, 1863 is under the status of species inquirendae (see more detail in Fernández-Triana et al. 2020).

nigritus

Etymology. The Latin term *nigritus* means blackened or blackish. In taxonomy, as well as the epithets *niger*, *nigritus* describe a species with black or dark coloration on the whole body or in a specific morphological trait.

Taxa. The epithet has been used in two genera: *Hygroplitis nigritus* Luo & You, 2005; and *Microplitis nigritus* Muesebeck, 1922.

Category. Morphology.

nixonii

Etymology. The epithet honors the British entomologist Gilbert Edward James Nixon, one of the most recognized and illustrious experts of Microgastrinae. The suffix *-ii* added to the term is a masculine Latin genitive.

Taxa. The epithet has been used in five genera: *Apanteles nixonii* Song, 2002; *Diolcogaster nixonii* Saeed, Austin & Dangerfield, 1999; *Microgaster nixonii* Austin & Dangerfield, 1992; *Prasmodon nixonii* Fernández-Triana & Whitfield, 2014; and *Semionis nixonii* Tobias, 1987.

Category. People.

Note. *Semionis nixonii* Tobias, 1987 is a species only known from fossils (see more detail in Fernández-Triana et al. 2020).

oculatus

Etymology. The Latin adjective *oculatus* means having eyes or with eyes. In taxonomy, *oculatus* describes a species with distinctive eye markings or coloration around the eyes.

Taxa. The epithet has been used in two genera: *Apanteles oculatus* Tobias, 1967; and *Palaeomicrogaster oculatus* Belokobylskij, 2014.

Category. Morphology.

Note. *Palaeomicrogaster oculatus* Belokobylskij, 2014 is a species only known from fossils (see more detail in Fernández-Triana et al. 2020).

orientalis

Etymology. The term *orientalis* comes from the Latin word *oriens* which means east or rising. In taxonomy, *orientalis* indicates a species that is native to the eastern region of its distribution or was originally described from specimens collected in the East.

Taxa. The epithet has been used in six genera: *Apanteles orientalis* Szépligeti, 1913; *Buluka orientalis* Chou, 1985; *Cotesia orientalis* Chalikwar & Nikam, 1984; *Diolcogaster orientalis* (Rao & Chalikwar, 1970); *Miropotes orientalis* Fernández-Triana & van Achterberg, 2014; and *Tobleronius orientalis* Fernández-Triana & Boudreault, 2018.

Category. Geography.

oryzae

Etymology. The term *oryzae* derives from *Oryza* L., (Poaceae), the genus to which the rice belongs. The suffix *-ae* added to the term is a Latin feminine genitive. Many adult microgastrine species have been associated with rice plants or rice grains.

Taxa. The epithet has been used in two genera: *Dolichogenidea oryzae* Bhoje & Sathe, 2002; and *Exoryza oryzae* (Walker, 1994).

Category. Other.

Note. *Dolichogenidea oryzae* Bhoje & Sathe, 2002 is under the status of unavailable name (see more detail in Fernández-Triana et al. 2020).

osvaldoespinozai

Etymology. The epithet refers to Osvaldo Espinoza for his contributions to the Área de Conservación Guanacaste (ACG) in the Programa de Parataxónomos in Costa Rica (Central America). The suffix *-i* added to the term is a masculine Latin genitive.

Taxa. The epithet has been used in two genera: *Alphomelon osvaldoespinozai* Fernández-Triana & Shimbori, 2023; and *Apanteles osvaldoespinozai* Fernández-Triana, 2014.

Category. People.

pappi

Etymology. The name honors the Hungarian entomologist Jenő Papp (1933–2017) in recognition of his significant contributions to the knowledge of Braconidae of the world, and his work on Palearctic Microgastrinae. The suffix *-i* added to the term is a masculine Latin genitive.

Taxa. The epithet has been used in two genera: *Choeras pappi* Narendran, 1998; and *Cotesia pappi* Inanç, 2002.

Category. People.

Note. *Choeras pappi* Narendran, 1998 is under the status of species inquirendae (see more detail in Fernández-Triana et al. 2020).

paranaensis

Etymology. The term *paranaensis* contains two words, Paraná, of the Paraná River in South America, which runs through Brazil, Paraguay, and Argentina, and the Latin suffix *-ensis* which means belonging to or inhabiting. In taxonomy, *paranaensis* refers to a species that is found in or near the Paraná River region.

Taxa. The epithet has been used in two genera: *Illidops paranaensis* Pentead-Dias & Scatolini, 2000; and *Sendaphne paranaensis* Scatolini & Pentead-Dias, 1999.

Category. Geography.

peckorum

Etymology. The term *peckorum* contains two words, Peck honors the married couple Stewart Blaine Peck and Jarmila Kukalová-Peck, tireless insect collectors during the last 30+ years, their contributions are significant to the study of the insect fauna of southern Florida, USA. And the suffix *-orum* which indicates the genitive plural, is typically used to honor a group of people, such as a family or a team of researchers.

Taxa. The epithet has been used in two genera: *Keylimepie peckorum* Fernández-Triana, 2016; and *Papanteles peckorum* Mason, 1981.

Category. People.

peruensis

Etymology. The term *peruensis* contains two words, Peru, a country in South America, and the Latin suffix *-ensis* which means belonging to or inhabiting. In taxonomy, *peruensis* indicates that the species is from Peru.

Taxa. The epithet has been used in two genera: *Snellenius peruensis* Shenefelt, 1968; and *Venusus peruensis* Mason, 1981.

Category. Geography.

petronariosae

Etymology. The epithet refers to Petrona Ríos for her contributions to the Área de Conservación Guanacaste (ACG) in the Programa de Parataxónomos in Costa Rica (Central America). The suffix *-ae* added to the term is a feminine Latin genitive.

Taxa. The epithet has been used in two genera: *Alphomelon petronariosae* Fernández-Triana & Shimbori, 2023; and *Apanteles petronariosae* Fernández-Triana, 2014.

Category. People.

phildevriesi

Etymology. The epithet honors Philip (Phil) James DeVries, an American tropical ecologist, for his diligent contributions to this field. The suffix *-i* added to the term is a masculine Latin genitive.

Taxa. The epithet has been used in two genera: *Glyptapanteles phildevriesi* Arias-Penna, 2019; and *Snellenius phildevriesi* Fernández-Triana & Whitfield, 2015.

Category. People.

philippinensis

Etymology. The term *philippinensis* contains two words, the Philippine, an archipelagic country in southeast Asia, and the Latin suffix *-ensis* which means belonging to or inhabiting. In taxonomy, *philippinensis* refers to a species that is native or discovered in the Philippines.

Taxa. The epithet has been used in two genera: *Glyptapanteles philippinensis* (Ashmead, 1904); and *Snellenius philippinensis* (Ashmead, 1904).

Category. Geography.

phthorimaeae

Etymology. The term *phthorimaeae* contains two words, *phthorima* a Greek word that means destruction or ruin, and the Latin suffix *-ae*, a feminine genitive. In taxonomy, *Phthorimaea* Meyrick refers to a gelechiid moth genus that is used as an herbivore host by these wasps and that may cause potential damage to their food plants.

Taxa. The epithet has been used in two genera: *Dolichogenidea phthorimaeae* (Muesebeck, 1921); and *Microgaster phthorimaeae* Muesebeck, 1922.

Category. Biology.

pinicola

Etymology. The term *pinicola* contains two Latin words, *pinus* which means pine and *cola* which means inhabitant of or dweller. In taxonomy, *pinicola* refers to a species that is commonly associated with pine trees or dwelling in pines.

Taxa. The epithet has been used in two genera: *Glyptapanteles pinicola* (Lyle, 1917); and *Venanus pinicola* Mason, 1981.

Category. Biology.

prodeniae

Etymology. The term *prodeniae* contains two words, *Prodenia* Guenée, a noctuid moth genus, (currently, is a synonym of *Spodoptera* Guenée), and the Latin suffix *-ae*, a feminine genitive.

Taxa. The epithet has been used in two genera: *Dolichogenidea prodeniae* (Viereck, 1912); and *Microplitis prodeniae* Rao & Kurian, 1950.

Category. Biology.

punctata

Etymology. The Latin word *punctata* means spotted or dotted. In taxonomy, *punctata* refers to a species that has visible dots or spots or a specific type of surface sculpturing (punctate) on its body.

Taxa. The epithet has been used in two genera: *Diolcogaster punctata* (Rao & Chalikwar, 1976); and *Neoclarkinella punctata* Ahmad, Pandey, Haider & Shujaiddin, 2005.

Category. Morphology.

pyrene

Etymology. The epithet probably refers to the butterfly species, *Ixias pyrene* Linnaeus (Pieridae) which is used as the herbivore host by these wasps. However, it is necessary to confirm the etymology.

Taxa. The epithet has been used in two genera: *Diolcogaster pyrene* (Nixon, 1965); and *Iconella pyrene* (Nixon, 1965).

Category. Biology.

randallgarciai

Etymology. The epithet is dedicated to Randall García in recognition of his key role in the founding of the Área de Conservación Guanacaste (ACG) and subsequent diligent efforts in the administration of the Instituto Nacional de Biodiversidad (INBio) in Costa Rica (Central America). The suffix *-i* added to the term is a masculine Latin genitive.

Taxa. The epithet has been used in two genera: *Apanteles randallgarciai* Fernández-Triana, 2014; and *Venanus randallgarciai* Fernández-Triana & Whitfield, 2014.

Category. People.

rarus

Etymology. The Latin adjective *rarus* means rare or uncommon. In taxonomy, *rarus* indicates a species that is rare or has a limited distribution.

Taxa. The epithet has been used in two genera: *Parapanteles rarus* Valerio & Whitfield, 2009; and *Semionis rarus* Nixon, 1965.

Category. Other.

ricardocaleroi

Etymology. The epithet refers to Ricardo Calero for his contributions to the Área de Conservación Guanacaste (ACG) in the Programa de Parataxónomos in Costa Rica (Central America). The suffix *-i* added to the term is a masculine Latin genitive.

Taxa. The epithet has been used in two genera: *Alphomelon ricardocaleroi* Fernández-Triana & Shimbori, 2023; and *Apanteles ricardocaleroi* Fernández-Triana, 2014.

Category. People.

robertoespinozai

Etymology. The epithet is dedicated to Roberto Espinoza in recognition of his diligent efforts for the Programa de Parataxónomos and the plant inventory of the Área de Conservación Guanacaste (ACG), Costa Rica (Central America). The suffix *-i* added to the term is a masculine Latin genitive.

Taxa. The epithet has been used in two genera: *Apanteles robertoespinozai* Fernández-Triana, 2014; and *Snellenius robertoespinozai* Fernández-Triana & Whitfield, 2015.

Category. People.

rodrigogamezi

Etymology. The epithet honors Rodrigo Gámez in recognition of his enormous efforts in support of founding the Área de Conservación Guanacaste (ACG), and founding and directing the Instituto Nacional de Biodiversity (INBio) in Costa Rica (Central America). The suffix *-i* added to the term is a masculine Latin genitive.

Taxa. The epithet has been used in two genera: *Apanteles rodrigogamezi* Fernández-Triana, 2014; and *Pseudapanteles rodrigogamezi* Fernández-Triana & Whitfield, 2014.

Category. People.

rogerblancoi

Etymology. The epithet is dedicated to Roger Blanco in recognition of his diligent efforts for the Programa de Investigacion and administration of the Área de Conservación Guanacaste (ACG) in Costa Rica (Central America). The suffix *-i* added to the term is a masculine Latin genitive.

Taxa. The epithet has been used in three genera: *Apanteles rogerblancoi* Fernández-Triana, 2014; *Dolichogenidea rogerblancoi* Fernández-Triana & Boudreault, 2019; and *Sendaphne rogerblancoi* Fernández-Triana & Whitfield, 2014.

Category. People.

ronaldzunigai

Etymology. The epithet refers to Ronald Zúñiga in recognition of his diligent efforts for the Programa de Parataxónomos of the Área de Conservación Guanacaste (ACG) and Hymenoptera curatorial taxonomy for Instituto Nacional de Biodiversidad (INBio) in Costa Rica (Central America). The suffix *-i* added to the term is a masculine Latin genitive.

Taxa. The epithet has been used in two genera: *Apanteles ronaldzunigai* Fernández-Triana, 2014; and *Glyptapanteles ronaldzunigai* Arias-Penna, 2019.

Category. People.

rostermoragai

Etymology. The epithet refers to Roster Moraga for his contributions to the Área de Conservación Guanacaste (ACG) in the Programa de Parataxónomos in Costa Rica (Central America). The suffix *-i* added to the term is a masculine Latin genitive.

Taxa. The epithet has been used in two genera: *Alphomelon rostermoragai* Fernández-Triana & Shimbori, 2023; and *Apanteles rostermoragai* Fernández-Triana, 2014.

Category. People.

ruficoxis

Etymology. The term *ruficoxis* contains two Latin words, *rufus* which means red or reddish and *coxa* which means hip or thigh. In taxonomy, *ruficoxis* refers to the reddish coloration of the coxa.

Taxa. The epithet has been used in two genera: *Cotesia ruficoxis* (Hedwig, 1962); and *Microgaster ruficoxis* Ruthe, 1858.

Category. Morphology.

Note. *Microgaster ruficoxis* Ruthe, 1858 is under the status of species inquirendae (see more detail in Fernández-Triana et al. 2020).

rufipes

Etymology. The term *rufipes* contains two Latin words, *rufus* which means red and *pes* which means foot. In taxonomy, *rufipes* describe a species with red-colored legs.

Taxa. The epithet has been used in two genera: *Microgaster rufipes* Nees, 1834; and *Microplitis rufipes* Dutu-Lacatusu, 1961.

Category. Morphology.

rufithorax

Etymology. The term *rufithorax* contains two Latin words, *rufus* which means red or reddish, and *thorax* which means chest. In taxonomy, *rufithorax* refers to a species with a reddish-coloured metasoma or thorax.

Taxa. The epithet has been used in two genera: *Apanteles rufithorax* Hedqvist, 1965; and *Diolcogaster rufithorax* (Granger, 1949).

Category. Morphology.

rufiventris

Etymology. The term *rufiventris* derives from two Latin words, *rufus* which means reddish and *venter* which means abdomen, belly, or stomach. In taxonomy, *rufiventris* is commonly used to describe a species with a reddish-colored abdomen, metasoma, or ventral side.

Taxa. The epithet has been used in two genera: *Cotesia rufiventris* (Bingham, 1906); and *Microplitis rufiventris* Kokujev, 1914.

Category. Morphology.

rugosa

Etymology. The Latin word *rugosa* means wrinkled or rough. In taxonomy, *rugosa* describes a species that exhibits a specific type of surface sculpturing (rugose) on the body or body part, meaning a wrinkled appearance.

Taxa. The epithet has been used in three genera: *Cotesia rugosa* (Szépligeti, 1914); *Hypomicrogaster rugosa* Valerio, 2015; and *Rasivalva rugosa* (Muesebeck, 1922).

Category. Morphology.

rugulosus

Etymology. The term *rugulosus* is a Latin adjective that means wrinkled or rugose and derives from the noun *ruga* which means a wrinkle. In taxonomy, *rugulosus* describes a species with a body or a body part showing a specific type of surface sculpturing (rugulose). In other words, an appearance of roughness or wrinkledness.

Taxa. The epithet has been used in two genera: *Choeras rugulosus* Song & Chen, 2014; and *Hygroplitis rugulosus* (Nees, 1834).

Category. Morphology.

schizurae

Etymology. The term *schizurae* refers to a notodontid moth genus, *Schizura* Doubleday (currently a synonym of *Coelodasys* Packard). The suffix *-ae* added to the term is a Latin feminine genitive. In taxonomy, *schizurae* refers to the herbivore host used by these wasps.

Taxa. The epithet has been used in two genera: *Cotesia schizurae* (Ashmead, 1898); and *Diolcogaster schizurae* (Muesebeck, 1922).

Category. Biology.

scottmilleri

Etymology. The epithet honors Scott Everett Miller, an American entomologist for his pioneering research in the systematics of Lepidoptera (moths); biogeography of the Pacific Basin, New Guinea, and Africa; and plant-insect community ecology. The suffix *-i* added to the term is a masculine Latin genitive.

Taxa. The epithet has been used in two genera: *Glyptapanteles scottmilleri* Arias-Penna, 2019; and *Prasmodon scottmilleri* Fernández-Triana & Whitfield, 2014.

Category. People.

sergioriosi

Etymology. The epithet refers to Sergio Ríos for his contributions to the Área de Conservación Guanacaste (ACG) in the Programa de Parataxónomos in Costa Rica (Central America). The suffix *-i* added to the term is a masculine Latin genitive.

Taxa. The epithet has been used in two genera: *Alphomelon sergioriosi* Fernández-Triana & Shimbori, 2023; and *Apanteles sergioriosi* Fernández-Triana, 2014.

Category. People.

seyrigi

Etymology. The epithet refers to André Seyrig, a French entomologist for his groundbreaking work on the taxonomy of Hymenoptera. The suffix *-i* added to the term is a masculine Latin genitive.

Taxa. The epithet has been used in three genera: *Apanteles seyrigi* Wilkinson, 1936; *Diolcogaster seyrigi* (Granger, 1949); and *Fornicia seyrigi* Granger, 1949.

Category. People.

shivranginii

Etymology. The term *shivranginii* possibly refers to Shivanranjani, a Hindustani classical raga (melodic mode) in Indian classical music. The Latin suffix *-i* added also suggests that the term refers to a male person. Another possibility is that the epithet has some local or personal significance. Unfortunately, no information was available in the original description or subsequent literature.

Taxa. The epithet has been used in two genera: *Parapanteles shivranginii* Sathe & Ingawale, 1989; and *Protomicroplitis shivrangini* Sathe, Inamdar & Dawale, 2003.

Category. People.

Note. *Protomicroplitis shivranginii* Sathe, Inamdar & Dawale, 2003 is under the status of unavailable names (see more detail in Fernández-Triana et al. 2020).

shrii

Etymology. The term *shrii* refers to the Sanskrit word *Shri* which is often used as a prefix to convey respect or reverence, equivalent to the English Mr. or Ms. It is often used as an honorific title for deities, holy persons, and respected leaders.

Taxa. The epithet has been used in two genera: *Apanteles shrii* Sathe & Ingawale, 1995; and *Cotesia shrii* Sathe, Ingawale & Bhosale, 1994.

Category. Other.

Note. *Apanteles shrii* Sathe & Ingawale, 1995 is under the status of species inquirendae (see more detail in Fernández-Triana et al. 2020).

siderion

Etymology. The term *siderion* comes from the Greek word *sideros* which means iron. In taxonomy, *siderion* describes a species that is associated with iron-rich environments or exhibits metallic coloration resembling iron.

Taxa. The epithet has been used in two genera: *Glyptapanteles siderion* (Nixon, 1965); and *Hypomicrogaster siderion* Valerio, 2015.

Category. Morphology.

similis

Etymology. The Latin word *similis* means similar or like. In taxonomy, *similis* indicates a species that is closely related to another in appearance or behavior.

Taxa. The epithet has been used in two genera: *Microplitis similis* Lyle, 1921; and *Snellenius similis* Long & van Achterberg, 2013.

Category. Other.

spodopterae

Etymology. The epithet *spodopterae* refers to a moth genus, *Spodoptera* Guenée (Noctuidae), which is used as the herbivore host by these parasitoid wasps. In turn, *Spodoptera* derives from the Greek word *spodos* meaning ash wood, and the Latin suffix *-ptera*, which means winged. The suffix *-ae* added to the term is a Latin feminine genitive.

Taxa. The epithet has been used in two genera: *Glyptapanteles spodopterae* Ahmad, 2009; and *Microplitis spodopterae* Rao & Kurian, 1950.

Category. Biology.

striatus

Etymology. The Latin term *striatus* derives from the verb *strio* which means to mark with lines. In taxonomy, *striatus* describes a species with stripes or lines on their bodies or appendages.

Taxa. The epithet has been used in three genera: *Keylimepie striatus* (Muesebeck, 1922); *Philoplitis striatus* Fernández-Triana & Goulet, 2009; and *Wilkinsonellus striatus* Austin & Dangerfield, 1992.

Category. Morphology.

subcamilla

Etymology. The term *subcamilla* contains two Latin words, the prefix *-sub* which means below or under, and *Camilla*, a character that appears in the Aeneid, an epic poem written by Virgil.

Taxa. The epithet has been used in two genera: *Apanteles subcamilla* Long, 2007; and *Iconella subcamilla* (Tobias, 1976).

Category. Other.

sunflowari

Etymology. The term *sunflowari* contains two words, sunflower, the common name of the genus *Helianthus* L. (Asteraceae), and the suffix *-i*, an adjectival ending used to form species names. In taxonomy, *sunflowari* refers to the food plant of these parasitoid wasps.

Taxa. The epithet has been used in two genera: *Cotesia sunflowari* Sathe & Bhoje, 2000; and *Dolichogenidea sunflowari* Sathe & Bhoje, 2000.

Category. Other.

Note. Both species are under the status of unavailable names (see more detail in Fernández-Triana et al. 2020).

szelenyii

Etymology. The word refers to Gusztáv Szelényi (1904–1982), a Hungarian zoologist and entomologist from the 20th century for his outstanding contributions. The suffix *-i* added to the term is a masculine Latin genitive.

Taxa. The epithet has been used in two genera: *Dolichogenidea szelenyii* (Papp, 1972); and *Microgaster szelenyii* Papp, 1974.

Category. People.

taiwanensis

Etymology. The term *taiwanensis* contains two parts, Taiwan (officially the Republic of China), a country in East Asia, and the Latin suffix *-ensis* which means belonging to or of the place of. In taxonomy, *taiwanensis* refers to a species that was first identified or discovered in Taiwan or is endemic to Taiwan.

Taxa. The epithet has been used in three genera: *Buluka taiwanensis* Austin, 1989; *Dolichogenidea taiwanensis* (Sonan, 1942); and *Pholetesor taiwanensis* Liu & Chen, 2016.

Category. Geography.

taylori

Etymology. The term *taylori* probably refers to Taylor, a surname of English and Scottish origin, which is one of the most common surnames in English-speaking countries. The suffix *-i* added to the term is a masculine Latin genitive.

Taxa. The epithet has been used in two genera: *Glyptapanteles taylori* (Wilkinson, 1928); and *Microplitis taylori* Austin & Dangerfield, 1993.

Category. People.

testacea

Etymology. The term *testaceous* comes from the Latin word *testa* which means a piece of burned clay, a shell, or a potsherd. In taxonomy, *testaceous* refers to the dull, brick-red color of fired clay or terracotta, and later came to refer to any of the several pale colors of bricks. Over time, the term has been used to describe a range of colors, from pale pink to pale brown, which resemble the color of fired clay.

Taxa. The epithet has been used in two genera: *Cotesia testacea* Fujie, Shimizu & Fernández-Triana, 2018; and *Dolichogenidea testacea* Liu & Chen, 2018.

Category. Morphology.

thoseae

Etymology. The term *thoseae* refers to a moth genus, *Thosea* Walker (Limacodidae), which is used as an herbivore host by these parasitoid wasps. The suffix *-ae* added to the term is a Latin feminine genitive. The genus name *Thosea* presumably derives from the Greek word *thos*, which means a run, a course, or a career, possibly about the way the caterpillar moves like slugs or snails.

Taxa. The epithet has been used in two genera: *Fornicia thoseae* Wilkinson, 1930; and *Glyptapanteles thoseae* (Wilkinson, 1934).

Category. Biology.

tobiasi

Etymology. The epithet honors Vladimir Ivanovich Tobias (1929–2011), a Russian hymenopterologist, for his pioneering work on the systematics of Braconidae. The suffix *-i* added to the term is a masculine Latin genitive.

Taxa. The epithet has been used in three genera: *Dolichogenidea tobiasi* (Balevski, 1980); *Microplitis tobiasi* Kotenko, 2007; and *Wilkinsonellus tobiasi* Long, 2007.

Category. People.

townesi

Etymology. The epithet is dedicated to Henry Keith Townes, an American entomologist, for his significant contributions to our understanding of the family Ichneumonidae. The suffix *-i* added to the term is a masculine Latin genitive.

Taxa. The epithet has been used in two genera: *Apanteles townesi* Nixon, 1965; and *Buluka townesi* Austin, 1989.

Category. People.

typhon

Etymology. The Greek word *typhon* refers to *Typhon* (also *Typhoeus*, *Typhaon*, *Thyphos*), a giant serpentine monstrous and the deadliest creature in Greek mythology known as the Father of All Monsters. *Typhon* probably reflects the fiery nature and the destructive power of these parasitoids attacking the pests.

Taxa. The epithet has been used in two genera: *Alloplitis typhon* Nixon, 1965; and *Promicrogaster typhon* (Nixon, 1965)

Category. Other.

urios

Etymology. There is no specific information available on the origin of the term *urios*. Presumably, the term *urios* has the epithet *apertus* which means open, obvious, or uncover. Another possibility is that the word *urios* comes from the Messapic language, an extinct Indo-European Paleo-Balkan language of the southeastern Italian Peninsula, that means doors.

Taxa. The epithet has been used in two genera: *Diolcogaster urios* (Nixon, 1965); and *Glyptapanteles urios* Kotenko, 2007.

Category. Other.

Note. *Glyptapanteles urios* Kotenko, 2007 is under the status of *Nomina nuda* (see more detail in Fernández-Triana et al. 2020). Other.

variabilis

Etymology. The term *variabilis* derives from the Latin word *varius* which means varying or diverse. In taxonomy, *variabilis* describes a species that exhibits significant variation in its morphological traits.

Taxa. The epithet has been used in two genera: *Kiwigaster variabilis* Fernández-Triana & Ward, 2011; and *Pholetesor variabilis* Whitfield, 2006.

Category. Morphology.

varicolor

Etymology. The term *varicolor* contains two Latin words, *varius* which means diverse or varied and *color* which means color. In taxonomy, *varicolor* describes a species with variable or changing colors.

Taxa. The epithet has been used in two genera: *Choeras varicolor* Song & Chen, 2014; and *Microplitis varicolor* Viereck, 1917.

Category. Morphology.

vietnamensis

Etymology. The term *vietnamensis* contains two words, Vietnam, a country in Southeast Asia, and the Latin suffix *-ensis* which means belonging to or inhabiting. In taxonomy, *vietnamensis* indicates a species that is native to Vietnam.

Taxa. The epithet has been used in two genera: *Paroplitis vietnamensis* van Achterberg & Fernández-Triana, 2013; and *Ungunicus vietnamensis* Fernández-Triana & Boudreault, 2018.

Category. Geography.

vitobiasi

Etymology. The epithet is dedicated to Vladimir Ivanovich Tobias (the first two letters (vi) refer to his two names), a Russian hymenopterologist, for his pioneering work on the systematics of Braconidae. The suffix *-i* added to the term is a masculine Latin genitive.

Taxa. The epithet has been used in two genera: *Illidops vitobiasi* Kotenko, 2004; and *Microplitis vitobiasi* Fernández-Triana, 2019.

Category. People.

wittei

Etymology. The epithet honors Gaston François de Witte, a Belgian herpetologist, who led the expedition to Africa during which the wasps-type series were collected. The suffix *-i* added to the term is a masculine Latin genitive.

Taxa. The epithet has been used in two genera: *Diolcogaster wittei* (de Saeger, 1944); and *Dolichogenidea wittei* (de Saeger, 1944).

Category. People.

yanayacuensis

Etymology. The term *yanayacuensis* contains two words, Yanayacu, a Biological Station and Center for Creative Studies, an area with 100 hectares in the cloud forest of Ecuador (South America), and the Latin suffix *-ensis* which means belonging to or of the place of.

Taxa. The epithet has been used in three genera: *Alphomelon yanayacuensis* Fernández-Triana & Shimbori, 2023; *Glyptapanteles yanayacuensis* Arias-Penna, 2019; and *Venanus yanayacuensis* Arias-Penna & Whitfield, 2011.

Category. Geography.

yeimycedenoae

Etymology. The epithet is dedicated to Yeimy Cedeño Solis in recognition of her management of the Refugio Nacional de Vida Silvestre Ostional in the Área de Conservación Tempisque (ACT), Costa Rica (Central America).

Taxa. The epithet has been used in two genera: *Dolichogenidea yeimycedenoae* Fernández-Triana & Boudreault, 2019; and *Exoryza yeimycedenoae* Fernández-Triana, 2016.

Category. People.

yunnanensis

Etymology. The term *yunnanensis* contains two words, Yunnan, a landlocked province in the southwest of China, and the Latin suffix *-ensis* which means belonging to or of the place of. In taxonomy, *yunnaensis* refers to a species native to Yunnan.

Taxa. The epithet has been used in three genera: *Choeras yunnanensis* Song & Chen, 2014; *Microgaster yunnanensis* Xu & He, 1999; and *Protapanteles yunnanensis* (You & Xiong, 1987).

Category. Geography.

zhaoi

Etymology. The term *zhaoi* refers to Zhao, the most traditional surname in the Chinese language. The suffix *-i* added to the term is a masculine Latin genitive. In taxonomy, *zhaoi* possibly honors a male Chinese entomologist.

Taxa. The epithet has been used in two genera: *Microgaster zhaoi* Xu & He, 1997; and *Microplitis zhaoi* Xu & He, 2000.

Category. People.

Discussion

Within the subfamily Microgastrinae, the level of repetition of specific epithets was low. This indicates that there is a high degree of originality by the descriptors at the time of naming a new species. In other words, the authors have designated an original specific epithet for each new species they describe. Reviewing the taxonomic history, the approaches in species naming within the subfamily follow the traditional taxonomy practices, most epithets refer mainly to external morphological traits (morphology) and species distribution (geography). Nevertheless, the use of people's names has significantly increased in the 20th century (e.g., Guedes et al. 2023), although historically, a substantial portion of specific epithets was also attributed to people. These names primarily provide a way to pay homage to collectors and scientists. These are the cases of the Canadian William RM Mason and the English Gilbert EJ Nixon. They are among the most prominent entomologists whose contributions laid the foundation of knowledge of the subfamily Microgastrinae (Fig. 4); Mason in the Nearctic Region and Nixon in the Palearctic Region. Their influence has endured to the present day and this explains why the specific epithets *masoni* and *nixonii* are among the most repeated.

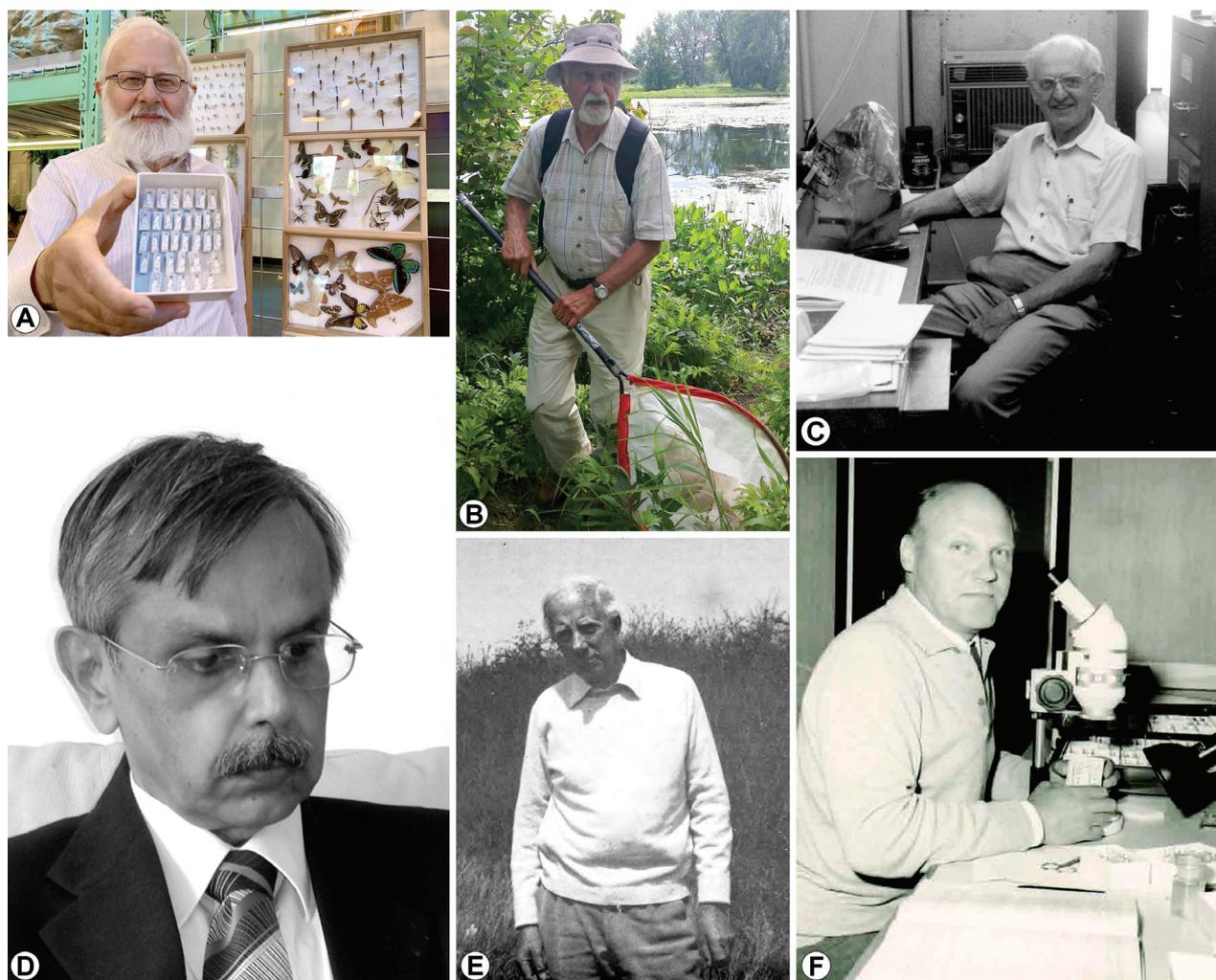


Figure 4. Photographs of the prominent entomologist, whose names have been chosen multiple times to name species of Microgastrinae (Hymenoptera, Braconidae) **A** Cornelis (Kees) van Achterberg (Courtesy of Naturalis Biodiversity Center, Leiden, Netherlands) **B** Lubomír Masner (Credit: Carolyn Trietsch) **C** William Richardson Miles Mason (Courtesy of Canadian National Collection of Insects, Arachnids and Nematodes (CNC) of Agriculture and Agri-Food Canada, Ottawa) **D** Thekke Curupathe Narendran (Courtesy of Indian Academy of Sciences, Bengaluru) **E** Gilbert Edward James Nixon (based on an edited photo from Huddleston 1988) **F** Vladimir Ivanovich Tobias (based on an edited photo from Belokobylskij and Sharkey 2011).

In recent years, the use of etymologies to pay tribute to artists, celebrities, sportsmen, politicians, or even loved ones has been striking in several taxonomic groups. However, within Microgastrinae, etymologies are mainly addressed to people who have had direct involvement in recent long-term projects. Those projects form an intricate network encompassing technicians (e.g., collectors, database managers, parataxonomists) and specialists (e.g., botanist, ecologist, environmentalist, geneticist, hymenopterologist, lepidopterologist) whose collaboration has been immortalized in the names of the described species (e.g., *Pseudapanteles laurachinchillae* Fernández-Triana & Whitfield, in Fernández-Triana et al. 2014). Some of those collaborative collecting efforts have been developed in Central America (in northwestern Costa Rica), South America (Colombia, the Eastern Andes in Ecuador), Asia (Iran, Philippines), and Pacific Ocean islands (Fiji) among others.

The presence of the largest specific epithets in the morphology, people, and geography categories is partly explained by the use of compound words. In these three categories, most of the specific epithets are created by linking two words. Thus, in morphology, the use of a noun (referring to the structure) + the adjective is frequent; to honor people, the use of the name + the surname is added most of the time, and for geography, a noun (place) + the suffix *-ensis* is used regularly.

It is well known that the Achilles' heel in the subfamily Microgastrinae is the lack of a sound phylogeny. However, another vulnerability is the deficiency of natural history knowledge (e.g., both lepidopteran hosts and food plants). The insufficiency of biological information could partly explain why the biology category is the one with the lowest number of species with repeated specific epithets (26 species out of 303).

It is important to acknowledge that these aforementioned conclusions are confined to the scope of identical specific epithets and the outcomes derived from the present study, and thus do not encompass the entirety of species belonging to this subfamily.

Recommendations

The taxonomist's creativity in conceiving a specific epithet is inspirational, and it prompts us to reflect on how scientific knowledge is communicated. Taxonomic confusion increases when a specific epithet is repeated. For that reason, it is important to reduce it as much as possible. In essence, the recurrence of specific epithets that are identical and initially described in different genera does not pose a particular issue and the International Code of Zoological Nomenclature accommodates the admissibility of numerous instances where species names are identical, as per its provisions. The sole concern arises when a species is transferred to another genus that already bears the same specific name, resulting in the emergence of two homonymous names (Articles 57–60). Such instances lead to an increase in the number of homonyms and the subsequent proliferation of new names within the taxa. It should be noted that the concept homonym established by the ICZN is followed here and not other alternative terms such as asthenonym (secondary homonym), and hadromonym (primary homonym), known as subcategories of homonym, proposed by Linz Zoological Committee (LZC: <https://skosmos.loterre.fr/th63/en/>) (Dubois 2011).

As shown in Fig. 5, there is one potential scenario for consideration of transferring *Pholetesor masoni* to *Parapanteles* based on the existing evidence (Fernández-Triana et al. 2020). Should this nomenclatural change take place, it would lead to homonymy, necessitating the replacement of the epithet *masoni* with a new name. As a precautionary measure, it is advisable to refrain from assigning a species name that duplicates one already present in a closely related genus, considering the potential future scenario of the two genera being recognized as synonymous and/or homonyms. The prevalence of identical specific epithets within certain taxonomic groups presents a modest inconvenience as it may lead to potential confusion among taxonomists. Nonetheless, from our perspective, this issue is relatively minor in Microgastrinae and can be effectively managed without significant ramifications. Hence, the matter of species name registration within a unified database (e.g., TaxonWorks: <https://taxonworks.org>) offers a promising opportunity for taxonomists. Simple actions,

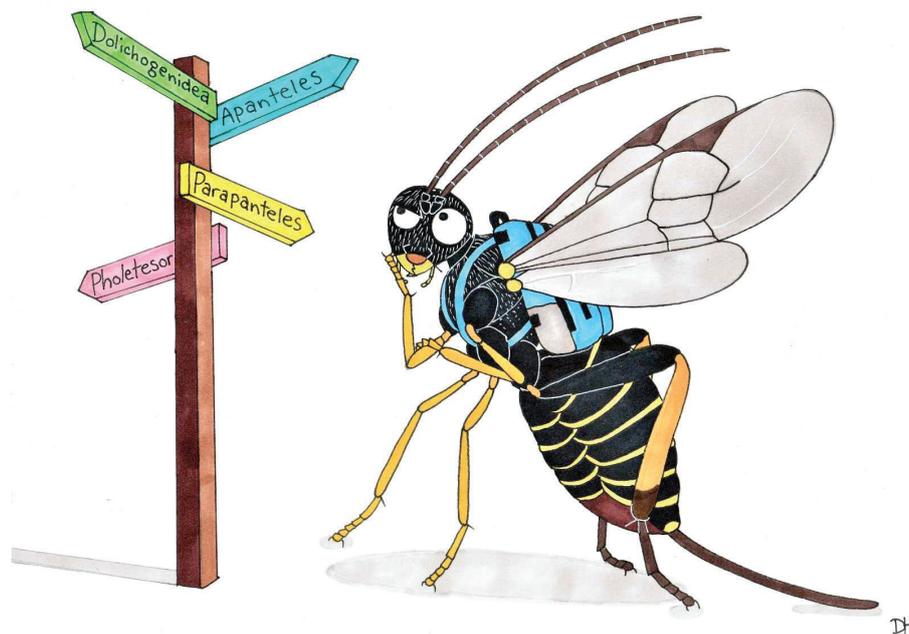


Figure 5. A microgastrine parasitoid wasp, with a potential identity crisis (e.g., the specific epithet, *masoni*), carrying a backpack, is observed studying a signpost with arrows pointing to different close genera. The parasitoid wasp has a befuddled expression as she contemplates which path to take. The Canadian artist, Devon Henderson, sketched the cartoon in response to our request (Waspaholic Comics).

such as verifying the provisional specific epithet across all available information (consolidated database and/or original descriptions) can prevent epithet replication and ensure accurate representation of the species under description. While the overall occurrence of duplicated specific epithets in the entire subfamily is minimal, it is advised to persist in avoiding duplicate names and minimizing identical epithets. To ensure the utmost clarity in nomenclature, researchers must endeavor to choose unique and distinctive specific epithets.

Here are some recommendations to enhance the accuracy of species datasets and minimize redundances:

- Taxonomic authorities should consider adopting a standardized nomenclature for species names to prevent the use of the same specific epithets for species within the same group.
- Researchers should verify and reconcile data sources to ensure accuracy, and timeliness, and to prevent overlapping or conflicting records.
- Data management systems should utilize quality control measures to detect and eliminate duplicate names, such as employing automated algorithms or conducting manual inspections.
- Collaborative data sharing between researchers, institutions, and organizations can aid in detecting and resolving species dataset duplication issues.
- Further research is necessary to comprehend the causes of duplication in species name datasets. This can include analyzing the data sources, scrutinizing the taxonomic literature, and exploring the ecological and biogeographical effects of duplication.

By implementing these recommendations, taxonomists could improve the accuracy of species name datasets while reducing duplication and improving the proper understanding of species diversity, distribution, and ecology. Adopting these recommended practices would lead to improved data quality and promote more reliable taxonomic research and analysis. Reducing duplication and enhancing understanding of species attributes would improve clarity and precision in scientific investigations. This would lead to better-informed conservation strategies, ecological assessments, and biodiversity management efforts. Implementing these recommendations would ultimately advance the field of taxonomy, enabling a more robust and accurate representation of the natural world.

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Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statement

No ethical statement was reported.

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Author contributions

Conceptualization: MGM. Formal analysis: MGM. Funding acquisition: MGM, BAB. Investigation: MGM, DCAP, MHL, BAB. Methodology: MGM. Project administration: BAB. Supervision: BAB. Validation: MGM, MHL, DCAP, BAB. Visualization: MGM, MHL, DCAP. Writing - original draft: MGM. Writing - review and editing: MGM, MHL, DCAP, BAB.

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Data availability

All of the data that support the findings of this study are available in the main text.

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Review of the genus *Xenicotela* Bates, 1884 (Cerambycidae, Lamiinae, Lamiini)

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Abstract

The species of the genus *Xenicotela* Bates, 1884 are reviewed. One new species, *Xenicotela mucheni* sp. nov., is described from Yunnan, China. *Monochamus binigricollis* Breuning, 1965 and *Monochamus villiersi* Breuning, 1960 are transferred to *Xenicotela* as follows: *Xenicotela villiersi* (Breuning, 1960) **comb. nov.** and *Xenicotela binigricollis* (Breuning, 1965) **comb. nov.** *Xenicotela distincta* (Gahan, 1888) is newly reported from Myanmar and *Xenicotela binigricollis* is excluded from the fauna of China. All species are redescribed and illustrated. A key to the known *Xenicotela* species is provided.

Key words: Coleoptera, Cerambycidae, identification key, new species, new combination, taxonomy



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Introduction

Bates (1884) established the genus *Xenicotela* for *Xenicotela fuscula* Bates, 1884 [currently considered a synonym of *Xenicotela pardalina* (Bates, 1884)] from Higo, Japan. Recently, Xie et al. (2022) reviewed the Chinese species of the genus, increasing the number of species to five, which are known from Japan, South Korea, China, Vietnam, Laos, Nepal and India.

The present paper is a further study. The genus is reviewed, a new species is described, two *Monochamus* Dejean, 1821 species are transferred to *Xenicotela*, new photographs of the types of *Monochamus distinctus* Gahan, 1888 and *Nephelotus tonkineus* Pic, 1926 are provided and a key to the known species is given.

Material and methods

Specimens from the following institutional or private collections were examined and/or photographed in this study:

BPBM Bernice Pauahi Bishop Museum, Honolulu, USA;
CQNU Chongqing Normal University, Chongqing, China;
GZNU School of Life Sciences, Guizhou Normal University, Guiyang, China;

IZAS	Institute of Zoology, Chinese Academy of Sciences, Beijing, China;
LGBC	Collection of Larry G. Bezark, Sacramento, California, USA;
MCC	Collection of Mu Chen, Shanghai, China;
MNHN	Muséum National d'Histoire Naturelle, Paris, France;
NHMUK	Natural History Museum, London, UK;
NOC	Collection of Nobuo Ohbayashi, Miura, Japan;
SWU	Southwest University, Chongqing, China;
YZU	Yangtze University, Jingzhou, China.

The male genitalia of the new species were dissected and soaked in glycerine in a centrifuge tube. The genitalia were prepared by first soaking the whole beetle in boiling water for several minutes, then opening the abdomen from the apex along the dorsopleural margin. The genitalia were then removed with fine forceps and ophthalmic scissors, and later cleared in 10% KOH at 80–100 °C for several minutes.

All photographs of the habitus were taken using a Canon 7D Mark II digital camera equipped with a Canon EF 100 mm f/2.8L IS USM, while images of genitalia were taken with a Leica DFC450 digital camera mounted on a Leica M205A microscope. Images of genitalia were taken by keeping them in glycerine. All images were edited using Adobe Photoshop 2020 release.

Taxonomy

Genus *Xenicotela* Bates, 1884

Xenicotela Bates, 1884: 242; Matsushita 1933: 346; Breuning 1944: 372; Gressitt 1951: 381; Breuning 1961: 353; Rondon and Breuning 1970: 458; Maki-hara 2007: 602; Hubweber et al. 2010: 288; Lin and Tavakilian 2019: 324; Xie et al. 2022: 145.

Type species. *Xenicotela fuscula* Bates, 1884 [= *Xenicotela pardalis* (Bates, 1884)].

Diagnosis. Small-bodied; body length usually less than 20 mm. Eyes coarsely faceted. Antennae long and slender, usually more than twice body length in male and about twice body length in female; antennomeres III–XI basally and apically annulated with light-coloured pubescence, basal antennomeres distinctly fringed with sparse setae ventrally; scape short, distinctly constricted before the apex, with a narrow and completely closed cicatrix at apex; antennomere III distinctly longer than fourth, about 2.0 times as long as scape. Pronotum transverse, lateral spine short, tapered. Elytra elongate, with subparallel sides, apices rounded. Procoxal cavities closed posteriorly. Mesosternal process not tuberculate, mesocoxal cavities open at sides. Legs moderately long, femora clavate, mesotibiae without grooves near external apex, claws widely divergent.

Distribution. Japan, South Korea, China, Vietnam, Laos, Myanmar (new country record), Nepal, India.

Comments. The genus was often confused with *Monochamus* (Bates 1884; Gahan 1888; Gressitt 1942; Breuning 1960, 1965), probably due to the small body size, which makes it difficult to observe their differences. In fact, it can be easily distinguished from *Monochamus* by the mesotibiae lacking grooves near the apex.

***Xenicotela pardalina* (Bates, 1884)**

Figs 1, 2

Monochamus pardalinus Bates, 1884: 239; Aurivillius 1922: 87; Matsushita 1933: 325. Type locality: Yuyama, Honshu, Japan.

Xenicotela pardalina: Breuning 1944: 373; Breuning 1961: 353; Makihara 2007: 602; Hubweber et al. 2010: 288.

Xenicotela fuscula Bates, 1884: 242; Aurivillius 1922: 216; Matsushita 1933: 346; Cho et al. 1963: 3. Type locality: Higo, Kyushu, Japan.

Type material examined. *Holotype* of *Monochamus pardalinus*, female (NHMUK); label details are shown in Fig. 1g. *Holotype* of *Xenicotela fuscula*, female (NHMUK); label details are shown in Fig. 2d.

Other material examined. One male, JAPAN: Honshu, Tottori Pref., Mt. Daisen, July 22–23, 1974, coll. Y. Notsu (NOC); One female, JAPAN: Shikoku, Tokushima Pref., Dosu-toge, July 29, 1973, coll. M. Sakai (NOC).

Redescription. Female. Body length 7.0–13.0 mm, humeral width 2.0–3.5 mm. Body reddish brown to blackish brown, clothed with greyish-yellow pubescence forming mottling on dorsal surface. Antennae slightly lighter in colour, basal four to six segments fringed with rather sparse setae ventrally, base and extreme apex of antennomeres III–X, base and apex of antennomere XI annulated with greyish-white pubescence. Elytra clothed with rather uneven pubescence forming irregular light patches interspersed with dark patches formed by ground colour of elytra, with a vague, incomplete, dark transverse band behind middle. Underside clothed with fairly even pubescence.

Head finely punctate; frons transverse, with a smooth longitudinal median sulcus extending to occiput; eyes coarsely faceted, lower lobe longer than gena. Antennae slender, about 2.0 times as long as body, with the apex of the sixth segment surpassing elytral apex; scape robust and short, base thin, apex distinctly constricted before cicatrix; antennomere III distinctly longer than antennomere IV, about 2.5 times as long as scape; antennomeres III–X slightly thickened at extreme apex. Pronotum transverse, lateral spine small and short, coniform; surface punctured similarly to head, disc slightly uneven. Scutellum lingulate. Elytra elongate, about 2.5 times as long as width across humeri; sides slightly expanded outwards after basal third, then evenly arched and narrowed backwards; apices rounded; surface punctures coarser and sparser than those on head and pronotum, sparser and even finer towards the apex; disc slightly depressed on the basal third. Legs moderately long, femora slightly clavate, claws divaricate.

Male. Similar to female, antennae thicker and longer, about 2.5–3.0 times as long as body, with the apex of the fifth segment or the base of the sixth segment exceeding the elytral apex.

Distribution. Japan (Hokkaido, Honshu, Sado, Oki, Shikoku, Kyushu, Tanegashima, Yakushima), South Korea (Seoraksan).

Comments. Bates (1884) described this species twice in the same publication, as *M. pardalinus* and *X. fuscula*, based on specimens from different localities. Breuning (1944) transferred *M. pardalinus* into the genus *Xenicotela* and proposed *X. fuscula* as its synonym. The holotype of *M. pardalinus* is larger in size than the holotype of *X. fuscula*, with longer antennae with the basal

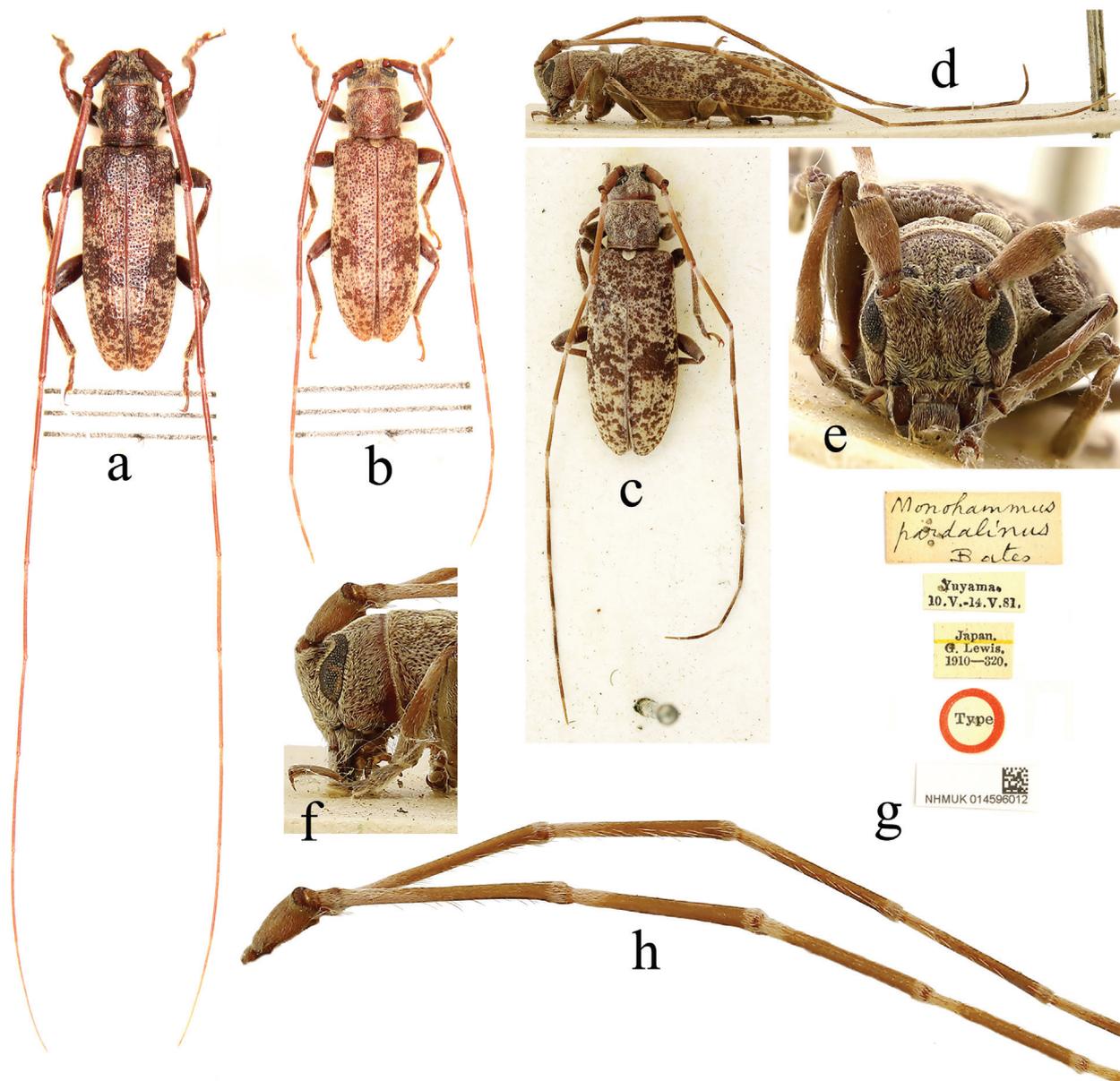


Figure 1. *Xenicotela pardalina* (Bates, 1884) **a** male, from Tottori Pref. (Mt. Daisen), Japan **b** female, from Tokushima Oref. (Dosu-toge), Japan **c–h** holotype of *Monohammus pardalinus* Bates, 1884, female **a–c** dorsal view **d** lateral view **e** frontal view **f** head in lateral view **g** labels **h** antennomeres.

six antennomeres fringed with setae, the antennae appear darker in colour and the pubescent rings on the antennomeres look more obvious, while in the holotype of *X. fuscula*, only the basal four segments of the antennae are fringed with sparse setae, the fifth segment is only fringed with one or two setae and the pubescent rings on the antennomeres appear less distinct than those of the former specimen. These characters made them look like different species. Bates (1884) considered both holotypes to be males. In fact, they are females, according to the antennae / body length ratio (about 2: 1, in males 2.5–3: 1). Tavakilian and Chevillotte (2023) stated that types of both *X. pardalinus* and *X. fuscula* are conserved in the MNHN. This is not correct, as Bates described them from the collection of George Lewis (1839–1926), which is in the NHMUK.

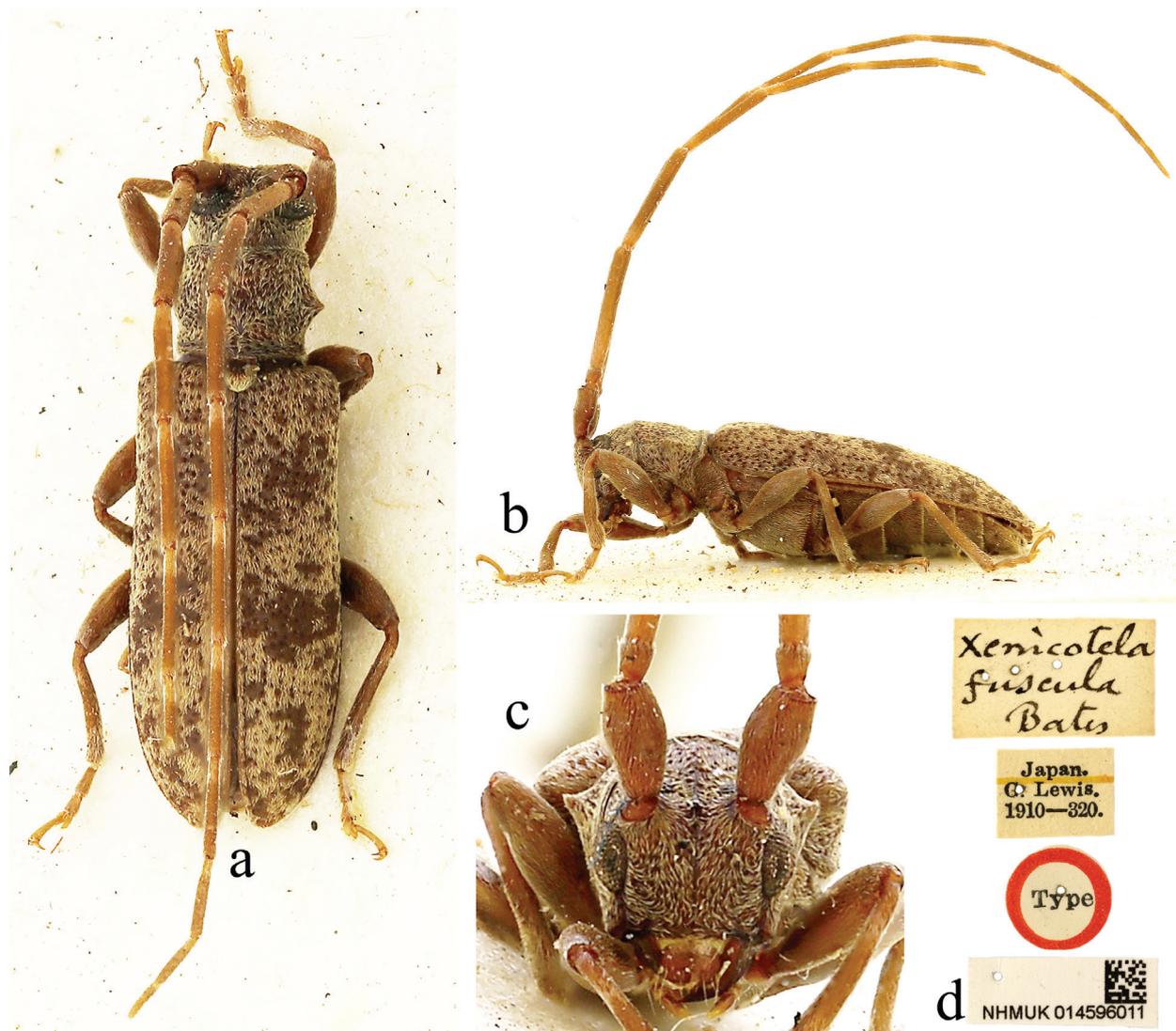


Figure 2. Holotype of *Xenicotela fuscula* Bates, 1884, female a dorsal view b lateral view c frontal view d labels.

***Xenicotela distincta* (Gahan, 1888)**

Figs 3–5

Monohammus distinctus Gahan, 1888: 392; Aurivillius 1922: 95. Type locality: Assam, India.

Xenicotela distincta: Breuning 1944: 373; Gressitt 1951: 382; Breuning 1961: 354; Rondon and Breuning 1970: 458; Hubweber et al. 2010: 288; Weigel et al. 2013: 288; Kariyanna et al. 2017: 253; Lin and Tavakilian 2019: 324; Xie et al. 2022: 147.

Nephelotus 4-maculatus Pic, 1925: 16. Type locality: Tonkin, Vietnam.

Nephelotus tonkineus Pic, 1926: 143. Type locality: Tonkin (Hoa Binh), Vietnam.

Xenicotela distincta m. *tonkinensis* Breuning, 1944: 373.

Monochamus binigracollis: Wang 1998: 599, misidentification.

Type material examined. *Holotype* of *Monohammus distinctus*, male (NHMUK); label details are shown in Fig. 4e. *Syntypes* of *Nephelotus tonkineus*, one male and one female (MNHN); label details are shown in Fig. 5e, j.

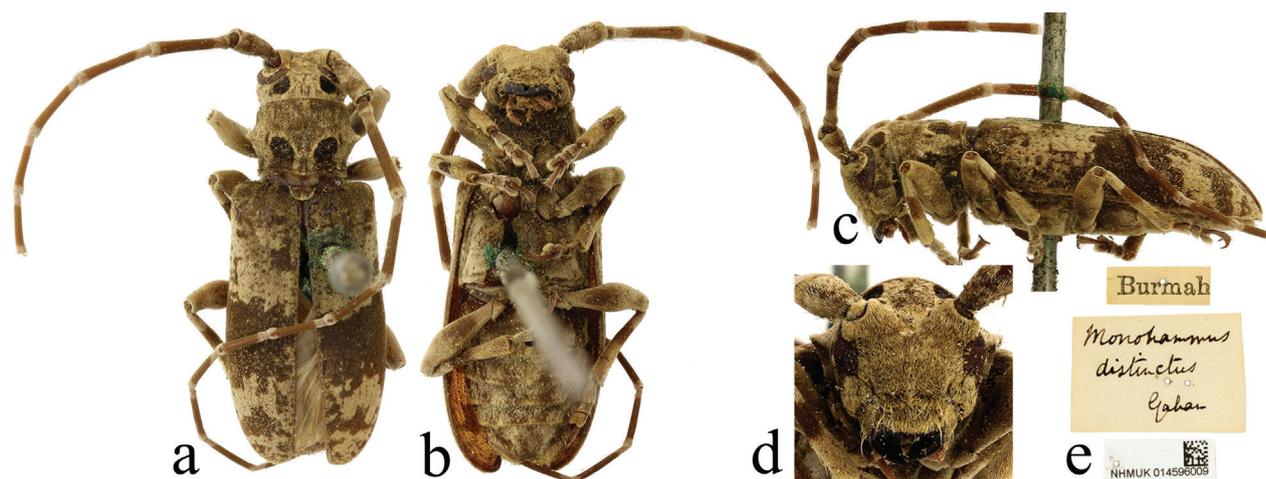


Figure 3. *Xenicotela distincta* (Gahan, 1888), specimen from Myanmar a dorsal view b ventral view c lateral view d frontal view e labels.

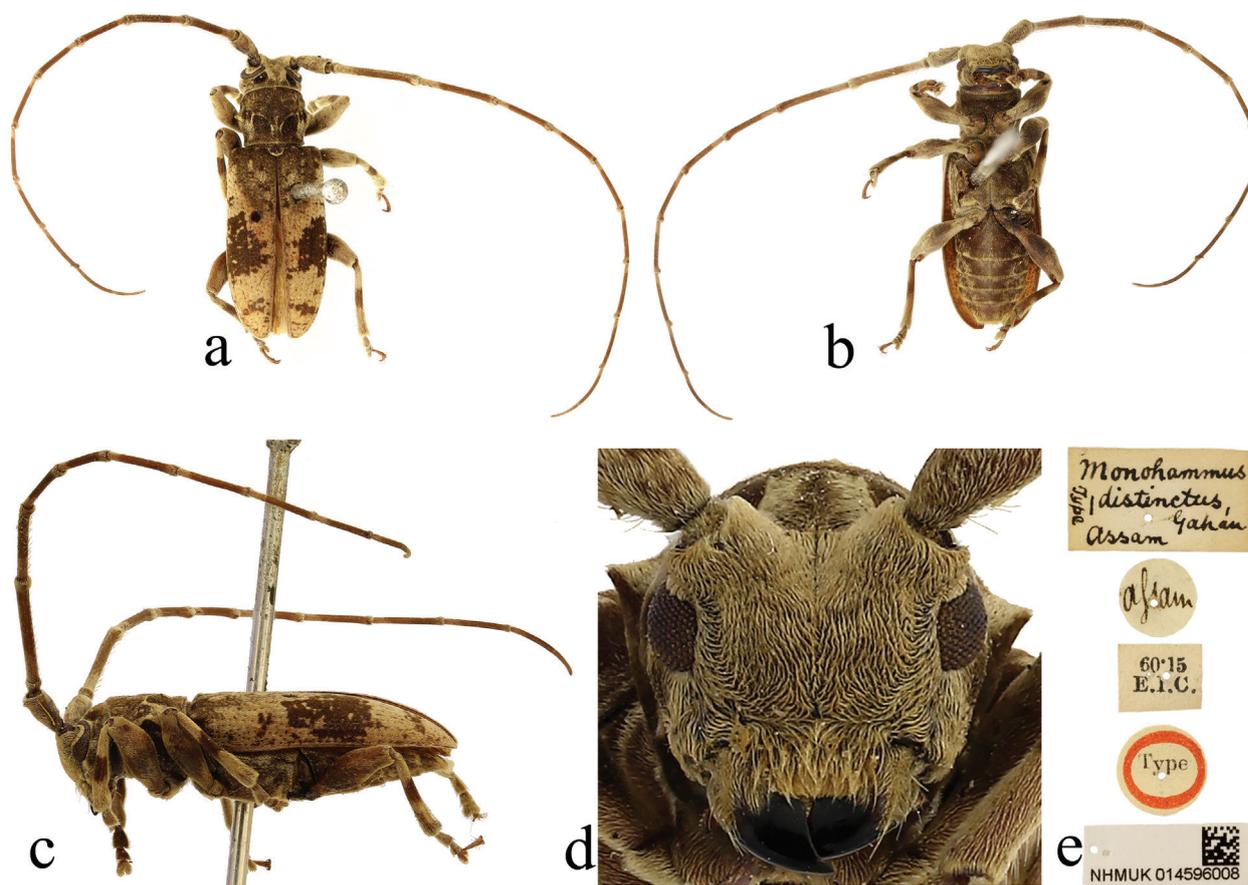


Figure 4. Holotype of *Monohammus distinctus* Gahan, 1888 a dorsal view b ventral view c lateral view d frontal view e labels.

Other material examined. One female, 'Burmah' (NHMUK); one female, INDIA: Assam (NHMUK); One male, CHINA: Yunnan Province, Cangyuan County, Daheishan, alt. 2400 m, May 15, 1980, coll. Kaiquan Li (SWU); One female, CHINA: Guizhou Province, Ziyun County, Nazuo Village, June 8, 2019, coll. Shulin Yang (GZNULS); one female, CHINA: Yunnan Province, Xishuangbanna Prefecture,

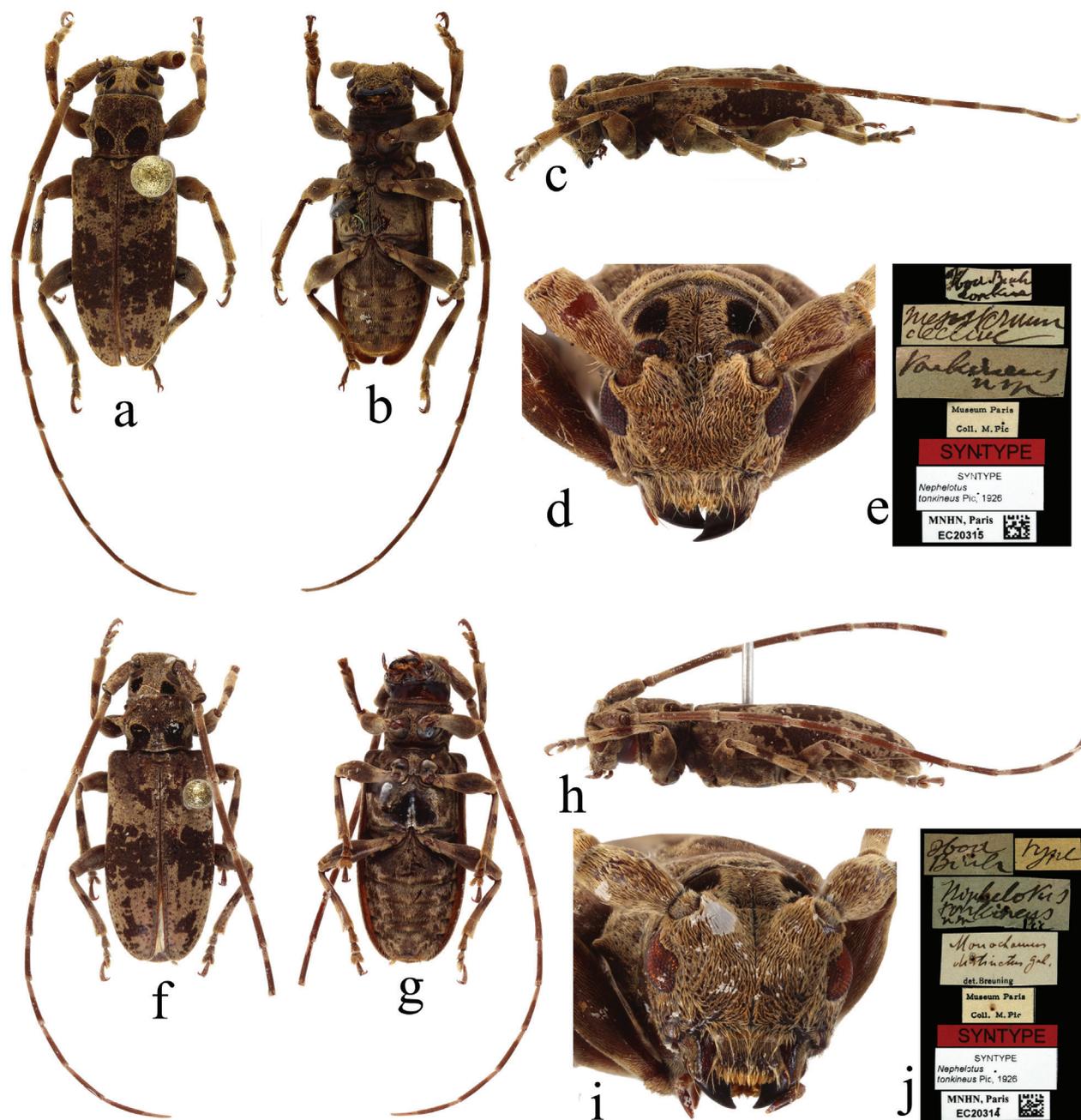


Figure 5. Syntypes of *Nephelotus tonkineus* Pic, 1926 a–e male f–j female. a, f dorsal view b, g ventral view c, h lateral view d, i frontal view e, j labels.

Danuoyou, May 29, 2008, coll. Meiyang Lin (IZAS); one male, CHINA: Yunnan Province, Jiangcheng County, Qushui Township, alt. 564 m, 22°37'1"N, 102°9'49"E, June 8, 2019, coll. Lanbin Xiang (YZU).

Distribution. China (Yunnan, Guizhou), India (Assam, Sikkim), Vietnam (Tonkin), Nepal, Laos, Myanmar (new country record).

Remarks. One female specimen of this species labelled 'Burmah' (old spelling of Burma, i.e., Myanmar) was found in NHMUK (Fig. 3). This represents a new country record. A redescription and other comments about this species are provided by Xie et al. (2022).

***Xenicotela bimaculata* (Pic, 1925)**

Fig. 6

Nephelotus bimaculatus Pic, 1925: 16. Type locality: Tonkin (Hoa Binh), Vietnam.
Xenicotela bimaculatus: Breuning 1944: 373; Breuning 1961: 354.

Type material examined. *Holotype*, male (MNHN); label details are shown in Fig. 6e.

Redescription. Male. Body length 13.0 mm, humeral width 4.0 mm. Body mostly blackish brown, clothed with yellowish and dark-brown pubescence. Frons clothed with uniform yellowish pubescence, decorated with a black velvet patch behind each upper eye lobe. Antennae reddish brown, basal five segments fringed with sparse setae ventrally, base and extreme apex of antennomeres III–X, base and apical half of antennomere XI annulated with sparse greyish-yellow pubescence. Pronotum decorated with a black velvet patch edged with greyish-yellow to yellow pubescent border on each side of basal half. Scutellum clothed with yellowish pubescence at edges. Elytra dark brown, clothed with yellowish and dark-brown pubescence forming a mixture of irregular dark and light markings. Underside mostly clothed with greyish-yellow pubescence, ventrites fringed with short yellowish setae at posterior edge and with two dark-brown spots on each side forming two incomplete longitudinal stripes. Legs mostly reddish brown; femurs and tibiae decorated with a dark-brown median annulation.

Head finely punctate, frons transverse, lower eye lobes shorter than genae. Antennae long, about 2.0 times as long as body, scape robust, distinctly constricted before cicatrix; antennomere III a little longer than antennomere IV, about 2.0 times as long as scape; antennomeres III–X slightly protruding

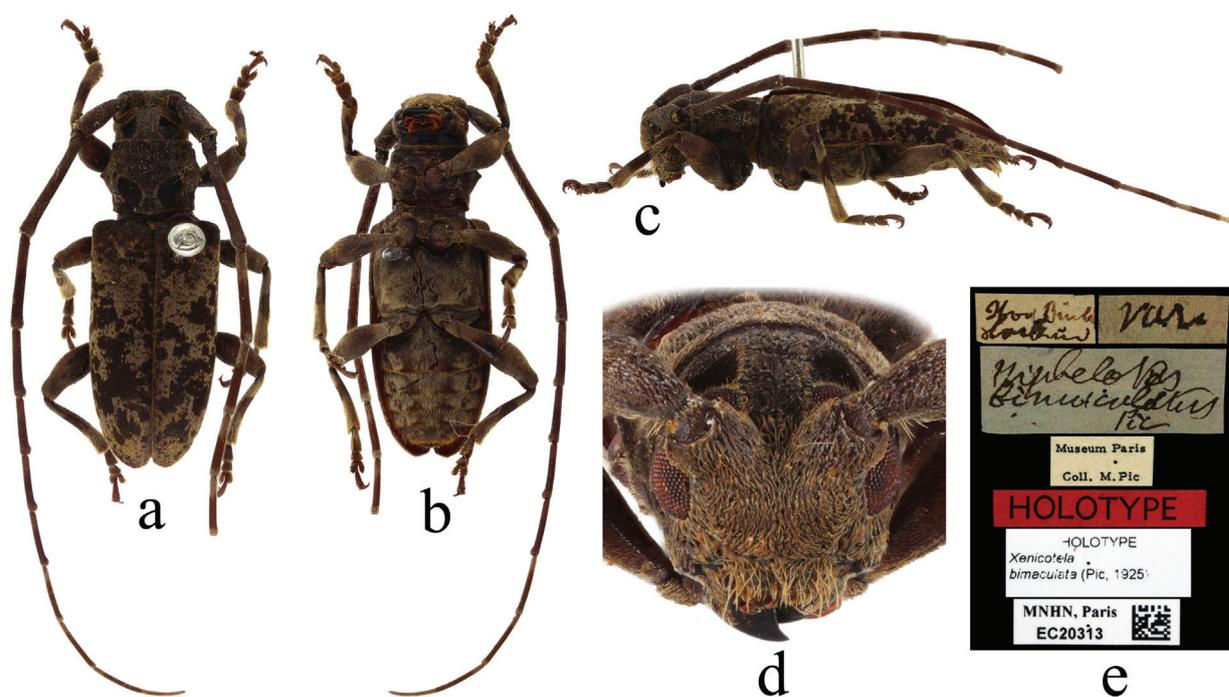


Figure 6. Holotype of *Nephelotus bimaculatus* Pic, 1925 **a** dorsal view **b** ventral view **c** lateral view **d** frontal view **e** labels.

inwards at apex. Pronotum transverse; lateral spine short and blunt, coniform; disc punctured similarly to head. Scutellum lingulate. Elytra elongate, about 2.0 times as long as width across humeri, with subparallel sides and rounded apices; surface punctures similar to those of pronotum, gradually inconspicuous towards apex. Legs moderately long, femora slightly clavate, claws divaricate.

Female. Unknown.

Distribution. Vietnam (Tonkin).

Comments. This species is very similar to *X. distincta*, differing mainly in the elytral pattern. The irregular dark patches on the middle of each elytron are not connected into a large transverse band, while *X. distincta* shows a clear broad transverse middle dark band on each elytron. In addition, this species has the scutellum with the wider lighter-coloured pubescent border. The taxonomic status of this species needs to be further confirmed based on additional material.

***Xenicotela convexicollis* (Gressitt, 1942)**

Fig. 7a–f

Monochamus convexicollis Gressitt, 1942: 83; Gressitt 1951: 393; Breuning 1961: 370; Chou 2004: 296; Hubweber et al. 2010: 282; Lin and Tavakilian 2019: 310. Type locality: Zhejiang (Tianmushan), China.

Xenicotela convexicollis: Xie et al. 2022: 149.

Type material examined. *Holotype*, female (IZAS); label details are shown in Fig. 7f.

Other material examined. One male and one female: CHINA, Zhejiang, Lin'an, West Tianmushan, July 13, 2012, collected by Guanglin Xie (YZU); one female: CHINA, Zhejiang, Lin'an, Qingliangfeng, May 22, 2012, collected by Guanglin Xie (YZU).

Distribution. China (Zhejiang, Taiwan).

Remarks. The redescription and comments about this species refer to Xie et al. (2022).

***Xenicotela villiersi* (Breuning, 1960), comb. nov.**

Fig. 8

Monochamus villiersi Breuning, 1960: 33; Breuning 1961: 370. Type locality: Tonkin (Hoa Binh), Vietnam.

Type material examined. *Holotype*, male (MNHN), the label details are shown in Fig. 8e.

Redescription. Male. Body length 13.0 mm, humeral width 4.5 mm. Body mostly dull reddish brown, clothed with greyish-yellow to pale-yellow and brown pubescence mottled on dorsal surface. Head and pronotum slightly darker than elytra; legs somewhat blackish brown. Head decorated with a dark-brown pubescent patch behind each upper lobe of eyes and a pair of homogeneous patches located at the basal half of pronotum, edged with pale-yellow pubescence and widely separated anteriorly. Antennae reddish brown; scape and

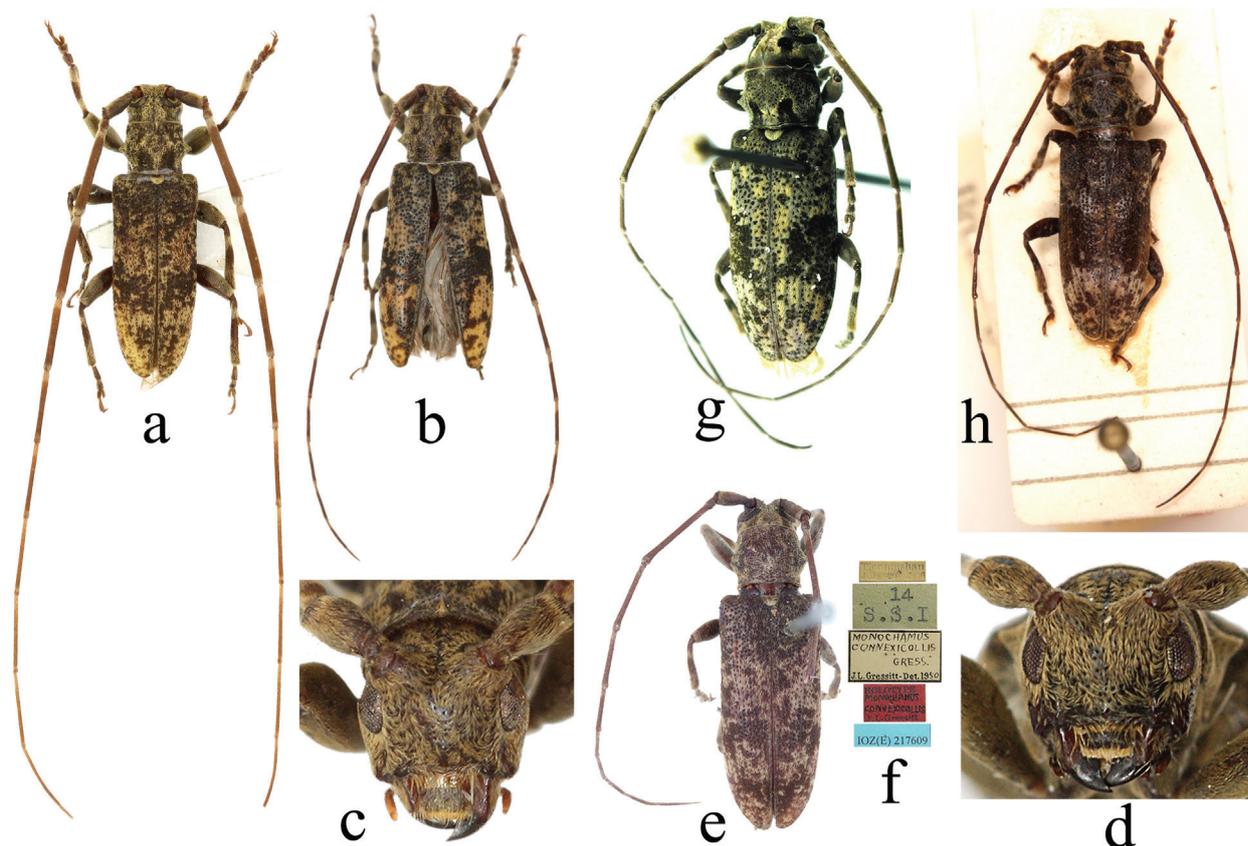


Figure 7. *Xenicotela* spp. **a–f** *Xenicotela convexicollis* (Gressitt, 1942) **g–h** *Xenicotela binigracilis* (Breuning, 1965) comb. nov. **a, c** male, from Zhejiang (Tianmushan), China **b, d** female, from Zhejiang (Tianmushan), China **e, f** holotype (female) and labels **g** female, from Bac Kạn (Ba Be national park), Vietnam **h** holotype, female.

pedicel densely clothed with greyish-yellow pubescence; base and extreme apex of antennomeres III–X; base and apical half of antennomere XI annulated with greyish-yellow pubescence; basal five segments fringed with sparse greyish-yellow setae ventrally. Scutellum covered with whitish yellow throughout. Elytra dull reddish brown, mottled with greyish-yellow to pale-yellow and brown pubescence. Tibiae decorated with a narrow subbasal and a wide apical annulus of greyish-yellow to pale-yellow pubescence.

Frons transverse, densely and finely punctate; lower lobes of eyes about as long as genae. Antennae long, about 2.5 times as long as body, with the apex of the fifth segment or the base of the sixth one exceeding the elytral apex; scape robust and short, base narrowed, apex distinctly constricted before cicatrix; antennomere III slightly longer than antennomere IV, about 2.5 times as long as scape; extreme apex of antennomeres III–X obviously thickened inwards. Pronotum transverse; lateral spine short and blunt, coniform; disc dotted with fine punctures. Scutellum lingulate. Elytra elongate, about 2.2 times as long as width across humeri, with subparallel sides and rounded apices; surface finely punctate, the punctures gradually becoming finer and sparser towards apex; disc slightly raised at centre of basal third, followed by a weak central depression. Legs moderately long, femora slightly clavate, claws divaricate.

Female. Unknown.

Distribution. Vietnam (Tonkin).

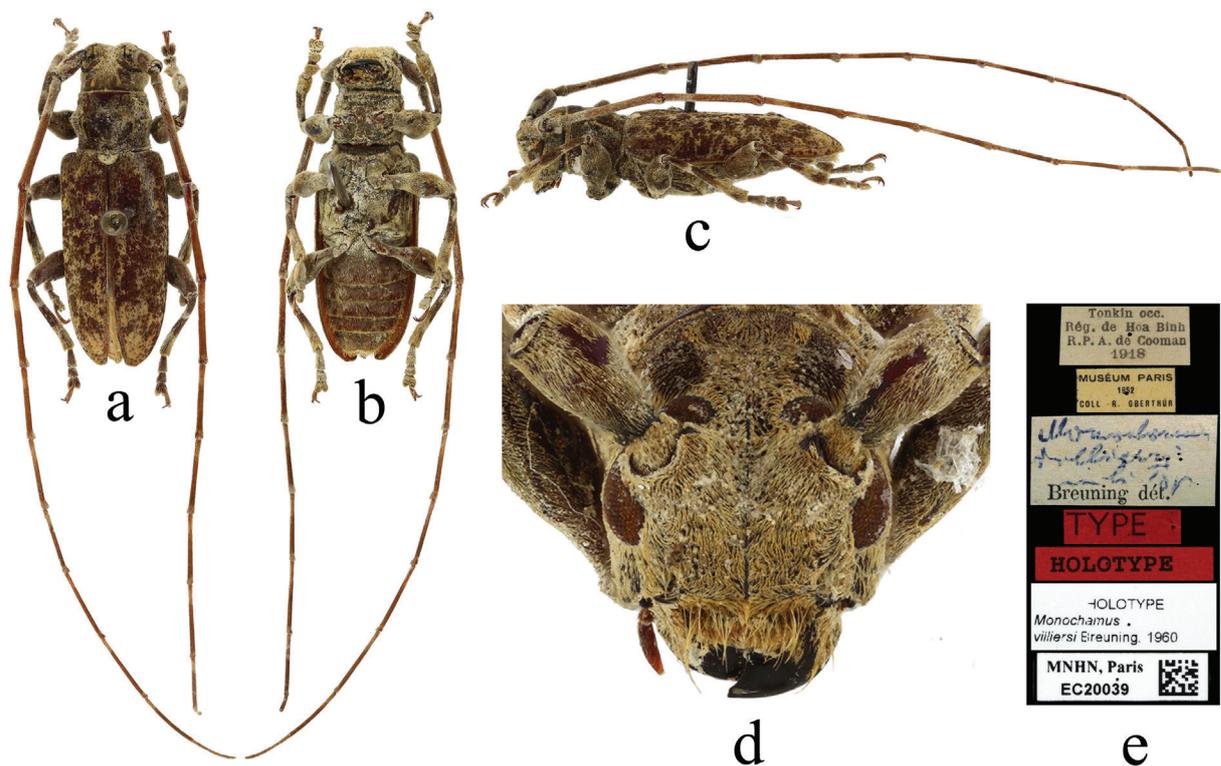


Figure 8. *Xenicotela villiersi* (Breuning, 1960) comb. nov. a dorsal view b ventral view c lateral view d frontal view e labels.

Comments. This species has the mesotibiae without grooves near the apex, the head decorated with two black velvet patches behind the upper eye lobes, the scape distinctly constricted before the apical cicatrix, the basal five antennomeres fringed ventrally and antennomeres III–XI annulated with light-coloured pubescent rings on the base and apex, the pronotum with two black velvet patches on the base, the elytra mottled with light-coloured pubescence mixed with brown pubescence and the tibiae ringed with dark and light-coloured pubescence. All characters are consistent with the genus *Xenicotela*.

This species is very similar to *X. bimaculata*, from which it can be distinguished by the male antennae being much longer (about 2.5 times as long as body), the scutellum wholly covered with light-coloured pubescence, the base of the tibiae mostly dark with a light-coloured pubescent ring and the elytra more mottled. In *X. bimaculata*, the male antennae are only about 2.0 times as long as body, the scutellum is mostly clothed with light-coloured pubescence and the base of the tibiae is mostly clothed with light-coloured pubescence. *Xenicotela villiersi* is also similar to *X. convexicollis* but differs in antennomeres V–VIII more protruding inwards at the apex and the elytra less elongate, without a transverse dark band behind the middle.

***Xenicotela binigracollis* (Breuning, 1965), comb. nov.**

Fig. 7g, h

Monochamus binigracollis Breuning, 1965: 51; Rondon and Breuning 1970: 461; Lin and Tavakilian 2019: 310. Type locality: Pak Kading, Laos.

Type material examined. *Holotype*, female (BPBM), Laos: Pak Kading, Paksane area, May, 1964, coll. J. A. Rondon.

Other material examined. One female, VIETNAM: Bac Kạn Province, National Park (LGBC).

Redescription. Female. Body length 13.0 mm, humeral width 4.0 mm. Body mostly blackish brown, clothed with off-white, pale yellowish-brown to greyish-yellow and dark-brown pubescence. Head decorated with a dark-brown pubescent patch behind each upper eye lobe, a pair of homogeneous patches located at the base half of pronotum, widely separated anteriorly and indistinctly edged with pale-yellow pubescence on anterior and lateral sides. Antennae reddish brown; scape and pedicel densely clothed with greyish-yellow pubescence; base and extreme apex of antennomeres III–X; base and apical half of antennomere XI annulated with greyish-yellow pubescence; basal five segments fringed with sparse greyish-yellow setae ventrally. Scutellum completely clothed with greyish-yellow pubescence. Elytra dark brown, clothed with off-white, pale yellowish-brown to greyish-yellow and dark-brown pubescence forming a mottled pattern, distinctly dotted with irregular dark-brown spots; each elytron adorned with a large broad dark-brown median patch, slightly reduced near the suture. Tibiae decorated with a narrow subbasal and a wide apical annulus of greyish-yellow to pale-yellow pubescence.

Frons transverse, finely punctate; lower eye lobes slightly longer than genae. Antennae long, about 1.9 times as long as body; scape robust and short; base narrowed; apex distinctly constricted before cicatrix; antennomere III a little longer than antennomere IV, about 2.0 times as long as scape; antennomeres III–X slightly thickened at extreme apex. Pronotum transverse; lateral spine coniform, with pointed apex; disc dotted with fine punctures. Scutellum lingulate. Elytra elongate, about 2.3 times as long as width across humeri, with subparallel sides and rounded apices; punctures a little coarser and sparser than those on head and pronotum, sparser and even finer towards the apex; disc slightly raised at centre of basal third, followed by a weak central depression. Legs moderately long, femora slightly clavate, claws divaricate.

Male. Unknown.

Distribution. Laos (Pak Kading), Vietnam (Tonkin).

Comments. This species has the antennae with the scape robust and short and distinctly constricted before the cicatrix, basal five antennomeres fringed with sparse setae ventrally, and antennomeres III–XI annulated with light-coloured pubescence on base and apex; the pronotum with the lateral spine small, short and coniform, and the middle legs with the tibia without grooves. These characters are consistent with the genus *Xenicotela*.

This species is similar to *X. distincta* and *X. griseomaculata*, from which it differs in the lower eye lobe being longer than gena, the scutellum completely covered with light-coloured pubescence, and the base and the apex of elytra mostly clothed with light-coloured pubescence interspersed with small irregular dark-brown spots. In *X. distincta*, the lower eye lobe is about as long as gena, the scutellum is only clothed with the light-coloured pubescence on the edge and the elytra are not dotted with small irregular dark-brown spots. In *X. griseomaculata*, the lower eye lobe is shorter than gena, the scutellum is not clothed with light-coloured pubescence on the basal centre, and the base and apex of the elytra are mostly dark, adorned with light-coloured pubescent patches.

Wang (1998) incorrectly identified the specimens of *X. distincta* from Guizhou and Yunnan as this species on the basis of the main features of two black spots behind the upper eye lobes and at the base of pronotum respectively. In fact, *X. binigracollis* can be easily distinguished from *X. distincta*, as mentioned above. Consequently, it must be excluded from the fauna of China based on the information currently available.

***Xenicotela griseomaculata* Xie, Barclay & Chen, 2022**

Fig. 9a, b, g

Xenicotela griseomaculata Xie et al, 2022: 152. Type locality: Chongqing (Wuxi County), China.

Type material examined. Holotype, male, CHINA: Chongqing, Wuxi County, Xiaobao township, Shuanghe Village, 31°21'4"N, 109°11'24"E, July 26, 2019, coll. Bin Chen.

Distribution. China (Chongqing).

Remarks. Description and comments on this species are provided by Xie et al. (2022).

***Xenicotela mucheni* sp. nov.**

<https://zoobank.org/ED984BE9-2323-4C9A-923B-F31931DAC3B2>

Fig. 9c–f, h–o

Type material. Holotype: male, CHINA: Yunnan Province, Ruili (瑞丽), July 29, 2018, coll. local collector, deposited in the Insect Collection, College of Agriculture, Yangtze University (YZU). **Paratypes:** one male and two females, CHINA: Yunnan Province, Yingjiang County (盈江), Xima (昔马), Alt. 600–1200 m, July 29 to August 10, 2018, coll. by local collector, deposited in the Collection of Mu Chen (MCC, Shanghai, China).

Description. Male. Body length 16.2–19.0 mm, humeral width 5.1–5.7 mm. Body mostly dark brown; antennae and legs mostly dull reddish brown, clothed with greyish-yellow, greyish-white and black pubescence forming maculations. Head densely clothed with greyish-yellow pubescence, denser and longer on labrum and clypeus, with a long oval black velvet spot behind each upper eye lobe. Antennae clothed with greyish-yellow pubescence; base and extreme apex of antennomeres III–X, basal fifth and apical two-fifths of antennomere XI annulated with sparse greyish-yellow to greyish-white pubescence. Pronotum clothed with greyish-yellow pubescence on the middle and greyish-white pubescence at sides, decorated with a short finger-like black spot on each side of basal half with apex directed obliquely outwards, base broken by a patch of greyish-yellow pubescence on the middle. Scutellum clothed with greyish-yellow pubescence, thinly edged with more light-coloured pubescence. Elytra mostly clothed with greyish-yellow pubescence, interspersed with irregular dark-brown pubescent spots throughout and white spots mainly on basal and apical fourth. Underside clothed with denser pubescence, decorated with irregular dark-brown spots on both sides; ventrites fringed with greyish-yellow pubescence on the apical

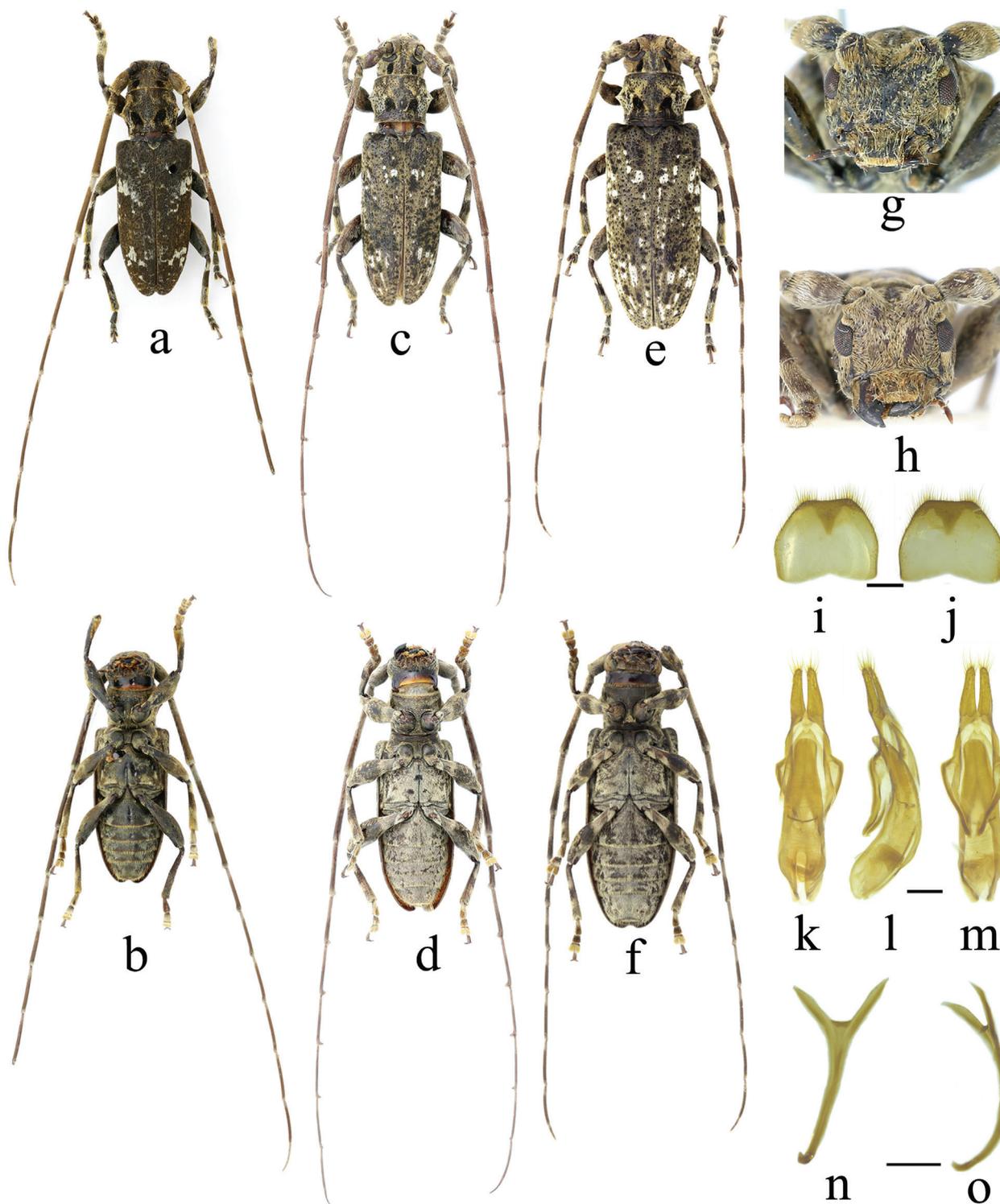


Figure 9. *Xenicotela* spp. **a, b, g** holotype of *Xenicotela griseomaculata*, male **c–f, h–o** *Xenicotela mucheni* sp. nov. **c, d, h** male **e, f** female **a, c, e, i, k** dorsal view **b, d, f, j, m, n** ventral view **l, o** lateral view **g, h** frontal view **i–o** male genitalia **i, j** tergite VIII **k–l** tegmen + median struts **n, o** spiculum gastrale. Scale: 0.5 mm.

margin. Legs mostly clothed with greyish-yellow pubescence; tibiae decorated with a dark pubescent ring at middle.

Head finely and sparsely punctate; frons transverse, slightly convex, with a smooth longitudinal median sulcus extending to occiput. Eyes coarsely

faceted; lower lobe about as long as gena. Antennae long, about 2.1–2.3 times as long as body; scape robust, thin at base, distinctly constricted before cicatrix; antennomere III distinctly longer than antennomere IV, about 2.7 times as long as scape; antennomere IV longer than antennomere V, antennomeres V–X strongly toothed inwards at apex. Pronotum transverse, anterior and posterior margins subequal in width; lateral spine coniform, with blunt apex; disc slightly convex, finely and sparsely punctate, with a little flat centre. Scutellum lingulate. Elytra elongate, about 2.3 times as long as width across humeri, with subparallel sides and rounded apices; surface punctures a little coarser than those on head and pronotum, gradually becoming finer and sparser towards apex, with basal fourth slightly longitudinally elevated centrally. Underside inconspicuously punctate; apical margin of distal ventrite nearly straight. Legs moderately long, femora slightly clavate, mesotibiae without grooves near external apex, claws divaricate.

Male genitalia. Tergite VIII with both sides subparallel at basal third, then converging straight to apex, apex broadly truncated, clothed with short to medium straight setae along apical and lateral sides. Tegmen about 2.37 mm long, maximum width of ringed part about 0.97 mm. Paramere about 0.39 mm long, base about 0.25 mm wide, length/width ratio about 1.56, rounded apically, clothed with setae of different lengths and thicknesses at apex. Median lobe about as long as tegmen, slightly arcuate in lateral view, apical margin of dorsal plate and ventral plate rounded; median struts relatively broad, about one-half as long as median lobe.

Female. Body length 24.1–27.1 mm, humeral width 7.3–8.5 mm. Similar to male, antennae about 1.8 times as long as body; elytra about 2.2 times as long as width across humeri; antennomeres V–X slightly thickened apically.

Distribution. China: Yunnan.

Etymology. The new species is named after Mr Chen Mu, in gratitude for his offering the material of this new species for this study.

Comments. The new species differs from other species of the genus in the elytra with distinct, small, separate, irregular, white spots and the male antennae with prominent teeth on the apices of antennomeres V–IX.

Key to the known species of *Xenicotela* Bates

- 1 Elytra mostly clothed with greyish-yellow pubescence, without whitish pubescent patches **2**
- Elytra decorated with distinct greyish white or white pubescent spots or, at least, with light-coloured pubescent maculations of off-white pubescence mixed with greyish-yellow pubescence **6**
- 2 Pronotum with two distinct dark-brown spots **3**
- Pronotum without such spots; elytral pubescence thin; each elytron with an incomplete transverse dark-brown patch after middle **Xenicotela pardalina** (Bates, 1884)
- 3 Scutellum wholly covered with light-coloured pubescence **4**
- Scutellum only clothed with light-coloured pubescence on edge, with dark-brown pubescence on central part **5**
- 4 Light-coloured pubescent ring at base of antennomere III relatively long, about one-fourth as long as antennomere III; dark-brown spots on pronotal

- base distinctly edged with pale-yellow pubescence; each elytron without distinct transverse dark patches
 ***Xenicotela villiersi* (Breuning, 1960), comb. nov.**
- Light-coloured pubescent ring on base of antennomere III shorter than one-fourth of length of antennomere III; dark-brown spots on pronotal base without conspicuous pubescent border; each elytron with a distinct but incomplete transverse dark patch
 ***Xenicotela convexicollis* (Gressitt, 1942)**
- 5 Each elytron with a distinct large transverse dark-brown patch on the middle ***Xenicotela distincta* (Gahan, 1888)**
- Each elytron with irregular dark-brown patches that do not fuse into a distinct large transverse dark-brown patch on middle.....
 ***Xenicotela bimaculata* (Pic, 1925)**
- 6 Apex of male antennomeres V–IX only weakly protruding inwards; elytra with relatively large light-coloured pubescent patches **7**
- Apex of male antennomeres V–IX strongly toothed inwards; elytra with scattered irregular small white pubescent spots.....
 ***Xenicotela mucheni* sp. nov.**
- 7 Apical fourth of elytra mostly clothed with light-coloured pubescence, with irregular dark spots
 ***Xenicotela binigracollis* (Breuning, 1965), comb. nov.**
- Apical fourth of elytra mostly dark, with greyish-white pubescent patches...
 ***Xenicotela griseomaculata* Xie, Barclay & Chen, 2022**

Discussion

The species of the genus *Xenicotela* have a small body size (usually less than 20 mm in length) and are similar in appearance to the small-bodied species of the genus *Monochamus* and are often treated as members of the latter. The key distinguishing feature between these two genera is the presence or absence of an oblique groove near the apex of the mesotibia. In *Xenicotela*, the mesotibia lacks a groove near the apex. Furthermore, the scape is short, distinctly narrowed at the base, slightly swollen in the middle, clearly constricted before the apex, appearing subfusiform; the lateral spine of the pronotum is short and blunt, coniform. Antennomeres with light-coloured pubescent rings at the base and apex and fringes on the lower sides appear to be stable generic features in *Xenicotela*, while the presence or absence of fringes on the lower sides of the antennae cannot be used to distinguish these two genera, as several subgenera of *Monochamus* occurring in Africa, such as *Ethiopiochamus* Dillon & Dillon, 1961, *Parochamus* Dillon & Dillon, 1961 and *Quasiochamus* Dillon & Dillon, 1961, are all fringed on the lower edge of the antennae (Dillon and Dillon 1961).

An African species, *Monochamus* (*Quasiochamus*) *nigrobasimaculatus* Breuning, 1981 (Fig. 10), is very similar to members of *Xenicotela* in appearance, being of comparable body size, with two black velvet spots behind the upper eye lobes, the light-coloured pubescent rings at the base and apex on antennomeres III–XI, the light-coloured and dark pubescent rings on the femur, and the elytra mostly mottled, with two inconspicuous transverse dark spots after the middle. Although Breuning (1981) stated that there are no fringes on the lower sides of the antennae (non frangées en dessous), photographs of the

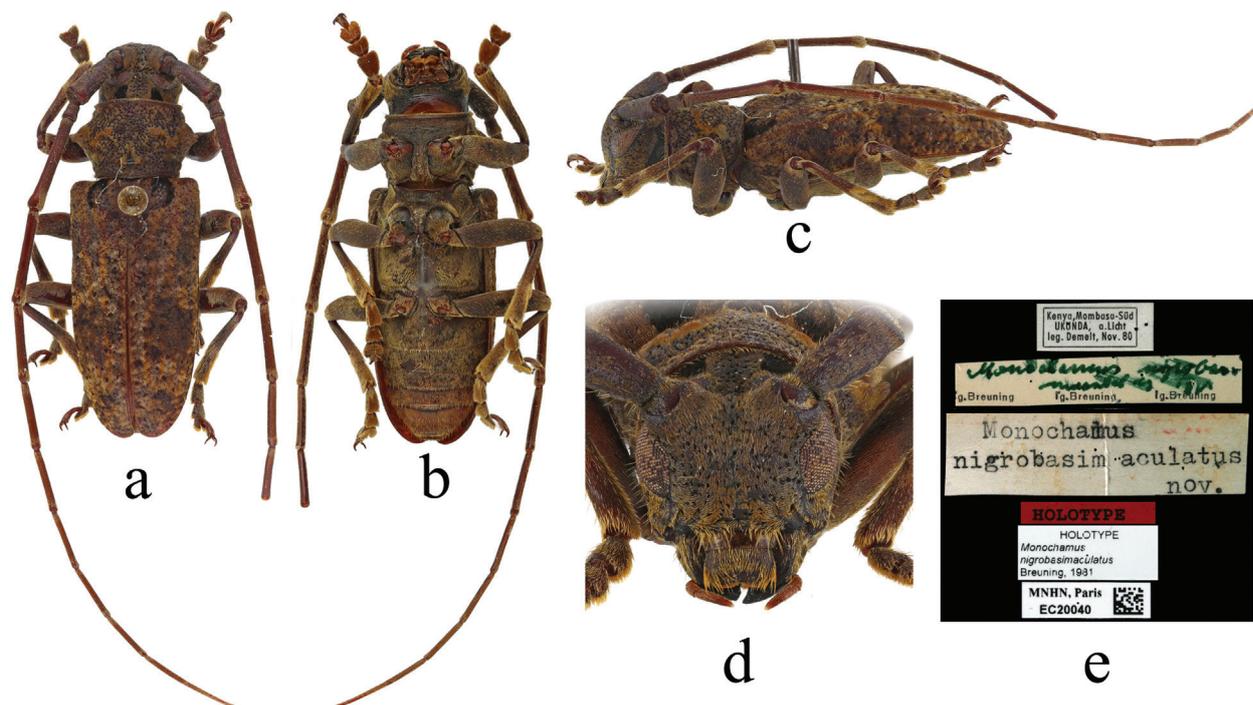


Figure 10. Holotype of *Monochamus nigrobasimaculatus* Breuning, 1981, Mombasa (Ukunda), Kenya **a** dorsal view **b** ventral view **c** lateral view **d** frontal view **e** labels.

holotype show that the antennae are distinctly fringed with the sparse pale-yellow setae below on basal five antennomeres, which also matches well with the features of *Xenicotela*. However, this species has large lateral pronotal spines and cylindrical scapes with unexpanded middle parts, which make it slightly different from *Xenicotela*. The presence or absence of a groove near the apex of the mesotibia is difficult to determine from the photographs and can only be determined after examination of the holotype. If the mesotibia has no groove, this species should be transferred into *Xenicotela*; conversely, if the mesotibia has a groove, its current status should be retained. As we were so far unable to directly examine the holotype, we are unable to draw a conclusion.

Monochamus is a large genus in the tribe Lamiini, currently comprising 21 subgenera and over 160 species. It shows a considerable morphological variation among subgenera, which is well worth reviewing. In recent years, some species have been removed from *Monochamus* to other genera: *M. gravidus* Pascoe, 1858 to *Meges* Pascoe, 1866 (Bi et al. 2022), *M. serratus* Gahan, 1906, *M. semigranulatus* Pic, 1925, *M. asper* Breuning, 1935 and *M. latefasciatus* Breuning, 1944 to *Trachystohamus* Pic, 1936 (Vitali and Gouverneur 2022), *M. convexicollis* Gressitt, 1942 to *Xenicotela* (Xie et al. 2022), and *M. fruhstorferi* Breuning, 1964 to *Annamanum* Pic, 1925 [sub *Annamanum lunulatum* (Pic, 1934)] (Lin and Lingafelter 2018). In the present study, two additional species, *M. binigracollis* and *M. villiersi*, are transferred to *Xenicotela*. As the genera are studied in more depth it is likely that more species will change their current status.

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deposited in MNHN, to Nobuo Ohbayashi (Miura, Japan) and Junsuke Yamashiro (Institute for Plant Protection, NARO, Japan) for offering the holotype photograph of *M. binigracollis* and the photograph of *X. pardalina*, to Larry Bezark (Sacramento, USA) for offering the photograph of *M. binigracollis* and revising the manuscript, to Meiyang Lin (Mianyang Normal University, Sichuan, China) for providing the holotype photograph of *M. convexicollis* and revising the manuscript, to Ping Wang (Yangtze University, Jingzhou, China) for dissecting and photographing the genitalia of the new species, to Shulin Yang (Guizhou Normal University, Guiyang, China) for sharing the photograph of *X. distincta*, to Chen Mu (Shanghai, China) for offering the specimens of the new species for this study, and especially to Francesco Vitali (Musée national d'histoire naturelle de Luxembourg, Luxembourg), subject editor of ZooKeys, for carefully revising and patiently handling the manuscript.

Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statement

No ethical statement was reported.

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Data availability

All of the data that support the findings of this study are available in the main text.

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Three new species of *Grandilithus* Liu & Li, 2022 (Araneae, Phrurolithidae) from southern China

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Abstract

Three new species of *Grandilithus* Liu & Li, 2022 are described from southern China on the basis of both sexes: *G. chongzuo* **sp. nov.** from Guangxi, *G. xiaohuangshan* **sp. nov.** from Guangdong and *G. lanxi* **sp. nov.** from Jiangxi. A distribution map of these three species is provided.

Key words: Diagnosis, morphology, spider, taxonomy

Introduction

Phrurolithidae Banks, 1892 is a spider family comprising 26 genera and 388 species from most parts of the world, with 17 genera and 202 species reported from China (WSC 2023). Among them, seven newly established and three newly recorded genera have been reported from China in recent years (Liu et al. 2020; Jin et al. 2022; Liu et al. 2022; Mu and Zhang 2022; Mu et al. 2022; Mu and Zhang 2023a, 2023b).

The genus *Grandilithus* Liu & Li, 2022 was established based on the type species *G. anyuan* Liu & Li, 2022. There are 29 species known from China, and two each have been reported from Vietnam and Japan (WSC 2023). Species of *Grandilithus* can be recognized by the straight posterior eye row and the narrow dorsal scutum less than 1/2 of the abdomen length. Males of this genus can be distinguished by the presence of a strong, well-developed extension on the distal palpal femur (femoral apophysis), a small tubercle on the ventral tibia, a retrolateral tibial apophysis with a curved tip, the thin embolus curved as a semicircle, and the absence of a conductor. The females of this genus can be distinguished by the broad median septum and the elongated spermathecae (Liu et al. 2022).

While examining specimens from southern China, three new *Grandilithus* species were discovered, which are described in this paper.

Materials and methods

All measurements are given in millimeters. The leg measurements are shown as: total length (femur, patella, tibia, metatarsus, tarsus). The epigynes were



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removed and cleared in a pancreatin solution (Álvarez-Padilla and Hormiga 2007) and then transferred to 95% ethanol. All specimens are preserved in 95% alcohol. Photographs were taken using the Leica M205A stereomicroscope equipped with a DFC 550 CCD. Final figures were retouched using Adobe Photoshop. All specimens are deposited in the Museum of Hebei University (MHBHU), Baoding, China.

The following abbreviations are used: AER, anterior eye row; ALE, anterior lateral eye; AME, anterior median eye; CH, clypeal height; CRW, cephalic region width; CW, carapace width; EAW, eye area width; MOA, median ocular area; PLE, posterior lateral eye; PME, posterior median eye; Spination: d, dorsal; pl, prolateral; pv, proventral; rv, retroventral.

Taxonomy

Family Phrurolithidae Banks, 1892

Genus *Grandilithus* Liu & Li, 2022

Type species. *Grandilithus anyuan* Liu & Li, 2022.

Grandilithus chongzuo sp. nov.

<https://zoobank.org/DAFF490C-B867-47EB-95B2-7A8A19381A3F>

Figs 1, 2

Chinese name: 崇左大斑蛛

Type material. *Holotype* ♂ (GXCZ-16-46): CHINA: Pairu Village, Zuozhou Town, Chongzuo City, Guangxi Zhuang Autonomous Region (22°34.40'N, 107°25.36'E; 203 m a.s.l.), 4 November 2016, leg. Guiqiang Huang. *Paratype*: 2♀, with same data as holotype.

Etymology. The specific epithet refers to the type locality.

Diagnosis. This species resembles *G. nonggang* (Liu, Xu, Xiao, Yin & Peng, 2019) in having a similarly shaped embolus and sperm duct, but can be recognized by: 1) the long RTA, with thin base and coracoid-shaped tip (vs RTA short, base wide, cf. Fig. 2B–D with fig. 11B–D in Liu et al. 2019); 2) the oval tegulum and the slightly curved tegular apophysis without an expanded tip (vs tegulum nearly circular, tegular apophysis straight with an expanded tip, cf. Fig. 2B–D with fig. 11C in Liu et al. 2019); 3) the short copulatory duct (vs long, cf. Fig. 2E, F with fig. 12B, C in Liu et al. 2019); 4) the small, thin glandular appendage (vs thick, cf. Fig. 2E, F with fig. 12B, C in Liu et al. 2019); and 5) the small spermathecae, with thin connecting tubes (vs connecting tubes strong and thick, spermathecae large, cf. Fig. 2E, F with fig. 12B, C in Liu et al. 2019).

Description. Male (holotype): total length 3.27, carapace 1.56 long, 1.34 wide; abdomen 1.71 long, 1.00 wide. Eye sizes and interdistances: AME 0.14, ALE 0.12, PME 0.09, PLE 0.11; AME–AME 0.05, AME–ALE 0.02, ALE–ALE 0.33, PME–PME 0.10, PME–PLE 0.04, PLE–PLE 0.37, ALE–PLE 0.08. EAW 0.52, CRW 0.68, EAW/CRW 0.76, CRW/CW 0.51. MOA 0.34 long, anterior width 0.32, posterior width 0.29. CH 0.13. CH/AME 0.93. Labium 0.14 long, 0.23 wide. Sternum

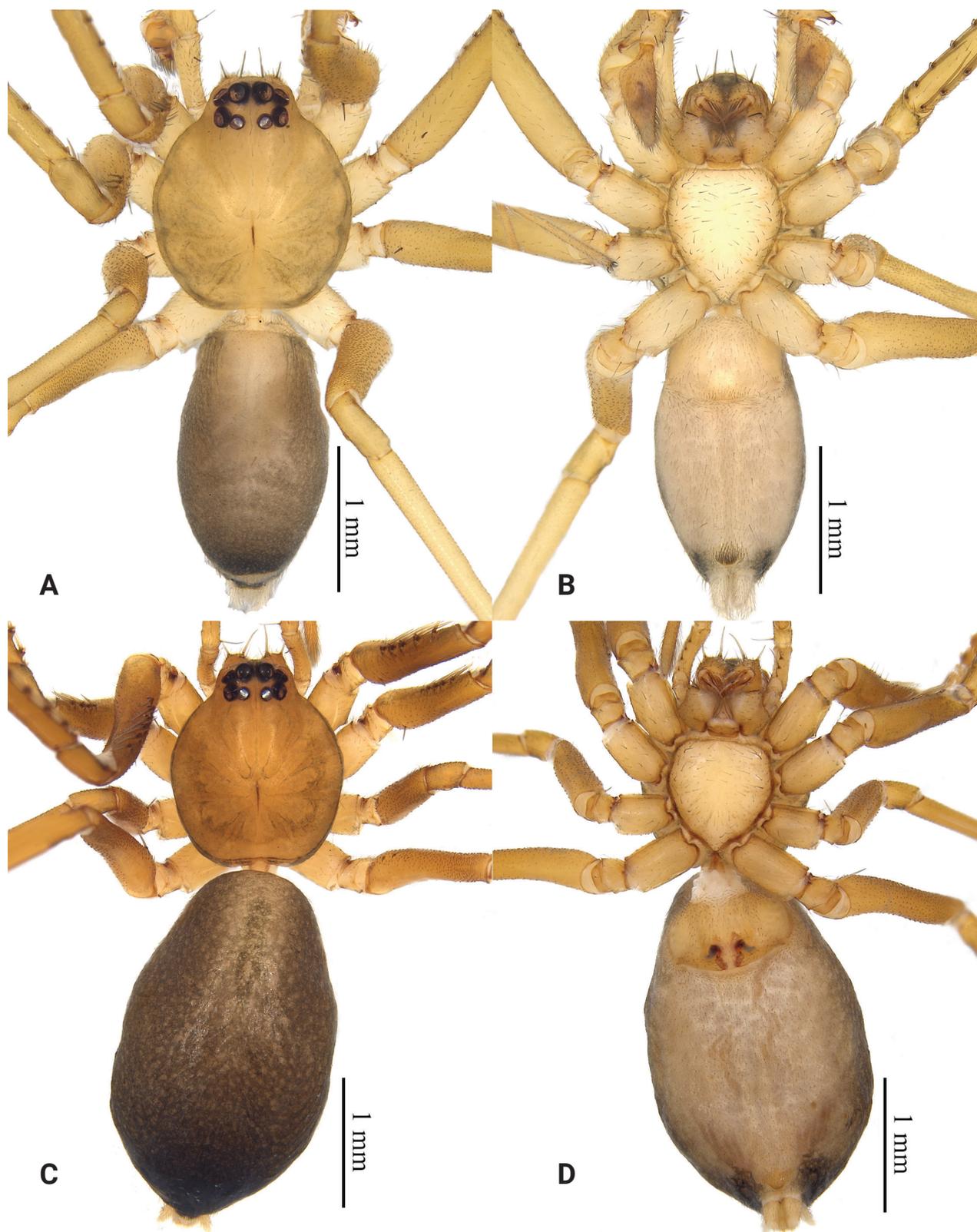


Figure 1. Habitus of *Grandilithus chongzuo* sp. nov. **A** male holotype, dorsal view **B** same, ventral view **C** female paratype, dorsal view **D** same, ventral view.

0.89 long, 0.77 wide. Leg measurements: I 8.41 (2.07, 0.56, 2.36, 1.92, 1.50), II 6.58 (1.73, 0.51, 1.70, 1.44, 1.20), III 5.42 (1.44, 0.47, 1.16, 1.42, 0.93), IV 8.79 (2.37, 0.57, 2.04, 2.44, 1.37), leg pattern: 4123. Spination: femur I–IV d 1, femur

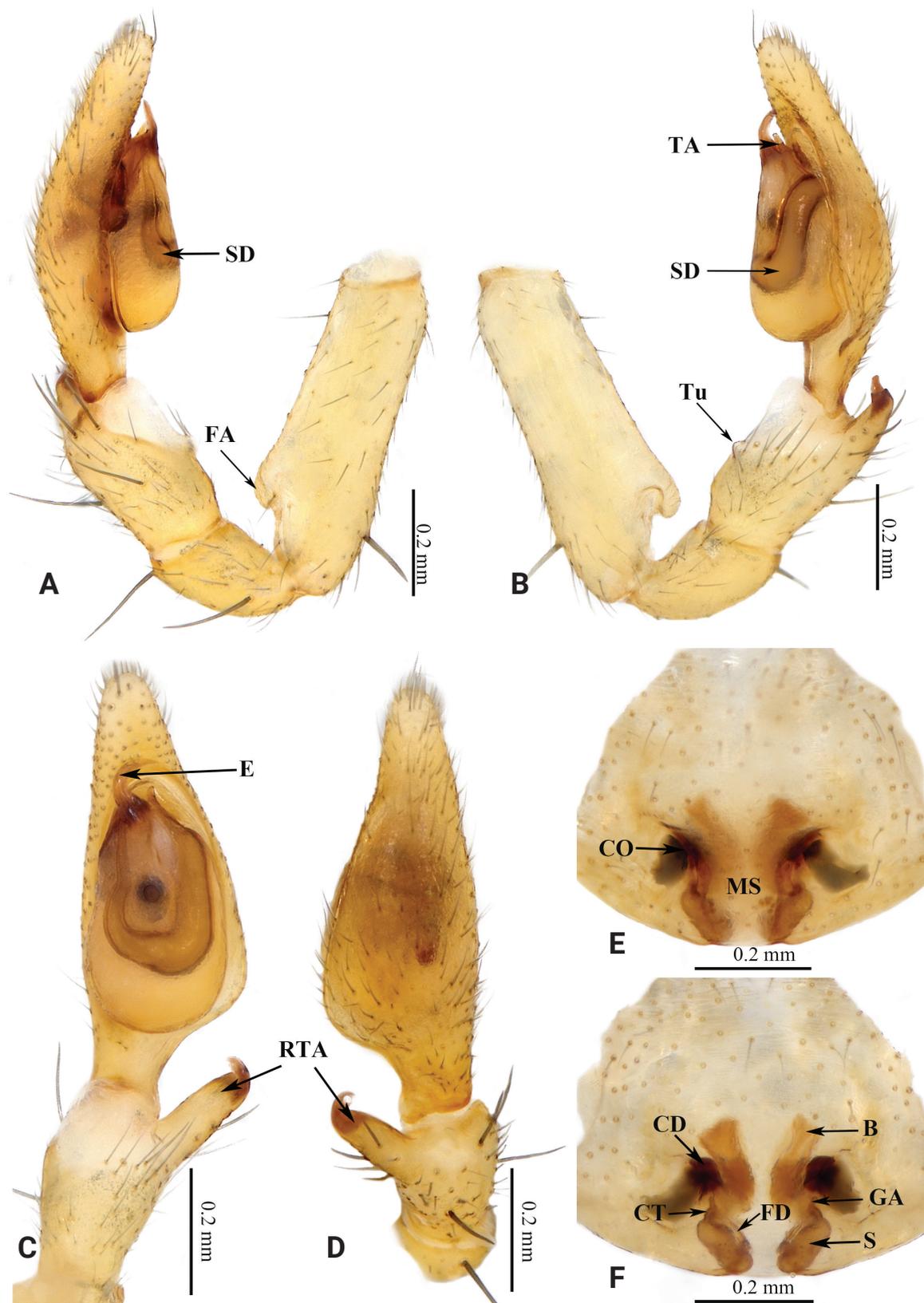


Figure 2. Copulatory organs of *Grandilithus chongzuo* sp. nov. **A** male left palp, prolateral view **B** same, retrolateral view **C** same, ventral view **D** same, dorsal view **E** epigyne, ventral view **F** same, dorsal view. Abbreviations: B—bursa; CD—copulatory duct; CO—copulatory opening; CT—connecting tube; E—embolus; FA—femoral apophysis; FD—fertilization duct; GA—glandular appendage; MS—median septum; RTA—retrolateral tibial apophysis; S—spermatheca; SD—sperm duct; TA—tegular apophysis; Tu—tubercle.

I pl 5, femur II pl 3, tibia I pv 9 rv 9, tibia II pv 9 rv 8, metatarsus I pv 4 rv 4, metatarsus II pv 4 rv 3.

Coloration. Carapace yellowish, with several patches resembling flowing droplets beside fovea. Abdomen gray, with a small, fawn dorsal scutum anteriorly and several lighter colored transverse stripes posteriorly. A small, irregular, slightly sclerotized area in front of the spinnerets with black setae. Leg light yellow.

Palp as in Fig. 2A–D. Femoral apophysis protruding. Tubercle distinct. Retrolateral tibial apophysis long, tip curved, coracoid-shaped. Tegulum oval, thinner than cymbium; tegular apophysis slightly curved, tip not expanded. Sperm duct distinct, tapering from retrolateral of tegulum to base of embolus. Embolus curved, tip sharp.

Female (paratype): total length 4.18, carapace 1.51 long, 1.30 wide; abdomen 2.67 long, 1.61 wide. Eye sizes and interdistances: AME 0.13, ALE 0.12, PME 0.08, PLE 0.10; AME–AME 0.05, AME–ALE 0.01, ALE–ALE 0.32, PME–PME 0.09, PME–PLE 0.04, PLE–PLE 0.35, ALE–PLE 0.06. EAW 0.51, CRW 0.66, EAW/CRW 0.77, CRW/CW 0.51. MOA 0.30 long, anterior width 0.30, posterior width 0.27. CH 0.11, CH/AME 0.85. Labium 0.13 long, 0.24 wide. Sternum 0.85 long, 0.77 wide. Leg measurements: I 7.75 (1.94, 0.56, 2.30, 1.70, 1.25), II 6.15 (1.55, 0.48, 1.77, 1.23, 1.12), III 4.99 (1.32, 0.45, 1.11, 1.32, 0.79), IV 7.97 (2.15, 0.54, 1.86, 2.27, 1.15), leg pattern: 4123. Spination: femur I–IV d 1, femur I pl 6, femur II pl 4, tibia I pv 10 rv 10, tibia II pv 9 rv 9, metatarsus I pv 4 rv 4, metatarsus II pv 4 rv 3.

Coloration. Carapace yellow-brown, darker than male, with several patches resembling flowing droplets beside fovea. Abdomen dark gray without dorsal scutum. A small, irregular, slightly sclerotized area in front of the spinnerets with black setae. Leg yellow-brown.

Epigyne as in Fig. 2E, F. Epigynal plate slightly sclerotized. Median septum broad. Copulatory openings small, separated by median septum. Copulatory ducts bent. Bursa nearly rectangular. Glandular appendages thin, short, cylindrical. Connecting tubes curved, thinner than copulatory ducts. Spermathecae small, oval, slanted, separated. Fertilization ducts located at posterior of spermathecae.

Distribution. China: Guangxi Zhuang Autonomous Region (Fig. 7).

***Grandilithus xiaohuangshan* sp. nov.**

<https://zoobank.org/F7AB13E6-C2BD-4AB5-8CDF-BEF871120A06>

Figs 3, 4

Chinese name: 小黄山大斑蛛

Type material. Holotype ♂ (HBUARA#2021-63): CHINA: Xiaohuangshan Scenic Spot, the Nanling Mountain National Forest Park, Ruyuan County, Shaoguan City, Guangdong Province (24°53.72'N, 113°1.24'E; 1338 m a.s.l.), 23 May 2021, leg. Yannan Mu. **Paratype:** 2♀, with same data as holotype.

Etymology. The specific epithet refers to the type locality.

Diagnosis. This new species resembles *G. florifer* (Fu, He & Zhang, 2015) in having a similarly shaped embolus, but can be recognized by: 1) the different color pattern and lighter color (vs darker color, cf. Fig. 3 with figs 21, 22 in Fu et

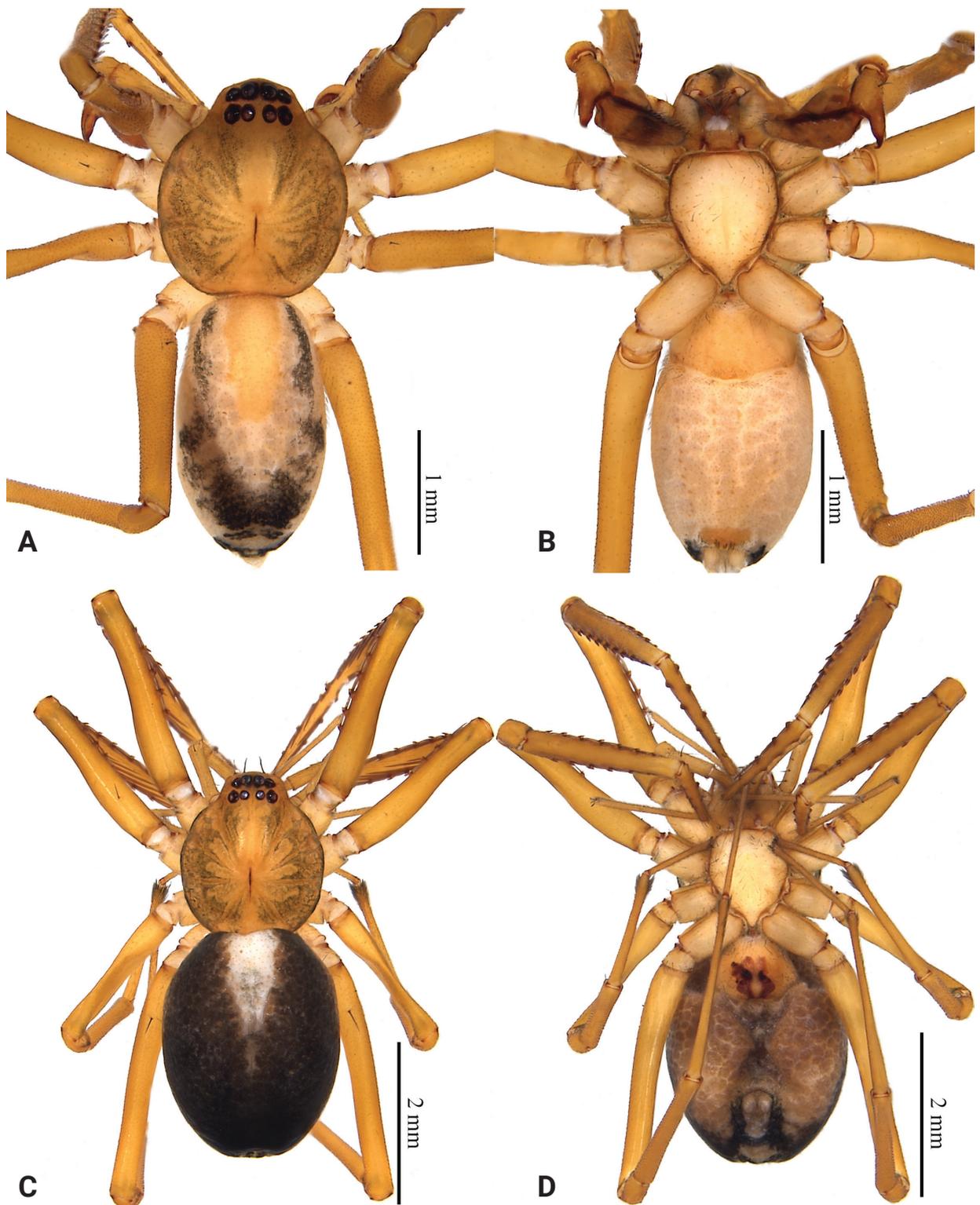


Figure 3. Habitus of *Grandilithus xiaohuangshan* sp. nov. A male holotype, dorsal view B same, ventral view C female paratype, dorsal view D same, ventral view.

al. 2015); 2) the broad tegulum (wider than cymbium), the small, arch-shaped tegular apophysis (vs tegulum thinner than cymbium, tegular apophysis long, straight, cf. Fig. 4B, C with figs 25, 26 in Fu et al. 2015); 3) the thin median

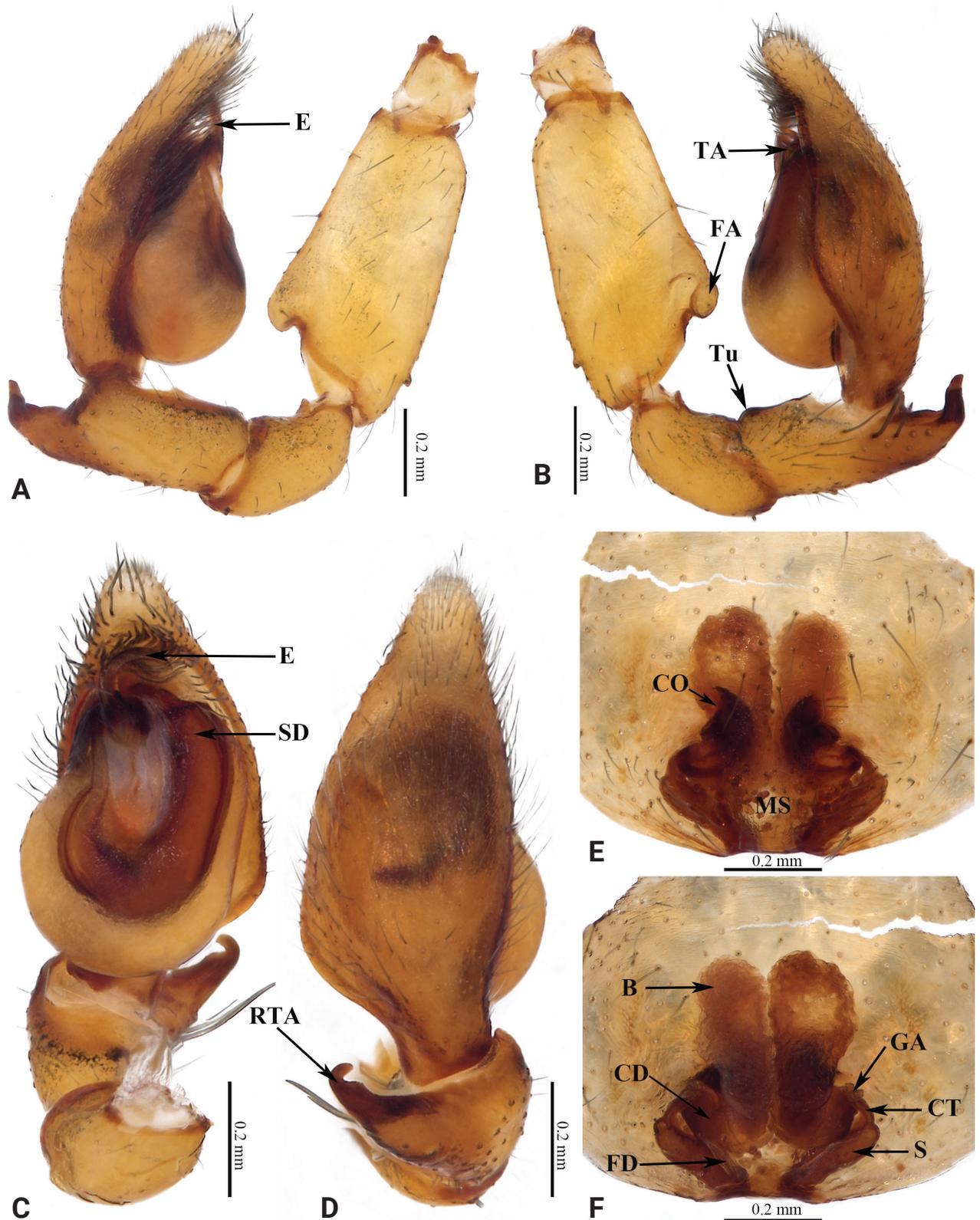


Figure 4. Copulatory organs of *Grandilithus xiaohuangshan* sp. nov. **A** male left palp, prolateral view **B** same, retrolateral view **C** same, ventral view **D** same, dorsal view **E** epigyne, ventral view **F** same, dorsal view. Abbreviations: B—bursa; CD—copulatory duct; CO—copulatory opening; CT—connecting tube; E—embolus; FA—femoral apophysis; FD—fertilization duct; GA—glandular appendage; MS—median septum; RTA—retrolateral tibial apophysis; S—spermatheca; SD—sperm duct; TA—tegular apophysis; Tu—tubercle.

septum (vs wide, cf. Fig. 4E with figs 27, 28 in Fu et al. 2015); 4) the thick and strong copulatory ducts (vs thin and small, cf. Fig. 4E, F with figs 27, 28 in Fu et al. 2015); and 5) the long, straight spermathecae, with thin connecting tubes (vs connecting tubes thick, spermathecae short and curved, cf. Fig. 4F with figs 27, 28 in Fu et al. 2015).

Description. Male (holotype): total length 3.70, carapace 1.67 long, 1.48 wide; abdomen 2.03 long, 1.18 wide. Eye sizes and interdistances: AME 0.12, ALE 0.10, PME 0.08, PLE 0.09; AME–AME 0.06, AME–ALE 0.01, ALE–ALE 0.32, PME–PME 0.10, PME–PLE 0.06, PLE–PLE 0.40, ALE–PLE 0.10. EAW 0.54, CRW 0.75, EAW/CRW 0.72, CRW/CW 0.51. MOA 0.29 long, anterior width 0.30, posterior width 0.27. CH 0.12. CH/AME 1.00. Labium 0.16 long, 0.24 wide. Sternum 0.98 long, 0.80 wide. Leg measurements: I 9.10 (2.14, 0.62, 2.66, 2.20, 1.48), II 7.14 (1.82, 0.57, 1.90, 1.68, 1.17), III 5.95 (1.57, 0.49, 1.34, 1.58, 0.97), IV 8.94 (2.41, 0.56, 2.19, 2.49, 1.29), leg pattern: 1423. Spination: femur II–IV d 1, femur I pl 5, femur II pl 3, tibia I pv 8 rv 9, tibia II pv 8 rv 8, metatarsus I pv 4 rv 4, metatarsus II pv 4 rv 3.

Coloration. Carapace yellow-brown, with several patches resembling flowing droplets beside fovea. Abdomen fawn, with a small, yellow dorsal scutum anteriorly and black pattern posteriorly. A small, irregular, slightly sclerotized area in front of the spinnerets with black setae. Leg yellow-brown.

Palp as in Fig. 4A–D. Femoral apophysis protruding. Tubercle indistinct. Retrolateral tibial apophysis with broad base, curved, with coracoid-shaped tip. Tegulum nearly circular, wider than cymbium; tegular apophysis small. Sperm duct distinct, tapering from retrolateral of tegulum to base of embolus. Embolus thin, curved, tip sharp.

Female (paratype): total length 4.78, carapace 2.03 long, 1.75 wide; abdomen 2.75 long, 2.17 wide. Eye sizes and interdistances: AME 0.14, ALE 0.12, PME 0.09, PLE 0.10; AME–AME 0.07, AME–ALE 0.01, ALE–ALE 0.34, PME–PME 0.11, PME–PLE 0.08, PLE–PLE 0.46, ALE–PLE 0.13. EAW 0.61, CRW 0.82, EAW/CRW 0.74, CRW/CW 0.95. MOA 0.32 long, anterior width 0.31, posterior width 0.30. CH 0.13, CH/AME 1.08. Labium 0.22 long, 0.30 wide. Sternum 1.18 long, 0.96 wide. Leg measurements: I 10.98 (2.52, 0.69, 3.06, 2.13, 2.58), II 8.31 (2.21, 0.66, 2.38, 1.79, 1.27), III 6.67 (1.81, 0.61, 1.46, 1.77, 1.02), IV 10.42 (2.87, 0.67, 2.50, 2.94, 1.44), leg pattern: 1 4 2 3. Spination: femur I pl 5, femur II d 1 pl 5, femur IV d 1, tibia I pv 9 rv 10, tibia II pv 9 rv 8, metatarsus I pv 4 rv 4, metatarsus II pv 4 rv 3.

Coloration. Carapace darker than male, with several patches resembling flowing droplets beside fovea. Abdomen black, with a small, white inverted triangular mark anteriorly. A small, irregular, slightly sclerotized area in front of the spinnerets with black setae. Leg yellow-brown.

Epigyne as in Fig. 4E, F. Epigynal plate slightly sclerotized. Median septum narrow, inverted goblet-shaped. Copulatory openings distinct, separated by median septum. Copulatory ducts thick and strong, bent, J-shaped. Bursa medium, balloon-shaped, the right one larger than left in dorsal view. Glandular appendages large. Connecting tubes short, curved, thinner than copulatory ducts. Spermathecae long, clavate, separated from each other. Fertilization ducts located at posterior of spermathecae.

Distribution. China: Guangdong Province (Fig. 7).

***Grandilithus lanxi* sp. nov.**

<https://zoobank.org/60B90CE6-543D-4BBD-8868-B2DC66F5354D>

Figs 5, 6

Chinese name: 兰溪大斑蛛

Type material. *Holotype* ♂ (HBUARA#2021-68): CHINA: Yangmingshan Park, Chongyi County, Ganzhou City, Jiangxi Province, Lanxi Valley (25°39.22'N, 114°18.99'E; 506 m a.s.l.), 28 May 2021, leg. Yannan Mu. *Paratype*: 3 ♀, with same data as holotype.

Etymology. The specific epithet refers to the type locality.

Diagnosis. This species resembles *G. fengshan* Liu & Li, 2022 in having a similarly shaped embolus and tegular apophysis, but can be recognized by: 1) the long, distally sharp, nearly ensiform-shaped RTA (vs RTA short, tip curved, coracoid-shaped, cf. Fig. 6C, D with fig. 45D–F in Liu et al. 2022); 2) the narrow tegulum (thinner than cymbium) (vs tegulum wider than cymbium, cf. Fig. 6C, D with fig. 45D in Liu et al. 2022); 3) the wide median septum (vs narrower, cf. Fig. 6E, F with fig. 15D, E in Mu and Zhang 2023b), 4) the long, cylindrical glandular appendage (vs short, discoidal, cf. Fig. 6E, F with fig. 15D, E in Mu and Zhang 2023b); and 5) the large spermathecae, connecting tubes thick with broad base (vs connecting tubes thin without broad base, spermathecae small, cf. Fig. 6E, F with fig. 15D, E in Mu and Zhang 2023b).

Description. Male (holotype): total length 3.68, carapace 1.70 long, 1.44 wide; abdomen 1.98 long, 1.12 wide. Eye sizes and interdistances: AME 0.12, ALE 0.10, PME 0.08, PLE 0.09; AME–AME 0.05, AME–ALE 0.01, ALE–ALE 0.29, PME–PME 0.11, PME–PLE 0.06, PLE–PLE 0.38, ALE–PLE 0.08. EAW 0.53, CRW 0.69, EAW/CRW 0.77, CRW/CW 0.48. MOA 0.29 long, anterior width 0.28, posterior width 0.28. CH 0.13. CH/AME 1.08. Labium 0.20 long, 0.25 wide. Sternum 0.96 long, 0.83 wide. Leg measurements: I 8.73 (2.20, 0.63, 2.46, 1.96, 1.48), II 6.79 (1.66, 0.56, 1.84, 1.55, 1.18), III 5.72 (1.44, 0.53, 1.22, 1.60, 0.93), IV 8.86 (2.36, 0.60, 2.04, 2.56, 1.30), leg pattern: 4123. Spination: femur I–IV d 1, femur I pl 5, tibia I pv 8 rv 9, tibia II pv 8 rv 7, metatarsus I pv 4 rv 4, metatarsus II pv 4 rv 2.

Coloration. Carapace yellow-brown, with several patches resembling flowing droplets beside fovea. Abdomen black-gray, with a yellow-brown dorsal scutum longer than 1/2 abdomen length. A small, irregular, slightly sclerotized area in front of the spinnerets with black setae. Leg yellow-brown.

Palp as in Fig. 6A–D. Femoral apophysis protruding. Tubercle distinct. Retrolateral tibial apophysis long, curved, with wide base and sword-like tip. Tegulum oval, slightly thinner than cymbium; tegular apophysis nearly triangular. Sperm duct distinct, tapering from retrolateral of tegulum to base of embolus. Embolus curved, tip blunt.

Female (paratype): total length 4.93, carapace 2.07 long, 1.75 wide; abdomen 2.86 long, 1.95 wide. Eye sizes and interdistances: AME 0.14, ALE 0.12, PME 0.09, PLE 0.10; AME–AME 0.07, AME–ALE 0.01, ALE–ALE 0.35, PME–PME 0.13, PME–PLE 0.09, PLE–PLE 0.48, ALE–PLE 0.09. EAW 0.64, CRW 0.88, EAW/CRW 0.73, CRW/CW 0.50. MOA 0.32 long, anterior width 0.32, posterior width 0.30. CH 0.15, CH/AME 1.07. Labium 0.23 long, 0.32 wide. Sternum 1.25 long, 0.92 wide. Leg measurements: I 9.54 (2.36, 0.76, 2.90, 2.20, 1.32), II 7.68 (1.96, 0.61, 2.17, 1.74, 1.20), III 6.18 (1.65, 0.56, 1.37, 1.67, 0.93), IV 9.63 (2.69,

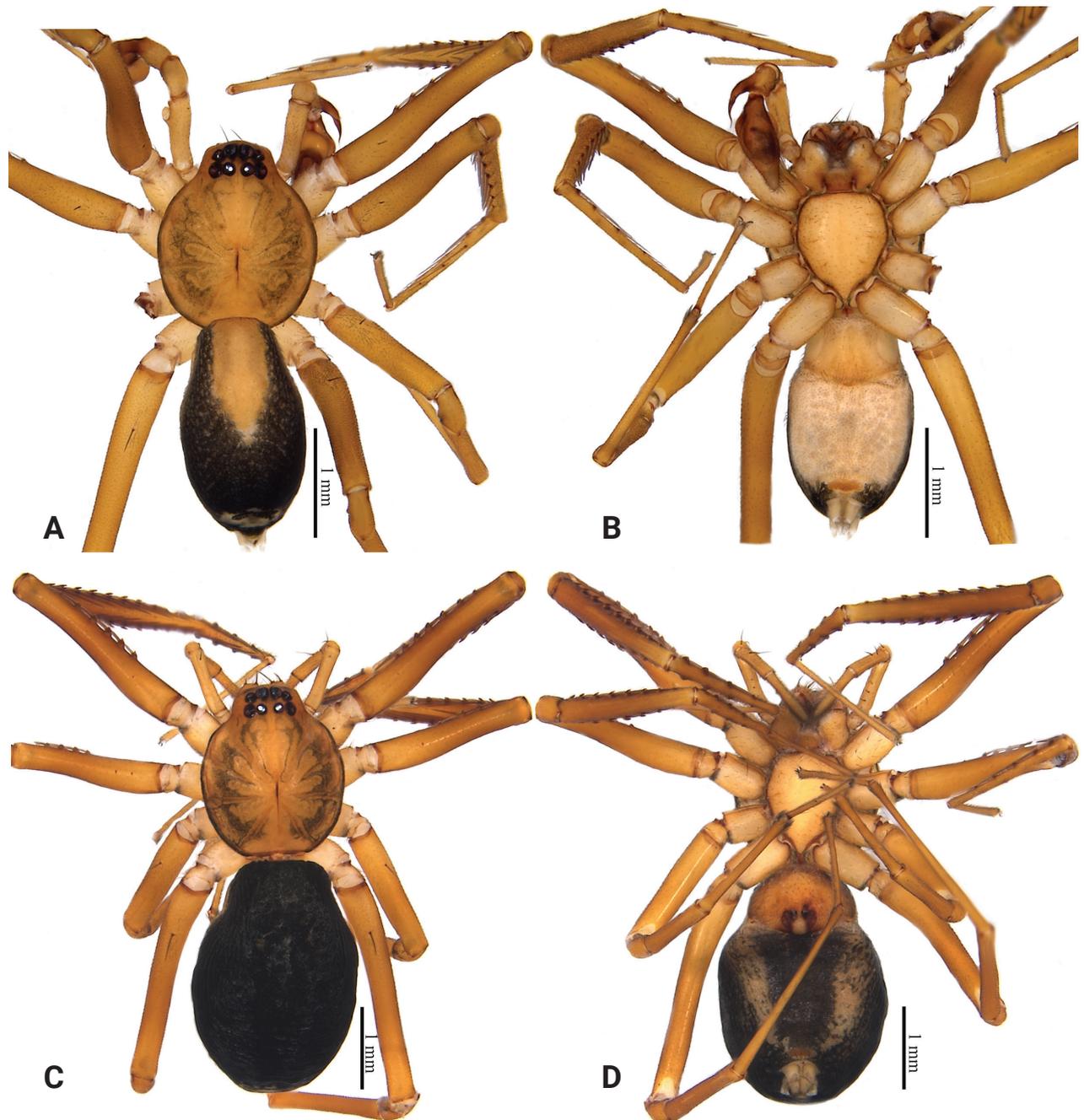


Figure 5. Habitus of *Grandilithus lanxi* sp. nov. **A** male holotype, dorsal view **B** same, ventral view **C** female paratype, dorsal view **D** same, ventral view.

0.67, 2.21, 2.86, 1.20), leg pattern: 4123. Spination: femur I d 1 pl 6, femur II d 2 pl 4, femur III–IV d 1, tibia I pv 10 rv 10, tibia II pv 9 rv 8, metatarsus I pv 4 rv 4, metatarsus II pv 5 rv 4.

Coloration. Carapace slightly darker than male, with several patches resembling flowing droplets beside fovea. Abdomen black. A small, irregular, slightly sclerotized area in front of the spinnerets with black setae. Leg yellow-brown.

Epigyne as in Fig. 6E, F. Epigynal plate slightly sclerotized. Median septum wide, inverted goblet-shaped. Copulatory openings small, separated by median septum. Copulatory ducts thick. Glandular appendages thick, short-cylindrical. Connecting tubes thinner than copulatory ducts, base broad. Bursa

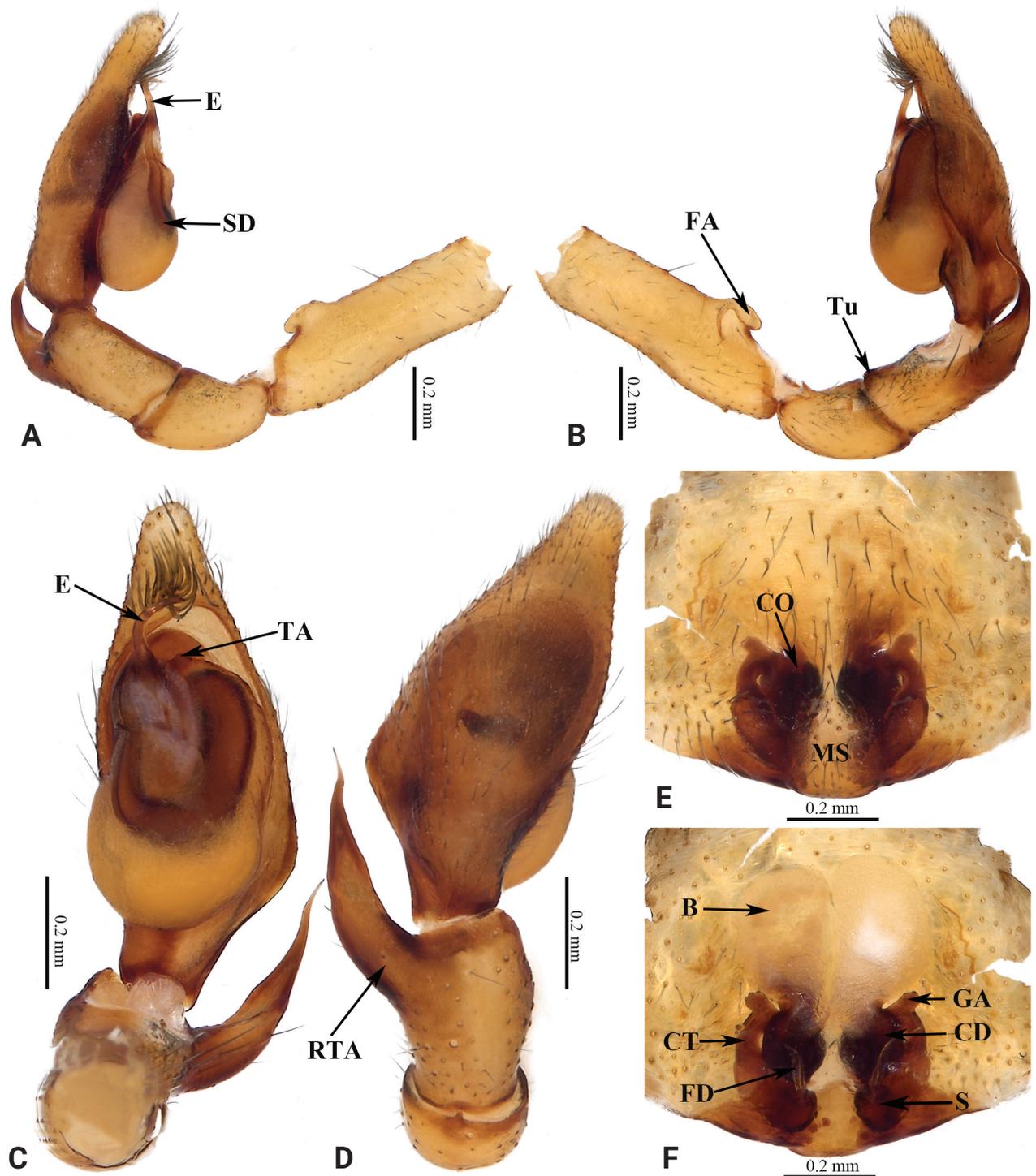


Figure 6. Copulatory organs of *Grandilithus lanxi* sp. nov. **A** male left palp, prolateral view **B** same, retrolateral view **C** same, ventral view **D** same, dorsal view **E** epigyne, ventral view **F** same, dorsal view. Abbreviations: B—bursa; CD—copulatory duct; CO—copulatory opening; CT—connecting tube; E—embolus; FA—femoral apophysis; FD—fertilization duct; GA—glandular appendage; MS—median septum; RTA—retrolateral tibial apophysis; S—spermatheca; SD—sperm duct; TA—tegular apophysis; Tu—tubercle.

nearly reniform, the right one slightly larger than left in dorsal view. Spermathecae oval, slanted, separated from each other. Fertilization ducts located at posterior of spermathecae.

Distribution. China: Jiangxi Province (Fig. 7).

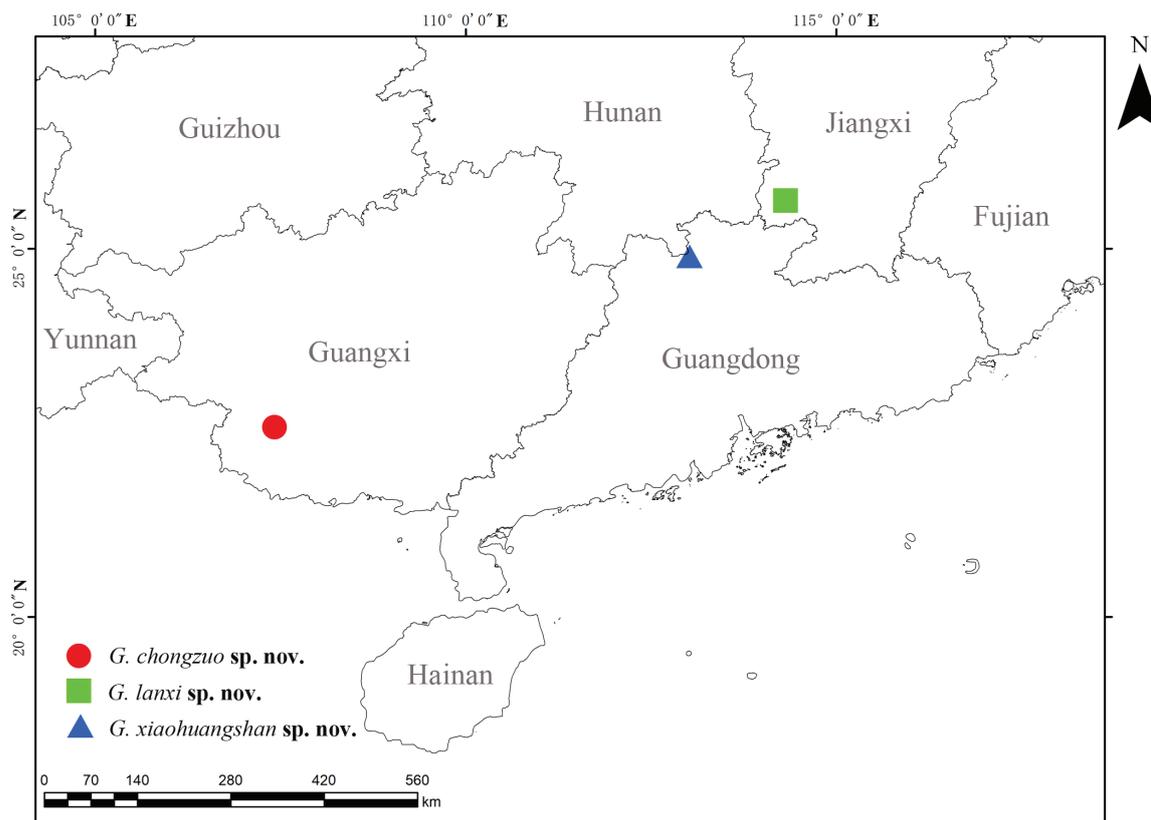


Figure 7. Collection localities of the new *Grandilithus* species described in this paper.

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Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statement

No ethical statement was reported.

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Data availability

All of the data that support the findings of this study are available in the main text.

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The Oriental fungus-feeding genus *Azaleothrips* Ananthakrishnan, 1964 from China with one new species and four new records (Thysanoptera, Phlaeothripidae, Phlaeothripinae)

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Abstract

Azaleothrips, a genus of fungus-feeding Phlaeothripinae, is easily recognized by the complex sculpture on the body surface. It is species-rich in the Oriental region, with 10 species here recognized from China, including *A. sphaericus* sp. nov. and four new records. An illustrated key to the species from China is provided.

Key words: Identification key, mycophagous, *Phlaeothrips*-lineage, taxonomy



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Introduction

The fungus-feeding species in Phlaeothripinae belong to the *Phlaeothrips*-lineage and are usually found in dry, dead leaves, twigs, branches, and grasses (Mound and Marullo 1996). Of the 32 genera in this group recorded from China (Dang et al. 2014), *Azaleothrips* is easily recognized by the following combination of characters: body surface strongly reticulate, with many wrinkles or tubercles in lines (Figs 1–7); major setae short and broadly expanded at apex (Figs 15–19); postocular setae close together and placed near inner margin of eyes; maxillary stylets retracted to eyes and medially close together. This genus was treated as a member of the *Idiothrips* group, with three genera, *Idiothrips*, *Stegothrips*, and *Strepterothrips* (Okajima 1976), of which the first two are unknown in China but easily distinguished from *Azaleothrips*, as indicated by Okajima and Masumoto (2014). *Strepterothrips*, of which only *S. orientalis* of the 15 known species is recorded from Taiwan, is closely related to the genus *Azaleothrips* (Okajima 1995; ThripsWiki 2023), but it can be distinguished by having one sense cone on antennal segment III and a well-developed fore tarsal ventral hamus (Okajima and Masumoto 2014). In addition, *Strepterothrips* species have seven antennal segments, with the morphological VIII joined to VII without a suture, are usually wingless, and have antennal segment II obviously

larger than segment I. In comparison, *Azaleothrips* has antennal segment VIII distinct from VII and with at least a complete suture (Figs 8–14), is usually macropterous, and antennal segment II is regular. A related genus, *Stictothrips*, also shares the complex body sculpture and fan-shaped major setae with *Azaleothrips*, but it has the fore wings curiously constricted and twisted (Mound and Tree 2015).

In the process of identifying slides of *Azaleothrips* from China, two species were recognized, *A. laevigatus* and *A. dentatus*, which seem to be unusual in having the dorsal view of body not heavily reticulate (Fig. 2), the maxillary stylets and mouth cone elongate (Fig. 3), and the major setae relatively longer. These two are similar to females of the genus *Ablemothrips*, with which they share the following characters: postocular setae close, antennal segments VII–VIII fused, antennal segments III–IV with three and four sense cones respectively, and forewings slender and weakly medially constricted. The only character state that distinguishes *Ablemothrips* from the above two species is the sexual dimorphism in the position of the postocular setae, which are widely separated in males of all three *Ablemothrips* species (Okajima 1999). This condition is not recorded in any *Azaleothrips*.

Among the 35 species of *Azaleothrips*, two species groups have been recognized: the *amabilis* species group with nine species, and the *moundi* species group with 26 species (Okajima and Masumoto 2014). In China, only two species have been recorded (Han 1992; Dang et al. 2014), *A. moundi* and *A. siamensis*, but three more were described from Taiwan by Okajima and Masumoto (2014): *A. formosae*, *A. taiwanus*, and *A. atayal*.

The objective here is to recognize species of the Oriental genus *Azaleothrips* in the first author's thrips collection, to describe a new species, and to provide an illustrated key to 10 Chinese *Azaleothrips* species, including four new records for *A. laevigatus*, *A. laocai*, *A. lepidus* and *A. templeri*. The new species, *A. sphaericus* sp. nov., obviously belongs to the *moundi* species group because it has two sense cones on antennal segment III (Fig. 13), closely fused VII–VIII (Fig. 13), no fore-tarsal tooth in either sex, an expanded S2 on male tergite IX (Fig. 28), and many short discal setae on the pronotum and metanotum (Figs 19–21).

Materials and methods

The descriptions and photomicrographs were produced from slide-mounted specimens under a Nikon Eclipse 80i microscope with a Leica DM2500 camera and using differential interference contrast illumination. These images were processed with Automontage and Photoshop v. 7.0. The abbreviations used for the pronotal setae are as follows: am – anteromarginal, aa – anteroangular, ml – midlateral, epim – epimeral, pa – posteroangular. The unit of measurement in this study is the micrometre. Most specimens studied here are available in the School of Bioscience and Engineering, Shaanxi University of Technology (SNUT), Hanzhong, China, the Australian National Insect Collection (ANIC), Canberra, Australia, and the National Zoological Museum of China (NZMC), Institute of Zoology, Chinese Academy of Sciences, Beijing, China. Additionally, two slides of types were loaned from Taiwan Agricultural Research Institute (TARI), Taiwan, China.

Taxonomy

Azaleothrips Ananthkrishnan, 1964

Azaleothrips Ananthkrishnan, 1964: 220. Type species *Azaleothrips amabilis* Ananthkrishnan 1964, by monotypy.

Note. The number of sense cones on antennal segments III–IV is a very diagnostic character in many thysanopteran taxa. Especially in *Azaleothrips*, two species groups were proposed because of two sense cones on III and two or three cones on IV in the *moundi* species group, and three and four on antennal segments III–IV, respectively, in the *amabilis* species group. These numbers vary between species, but are stable within each species. Furthermore, the macropterous forms in this genus are very common, but three species also have micropterae which usually bear three well-developed sub-basal setae, *A. moundi*, *A. simulans* and *A. sphaericus* sp. nov., that all belong to *moundi* species group. The complex sculptures on the body surface are also various ranged from weakly reticulate to strongly reticulate with wrinkles or tubercles inside or along lines. Therefore, these variations are not helpful to give a clear generic diagnosis, but fortunately an excellent one is available in a recent paper (Okajima and Masumoto 2014).

Key to species of *Azaleothrips* from China

A. taiwanus and *A. atayal* are included in the key based on the excellent original descriptions.

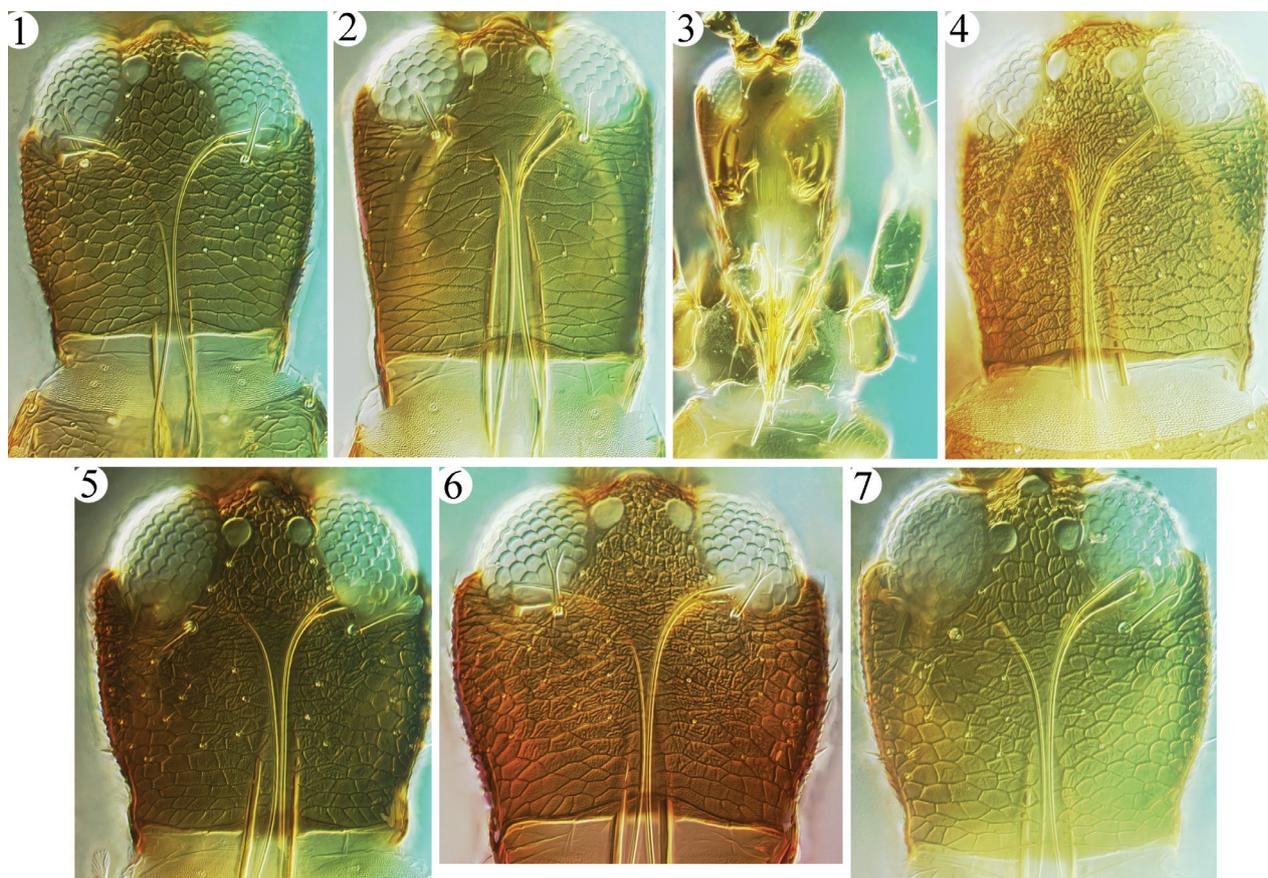
- | | | |
|---|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------|
| 1 | Antennal segment III with two sense cones..... | 2 |
| – | Antennal segment III with three sense cones | 3 |
| 2 | Antennal segment IV with two sense cones (Fig. 11) | <i>A. moundi</i> |
| – | Antennal segment IV with three sense cones (Fig. 13) | <i>A. sphaericus</i> sp. nov. |
| 3 | Fore-femora yellow to pale brown, much paler than head..... | 4 |
| – | Fore-femora brown to dark brown, as dark as head | 6 |
| 4 | Metanotum longitudinally reticulate on anterior half, and with polygonal reticulations on posterior half (Fig. 23) | <i>A. templeri</i> |
| – | Metanotum longitudinally reticulate or striate, and without polygonal reticulations | 5 |
| 5 | S1 setae on abdominal tergite IX slightly shorter than half the length of tube in both sexes | <i>A. lepidus</i> |
| – | S1 setae on abdominal tergite IX longer than half the length of tube in both sexes | <i>A. formosae</i> |
| 6 | Pronotum yellowish brown, at least paler than head..... | <i>A. siamensis</i> |
| – | Pronotum uniformly brown, as dark as head..... | 7 |
| 7 | Head sculptured with very weak lines of reticulation (Fig. 2); mouth-cone long and sharply pointed that reaches to mesopresternum (Fig. 3); S2 on tergite IX sharply pointed at apex in both sexes (Fig. 29) | <i>A. laevigatus</i> |
| – | Head strongly sculptured with reticulation; mouth-cone moderately long that reaches to posterior margin of ferna at most; S2 on tergite IX expanded at apex in female..... | 8 |

- 8 Pronotum sculptured with lines of reticulation as well as many small tubercles along lines **A. taiwanus**
- Pronotum finely reticulated, but almost smooth along reticles, without tubercles..... **9**
- 9 Tergite IX setae S1 much shorter than half of tube length; antennal segment III clearly yellow (Fig. 9)..... **A. laocai**
- Tergite IX setae S1 almost as long as half of tube length; antennal segment III somewhat shaded at apical half..... **A. atayal**

***Azaleothrips atayal* Okajima & Masumoto, 2014**

Azaleothrips atayal Okajima & Masumoto, 2014: 309.

Comments. Described from Taiwan on dead leaves and branches, this species is a member of the *amabilis* species group, as indicated by Okajima and Masumoto (2014). *Azaleothrips atayal* is closely related to another Taiwan species, *A. formosae*, which can be distinguished from *A. formosae* by its darker body; it has also been collected at lower altitudes, as mentioned by Okajima and Masumoto (2014). Unfortunately, no specimen was studied here, but the species is readily placed in the above key using the excellent illustrated description.



Figures 1–7. Heads of *Azaleothrips* species **1** *A. formosae* **2** *A. laevigatus* **3** *A. laevigatus*, ventral view of head **4** *A. sphaericus* sp. nov. **5** *A. lepidus* **6** *A. siamensis* **7** *A. templeri*.

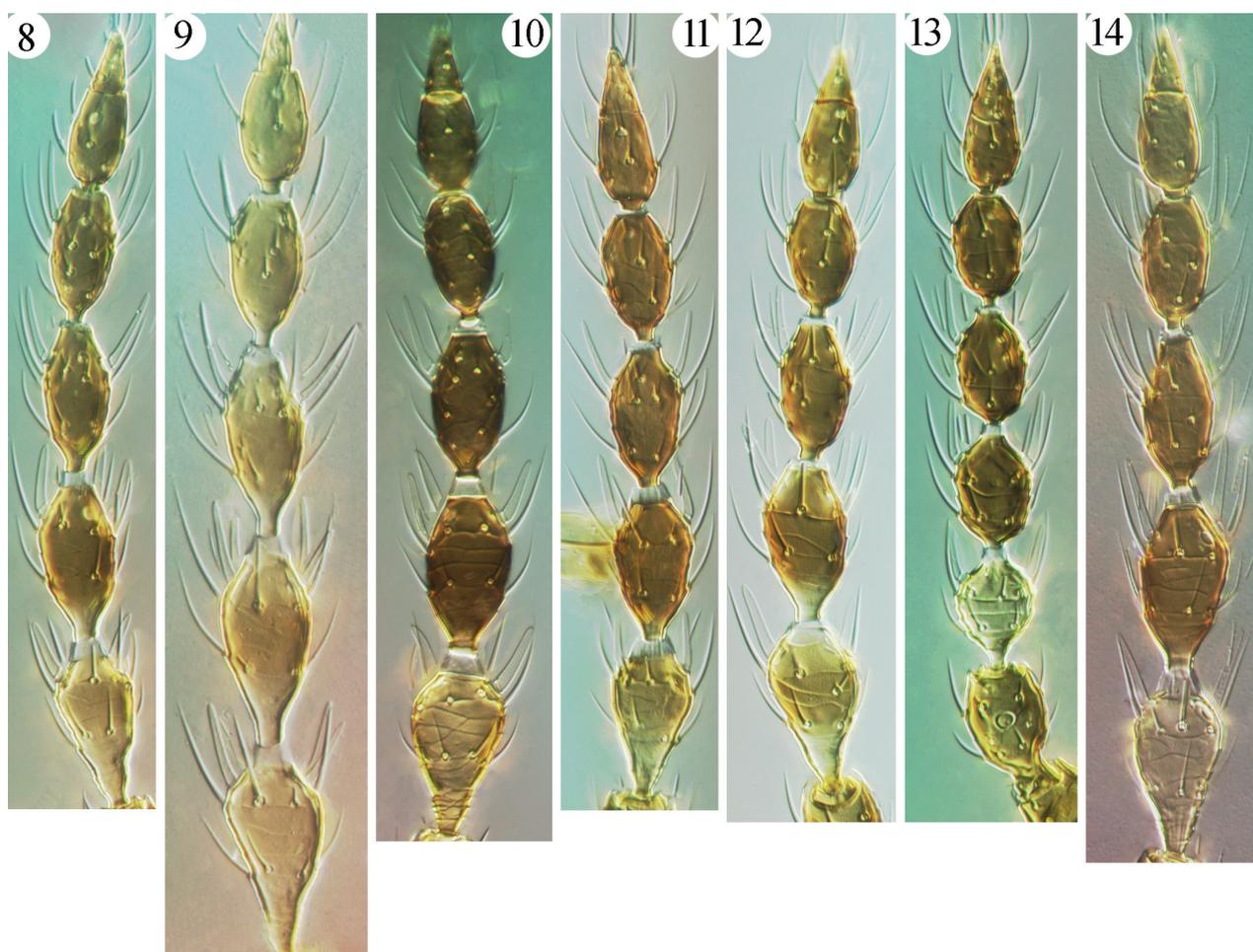
***Azaleothrips formosae* Okajima & Masumoto, 2014**

Figs 1, 8, 15, 27

Azaleothrips formosae Okajima & Masumoto, 2014: 320.

Specimens studied. CHINA – Yunnan • 1♀ (SNUT); Puer, Zhenyuan; on dead leaves; 8.vii.2022; Yanqiao Li leg. • 1♂ (SNUT); Lincang, Cangyuan; on dead leaves; 8.vi.2021; Xia Wang & Chengwen Li leg. • 1♂ (ANIC); Kunming; on bamboo grass; 24.ix.2019; Laurence Mound leg.

Comments. This species was described on many specimens, including types and non-types, from Taiwan that were collected on dead branches. A female and two males from Yunnan are identified as *A. formosae* because they show no difference in their morphology. However, they differ in their coloration; the female has the prothorax largely yellow, like non-paratypic specimens from Kenting National Park (Taiwan), and one male has a brownish prothorax (Fig. 15), slightly paler than the head, and all femora yellowish brown with the apical quarter pale; the other male has a pale prothorax, like the paratypes. Moreover, the pore plate on abdominal sternite VIII is a little broader in the Yunnan specimens (Fig. 27), but S2 setae on tergite IX are pointed at the apex, as in the types.



Figures 8–14. Antennae of *Azaleothrips* species **8** *A. formosae* **9** *A. laocai* **10** *A. laevigatus* **11** *A. moundi* **12** *A. siamensis* **13** *A. sphaericus* sp. nov. **14** *A. templeri*.

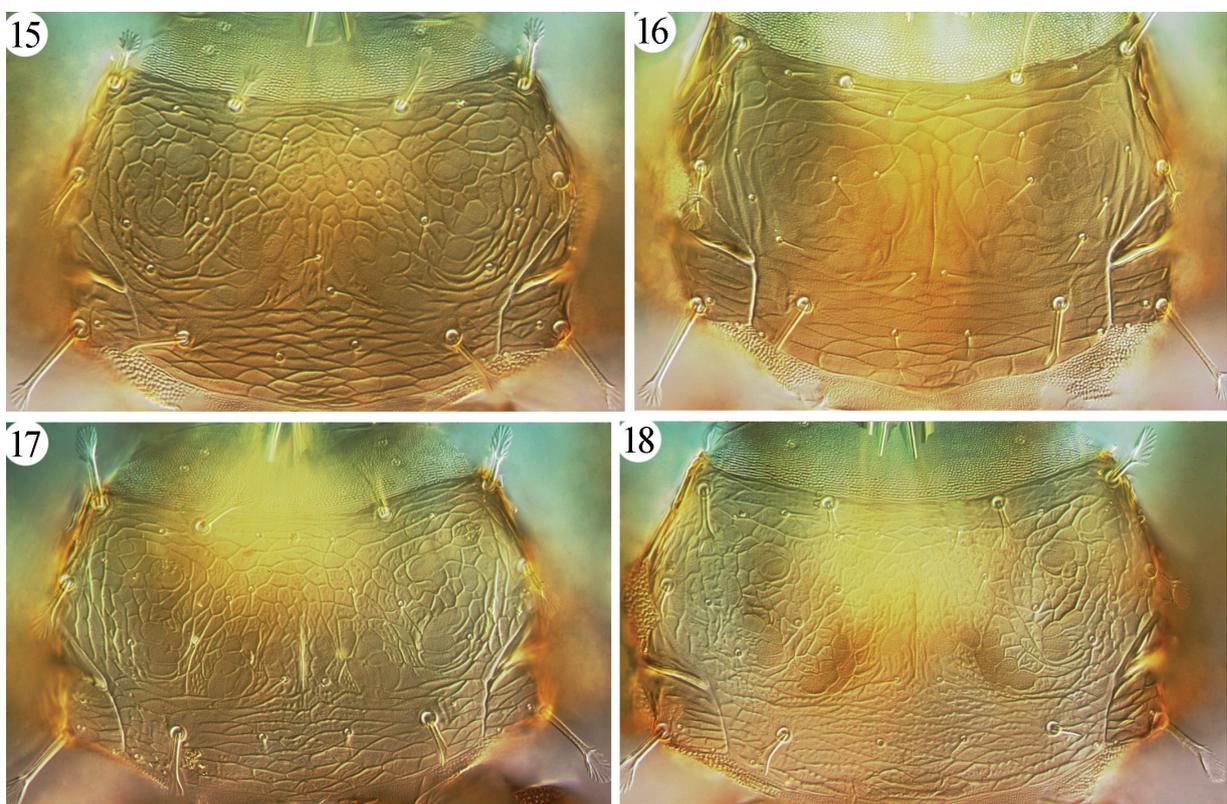
***Azaleothrips laevigatus* Okajima, 2006**

Figs 2, 3, 10, 16, 25, 29

Azaleothrips laevigatus Okajima, 2006: 192.

Specimen studied. CHINA – Guangxi • 1♀1♂ (SNUT); Chongzuo; on dead wood; 9 & 25.vii.2021; Xia Wang leg.

Comments. Described from Japan on dead *Casuarina* branches, this species is distinguished easily from other *Azaleothrips*, except for two Philippine species, *A. philippinensis* and *A. bifidius*, in having S2 on abdominal tergite IX of males pointed at its apex (Fig. 29). *Azaleothrips laevigatus* can be distinguished from these Philippine species by the weaker sculpture on the head and pronotum and transverse pore plate on male sternite VIII (Figs 2, 16, 29). This species is closely related to an Indonesian species, *A. dentatus*, in having weak sculpture on the body surface and shorter major setae, and in the head shape, but in *A. dentatus* the fore-tibia has an apical inner tubercle. Additionally, the head of *A. laevigatus* has weak sculpture, almost straight cheeks, postocular setae close together and slender, and long stylets that reach the eyes (Fig. 2), similar to species of *Ablemothrips*. However, *A. laevigatus* has a long mouth-cone which is sharply pointed and reaching the mesopresternum (Fig. 3), and the postocular setae are also close together in male, while *Ablemothrips* species have the mouth cone short and rounded, and the postocular setae of males are sexually dimorphic and widely separated (Okajima 1999). A female and male from Guangxi, China are recognized as *A. laevigatus* because there is no differences in morphology and coloration, as compared to the original description (Okajima 2006).



Figures 15–18. Pronotum of *Azaleothrips* species 15 *A. formosae* 16 *A. laevigatus* 17 *A. lepidus* 18 *A. siamensis*.

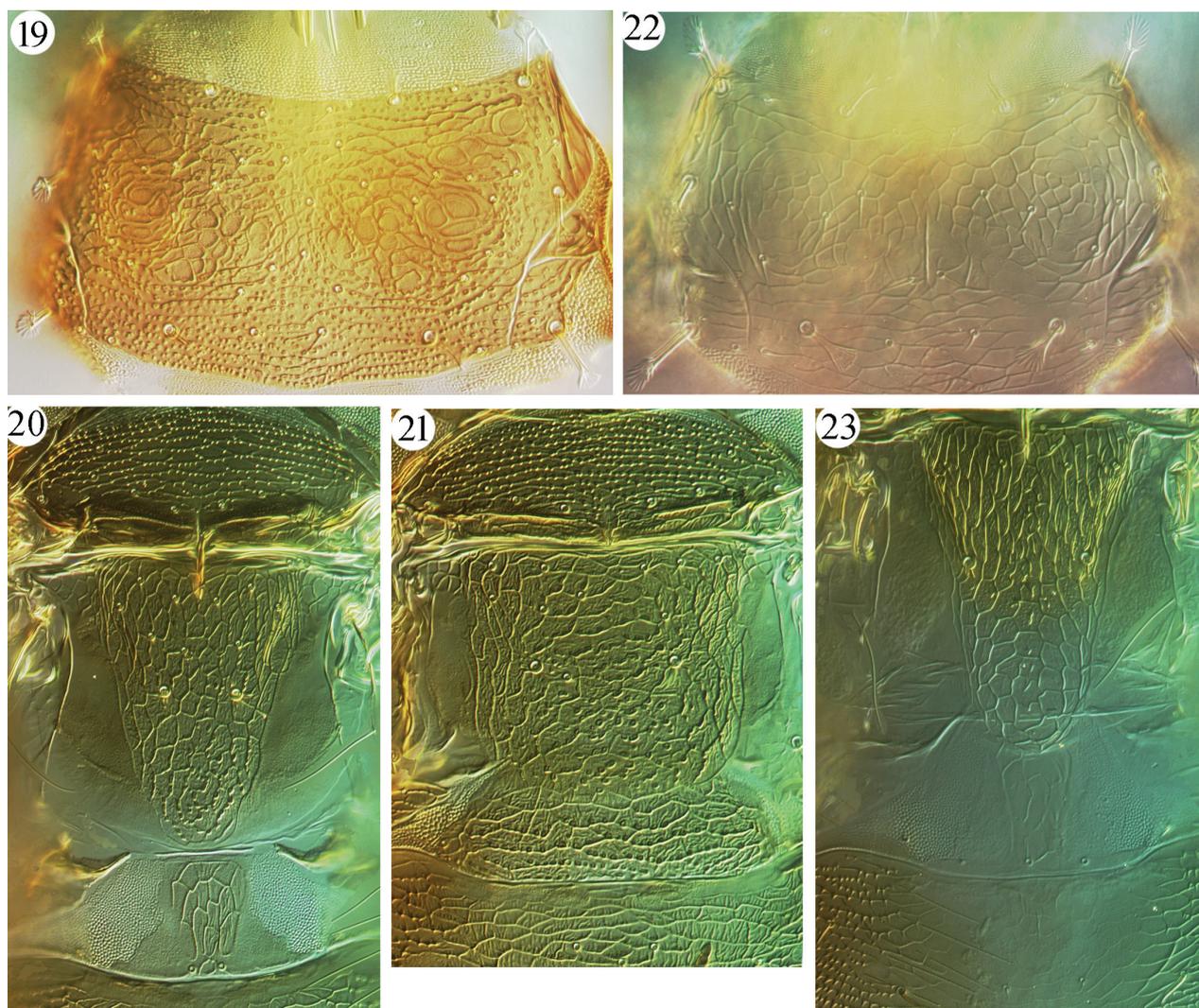
***Azaleothrips laocai* Okajima & Masumoto, 2014**

Fig. 9

Azaleothrips laocai Okajima & Masumoto, 2014: 325.

Specimens studied. CHINA – Shaanxi • 1♀ (SNUT); Hanzhong; on dead leaves; 20.vii.2017; Lihong Dang leg. • 1♀ (SNUT); Yanan; 25.vii.2019; Weiyan Liu leg.

Comments. *Azaleothrips laocai* was described from Vietnam on dead branches. It belongs to the *amabilis* species group, which bears three and four sense cones on antennal segments III and IV, respectively. Currently, this species has the largest body size of any known *Azaleothrips* species, with two females from Shaanxi, China about 2270–2350 µm in body length, whereas the body lengths of other *Azaleothrips* species are usually no more than 2000 µm. These two females from Shaanxi show a little difference in antennae coloration; segment IV is brown, with the apex and base pale, as well as the base of V pale (Fig. 9), but in the original description of *A. laocai* the basal neck of IV is yellowish and V is uniformly brown.



Figures 19–23. *Azaleothrips* species **19–21** *A. sphaericus* sp. nov. **19** pronotum **20** mesonotum, metanotum, and pelta of macropteran female **21** mesonotum, metanotum, and pelta of micropterous female **22–23** *A. templeri* **22** pronotum **23** metanotum and pelta, macropterous female.

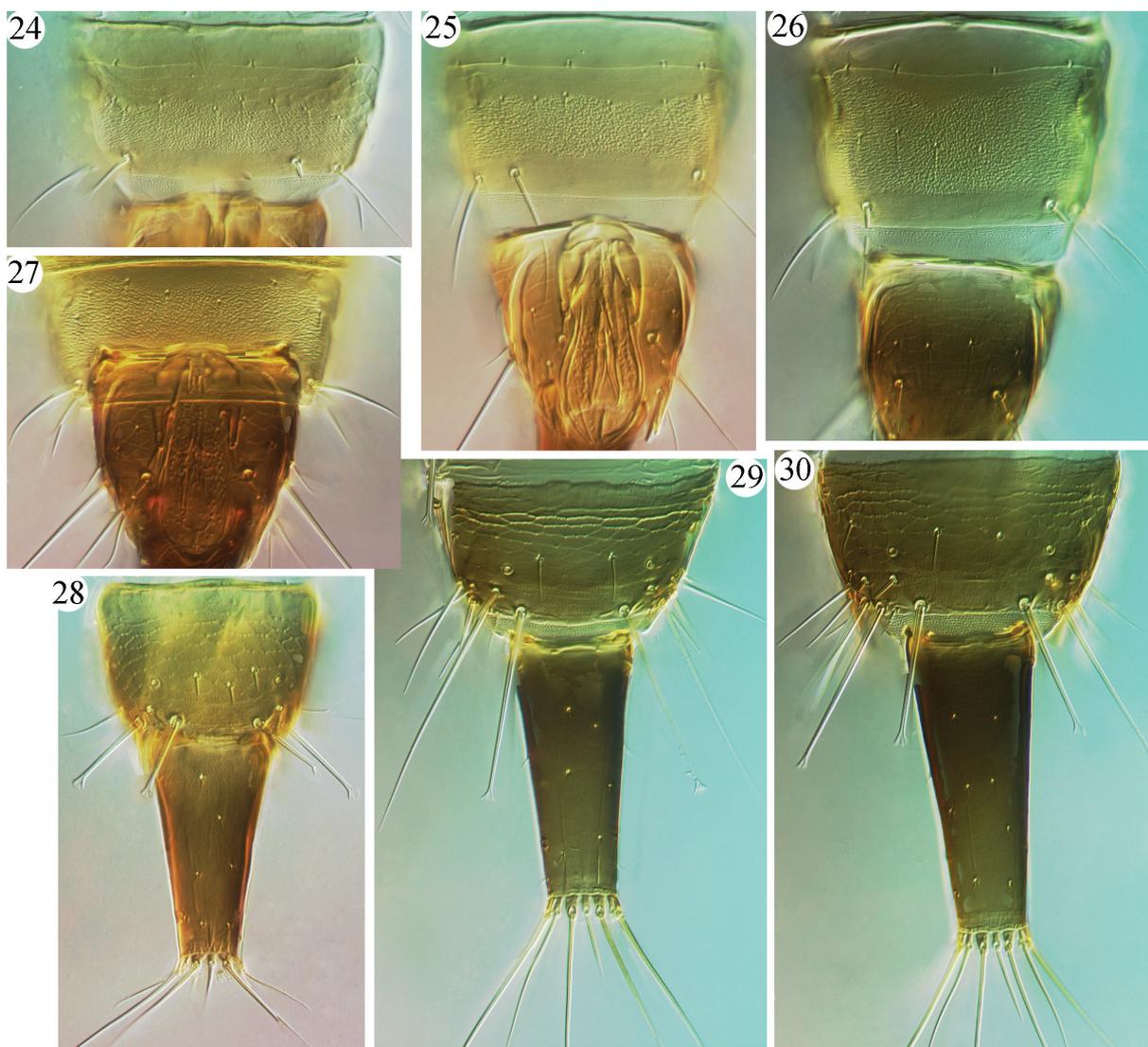
***Azaleothrips lepidus* Okajima, 1978**

Figs 5, 17, 26

Azaleothrips lepidus Okajima, 1978: 386.

Specimens studied. CHINA – Yunnan • 1♀1♂ (SNUT); Lincang; on dead branches; 4 & 7.vi.2021; Xia Wang & Chengwen Li leg. LAOS – Champasak • 4♀1♂ (ANIC); on dead wood; 12.vi.2018; Alice Wells leg.

Comments. Described from Thailand on dead leaves, this species is here newly recorded from China. *Azaleothrips lepidus* is very similar to *A. toshifumii*, with which it is sympatric, but they can be distinguished by the coloration of antennae and legs (Okajima and Masumoto 2014). Two specimens from China have antennal segment IV uniformly brown, fore-coxae and femora largely yellow, with outer side shaded, and the mid- and hind-tibiae slightly medially shaded. Especially, their antennal segment III is clear yellow, as are the specimens from Laos, which were originally described as yellow to yellowish brown (Okajima 1978).



Figures 24–30. Abdomen of *Azaleothrips* species **24–27** pore plate on sternite VIII **24** *A. sphaericus* sp. nov. **25** *A. laevigatus* **26** *A. lepidus* **27** *A. formosae* **28–30** tergites IX–X **28** *A. sphaericus* sp. nov. **29** *A. laevigatus* **30** *A. siamensis*.

***Azaleothrips moundi* Okajima, 1976**

Fig. 11

Azaleothrips moundi Okajima, 1976: 19.

Specimens studied. CHINA – **Taiwan** • 2♀ (TARI, female holotype and paratype of '*magnus*'); Taipei, Hsien; on dead twigs of *Morus australis*; 12.viii.1978; Lian-sheng Chen leg. **Sichuan** • 1♀ (SNUT); Chengdu; on dead leaves; 14.viii.2021; Xin Li leg. **Shanxi** • 1♂ (SNUT); Jincheng, Mishui; 16.vi.2022; Yuxin Gao leg.

Comments. This species, one of the two species from China that belong to the *moundi* species group, was described from Japan and Taiwan on dead twigs. It is unique in *Azaleothrips* because antennal segments III–IV both have two major sense cones (Fig. 11). The holotype female and paratype male of *A. magnus* Chen, 1980, which was synonymized with *A. moundi* by Okajima and Masumoto (2014), were here studied, but both specimens had crack inside the balsam that seems to have allowed entry of air under the cover slip. These specimens have the third antennal segment III clear yellow, as in the original description of *A. moundi*. Two micropterous female and male from Sichuan and Shanxi recognized here as *A. moundi* have antennal segment III shaded on apical half. This was also noted for *A. Lepidus*, as mentioned above.

***Azaleothrips siamensis* Okajima, 1978**

Figs 6, 12, 18, 30

Azaleothrips siamensis Okajima, 1978: 389.

Specimens studied. CHINA – **Guangxi** • 1♀ (SNUT); Chongzuo, Daxin; on dead wood; 25.vii.2021; Xia Wang leg. **Yunnan** • 4♀1♂ (NZMC); Mengla; one dead branch; 10 & 17.iv.1997; Yunfa Han leg. **Chongqing** • 1♀ (NZMC); one dead branch; 1.viii.1999; Yunfa Han leg.

Comments. Described from northern Thailand on dead leaves, this species was first recorded from China, Guizhou, by Han (1992). Here, six females and one male each from Guangxi, Chongqing, and Yunnan suggest that this species may be common in southern China. These specimens have much paler pronotum (Fig. 18) and shorter anal setae than the specimens described from Thailand in the original description (Okajima 1978), but no other differences have been observed.

***Azaleothrips sphaericus* sp. nov.**

<https://zoobank.org/43025455-5059-4D41-82A1-7E538200640D>

Figs 4, 13, 19–21, 24, 28

Specimens studied. **Holotype**, CHINA – **Guangxi** • ♀ macroptera (SNUT); Chongzuo, Fusui; on dead branch; 8.viii.2021; Xia Wang leg. **Paratypes**, CHINA – **Guangxi** • 1♀ macroptera (SNUT); Nanning, Wuming; 18.vii.2021; Xia Wang leg. • 3♀ microptera (SNUT, ANIC); Chongzuo, Daxin; 25.vii.2021; Xia Wang leg. • 1♂ microptera (SNUT); Nanning, Shanglin; 18.vii.2021; Xia Wang leg.

Description. Holotype. Female macroptera. Body uniform brown. Antennal segment III clear yellow (Fig. 13); other segments brown, but I–II slightly lighter than head. All femora brown, with apices and extreme bases yellowish; all tibiae brown at middle, with apices and bases yellowish; mid- and hind-tibiae slightly paler. Fore-wing shaded with brown, paler in basal quarter.

Head (Fig. 4). Head distinctly longer than wide; dorsal surface strongly sculptured with reticles, with scattered small wrinkles among reticles, especially between postocular setae. Compound eyes comparatively small, about 0.3 times as long as head. Postocular setae shorter than half length of eyes. Antennal segments VII and VIII tightly fused (Fig. 13); median segments spherical, III smaller than IV; segment III with two (1 + 1), segment IV with three (1 + 2) sense cones.

Thorax (Figs 19, 20). Pronotum distinctly sculptured with rows of small tubercles, but median portion with distinctive circular sculpture; pronotum with 26 short setae (Fig. 19). Basantra present, but weak. Mesonotum with small, dentate microtrichia or tubercles along transverse lines of sculpture, almost smooth between lines (Fig. 20). Metanotum with polygonal reticulations, with delicate wrinkles within reticles, and with small tubercles along lines of reticles on posterior quarter (Fig. 20); anterior half with 15 short setae, including three pairs in anterior angles. Mesopresternum boat-shaped but narrowed laterally. Metathoracic sternopleural suture present. Fore-tarsus unarmed. Fore-wing contracted medially with 4/7 duplicated cilia; subbasal setae S3 longer than S1 and S2, but much shorter than the contracted portion of fore-wing.

Abdomen (Figs 24, 28). Pelta distinctly medially reticulate, with delicate wrinkles within reticles (Fig. 20). Abdominal tergites II–VII weakly sculptured with transverse reticles or lines, dentate microtrichia in lateral third, with two pairs of wing-retaining setae; posterior pair much larger than anterior pair. Tergite VIII with a pair of small setae medially; tergite IX with four short setae at middle (Fig. 28); S1 setae on tergite IX a little shorter than half length of tube, expanded at apex (Fig. 28); S2 slightly longer than S1, expanded at apex (Fig. 28); S3 as long as tube, pointed at apex. Tube short, about 0.6 times as long as head. Anal setae longer than tube.

Measurements (holotype female in μm). Body length 1580. Head length 170, width across cheeks 165. Compound eye dorsal length 55. Pronotum length 110, width 200. Fore wing length 550. Tube length 105, width across base 55, apical width 30. Antenna length 270, segments I–VIII length (width) as follows: 30 (30), 40 (30), 35 (28), 40 (28), 37 (25), 37 (25), 30 (20), 20 (15). Postocular setae about 23. S1–S3 on tergite IX 43, 53, 115. Anal setae 115.

Female microptera. Color and structure similar to macropterous female, but tubercles on lines of reticles in most part of head, metanotum, pelta, and posterior median portion of tergites II–VII; metanotum and pelta broad (Fig. 21); eyes and two pairs of wing-retaining setae relatively small.

Measurements (paratype micropterous female in μm). Body length 1470. Head length 180, width across cheeks 170. Compound eye dorsal length 45. Pronotum length 125, width 210. Fore wing length 125. Tube length 100, width across base 55, apical width 30. Antenna length 305, segments I–VIII length (width) as follows: 30 (30), 42 (30), 35 (27), 40 (27), 40 (27), 40 (27), 27 (20), 25 (17). Postocular setae about 25. S1–S3 on tergite IX 37, 67, 110. Anal setae 125.

Male microptera. Color and structure very similar to micropterous female, but mid- and hind-tibiae yellow with slightly shaded medially. Pore plate on abdominal sternite VIII distinct, narrow (Fig. 24). S2 on abdominal tergite IX expanded at apex, slightly longer than S1.

Measurements (paratype micropterous male in μm). Body length 1350. Head length 170, width across cheeks 155. Compound eye dorsal length 45. Pronotum length 120, width 185. Fore wing length 100. Tube length 95, width across base 50, apical width 25. Antenna length 260, segments I–VIII length (width) as follows: 27 (27), 35 (27), 30 (27), 35 (25), 35 (25), 35 (25), 27 (20), 22 (15). Postocular setae 20. S1–S3 on tergite IX 35, 40, 95. Anal setae 105.

Etymology. Latin, *sphaericus*, referring to the spherical antennal segment III.

Comments. This new species is unusual among *Azaleothrips* species in having antennal segment III almost spherical and smaller than IV, a condition somewhat similar with some *Strepterothrips* species. The new species is similar to *A. phuketanus* and *A. simulans* in having two and three sense cones on antennal segments III and IV, respectively, but it differs from *A. phuketanus* in having antennal segment III shorter than IV (Fig. 13), the anterior part of metanotum with 15 small setae before the major pair of setae, whole of pronotum covered with tubercles (Figs 19, 20), and S1 setae of tergite IX shorter than one-half the length of the tube (Fig. 28); in *A. phuketanus* antennal segment III is much longer than IV, the anterior part of metanotum bears seven small setae before the major pair of setae, the pronotum only has tubercles posterior to median, and S1 setae of tergite IX is longer than half the length of tube. It is distinguished from *A. simulans* in having antennal segments I–II concolorous with the head, VI uniformly brown, antennal segment III shorter than IV (Fig. 13), the dorsal surface of head reticulate and without an asperate area (Fig. 4), the metanotum with wrinkles among reticles and the anterior part of metanotum with 15 small setae before the major pair of setae (Fig. 20), and a hat-shaped pelta; in *A. simulans* antennal segments I and II are paler than the brown head, the basal neck of VI is yellow, antennal segment III much longer than IV, the dorsal surface of the head is reticulate but medially is aspirate and not reticulate, the metanotum is strongly asperate and without lines of reticulation at centrally, the anterior part of metanotum has at most 10 small setae before the major pair of setae, and the pelta is trapezoid. It is also similar to *A. moundi* in having antennae brown and only with III yellow and with two sense cones, in sculpture of the head and pronotum, and setae on tergite IX, but these species can be distinguished as follows. *Azaleothrips sphaericus* has antennal segment IV with three major sense cones, antennal segment III spherical, with a short stem (Fig. 13) which is almost as long as wide, antennal segment IV uniformly brown, postocular setae about half length of the eyes (Fig. 4), apices and bases of all tibiae pale, light brown, and pelta with tubercles on lines of transverse reticulation in microptera (Fig. 21); in *A. moundi* antennal segment IV has two major sense cones, antennal segment III is not spherical and longer than wide, basal neck of IV is paler, postocular setae shorter than one-half length of the eyes, all tibiae brown to dark brown, apices and bases of mid- and hind-tibia pale, and pelta polygonally reticulate in microptera.

***Azaleothrips taiwanus* Okajima & Masumoto, 2014**

Azaleothrips taiwanus Okajima & Masumoto, 2014: 342.

Comments. Described from Taiwan on dead branches, this species was not satisfactorily distinguished from another Taiwan species, *A. atayal*, in the original description (Okajima and Masumoto 2014). The only difference between these two species is the presence or absence of many small tubercles in the reticulation of head and pronotum, as indicated in the above key.

***Azaleothrips templeri* Okajima & Masumoto, 2014**

Figs 7, 14, 22, 23

Azaleothrips templeri Okajima & Masumoto, 2014: 342.

Specimens studied. CHINA – **Guangxi** • 1 ♀ (SNUT); Qianzhou, Shiwandashan; 5.viii.2015; Chunfeng Li leg. LAOS – **Champasak** • 1 ♂ (ANIC); on dead leaves of Cordyline; 12.vi.2018; Alice Wells leg.

Comments. Described from West Malaysia on dead leaves, this species is similar to *A. lepidus* in having pale pronotum (Fig. 22) and fore-femora, but *A. templeri* can be easily distinguished from other Chinese species of *Azaleothrips*. It is distinguished by the presence of polygonal reticulation on the posterior half of the dorsal surface of metathorax (Fig. 23). A female from Guangxi is identified as *A. templeri*, and this is the first record of the species from China. A male from Laos is also recognized here as this species.

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Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statement

No ethical statement was reported.

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Author contributions

Lihong Dang: writing the original draft. Yaya Li: making slides and preparing images plates, Laurence Mound: reviewing and editing the manuscript and taking images. Gexia Qiao: reviewing final manuscript and funding support. All authors have read and agreed to the published version of the manuscript.

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Data availability

All of the data that support the findings of this study are available in the main text.

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Two new species of the bamboo-feeding planthopper genus *Neobelocera* Ding & Yang from China (Hemiptera, Fulgoromorpha, Delphacidae)

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Abstract

Two new species of the bamboo-feeding genus *Neobelocera* Ding & Yang, 1986, *N. furcata* **sp. nov.** and *N. parvula* **sp. nov.**, are described and illustrated from China. A key based on the male genitalia is given to distinguish species of this genus and a map provided to show their geographic distribution. Habitus photos for adults and illustrations of male genitalia are also given.

Key words: Fulgoromorpha, identification key, morphology, oriental region, taxonomy



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Introduction

Neobelocera is an Oriental bamboo-feeding planthopper genus, belonging to tribe Tropidocephalini under subfamily Delphacinae (Hemiptera, Fulgoroidea, Delphacidae). It was established by Ding and Yang (Ding et al. 1986) with type species *Neobelocera asymmetrica* Ding & Yang, 1986. This genus is only known to occur in southern China. Species in the genus exhibit morphological diversity in male genitalia. Detailed generic characteristics and a key for the identification of species in the genus were provided by Chen and Liang (2005). Subsequently, the genus and three species, *N. asymmetrica*, *N. zhejiangensis* (Zhu, 1988) and *N. hanyinensis* Qin & Yuan, 1998, were redescribed in a monograph on Delphacidae of China (Ding 2006). Hou and Chen (2010) revised the genus again and increased it to six species. Hu and Ding (2014) described a new species from Tibet, China. Recently, Li et al. (2020) updated the identification key of this genus and added two new species from southwest China, which led to total of nine species, viz., *N. asymmetrica* Ding & Yang, 1986, *N. zhejiangensis*

(Zhu, 1988), *N. hanyinensis* Qin & Yuan, 1998, *N. lanpingensis* Chen, 2003, *N. laterospina* Chen & Liang, 2005, *N. lii* Hou & Chen, 2010, *N. medogensis* Hu & Ding, 2014, *N. biprocessa* Li, Yang & Chen, 2020 and *N. russa* Li, Yang & Chen, 2020.

Currently the tribe Tropidocephalini includes 201 species in 37 genera, of which 113 species in 23 genera occur in China (Ren et al. 2014; Bourgoïn 2023). Of the Chinese genera of the tribe, *Belocera* Muir, 1913 and *Neobelocera*, have the antennae flattened, sagittate or subsagittate. A comparison of *Neobelocera* and *Belocera* shows that species in these genera look rather similar, but the two genera can be easily distinguished by the following characters: first segment of antennae with the apex unequally bifurcate, ventral apical angle much longer than dorsal apical angle, with median longitudinal carina (in *Belocera*, apex of first segment of antennae equally bifurcate, ventral apical angle subequal to dorsal apical angle, without median longitudinal carina); postclypeus in profile, apical part of median carina roundly bent (in *Belocera*, postclypeus in profile, apical part of median carina and lateral carinae sharply bent); rostrum very short, only reaching mesotrochanters (rostrum surpassing mesotrochanters in *Belocera*); and the surface of the forewing often has blackish-brown markings, in the dark portion veins bear white or yellowish-white spots (in *Belocera*, forewing often with a fuscous central longitudinal fascia, costal area light yellowish white).

Herein, two new species of *Neobelocera*, *N. furcata* sp. nov. and *N. parvula* sp. nov., are described and illustrated from Guizhou and Yunnan provinces, China. A key for identifying the species is provided and a map showing the geographic distribution of the species is also given.

Material and methods

The morphological terminology follows Yang and Yang (1986). Dry male specimens were used for the description and illustration. External morphology was observed under a stereoscopic microscope and characters were measured with an ocular micrometer. Color pictures for the adult habitus were obtained using the KEYENCE VHX-6000 system. The genital segments of the examined specimens were macerated in 10% KOH and drawn from preparations in glycerin jelly using a Leica MZ 12.5 stereo microscope. Illustrations were scanned with a Canon CanoScan LiDE 200 and imported into Adobe Photoshop 6.0 for labeling and plate composition.

The type specimens of the new species are deposited in the Institute of Entomology, Guizhou University, Guiyang, China (GUGC).

Taxonomy

Genus *Neobelocera* Ding & Yang, 1986

Figs 1–31

Neobelocera Ding & Yang, in Ding et al. 1986: 420; Chen and Liang 2005: 374; Ding 2006: 196; Hou and Chen 2010: 40; Li et al. 2020: 3.

Type species. *Neobelocera asymmetrica* Ding & Yang, 1986.

Diagnosis. *Neobelocera* can be distinguished from other related genera of Tropidocephalini by the following characters: antennae with first segment

subsagittate, markedly flattened, a longitudinal carina down middle, the ventral apical angle longer than dorsal apical angle (Figs 5, 8, 21, 24); when postclypeus viewed in profile, apical part of median carina roundly bent (Figs 4, 20); rostrum very short, only reaching mesotrochanters (Ding et al. 1986; Chen 2003; Chen and Liang 2005; Hou and Chen 2010; Hu and Ding 2014; Li et al. 2020).

Host plant. Bamboo.

Distribution. Oriental region (China).

Key to species (males) of *Neobelocera* Ding & Yang, 1986 (revised from Li et al. 2020)

- 1 Forewings yellowish white, hyaline, with a small dark-brown markings on furcation of ScP (Hu and Ding 2014: fig. 10)..... ***N. medogensis* Hu & Ding, 2014**
- Forewings with blackish-brown markings, with veins with white spots or white short stripes at intervals (Figs 6, 22) **2**
- 2 Frons with pale transverse band below level of lower margin of eyes (Figs 5, 21) **3**
- Frons without transverse band (Chen and Liang 2005: fig. 10) **8**
- 3 Ventral margin of pygofer with medioventral process (Figs 12, 25) **4**
- Ventral margin of pygofer concave medially, without process **7**
- 4 Anal segment (Fig. 27) with a long ventral process medially ***N. parvula* sp. nov.**
- Anal segment (Fig. 9) without process **5**
- 5 Genital styles with apex forked (Figs 13, 14) ***N. furcata* sp. nov.**
- Genital styles with apex not forked **6**
- 6 Frons with some short, yellowish-white transverse stripes subapically; genae with 2 or 3 light brown spots (Li et al. 2020: fig. 3E); pygofer with medioventral processes short, median one slightly longer than lateral ones (Li et al. 2020: fig. 4D) ***N. russa* Li, Yang & Chen, 2020**
- Frons without yellowish-white transverse stripe subapically; genae without light brown spot (Chen 2003: fig. 3); medioventral processes of pygofer with median one short, lateral ones very slender and long (Chen 2003: fig. 4) ***N. lanpingensis* Chen, 2003**
- 7 Phallus with basal half broad, compressed, apical half slender, tubular, acute at apex, with process at basal $\frac{1}{3}$ and node subapically; phyllobase with long straight spinous process basally and three processes apically (Li et al. 2020: fig. 2G) ***N. biprocessa* Li, Yang & Chen, 2020**
- Phallus slender, tubular, rounded at apex, without process and node; phyllobase slender, without processes (Ding et al. 1986: figs 6–4) ***N. asymmetrica* Ding & Yang, 1986**
- 8 Median carina of vertex, pronotum, mesonotum and frons white bordered, dark brown to blackish brown (Chen and Liang 2005: figs 9, 10) **9**
- Not as above, forewings at basal part and hind margin of apical part with blackish-brown markings (Hou and Chen 2010: fig. 19); ventral margin of pygofer concave medially, lateral side of which each with a short process (Hou and Chen 2010: fig. 24) ***N. lii* Hou & Chen, 2010**
- 9 Pygofer with ventral margin concave medially, on lateral side each with a long, slender process (Chen and Liang 2005: fig. 12); genital styles slender

- and long, with a spine-like process subapically (Chen and Liang 2005: figs 15, 16) ***N. laterospina* Chen, 2003**
- Pygofer with ventral margin without any process (Qin and Yuan 1998: fig. 1D)..... **10**
- 10 Genital styles long, parallel and slightly sinuate, with inner apical angle acute, without processes (Ding 2006: fig. 100C)
..... ***N. zhejiangensis* (Zhu, 1988)**
- Genital styles rather robust, apex acute, with branch lateral process terminating with 3–5 spinose processes (Qin and Yuan 1998: fig. 1F–G)
..... ***N. hanyinensis* Qin & Yuan, 1998**

***Neobelocera furcata* sp. nov.**

<https://zoobank.org/319D0F23-29CB-499D-B03E-D216DC93BA42>

Figs 1–16

Type materials. *Holotype* ♂, CHINA: Guizhou, Wengan County (26°985'N, 107°646'E), on bamboo, 5 Aug. 2020, S.S. Lv leg.; *paratypes*, 1♂, 1♀, same data as holotype.

Etymology. The species epithet is derived from the Latin word '*furcata*', referring to the genital styles forked at the apex. It is a feminine in gender.

Measurements. Body length including forewing: male 3.8–3.9 mm (*N* = 2), female 4.0 mm (*N* = 1).

Diagnosis. Forewings (Fig. 6) with blackish-brown markings, of which veins with white spots or white short stripes at intervals. Frons (Fig. 5) with pale transverse band below level of lower margin of eyes. Ventral margin of pygofer (Fig. 12) with 3 medioventral processes, lateral ones short, tapering, median one forked at apex, with 4 processes on each side and the middle two much smaller. Anal segment (Fig. 9) without process. Genital styles (Figs 13, 14) with apex forked, outer angle about twice as long as inner angle.

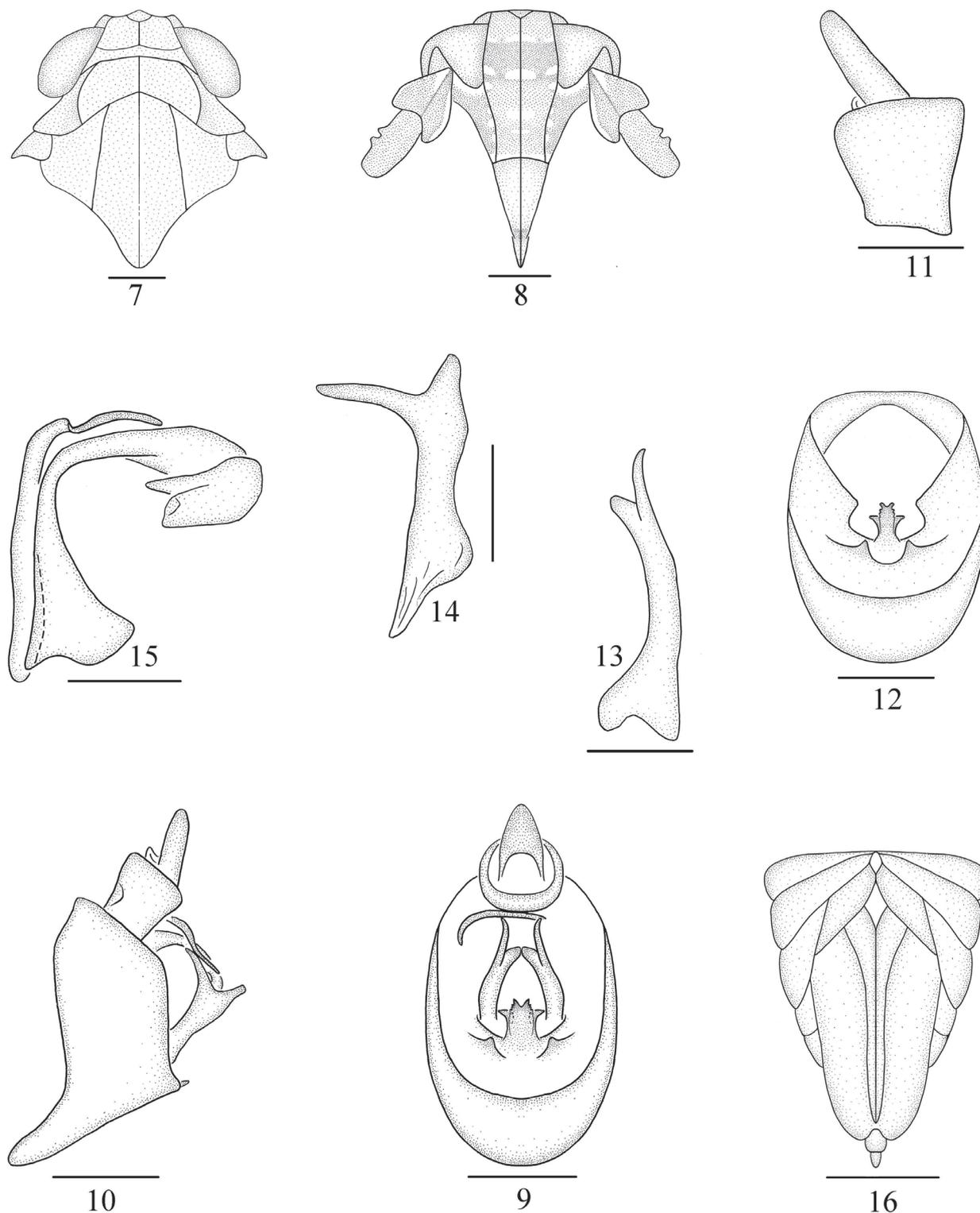
Description. Coloration. General coloration yellowish brown to dark brown (Figs 1–6). Vertex, pronotum, mesonotum (Fig. 3) dirty yellowish brown, with apex of scutellum yellowish white. Frons, genae and clypeus (Fig. 5) yellowish brown to dark brown, except broad transversal stripe below level of lower margin of eyes and narrow stripe on apex of frons yellowish white, near apex of median carina of frons and inner margin of lateral carinae of genae with several short transversal stripes yellowish white. Eyes and ocelli (Figs 4, 5) reddish brown. Antennae (Figs 3–5) yellowish brown to dark brown, except lateral margins of first segment and apex of second segment yellowish white. Legs (Fig. 5) yellowish white, with dark brown maculations. Forewing (Fig. 6) almost hyaline, along MP vein to apex with dark-brown markings, veins dark brown, with white spots at intervals. Wings hyaline, with veins dark brown. Abdomen yellowish brown to dark brown.

Head and thorax. Head including eyes slightly narrower than pronotum, in profile obtusely rounded into frons (Figs 3, 4). Vertex (Figs 3, 7) broad transversely, wider at base than long medially about 2.36: 1, width at apex narrower than at base about 1: 1.84, anterior margin produced medially, Y-shaped carina distinct. Frons (Figs 5, 8) in mid line longer than wide, at widest part about 1.93: 1, widest above level of lower margin of eyes, median carina forked at ex-



Figures 1–6. *Neobelocera furcata* sp. nov. **1** male adult, dorsal view **2** same, lateral view **3** head and thorax, dorsal view **4** same, lateral view **5** face **6** forewing. Scale bars: 0.5 mm (1–6).

treme base. Postclypeus (Figs 5, 8) wider at base than frons at apex. Antennae (Figs 5, 8) reaching median part of postclypeus, basal segment shorter at mid-line than second segment about 1: 1.35, second segment long oval, somewhat compressed, longer than wide about 2.28: 1. Pronotum (Figs 3, 7) tricarinate, with anterior margin truncate, posterior margin incised strongly, lateral carinae running near anterolateral margin, then curving inward and reaching hind margin. Mesonotum (Figs 3, 7) tricarinate, longer in midline than vertex and pronotum together about 2.16: 1, median carina reaching end of scutellum. Forewing (Fig. 6) elongate, much longer than abdomen, longer in mid line than wide at widest part about 3.47: 1, predominately clear with distinctive white markings, wing apex acutely rounded; Sc, RA and RP unbranched; MP branched near wing apex, CuA 3-branched; junction of PCu + AA near mid length of clavus; fork of MP+CuA at near 2/3 length of clavus; fork RA+SC and RP near claval apex.



Figures 7–16. *Neobelocera furcata* sp. nov. **7** head and thorax, dorsal view **8** face **9** male genitalia, posterior view **10** same, lateral view **11** anal segment, lateral view **12** pygofer, posterior view **13** genital style, posterior view **14** same, lateral view **15** aedeagus, lateral view **16** female genitalia, posterior view. Scale bars: 0.5 mm (**16**); 0.2 mm (**7–10**, **12**); 0.1 mm (**11**, **13–15**).

Male genitalia. Anal segment (Fig. 9) small, ring-like, without process. Pygofer (Figs 9, 10, 12) in profile much longer ventrally than dorsally, in posterior view with opening longer than wide, ventral margin with 3 medioventral

processes, lateral ones short, tapering, median one forked at apex, with 4 processes on each side and the middle two much smaller. Genital styles (Figs 13, 14) moderately long, forked at apex, outer angle about twice as long as inner angle. Aedeagus (Fig. 15) with phyllobase, phallus tubular, long, expanded at base, bent ventrad medially, broad and forked at apex, curved sharply to the left apically. Phyllobase slender, tubular, arising from base of aedeagus, running dorsad, then curving caudad, after median part, turned left then ventrad, tapering apically.

Female genitalia. Female pygofer (Fig. 16) with gonocoxae broad and large, basal angle sharply acute. Ovipositor distinctly shorter than pygofer. Gonangulum broad and large, apex round with medial margin concave, connected at base to gonapophyses and gonocoxae.

Host plant. Bambusoideae.

Distribution. China (Guizhou).

Remarks. This new species is similar to *N. russa* Li, Yang & Chen, 2020, but can be distinguished from the latter by the following features: (1) forewing (Fig. 6) along MP vein to apex with dark-brown markings [forewing with apical part from transverse veins to apex with dark-brown markings in *N. russa* (Li et al. 2020: fig. 3F)]; (2) medioventral processes of pygofer (Fig. 12) with median one forked at apex, with 4 processes on each side and the middle two much smaller [medioventral processes with median one not forked at apex, without process on each side in *N. russa* pygofer (Li et al. 2020: fig. 4D)]; and (3) apex of phallus (Fig. 15) with two processes [apex of phallus with four processes in *N. russa* (Li et al. 2020: fig. 4G)].

***Neobelocera parvula* sp. nov.**

<https://zoobank.org/721F64BE-8FE0-4551-AC5F-88AF17A6CF9E>

Figs 17–31

Type material. *Holotype*: ♂, CHINA: Yunnan, Jinghong County (21°58'N, 100°68'E), 19 Apr. 2020; H.X. Li leg.; *paratypes*, 8♂♂, 5♀♀, same data as holotype.

Etymology. The species epithet is derived from the Latin word '*parvula*', referring to the small body. It is a feminine in gender.

Measurements. Body length including forewing: male 2.9–3.1 mm ($N = 8$), female 2.9–3.3 mm ($N = 5$).

Diagnosis. Forewings (Fig. 22) with blackish-brown markings, of which veins with white spots or white short stripes at intervals. Frons (Fig. 21) with pale transverse band below level of lower margin of eyes. Ventral margin of pygofer (Fig. 25) with medioventral process, three branched medially, right branch much longer than the other two, sinuate, median branch nearly equal to left branch, left branch with a small process near apex. Anal segment (Fig. 27) with a long ventral process medially, bent ventrad medially.

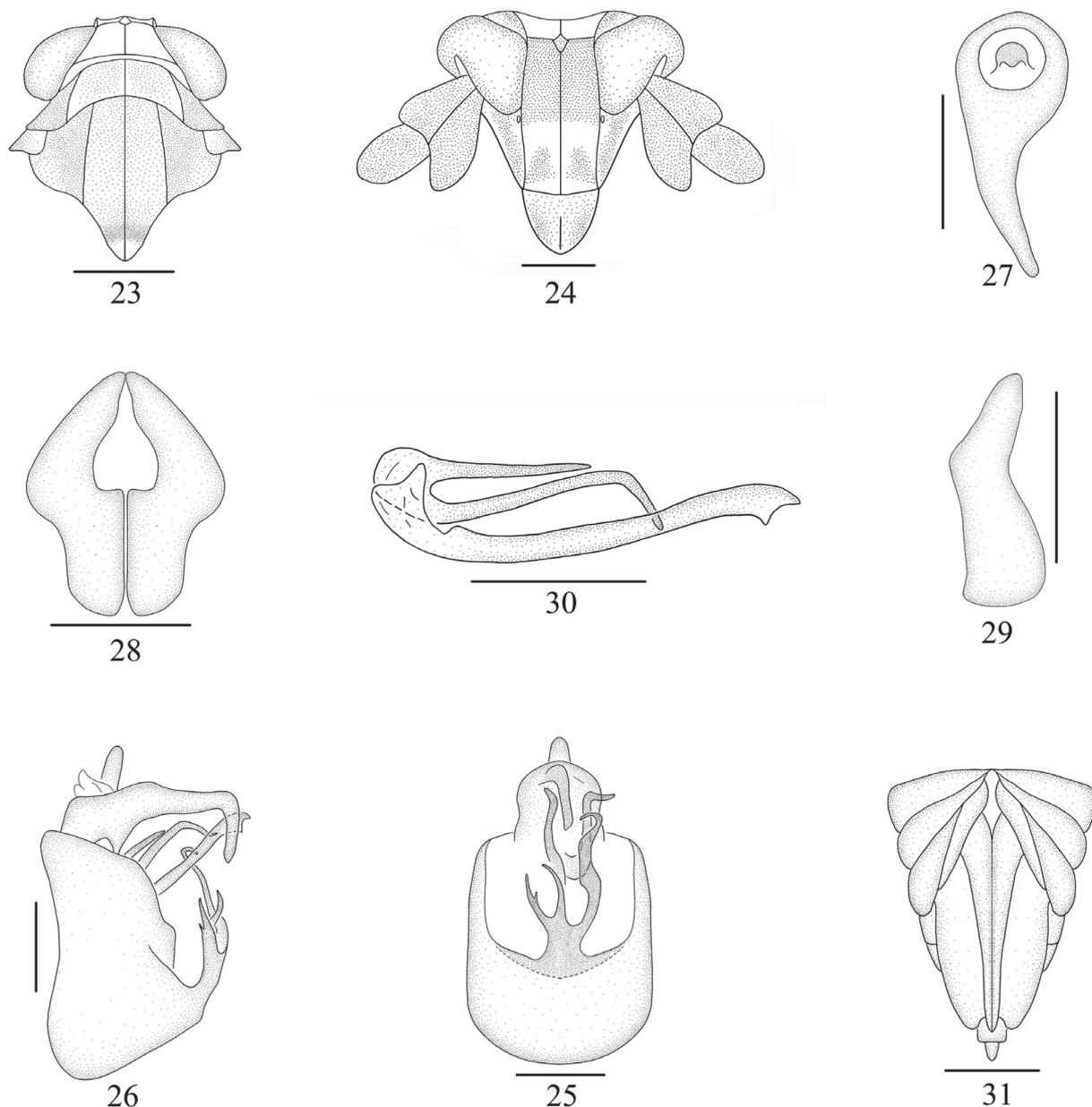
Description. **Coloration.** General coloration yellowish white to dark brown (Figs 17–22). Vertex (Fig. 19) yellowish white. Frons (Fig. 21) with basal half yellowish brown to brown, apical half yellowish white, with two triangular markings at apex. Genae (Fig. 21) dark brown, except longitudinal stripes below level of lower margin of ocelli yellowish white. Clypeus (Fig. 21) yellowish brown, except longitudinal stripes near lateral margin dark brown. Eyes (Figs 19–21) yellowish



Figures 17–22. *Neobelocera parvula* sp. nov. 17 male adult, dorsal view 18 same, lateral view 19 head and thorax, dorsal view 20 same, lateral view 21 face 22 forewing. Scale bars: 0.5 mm (16, 17, 21); 0.3 mm (18–20).

white to dark brown, ocelli (Fig. 20) reddish brown. Antennae (Figs 19–21) yellow to dark brown. Pronotum (Fig. 19) yellowish white to dark brown, median carina yellowish white. Mesonotum (Fig. 19) yellowish brown to dark brown, apex of scutellum yellowish white. Legs (Figs 17, 18) yellowish white, with dark brown maculations. Forewing (Fig. 22) light yellowish white, basal part near costal margin with large infuscate markings, and apical part from transverse veins to apex with dark-brown markings, veins with white spots at intervals. Wings hyaline with veins dark brown. Abdomen yellowish brown to dark brown.

Head and thorax. Head including eyes slightly narrower than pronotum, in profile obtusely rounding into frons (Figs 19, 20). Vertex (Figs 19, 23) broad transversely, wider at base than long medially about 2.72: 1, width at apex narrower than at base about 1:1.81, anterior margin produced medially, Y-shaped carina distinct. Frons (Figs 21, 24) in mid line longer than wide at widest part about 1.68: 1, widest above level of lower margin of eyes, median carina forked at extreme base. Postclypeus (Figs 21, 24) wider at base than frons at apex. Antennae (Figs 21, 24) reaching median part of postclypeus, basal segment shorter at



Figures 23–31. *Neobelocera parvula* sp. nov. **23** head and thorax, dorsal view **24** face **25** male genitalia, posterior view **26** same, lateral view **27** anal segment, dorsal view **28** genital style, posterior view **29** same, lateral view **30** aedeagus, lateral view **31** female genitalia, posterior view. Scale bars: 0.5 mm (**31**); 0.2 mm (**23–27**, **30**); 0.1 mm (**28**, **29**).

midline than second segment about 1: 1.38, second segment long oval, somewhat compressed, longer than wide about 2.30: 1. Pronotum (Figs 19, 23) tricarinate, with anterior margin truncate, posterior margin incised strongly, lateral carinae running near anterolateral margin and reaching hind margin. Mesonotum (Figs 19, 23) tricarinate, longer in mid line than vertex and pronotum together about 2.03: 1, median carina reaching end of scutellum. Forewing (Fig. 22) broad and elongate, much longer than abdomen, longer in mid line than wide at widest part about 2.81: 1, predominately clear with distinctive white markings, wing apex acutely rounded; Sc, RA and RP unbranched; MP branched near wing apex, CuA 3-branched; junction of PCu + AA near midlength of clavus; fork of MP+CuA at near 2/3 length of clavus; fork RA+SC and RP near claval apex.

Male genitalia. Anal segment (Figs 25–27) ring-like, ventral margin with a long process medially, bent ventrad medially. Pygofer (Figs 25, 26) in profile much longer ventrally than dorsally, in posterior view with opening longer than wide, ventral margin with medioventral process, three branched medially, right branch much longer than other two, sinuate, median branch nearly equal to left branch, left branch with a small process near apex. Genital styles (Figs 28, 29) stout, short, bent near middle, tapering apically. Aedeagus (Fig. 30) with phyllobase, phallus tubular, long, forked at apex, phyllobase slender, tubular, arising from base of aedeagus, two branched, longer branch bent ventrally near apex, shorter branch straight.

Female genitalia. Female pygofer (Fig. 31) with gonocoxae narrower and long, basal angle sharply acute. Ovipositor slightly longer than pygofer. Gonangulum broad and large, apex round with medial margin concave, connected at base to gonapophyses and gonocoxae.

Host plant. Bambusoideae.

Distribution. China (Yunnan).

Remarks. This new species is similar to *N. biprocessa* Li, Yang & Chen, 2020, but can be distinguished from the latter by the following features: (1) anal

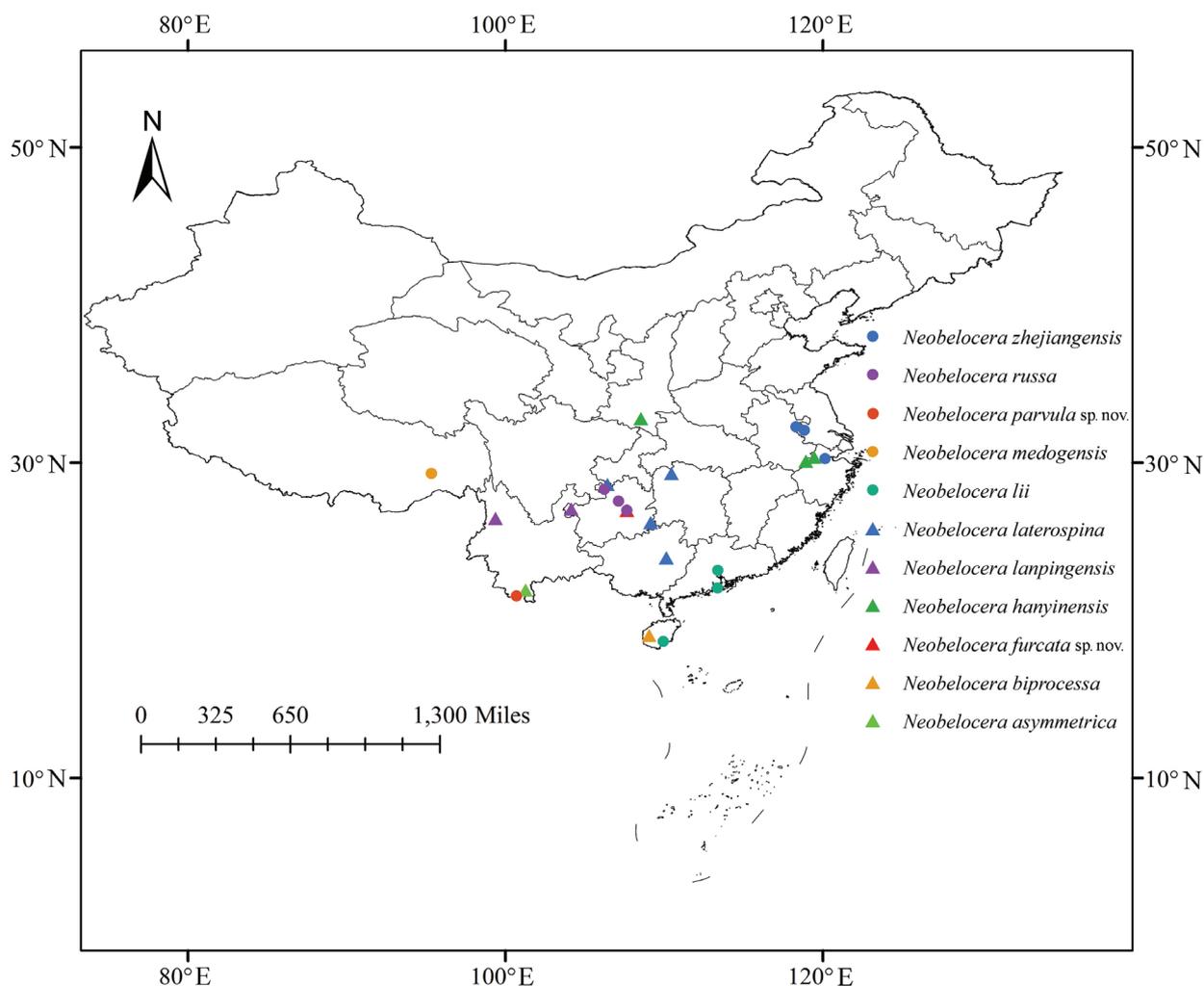


Figure 32. Distribution records of species of the genus *Neobelocera*.

segment of male (Figs 25–27) with a long ventral process medially [anal segment without process in *N. biprocessa* (Li et al. 2020: fig. 2D)]; (2) pygofer (Fig. 25) with medioventral process [pygofer without medioventral process in *N. biprocessa* (Li et al. 2020: fig. 2D)]; and (3) genital styles (Figs 28, 29) stout and short [genital styles slender and long in *N. biprocessa* (Li et al. 2020: fig. 2H)].

Discussion

Based on published data and our field surveys, the eleven described species within the genus *Neobelocera* are distributed in southern China (Fig. 32) in the Palaearctic region (Shaanxi) and the Oriental region (Guizhou, Yunnan, Hainan, Hunan, Guangxi, Guangdong, Chongqing, Zhejiang, Anhui, Jiangxi and Tibet). It seems that the genus is an endemic group of China. The complex and variable geomorphological environment and rich biological resources of the distribution area create a variety of habitat types, which are likely reasons for the rich species diversity of *Neobelocera*. We anticipate that additional species of *Neobelocera* will be found. Therefore, further investigation should be considered to fill the faunistic gaps, as it is obvious that many more taxa remain to be discovered and described.

Members of *Neobelocera* were found feeding exclusively on some native bamboos, with many specimens collected from the beginning of May to the end of September in Guizhou Province. So far, there are no collection records in other plants, which may suggest that the host of *Neobelocera* species are very limited.

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Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statement

No ethical statement was reported.

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Author contributions

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Data availability

All of the data that support the findings of this study are available in the main text.

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