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A new cave amphipod, *Pseudocrangonyx wonkimi* sp. nov. (Crustacea, Amphipoda, Pseudocrangonyctidae), from the Korean Peninsula

Chi-Woo Lee[1], Ko Tomikawa[2], Gi-Sik Min[1]

1 *Department of Biological Sciences, Inha University, Incheon 22212, South Korea* **2** *Department of Science Education, Graduate School of Education, Hiroshima University, Higashihiroshima 739-8524, Japan*

Corresponding author: Gi-Sik Min (mingisik@inha.ac.kr)

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Abstract

A new species of pseudocrangonyctid amphipod, *Pseudocrangonyx wonkimi* **sp. nov.**, was found in the groundwater of a cave in the southwestern Korean Peninsula. *Pseudocrangonyx wonkimi* **sp. nov.** is morphologically most closely related to *P. joolaei* Lee et al., 2020. However, *P. wonkimi* is clearly distinguished from *P. joolaei* by lacking sternal gills, fewer setae on maxilla 1 inner plate, fewer serrate robust setae on the carpus of the gnathopods, lacking bifid setae on the inner ramus of pleopod 3, and fewer articles of rami on pleopod 3. We also determined sequences of mitochondrial cytochrome c oxidase subunit I (COI) of *P. wonkimi* **sp. nov.** for molecular diagnosis. From the molecular analysis based on COI sequences, *P. wonkimi* showed the closest relationship with *P. joolaei* with 15.1% genetic distance.

Keywords

COI, Crangonyctoidea, groundwater, morphology, South Korea

Introduction

The genus *Pseudocrangonyx* Akatsuka & Komai, 1922 is one of the stygobitic groups of groundwater environments in Eastern Asia (Holsinger 1994). Species of the genus *Pseudocrangonyx* are known from subterranean waters and springs in the Korean Peninsula, Japan, Eastern China, and the Far East of Russia (Sidorov and Holsinger 2007;

Tomikawa et al. 2016; Zhao and Hou 2017). So far, the genus contains 27 species (Lee et al. 2020), four of which have been recorded in the Korean Peninsula: *P. asiaticus* Uéno, 1934; *P. coreanus* Uéno, 1966; *P. daejeonensis* Lee et al., 2018; and *P. joolaei* Lee et al., 2020.

Although only four species have been recorded in Korea, it is possible that the specific diversity of the genus *Pseudocrangonyx* in the Korean Peninsula may have been underestimated. This is because there are about 1,000 natural caves in South Korea (Kim et al. 2004), many of which are known to be inhabited by unidentified species of *Pseudocrangonyx*. In addition, as mentioned in previous studies (Uéno 1966; Lee et al. 2020), *P. asiaticus*, which is distributed in various regions of Korea, includes cryptic species.

Recently, we found an unidentified species of *Pseudocrangonyx* collected from a cave in the southwestern part of the Korean Peninsula. Based on the results of the morphological examination of these specimens, we herein describe and illustrate them as representing a new species. These specimens were also confirmed to represent a distinct new species through molecular analysis using the mitochondrial cytochrome c oxidase subunit I (COI) gene.

Methods

Sample collection and morphological examination

Pseudocrangonyx specimens were collected from the groundwater of Jungchangjin Cave, Yongseong-ri, Daedong-myeon, Hampyeong-gun, Jeollanam-do, South Korea (Fig. 1), using a fine-meshed hand net. A small pool where specimens were collected is 10 m from the entrance to the cave. Specimens were fixed and preserved in 99% ethanol. All appendages of the specimens were dissected in 80% ethanol and mounted in gum-chloral medium on glass slides under a stereomicroscope (Olympus SZX7). The specimens were examined using a light microscope (Nikon Eclipse Ni) and illustrated with the aid of a drawing tube. Body length (BL, to the nearest 0.1 mm) was measured from the tip of the rostrum to the base of the telson, along the curvature of the dorsal surface. The nomenclature of the setal patterns on the mandibular palp follows Stock (1974). The specimens examined in this study have been deposited in the collection of the Nakdonggang National Institute of Biological Resources, South Korea (NNIBR).

Molecular analysis

Genomic DNA was extracted from the muscles of the appendages of two Korean *Pseudocrangonyx* specimens using LaboPass Tissue Mini (Cosmo GENETECH, Seoul, South Korea), according to the manufacturer's instructions. The primer sets used for polymerase chain reaction (PCR) followed Tomikawa et al. (2016). Molecular analyses were performed using the COI sequences aligned by Geneious 8.1.9 (Biomatters, Auckland, New Zealand). Phylogenetic tree was constructed using maximum likeli-

Figure 1. Map marking with a star the collection locality of the specimens examined in this study.

hood (ML) and Bayesian inference (BI). ML analysis was performed using RAxML v. 8.2.10 (Stamatakis 2014) with the substitution model set as GTRCAT, immediately after nonparametric bootstrapping conducted with 1,000 replicates. The best fit-partitioning scheme for the ML analysis was identified with the Akaike information criterion using PartitionFinder v. 2.1.1 (Lanfear et al. 2017) with the "greedy" algorithm.

BI and posterior probabilities were estimated using MrBayes v. 3.2.6 (Ronquist et al. 2012). Two independent runs of four Markov chains were conducted for one million generations, and the tree was sampled every 100 generations. The parameter estimates and convergence were checked using Tracer v. 1.7.1 (Rambaut et al. 2018).

Systematics

Family Pseudocrangonyctidae Holsinger, 1989
Genus *Pseudocrangonyx* Akatsuka & Komai, 1922

***Pseudocrangonyx wonkimi* sp. nov.**
http://zoobank.org/4C4AD30E-D4BC-49A2-9E44-C4DD6ED2B33E
New Korean name: jung-chang-jin-dong-gul-yeop-sae-u

Material examined. ***Holotype:*** Female (NNIBRIV35119, BL = 8.9 mm), South Korea, Jeollanam-do, Hampyeong-gun, Daedong-myeon, Yongseong-ri, Jungchangjin Cave (35°6.05'N, 126°31.99'E), 17.II.2017, Yong Gun Choi leg.

Paratypes: 1 male (NNIBRIV36158, BL = 8.3 mm), 1 female (NNIBRIV36157, BL = 8.9 mm), collection data same as for the holotype.

Diagnosis. Female larger than male; antennal sinus with rounded angle; eyes absent; pereonites 3–5 with short dorsal setae; sternal gill absent; antenna 1 shorter than body length; antenna 2 with calceoli in both sexes; mandible palp article 3 longer than article 2; maxilla 1 inner plate with 4 plumose setae; maxilla 2 inner plate with oblique inner row of 4 setae; pleopod peduncles with anterodistal setae, inner margin of pleopods 1 and 2 inner rami with bifid setae; uropod 1 outer ramus with 2 marginal robust setae; uropod 3 terminal article of the outer ramus shorter than adjacent spines.; telson cleft for 25.0–27.4%.

Description. Female (NNIBRIV35119, 8.9 mm). Head (Fig. 2) without setae; rostrum short; lateral cephalic lobe rounded; antennal sinus shallow with rounded angle; eyes absent. Pereonites 3–5 with short dorsal setae; dorsal margin of pereonite 7 with long setae. Dorsal margins of pleonites 1–3 with long setae (Fig. 2). Posterior margin and posteroventral corner of epimeral plate 1 each with seta; ventral and posterior margins of plate 2 with 3 and 4 setae, respectively, posteroventral corner with seta; ventral and posterior margins of plate 3 with 2 and 4 setae, respectively, posteroventral corner subquadrate with seta (Fig. 2). Dorsal margin of urosomites 1 and 2 with seta, urosomite 3 lacking dorsal setae. Ventral margin of urosomite 1 with seta (Fig. 2).

Antenna 1 (Fig. 3A) 0.47 times as long as body length, peduncular articles 1–3 in length ratio of 1.0 : 0.8 : 0.4; accessory flagellum (Fig. 3B) 2-articulate, terminal article with 2 setae and aesthetascs; primary flagellum 1.5 times as long as peduncular articles 1–3 combined, 19-articulate, 1 aesthetasc on some articles. Antenna 2 (Fig. 3C, D) 0.65 times as long as antenna 1; peduncular article 5 with 2 calceoli; flagellum 0.53 times as long as peduncular articles 4 and 5 combined, consisting of 8 articles, flagellum articles 2–4 with calceolus.

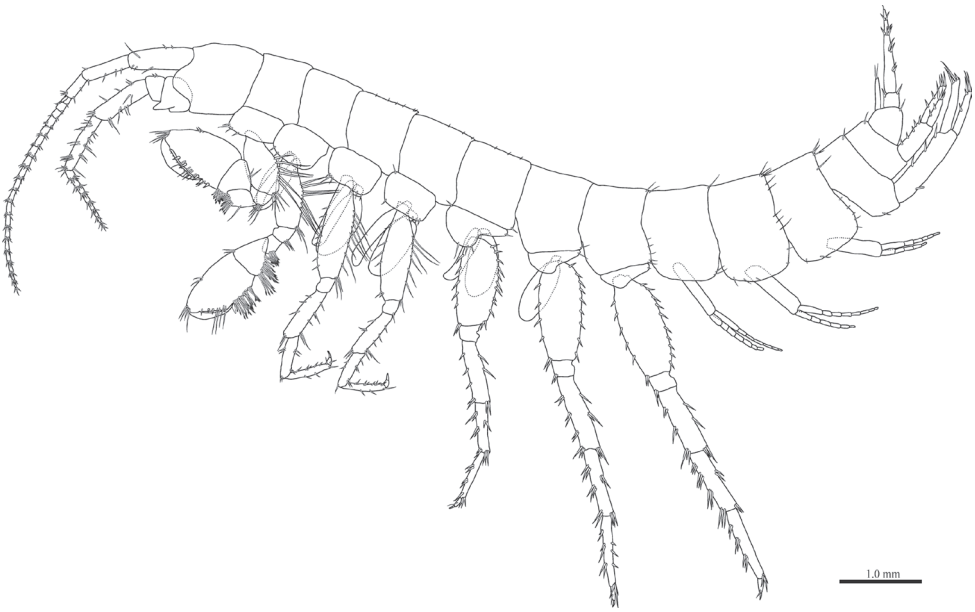

Figure 2. *Pseudocrangonyx wonkimi* sp. nov., holotype, female (BL = 8.9 mm). Habitus, lateral view.

Upper lip (Fig. 3E) with rounded anterior margin, with fine setae. Mandibles (Fig. 3F–H) with left and right incisors 5-dentate; left lacinia mobilis 5-dentate, right lacinia bifid, with many teeth; molar process triturative; accessory setal rows of left and right mandibles each with 5- and 4- pectinate setae; palp 3-articulate, article 3 with 2 A-, 14 D-, and 3 E-setae. Lower lip (Fig. 3J) with broad outer lobes with fine setae, mandibular process of outer lobe rounded apically; inner lobes indistinct. Maxilla 1 (Fig. 3K, L) with inner and outer plates, and palp; inner plate subquadrate with 4 plumose setae; outer plate subrectangular with 7 serrate teeth apically; palp 2-articulate, longer than outer plate, article 2 with weakly plumose 3 apical and 4 subapical robust setae. Maxilla 2 (Fig. 3M) with oblique inner row of 4 setae on inner plate. Maxilliped (Fig. 4A) with inner and outer plates, and palp; inner plate with 3 apical robust setae; outer plate with 6 apical plumose setae, 3 subapical robust setae, and some medial setae; palp 4-articulate, medial margin of article 2 lined with setae, article 4 with claw.

Gnathopod 1 (Fig. 4B, C) with subrectanqular coxal plate, bearing setae on anterior margin and anterodistal corner, width 1.7 times as long as depth; basis thick and short, anterior margin bare, submargin with setae, posterior margin with 7 long setae; posterodistal corner of carpus with serrate robust seta; propodus stout, subtriangular, palmar margin with 14 robust setae in 2 rows, some distally notched; posterior margin of dactylus dentate (Fig. 4D). Gnathopod 2 (Fig. 4E, F) with rounded subquadrate coxal plate, with setae on its anterior to ventral margins, width 1.3 times as long as depth; basis slender with short setae on anterior margin, posterior margin with 8 long setae; posterodistal corner of carpus with serrate robust seta; propodus more slender than that of gnathopod 1, palmar margin with 14 robust setae in 2 rows, some distally notched; posterior margin of dactylus dentate (Fig. 4G).

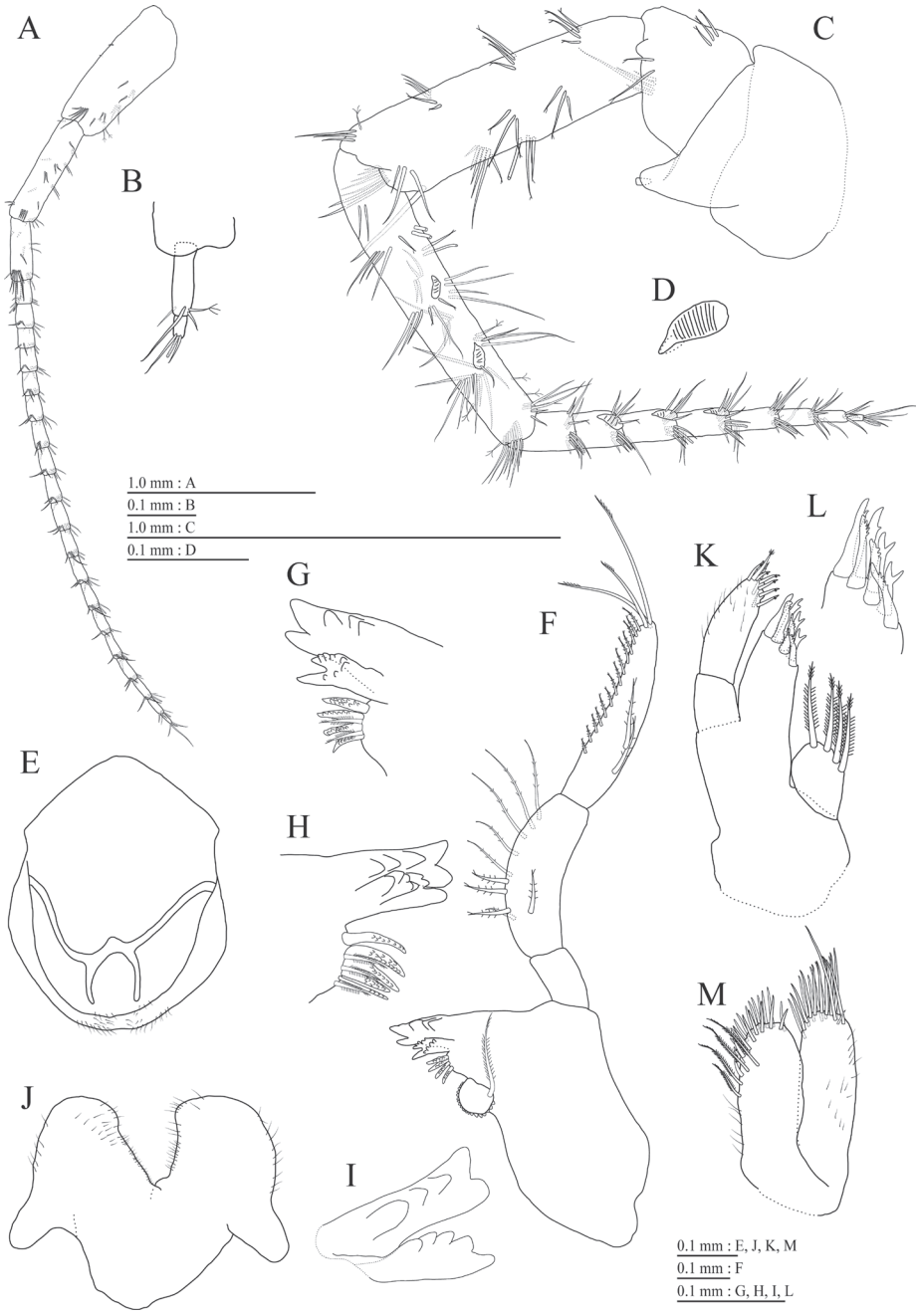

Figure 3. *Pseudocrangonyx wonkimi* sp. nov., holotype, female (BL = 8.9 mm): **A–H, J–M** paratype, female (BL = 8.9 mm): **I**. **A** Antenna 1, lateral view **B** accessory flagellum of antenna 1, lateral view **C** antenna 2, medial view **D** calceolus of antenna 2, medial view **E** upper lip, anterior view **F** right mandible, medial view **G** incisor and lacinia mobilis process of right mandible, medial view **H** incisor and lacinia mobilis process of left mandible, medial view **I** incisor process of left mandible, medial view **J** lower lip, dorsal view **K** maxilla 1, dorsal view **L** apical robust setae on outer plate of maxilla 1, dorsal view **M** maxilla 2, dorsal view.

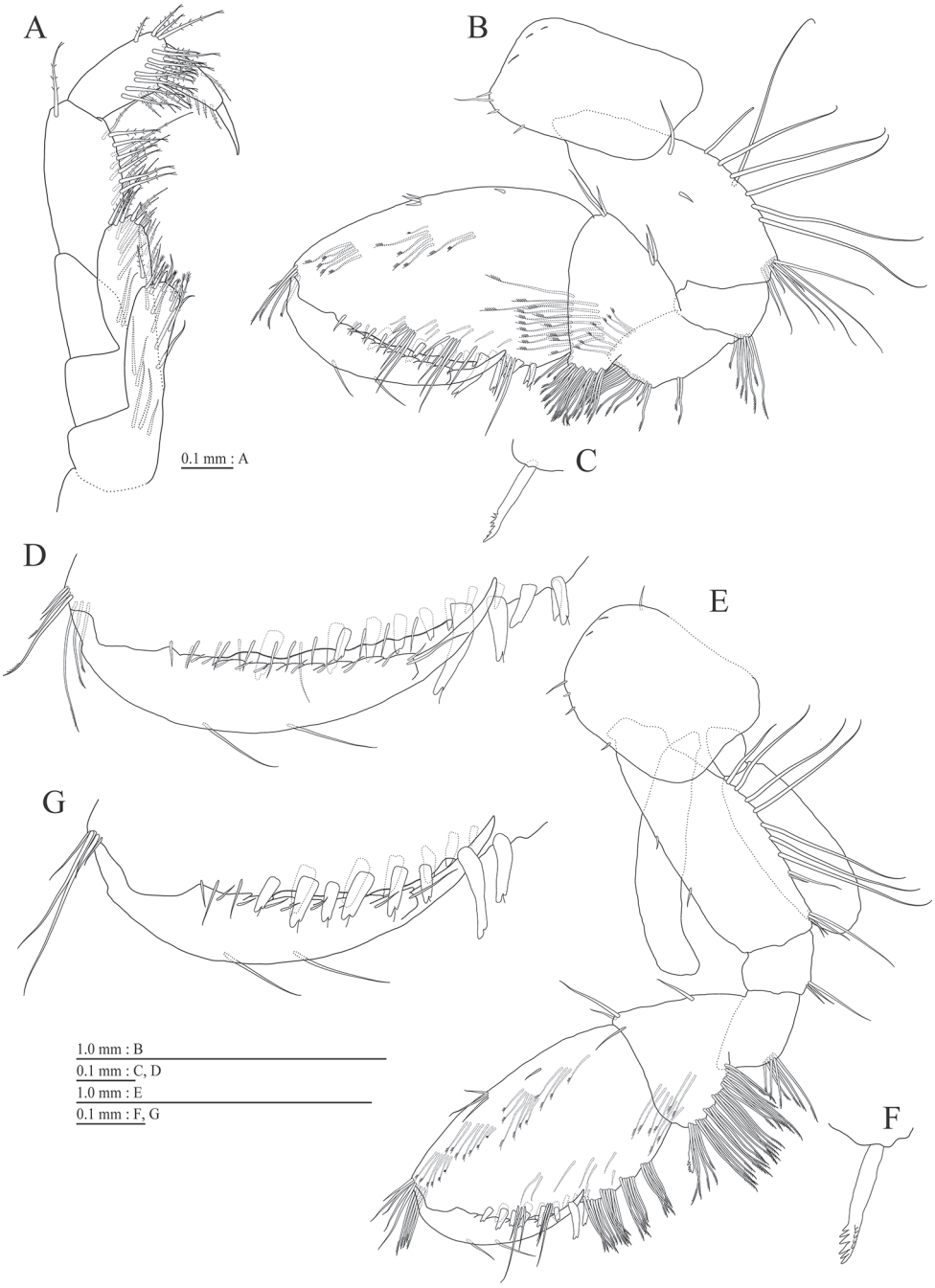

Figure 4. *Pseudocrangonyx wonkimi* sp. nov., holotype, female (BL = 8.9 mm). **A** Maxilliped, dorsal view **B** gnathopod 1, lateral view **C** serrate seta on posterodistal corner of carpus of gnathopod 1, lateral view **D** palmar margin of propodus and dactylus of gnathopod 1, lateral view **E** gnathopod 2, lateral view **F** serrate seta on posterodistal corner of carpus of gnathopod 2, lateral view **G** palmar margin of propodus and dactylus of gnathopod 2, lateral view.

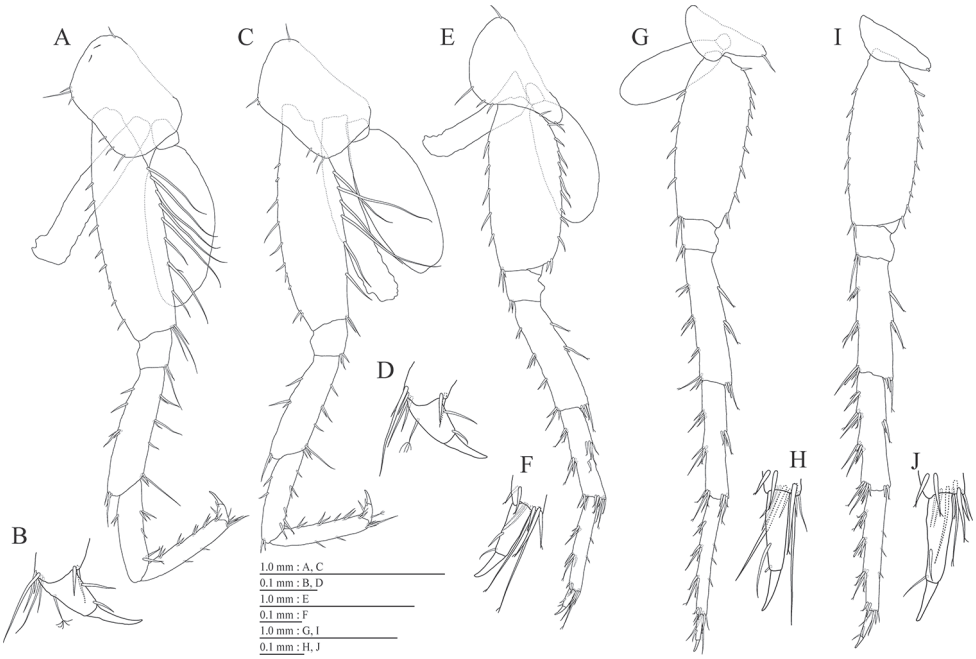

Figure 5. *Pseudocrangonyx wonkimi* sp. nov., holotype, female (BL = 8.9 mm). **A** Pereopod 3, lateral view **B** dactylus of pereopod 3, lateral view **C** pereopod 4, lateral view **D** dactylus of pereopod 4, lateral view **E** pereopod 5, lateral view **F** dactylus of pereopod 5, lateral view **G** pereopod 6, lateral view **H** dactylus of pereopod 6, lateral view **I** pereopod 7, lateral view **J** dactylus of pereopod 7, lateral view.

Pereopod 3 (Fig. 5A) with subquadrate coxal plate bearing setae on anterior to ventral margins, width 1.5 times as long as depth; anterior and posterior margins of basis with short and long setae, respectively; merus, carpus, and propodus in length ratio of 1.0 : 0.7 : 0.7; posterior margin of dactylus with 2 setae (Fig. 5B). Pereopod 4 (Fig. 5C) with subquadrate coxal plate bearing setae on anterior to ventral margins, width 1.7 times as long as depth; anterior and posterior margins of basis with setae; merus, carpus, and propodus in length ratio of 1.0 : 0.8 : 0.8; posterior margin of dactylus with 2 setae (Fig. 5D). Pereopod 5 (Fig. 5E) with weakly bilobed coxal plate bearing setae on anterior to posterior lobes; anterior and posterior margins of basis with setae; merus, carpus, and propodus in length ratio of 1.0 : 0.8 : 0.8; anterior margin of dactylus with 2 setae (Fig. 5F). Pereopod 6 (Fig. 5G) with weakly bilobed coxal plate bearing setae on posterior lobes; anterior and posterior margins of basis with setae; merus, carpus, and propodus in length ratio of 1.0 : 0.9 : 0.9; anterior margin of dactylus with 2 setae (Fig. 5H). Pereopod 7 (Fig. 5I) with posteriorly tapering coxal plate, ventral margin weakly concave, with seta on posterodistal corner; anterior and posterior margins of basis with short setae; merus, carpus, and propodus in length ratio of 1.0 : 1.0 : 1.0; anterior margin of dactylus with 2 setae (Fig. 5J).

Coxal gills (Fig. 4E, 5A, C, E, G) on gnathopod 2 and pereopods 3–6; sternal gills absent.

Brood plates (Fig. 4E, 5A, C, E) slender with numerous setae, on gnathopod 2 and pereopods 3–5.

Peduncles of pleopods 1–3 (Fig. 6A, C, E) lacking marginal setae, anterodistal corners with 2 setae. Pleopods 1–3 with paired retinacula (Fig. 6B, D, F). Pleopods 1 and 2 with bifid seta (clothes-pin seta) on inner basal margin of inner ramus; pleopods 1–3 inner ramus 7-, 7-, and 5-articulate, respectively; pleopods 1–3 outer ramus 8-, 7-, and 5-articulate, respectively.

Uropod 1 (Fig. 6G) with basofacial seta on peduncle; inner ramus 0.7 times as long as peduncle, inner and outer margins with 3 and 2 robust setae, respectively, basal part with 4 slender setae; outer ramus 0.8 times as long as inner ramus, with 2 outer marginal robust setae. Uropod 2 (Fig. 6H) with inner ramus 1.1 times as long as peduncle, inner and outer margins each with 2 robust setae; outer ramus 0.7 times as long as inner ramus, with 2 outer marginal robust setae, respectively. Uropod 3 (Fig. 6I, J) with peduncle 0.3 times as long as outer ramus; inner ramus absent; outer ramus 2-articulate, proximal article with robust setae, terminal article 0.1 times as long as proximal article, with 3 distal setae.

Telson (Fig. 6K) length 1.57 times as long as wide, cleft for 25.0% of its length, each telson lobe apical with penicillate seta and 2 robust setae.

Male (NNIBRIV36158, BL = 8.3 mm). Antenna 1 (Fig. 7A, B) 0.36 times as long as body length, primary flagellum 14-articulate, 1 aesthetasc on some articles. Antenna 2 (Fig. 7C) 0.66 times as long as antenna 1; flagellum 0.33 times as long as peduncular articles 4 and 5 combined, consisting of 5 articles, articles 1 and 2 with calceolus.

Gnathopod 1 (Fig. 7D) carpus with serrate seta on posterodistal corner; palmar margin of propodus with 10 robust setae in 2 rows, some distally notched. Gnathopod 2 (Fig. 7E) carpus with serrate seta on posterodistal corner; palmar margin of propodus with 11 robust setae in 2 rows, some distally notched.

Uropod 1 (Fig. 8A) with inner ramus 0.7 times as long as peduncle; inner and outer margins with 2 and 1 robust setae, respectively, basal part with 2 slender setae; outer ramus with 2 marginal robust setae. Uropod 2 (Fig. 8B) with peduncle 0.95 times as long as inner ramus; inner ramus 1.4 times as long as outer ramus, distal part with 3 serrate, 4 simple robust setae. Uropod 3 (Fig. 8C, D) with outer ramus terminal article 0.2 times as long as proximal article.

Telson (Fig. 8E) length 1.38 times as long as wide, cleft for 27.4% of its length.

Distribution. Known only from the type locality.

Etymology. The name of the new species is dedicated to Prof. Won Kim (Seoul National University, South Korea), who has significantly contributed to our knowledge of crustaceans in South Korea.

DNA sequences. Sequences of COI gene (MT316534 and MT316535) were determined from two specimens (NNIBRIV35119 and NNIBRIV36158).

Molecular analyses. The topologies of the BI and ML trees were identical (Fig. 9). *Pseudocrangonyx wonkimi* sp. nov. and *P. joolaei* Lee et al., 2020 showed the closest relationship.

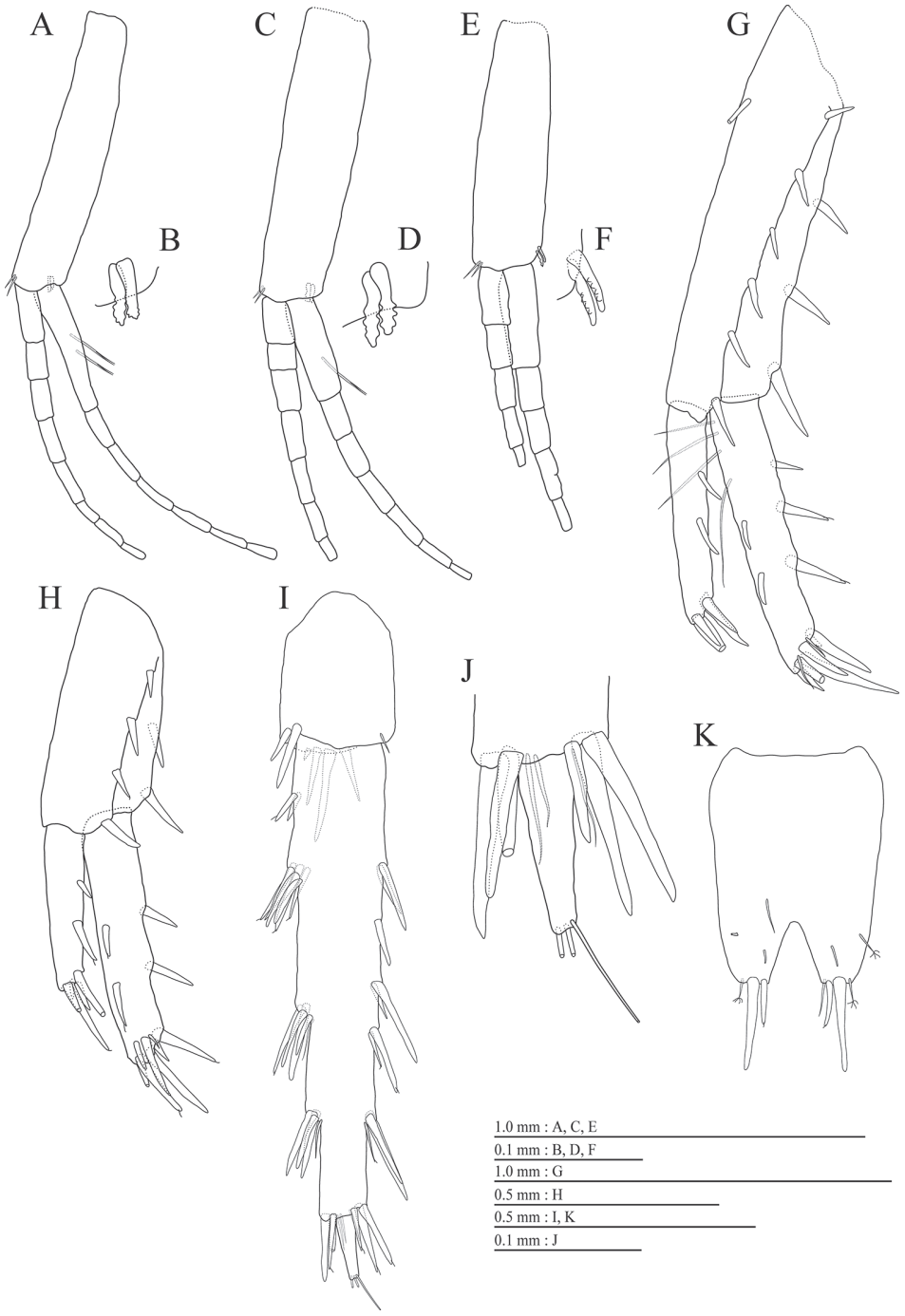

Figure 6. *Pseudocrangonyx wonkimi* sp. nov., holotype, female (BL = 8.9 mm). **A, C, E** Pleopods 1–3, lateral view, plumose setae on rami omitted **B, D, F** retinacula on peduncle of pleopod 1–3, lateral view **G** uropod 1, dorsal view **H** uropod 2, dorsal view **I** uropod 3, dorsal view **J** terminal article of uropod 3, dorsal view **K** telson, dorsal view.

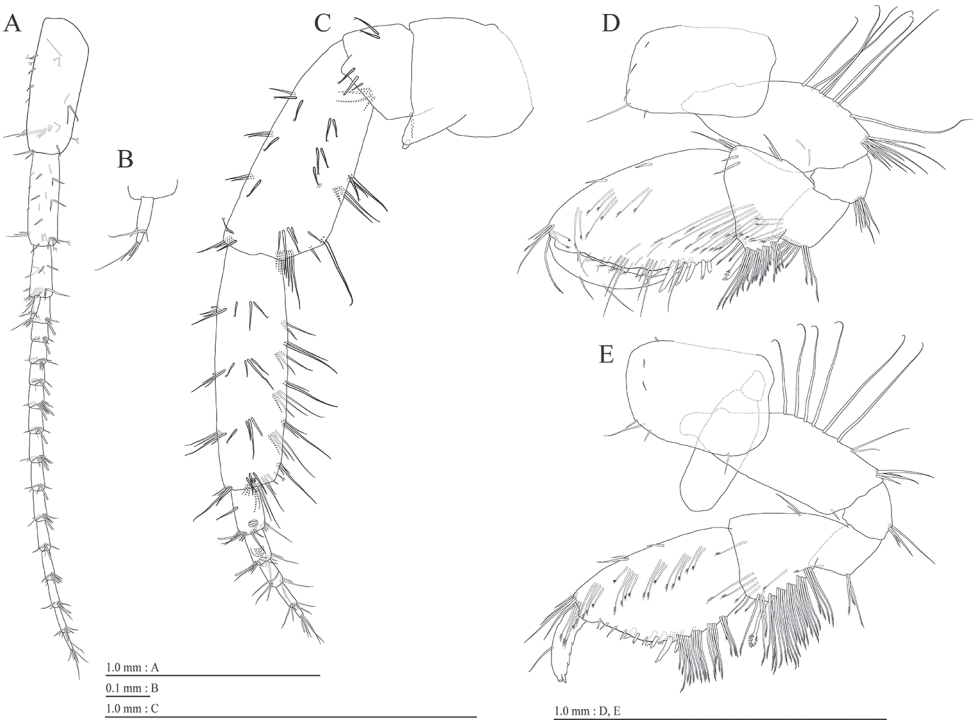

Figure 7. *Pseudocrangonyx wonkimi* sp. nov., paratype, male (BL = 8.3 mm). **A** Antenna 1, medial view **B** accessory flagellum of antenna 1, medial view **C** antenna 2, medial view **D** gnathopod 1, lateral view **E** gnathopod 2, lateral view.

Remarks. We revealed that *Pseudocrangonyx wonkimi* sp. nov. is most closely related to *P. joolaei* Lee et al., 2020 based on molecular analyses. The genetic distance between these two species was 15.1% for the COI gene, and this distance is larger than that between members of two distinct species among the other congeners examined. *Pseudocrangonyx wonkimi* sp. nov. is distinguished from *P. joolaei* in having the following features (features of *P. joolaei* in parentheses): 1) sternal gill absent (present), 2) maxilla 1 inner plate with 4 (6) plumose setae, 3) carpus of gnathopods 1 and 2 each with serrate robust seta (with 2–3) on the posterodistal corner, 4) inner basal margin of inner rami of pleopod 3 without (with) bifid seta, and 5) less than 10 (more than 10) articles on the rami of pleopods.

Pseudocrangonyx wonkimi sp. nov. is morphologically similar to *P. akatsukai* Tomikawa & Nakano, 2018 in having 1) eyes completely absent, 2) sternal gill absent 3) urosomite 1 with ventral robust seta, 4) antenna 2 with calceoli in both sexes 5) carpi of gnathopods 1 and 2 with serrate robust setae on posterodistal corner, and 6) inner rami of pleopods with bifid setae on inner margin. However, the former is distinguished from the latter by the following features (features of *P. akatsukai* in parentheses): 1) pereonites 3–5 (1–7) with short dorsal setae, 2) antenna 1 shorter (longer) than as long as body length half, 3) male antenna 2 flagellum 0.33 (0.53) times as long

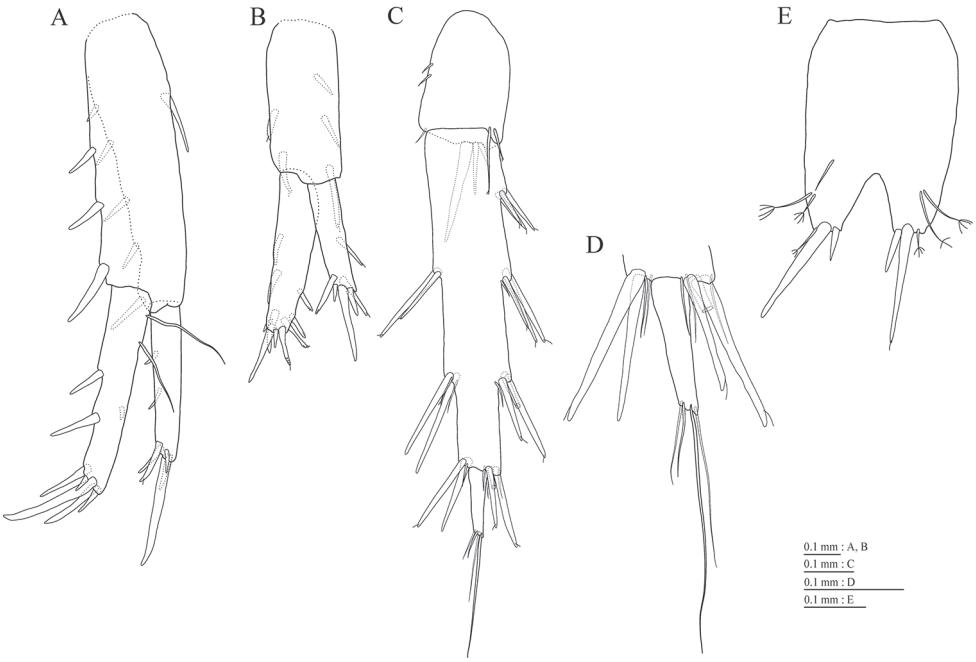

Figure 8. *Pseudocrangonyx wonkimi* sp. nov., paratype, male (BL = 8.3 mm). **A** Uropod 1, ventral view **B** uropod 2, ventral view **C** uropod 3, ventral view **D** terminal article of uropod 3, ventral view **E** telson, dorsal view.

as peduncular articles 4 and 5 combined, 4) carpi of gnathopods 1 and 2 with 1 (with 3–5) serrate robust setae on posterodistal corner, 5) length ratio of merus, carpus, propodus 1.0 : 1.0 : 1.0 (1.0 : 1.1 : 1.1) of pereopod 7, and 6) telson cleft for 25.0–27.4% (6.6–12.3%) of length.

Pseudocrangonyx wonkimi sp. nov. is similar to *P. elegantulus* Zhao & Hou, 2017 in having 1) urosomite 3 dorsal margin without seta, 2) sternal gill absent, 3) accessory flagellum of antenna 1 subequal first article of primary flagellum, and 4) antenna 2 with calceoli in both sexes. However, *P. wonkimi* is distinguished from the latter by the following features (features of *P. elegantulus* in parentheses), 1) pereonites 3–5 with (1–6 without) dorsal margin setae, 2) basal part of inner ramus of female uropod 1 with 4 (1) slender setae, 3) uropod 1 peduncle inner marginal with 3 (1) robust setae, 4) terminal article of uropod 3 almost reaching (fully exceed) robust setae on the distal part of the proximal article, and 5) carpus of male gnathopod 2 with (without) serrate robust seta on posterodistal corner. *Pseudocrangonyx wonkimi* sp. nov. is similar to *P. shikokunis* Akatsuka & Komai, 1922 in having 1) eyes absent, 2) mandible palp article 3 longer than article 2, and 3) carpi of gnathopods 1and 2 with serrate setae on the posterodistal corners. The new species is distinguished from the latter by the following features (features of *P. shikokunis* in parentheses), 1) antenna 1 shorter (longer) than half of the body length, 2) maxilla 1 inner plate with 4 or fewer setae (with 5 setae),

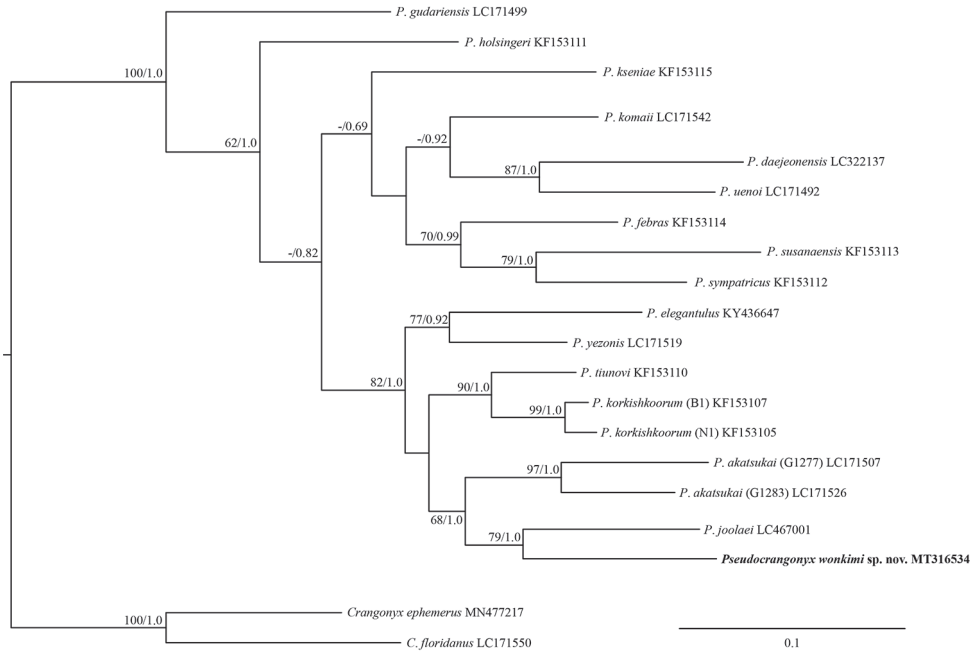

Figure 9. Maximum likelihood and Bayesian inference analyses based on mitochondrial COI sequences. Numbers on nodes represent bootstrap values for maximum likelihood and Bayesian posterior probabilities.

and 3) male telson cleft for 27.4% (11.7%) of length. The new species is similar also to *P. cavernarius* Hou & Li, 2003 in having 1) body size about 8.0 mm, and 2) maxilla 1 inner plate with 4 plumose setae. It differs from *P. cavernarius* Hou & Li, 2003 by the following features (features of *P. cavernarius* in parentheses), 1) antenna 2 calceoli present (absent), 2) mandible palp article 3 longer (shorter) than article 2, 3) urosomite 3 dorsal margin without (with) setae, and 4) telson each lobe with (without) setae.

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Two new species of *Hymenaphorura* Bagnall, 1948 (Collembola, Onychiuridae) from Romania and an updated key to the genus

Wanda Maria Weiner[1], Cristina Fiera[2]

1 *Institute of Systematics and Evolution of Animals, Polish Academy of Sciences, Sławkowska 17, Pl–31-016 Kraków, Poland* **2** *Institute of Biology Bucharest, Romanian Academy, 296 Splaiul Independenței, P.O. Box 56-53, 060031 Bucharest, Romania*

Corresponding author: Cristina Fiera (cristina.ivanescu@ibiol.ro)

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Abstract

Two new species of the genus *Hymenaphorura* from Romania, *H. urbana* **sp. nov**. and *H. kalindera* **sp. nov.**, are described and illustrated. *Hymenaphorura urbana* has a postantennal organ (PAO) with 13–15 simple vesicles, abdominal terga I–III with subequal setae p_2 and p_3, abdominal tergum V granular area with 3+3 distinct, long macrosetae, and *H. kalindera* **sp. nov**. has PAO with 9–12 simple vesicles, one border seta, abdominal terga I–III with setae p_2 slightly longer than setae p_3, abdominal tergum V granular area with 4+4 distinct macrosetae. Remarks on *H. subsimilis* Bagnall, 1948 are given. An updated key for the world distributed species of *Hymenaphorura* is presented.

Keywords

Hymenaphorurini, identification key, morphology, taxonomy

Introduction

The genus *Hymenaphorura* Bagnall, 1948 is mainly characterized by two diagnostic apomorphies within the Hymenaphorurini: the presence of four guard setae on the antennal III sense organ and the lack of labial papillae E. Other characters of importance include: the absence of pseudocellus (pso) on the posterior part of the head, the body with only dorsomedial pseudocelli and the postantennal organ with simple vesicles, sometimes bilobed, located parallely or obliquely to the long axis of the organ, absence of the chaeta d0 on head, number of chaetae in the distal whorl of tibiotarsi (9 or 11), and structure of furcal rudiment (Pomorski 1998, 2001).

Of the 46 species of *Hymenaphorura* known globally (Bellinger et al. 1996–2020; Paśnik and Weiner 2018), five species have been recorded in Romania: *Hymenaphorura subsimilis* (Bagnall, 1948), *H. polonica* Pomorski, 1990, *H. nova* Pomorski, 1990, *H. valdegranulata* (Stach, 1954) (see Stan and Weisner 1978), and *H. ioni* Buşmachiu, Popa & Weiner, 2014.

During a study of some collembolan material collected in the last six years from Romania, two new species of *Hymenaphorura* were revealed and are described in this paper.

Material and methods

Sampling and preparation

Samples of leaf litter and soil were collected between 2013 and 2017 and extracted with Berlese funnels. The specimens were cleared in lactic acid and KOH and subsequently mounted on slides using Marc Andre II or Swan's medium.

Repositories

Collections are referred to the following acronyms:

ISEA Institute of Systematic and Evolution of Animals
IBB Institute of Biology Bucharest
NHMUK Natural History Museum UK

Specimen examination

The taxonomic analysis was conducted using an Axio Scope A1 Zeiss microscope. Series of photographs were taken at different focal planes using an AxioCam ERC 5s camera mounted on microscope and processed with Adobe Photoshop CS3. Slide-mounted springtails were drawn using a Leica DM2500 compound microscope equipped with a camera lucida as well as phase-contrast and differential interference contrast (DIC) optical systems.

Labial papillae types are distinguished after Fjellberg (1999). Setae on the anal valves are named following Yoshii (1996). The nomenclature of the tibiotarsal chaetotaxy follows Deharveng (1983). Setae on furcal area are notated after Weiner (1996) and Paśnik and Weiner (2017). The pseudocelli, parapseudocelli, and pseudopores formulae give the number of pseudocelli, parapseudocelli, or pseudopores per half-tergum (dorsally) or half sternum (ventrally). The tibiotarsus chaetotaxy formula is expressed as the total number of setae (number of setae in row C, number of setae in row B, number of setae in row A+T), for example: 18 (1, 8, 9).

Abbreviations

Abd.	abdominal segments	**MVO**	male ventral organ
Ant.	antennal segments	**PAO**	postantennal organ
AS	anal spines	**Th.**	thoracic segments
AIIIO	Ant. III sensory organ	**pso**	pseudocellus
bc	basal seta on maxillary palp	**psx**	parapseudocellus
m	unpaired pseudopore of Abd. II–IV sterna	**psp**	pseudopore
		d0	unpaired seta on head
ms	microsensillum		

Taxonomy

***Hymenaphorura kalindera* sp. nov.**
http://zoobank.org/BBFE4452-F97D-4314-B851-79F1F4208F62
Figures 1A–H, 2A–H, Table 1

Material examined. ***Holotype*:** female (IBB: RO-Hym1-IBB): Romania, Prahova County, Bucegi Massif, Buşteni near Kalinderu ski slope, 45.4212N, 25.52458E, 1000 m a.s.l., fir and beech forest, litter sample, 14.XI.2017, coll. C. Fiera. ***Paratypes:*** female stored in Poland (ISEA: RO-17-1) and juvenile in Romania (IBB: RO-Hym2-IBB) same data as holotype.

Diagnosis. Body with distinct areas of coarser granules. Dorsal pso formula as 10/011/11112, ventral pso absent. PAO with 9–12 simple vesicles, parallel or oblique in relation to the long axis of this organ and one border seta. Abd. terga I–III with setae p_2 and p_3 subequal. Abd. tergum V granular area with 4+4 distinct macrosetae. Distal tibiotarsal whorl with 11 setae.

Description. ***Measurements*** (in mm). Holotype female length 0.81, paratype female: 0.78, paratype juvenile 0.71.

Body. Body elongate, cylindrical (Fig. 1C). Colour in alcohol white. Distinctive areas of granulation on dorsal side of the body of *c2* type (sensu Arbea and Jordana 1994). Usually 12–13 grains around each pseudocellus (Fig. 1B).

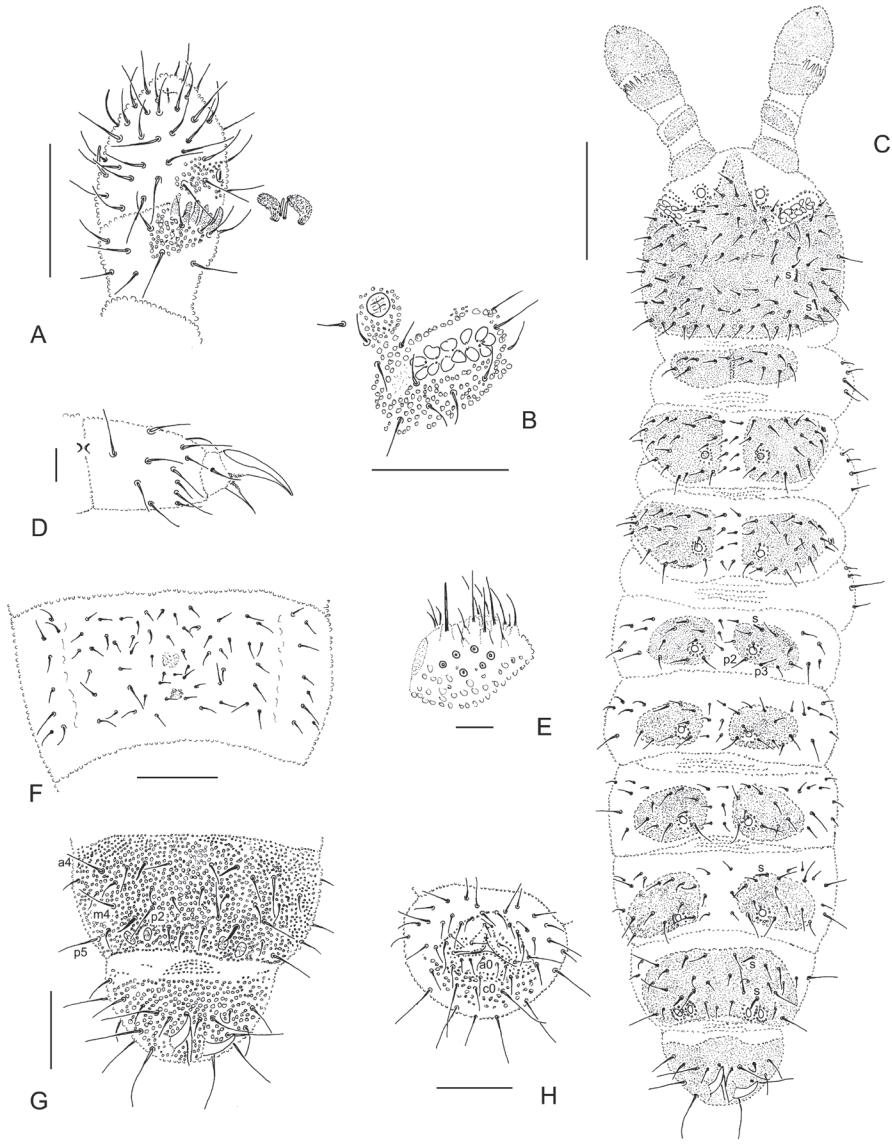

Figure 1. *Hymenaphorura kalindera* sp. nov. **A** antennal segment III and IV **B** postantennal sensory organ and anterior cephalic pseudocellus **C** habitus and dorsal chaetotaxy **D** leg III: tibiotarsal chaetotaxy and claw **E** labial palp **F** abdominal sternum IV with furcal rudiment **G** abdominal terga V and VI **H** abdominal sternum VI: anal valves. Scale bars: 0.05 mm (**A, B, F–H**); 0.01 mm (**B, E**); 0.1 mm (**C**).

Antennae and head. Antennae almost as long as head. Antennal segment I with 8 setae, antennal segment II with 15 setae. AIIIO consisting of four guard setae, five papillae, two smooth sensory rods, two granulated sense clubs: granulated and bent (Fig. 1A), ventro-lateral microsensillum present. Second external papilla in AIIIO forked in

holotype, simple in two other specimens. Antennal segment IV with one distinct sensillum, small subapical organite in deep, narrow pit and latero-external microsensillum in the last posterior row of setae (Fig. 1A).

PAO with 8–12 beanlike vesicles, parallel or oblique in relation to the long axis of this organ in: holotype 10/12, paratypes 8/11 and 10/10 simple; PAO groove border with 1 seta (Fig. 1B). Labral formula of setae: 4/3,2,2. Maxillary palp simple with two sublobal sensory hairs. Labial type A (sensu Fjellberg 1999) with four papillae, papilla E absent (Fig. 1E). Guards a_1, $b_{1–2}$ and d_2 (not well visible) as long as half of terminal sensilla of papillae. Five other guards as long as terminal sensilla.

Pseudocellar formula. Pseudocellar formula per half tergum dorsally: 10/011/11112 (Fig. 1C), ventrally and on subcoxae 1 absent. Parapseudocelli and pseudopores not visible.

Dorsal chaetotaxy. Dorsal chaetotaxy as in Figs 1C, 2A–H always with some asymmetry. Seta d0 on the head absent. Body with macro-and meso/microsetae, sensory setae s well distinguished on head, abdominal terga I, IV and V, their formula per half tergum: 2/000/10012.

Thoracic terga II and III with strong lateral microsensilla (ms). Thoracic tergum I with 7(6)+7(6) setae. Thoracic terga II and III with 5+5 macrosetae and 4+4 microsetae along midline. Abdominal terga I–III with 5+5 macrosetae and 3+3 microsetae along midline. Setae p_2 and p_3 on abdominal terga I−III subequal. Granulated area of abdominal terga I–III with 4+4 setae, in row p of abdominal tergum V with 4+4 macrosetae as p_2, p_5, m_4, a_4. One macroseta in the set of setae on subcoxae 1 and abdominal pleura I–IV and 2 macrosetae on abdominal pleurum V. Abdominal tergum V with medial seta p_0 (absent in juvenile), VI with medial setae a_0 and p_0. Anal spines as long as inner edge of claw III and 2.5 times as long as their basal diameter. Basal papillae low.

Ventral chaetotaxy, furcal rudiment. Thoracic sterna II and III with 1 + 1 setae. Ventral tube with 7–9+7–9 setae. Male unknown. Abdominal pleurae II–V with 1, 2, 2, 2 macrosetae respectively. Abdominal sternum IV (Fig. 1F) with furcal rudiment as small finely granulated area and with two manubrial rows of setae: row ma with two setulae and row mp (irregular) with two macrosetae and 3–4 microsetae between them. Anal valves with numerous acuminate setae; each of lateral valves with three setae in a-row (a1-a0-a1) and five setae in b-row (b2-b1-b0-b1-b2), upper valve with one seta in a-row (a0), with four setae in b-row (b2-b1-b1-b2) and with three subequal setae in row c (c2-c0-c2) (Fig. 1H).

Legs. Chaetotaxy of legs I, II and III as follows: subcoxae 1 with 4, 4, 4 setae, subcoxae 2 with 1, 4, 4 setae, coxae with 3, 9–10, 12 setae, trochanters with 8, 8, 9 setae, femora with 16, 14, and 14 setae, tibiotarsi with 3 whorls of setae: 20 (1,8,11), 20 (1,8,11), 19 (1,7,11) setae respectively (Fig. 1D). Seta M present. Claw without internal denticle. Empodial appendage with short basal lamella, length of empodium is about 2/3 of inner edge of claw III (Fig. 1D).

Ecology. This species is found in litter samples in mixed fir and beech forest.

Etymology. The name of the new species is inspired by the name of the ski slope: Kalinderu, Bușteni town, Prahova county, Romania.

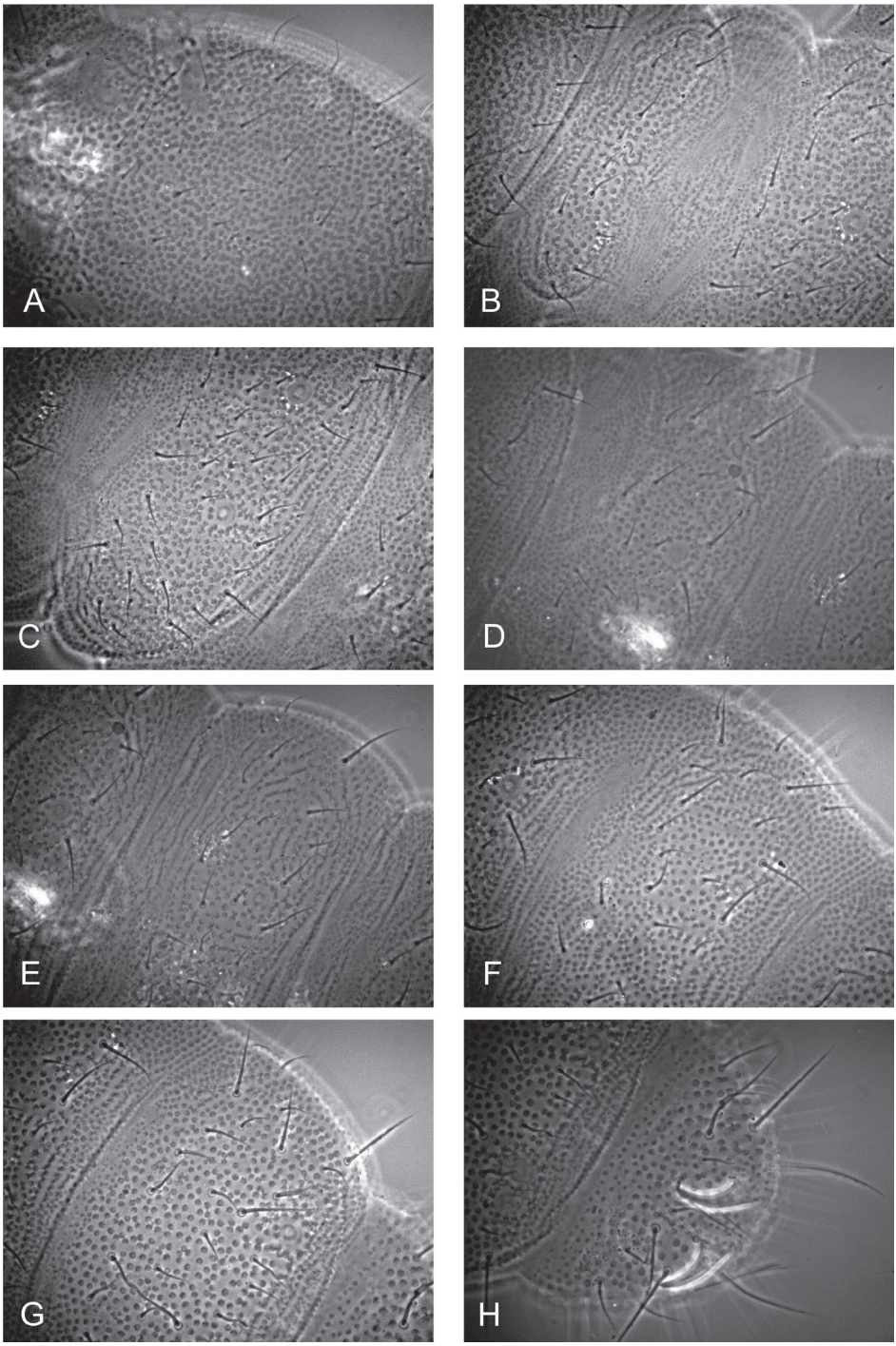

Figure 2. *Hymenaphorura kalindera* sp. nov.: dorsal chaetotaxy. **A** head **B** thoracic tergum I **C** thoracic tergum II **D** abdominal tergum II **E** abdominal tergum III **F** abdominal tergum IV **G** abdominal tergum V **H** abdominal tergum VI.

Table 1. Comparison of *Hymenaphorura* species with 4 macrochaetae on abdominal segment V.

Species	PAO vesicles	Setae in tibiotarsal distal whorl	Setae on border of PAO groove	Labial type	Dorsal pso formula	Claw: inner denticle and lateral teeth	Abd. I–III: p2/p3	Number of setae p in granulated area of Abd. I–III	Body size (mm)	Number of s-setae on abd. tergum V
***H. kalindera* sp. nov.**	10–12	11	1	A	10/011/11112	absent	p2 and p3 subequal	4	0.81–0.87	2+2
***H. anatolii* Pomorski, 2001**	14–16	11	1	A**	10/011/11112	absent	subequal or p2 sometimes longer than p3	2	females 1.65–1.8 males 1.2–1.55	1+1
***H. gamae* Arbea & Jordana, 1994**	11–12	11	1	?	10/011/11112	lateral teeth present	p2 shorter than p3	0	1.6–11.9	?
***H. ioni* Buşmachiu, Popa, Weiner, 2014**	15 (13–14)	11	1	0	10/011/11112	lateral teeth present	subequal	2	1.51–1.65	1+1
***H. maoerensis* Sun, 2014**	8–11	11	2	A	10/011/11112	absent	subequal	2	females 1.50–1.75 males 1.40–1.65	?
***H. palaearctica* Pomorski, 2001**	11–14	11	1	A**	10/011/11112	lateral teeth present	subequal or p2 slightly longer	2	females 1.65–2 males 1.5–1.7	1+1?
***H. rafalskii* Weiner & Szeptycki, 1997**	9–12	11	2	?	20/011/11113	denticle present, lateral teeth absent	subequal	2	1.08–1.31	2+2
***H. subsimilis* (Bagnall, 1948)**	12–13	11	1	A	10/011/11112	absent	subequal	3–4, 2, 2	1.25	1+1
H. wusuliensis* Sun & Wu, 2011	11–13	9	2	A	20/111/11113	absent	subequal	?	females 0.87–1.05 male 0.78	2+2

*Sun and Wu 2011: figs 1, 7; Sun pers. comm. **Babenko pers. comm.

Remarks. *Hymenaphorura kalindera* **sp. nov.** belongs to the group of species with 4+4 macrosetae on the granulated area of the abdominal tergum V (Table 1). *Hymenaphorura maoerensis* Sun, 2014, *H. rafalskii* Weiner & Szeptycki, 1997, and *H. wusuliensis* Sun & Wu, 2011 are different from this and other species by two border setae on the PAO. *Hymenaphorura rafalskii* and *wusuliensis* have 2+2 anterior pso on the head and 3+3 pso on the Abd. tergum V.

The other species: *H. anatolii* Pomorski 2001 (Russia, northern Palearctic), *H. gamae* Arbea & Jordana, 1994 (Spain), *H. ioni* Busmachiu, Popa & Weiner, 2014 (Romania), *H. palaearctica* Pomorski, 2001 (Russia), and *H. subsimilis* Bagnall, 1948 (Romania) form a group of more similar species with 11 setae in the tibiotarsal distal whorl, with the pso formula 10/011/11112, and with one setae on the border of the PAO. The new species differs from these species by the number of s-setae on Abd. V

(2+2 vs 1+1), by the presence of four setae on each of the granulated areas of Abd. I–III and by its smaller size (Table 1). A comparison with *H. subsimilis*, a species described from the same county (Prahova), is rather difficult because only one type specimen is not in good condition (see Remarks for *H. subsimilis*). These species differ in their size: *H. subsimilis* is larger than *H. kalindera* sp. nov. (1.01 mm vs 0.81 mm), and *H. subsimilis* has Th. I with 4+4 setae (juvenile specimens?) in one row vs 7+7 or 6+7 setae in two rows in the new species. Abd. V has 1+1 s-setae in *H. subsimilis* vs with 2+2 s-setae in the new species. The shape of vesicles in PAO are transversally lobed in *H. subsimilis* vs bean-like in shape in the new species. The upper anal valve setae in c-row are equal in the new species and, in *H. subsimilis*, seta c0 is longer than setae c2.

***Hymenaphorura urbana* sp. nov.**
http://zoobank.org/35D62DBF-71A7-48E7-81D5-3F4EEB6EB1EA
Figures 3A–H, 4A–F, Table 2

Hymenaphorura nova – Fiera 2009: 871

Material examined. ***Holotype*:** female (RO-Hym4-IBB): Romania, Bucharest, Cişmigiu park, soil under *Thuja orientalis* L., 44.4365N, 26.0901E, 72 m a.s.l., 05.XII.2013, coll. C. Fiera. ***Paratypes*:** 3 females (2 in IBB: RO-Hym5,6-IBB and one in ISEA: RO-13-1), 2 males preadults (one in IBB: RO-Hym7-IBB and one in ISEA: RO-13-2), 2 juveniles (one in IBB: RO-Hym8-IBB and one in ISEA:RO-13-3), Bucharest, Cişmigiu park, same data as holotype.

Other material. one male preadult and one female (IBB: RO-Hym9,10-IBB), Bucharest, Unirea park, 44,427980N, 26,101367E, 72 m a.s.l., 05.XII.2013, coll. C. Fiera.

Diagnosis. Body with distinct areas of coarser granules. Dorsal pso formula as 10/011/11112, ventral pso absent. PAO with 13–15 simple vesicles, parallel or oblique in relation to the long axis of this organ (Fig. 3B) and one border seta. Abd. terga I–III with subequal setae p2 and p3. Abd. tergum V granular area with 3+3 distinct, long macrosetae. Distal tibiotarsal whorl with 11 setae.

Description. ***Measurements*** (in mm). Holotype female length 1.82, length of paratypes males: preadult 1.34–1.47, paratypes females: 1.50–1.88, females juvenile: 1.26–1.34.

Body. Body elongate, cylindrical (Fig. 3C). Colour in alcohol white. Distinctive areas of granulation on dorsal side of the body of c2 type (sensu Arbea and Jordana 1994). Usually 9–11 grains around each pseudocellus (Fig. 3B).

Antennae and head. Antennae almost as long as head. Antennal segment I with 8 setae, antennal segment II with 16 setae. AIIIO consisting of four guard setae, five papillae, two smooth sensory rods, two granulated sense clubs: ribbed and bent, ventrolateral microsensillum present. Second external papilla in AIIIO not forked. Antennal segment IV without distinct sensilla, small subapical organite in deep, narrow pit and latero-external microsensillum last posterior row of setae (Fig. 3A).

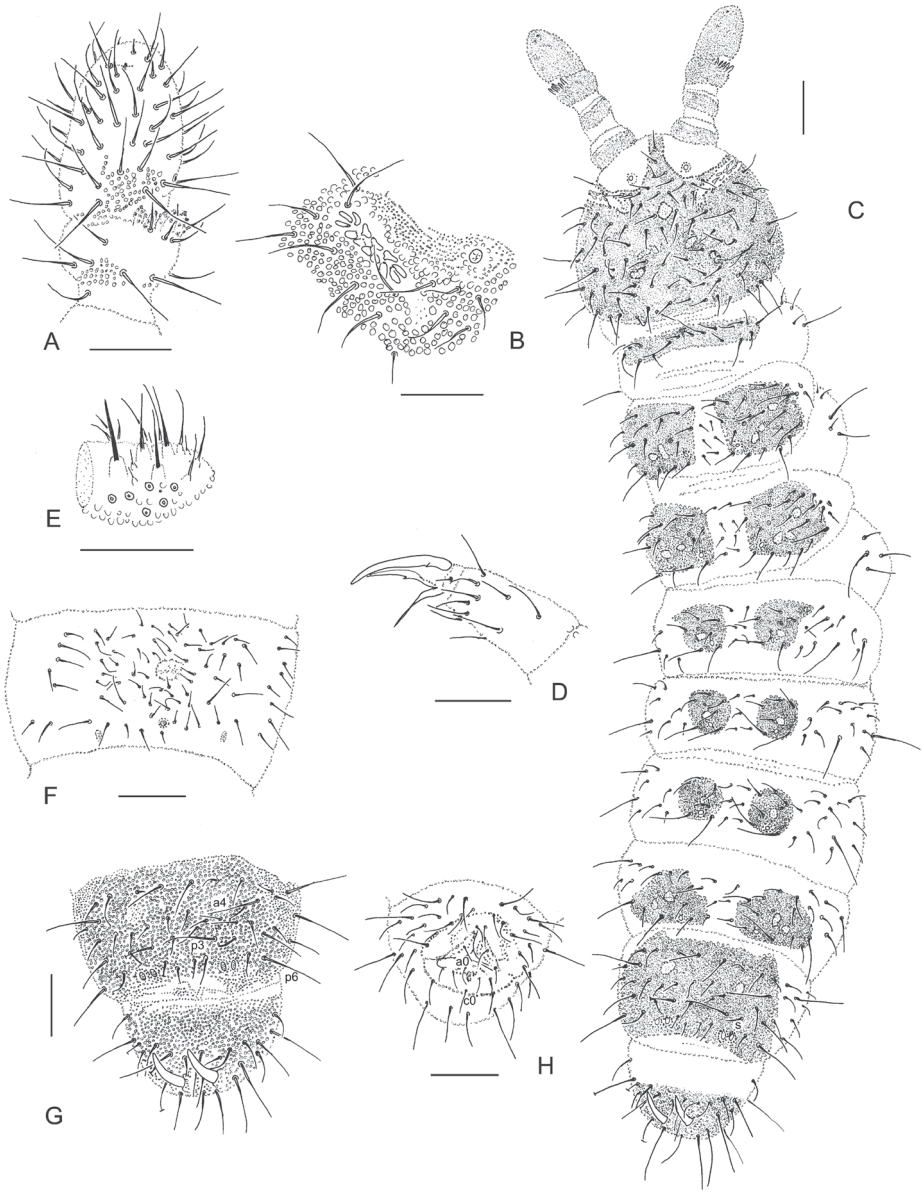

Figure 3. *Hymenaphorura urbana* sp. nov. **A** antennal segment III and IV **B** postantennal sensory organ and anterior cephalic pseudocellus **C** habitus and dorsal chaetotaxy **D** leg III: tibiotarsal chaetotaxy and claw **E** labial palp **F** abdominal sternum IV with furcal rudiment **G** abdominal terga V and VI **H** abdominal sternum VI: anal valves. Scale bars: 0.05 mm (**A, B, D–H**); 0.1 mm (**C**).

PAO with 13–15 simple vesicles, parallel or oblique in relation to the long axis of this organ, PAO groove border with one seta (Fig. 2B). Labral formula of setae: 4/3,2,2. Maxillary palp simple with two sublobal sensory hairs. Labial type A (sensu

Fjellberg 1999) with four papillae, papilla E absent (Fig. 3E). Small guards a_1, $b_{1–2}$, d_2. Five other guards as long as terminal sensilla of papillae.

Pseudocellar, Parapseudocellar, Pseudopores Formulae. Pseudocellar formula per half tergum dorsally: 10/011/11112 (Fig. 3C), ventrally and on subcoxae 1 absent. Parapseudocelli (psx) not always visible, their formula per half segment: 01/111/1111 dorsally and 111111^m ventrally. Subcoxae 1. with 2 psx each, each femur with one psx. Pseudopores 11/1111 dorsally. Abdominal sterna II–IV with one medial pseudoporus each: abdominal sternum II with pseudoporus between two rows of setae, abdominal

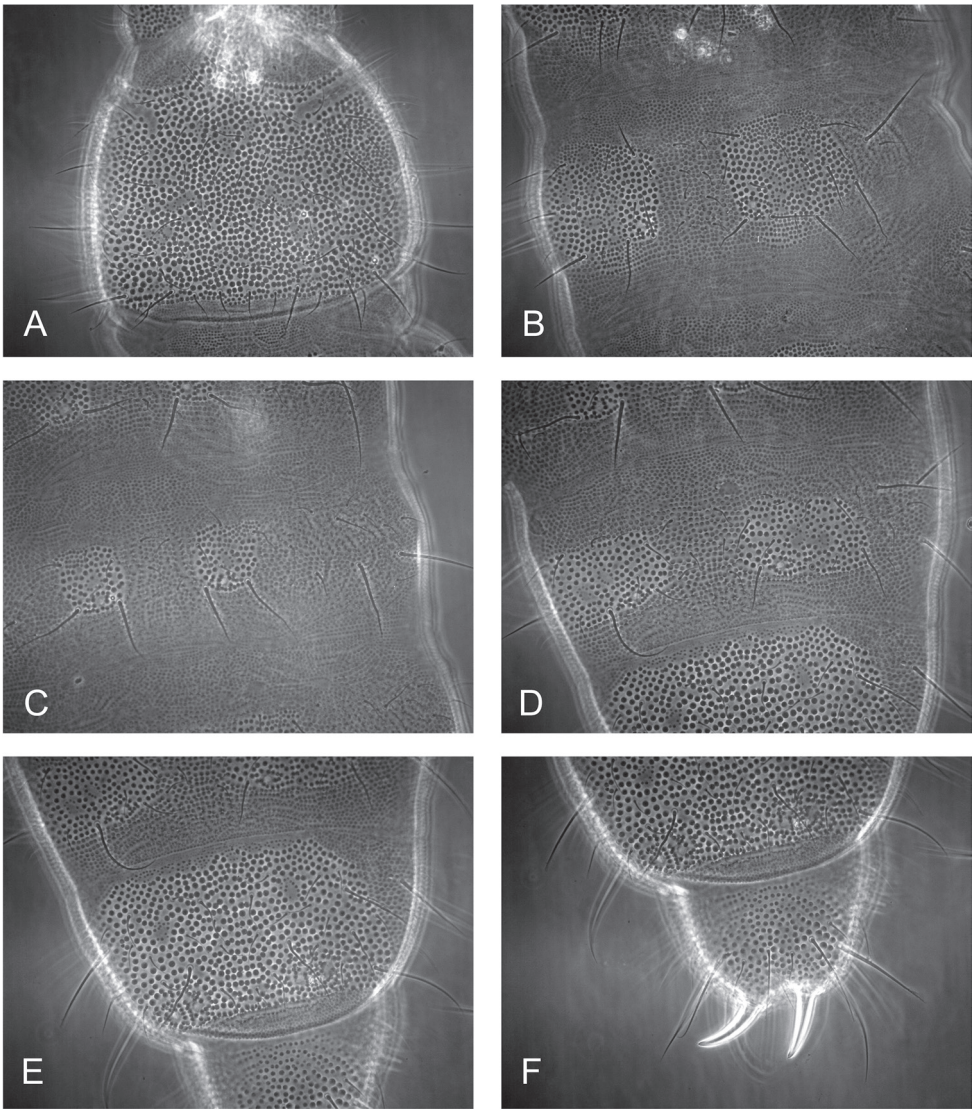

Figure 4. *Hymenaphorura urbana* sp. nov.: dorsal chaetotaxy. **A** head **B** thoracic tergum II **C** abdominal tergum II **D** abdominal tergum IV **E** abdominal tergum V **F** abdominal tergum VI.

sternum III with pseudoporus in posterior row, abdominal sternum IV with pseudoporus placed behind margin of manubrial area (below row p).

Dorsal chaetotaxy. Dorsal chaetotaxy, always with some asymmetry, as in Figs 3C, 4A–F with macro- and meso/microsetae of different length. Seta d0 on the head absent, Sensory setae s very slightly marked, well differentiated on abdominal tergum V. Thoracic terga II and III with lateral microsensilla (ms). Thoracic tergum I with 8–12+8–12 setae (holotype: 8+10). Thoracic terga II–III with 7+7 fairly strong and subequal short macrosetae. Abdominal terga I–IV with 3+3 macrosetae, abdominal terga I–III with subequal p2 and p3. Abdominal tergum V with three long macrosetae (a4, p3 and p6). One macroseta in the set of setae on subcoxae 1 and abdominal pleura I–IV and 2 macrosetae on abdominal pleurum V. Abdominal tergum VI with medial setae a0, m0 and p0. Anal spines as long as inner edge of claw and 3 times as long as their basal diameter. Basal papillae low.

Ventral chaetotaxy, furcal rudiment. Thoracic sterna II and III with 1–2 +1–2 setae respectively. Ventral tube with 8–12+8–12 setae (in holotype as 8+10). MVO in preadult males absent (adult males unknown).

Furcal rudiment with sternum with three irregular rows poorly distinguished comparing with other part of sternum. Setulae only sometimes distinguished (Fig. 3F). Basal papillae small as a half of width of spines. Each of even anal valves with 3 setae in row a (a1-a0-a1) and five setae in b-row (b2-b1-b0-b1-b2); upper valve with one seta in a-row (a0), four setae in b-row (b2-b1-b1-b2) and with three subequal setae in row c (c2-c0-c2) (Fig. 3H).

Legs. Chaetotaxy of legs I, II and III as follows: subcoxae 1 with 4, 5(6), 5(6) setae, subcoxae 2. with 1, 5(4), 5(4) setae, coxae with 4, 11(10), 11(14) setae, trochanters with 11 (10), 11(10), 10 setae, femora with 17 (16), 16, and 14(15) setae, tibiotarsi with 3 whorls of setae: 20 (1,8,11), 20 (1,8,11), 19 (1,7,11) setae respectively. Seta M present. Claw without internal denticle, with pair of lateral teeth. Empodial appendage with small, narrow basal lamella, length of empodium is about ⅔ of inner edge of claw (Fig. 3D).

Ecology. This species lives in the urban habitats of Bucharest.

Etymology. The species name refers to the urban area where it was sampled (Latin, urbanus).

Remarks. *Hymenaphorura urbana* sp. nov. belongs to the group of *Hymenaphorura* species with one seta in the PAO groove border, p2 seta subequal to p3 on abdominal terga I–III, and three macrosetae on the granulated area of abdominal tergum V. The new species shares these characters (Table 2) with *H. alticola* (Bagnall, 1935), *H. arantiana* Weiner & Stomp, 2001, *H. improvisa* Pomorski & Skarżyński, 2000, *H. nearctica* Pomorski, 2001, *H. nicol*ae Barra, 1998, *H. nova* Pomorski, 1990, *H. polonica* Pomorski, 1990, *H. similis* (Folsom, 1917), and *yoshii* Paśnik & Weiner, 2018 (Table 2).

Hymenaphorura urbana sp. nov. differs of *H. nearctica* and *H. yoshii* by the presence of one seta on border of PAO groove vs two setae; it differs of *H. yoshii* and *H. improvisa* by the pseudocelar formula (10/011/11112 vs 10/111/11112), of *H. improvisa* and *H. similis* by the number of setae in the tibiotarsal distal whorl (11 in the new species vs 9 in *H. improvisa* and *similis*). The new species differs of *H. nova* by the labial type

Table 2. Comparison of *Hymenaphorura* species with and 3+3 macrosetae on Abdominal segment V.

Species	PAO vesicles	Setae in tibiotarsal distal whorl	Setae on border of PAO groove	Labial type	Dorsal pso formula	Abd. I–III: p2/p3	Body size (mm)
***H. urbana* sp. nov.**	13–15	11	1	A	10/011/11112	subequal	females 1.64–1.92 males preadult 1.39–1.57
***H. alticola* (Bagnall, 1935)**	11(9–16)	11	1	?	20/111/11112	p3 longer than p2	1.6–2.0
***H. arantiana* Weiner & Stomp, 2001**	11–13	11	1	A	10/011/11112	subequal	females 0.89–1.18 males 0.77–1.0
***H. improvisa* Pomorski & Skarżyński, 2000**	10–11	9	2	AC	20/111/11112	p2 longer than p3	1.4–1.7
***H. nearctica* Pomorski, 2001**	14–16	11	2	?	10/011/11112	Subequal or p2 longer	females 1.8–2.3 male 1.6
***H. nicolae* Barra, 1998**	12–14	11	1	A	10/011/11112	p2 shorter than p3	1,9
***H. nova* Pomorski, 1990**	9–11	11	1	0	10/011/11112	subequal	1,5–2,2
***H. polonica* Pomorski, 1990**	10	11	1	A	10/011/11112	subequal	1.6–2.1
***H. similis* (Folsom, 1917)**	8–10	9	1 (rarely 2)	AC	10/011/11112	p2 longer than p3	females 1.5–1.7 males 1.4–1.5,
***H. yoshii* Paśnik & Weiner, 2018**	12–15	11	1	A	10/111/11112	subequal or p2 slightly longer	females 2.0–2.3 male 2.1

(A vs 0 in *nova*) as well as by the number of vesicles in PAO (13–15 vs 9–11). Setae p_2 and p_3 are subequal in the new species and p_3 is longer than p_2 in *H. alticola* and *H. nicolae*. *Hymenaphorura urbana* sp. nov. differs of *arantiana* by length of empodial appendage, which length is equal with the inner edge of claw III and size (1.39–1.92 mm for *urbana* vs 0.77–1.0 mm for *arantiana*). The new species is most similar to *polonica*, but *H. polonica* has only 10 vesicles in PAO and *urbana* has 13–15, and the granulation of Abd. tergum V is very coarse and presents cauliflower-like areas in *H. polonica*.

***Hymenaphorura subsimilis* Bagnall, 1948**

Figures 5A–E, 6A–C, Table 1

Material examined. Type specimen (NHMUK 012816837): Romania, Prahova, Sinaia, July 1934, coll. M. Manolache, among dead needles of *Larix*.

Complementary description. ***Antennae and head.*** AIIIO consisting of four guard setae, five papillae, two smooth sensory rods, two granulated sense clubs: ribbed and bent (Fig. 4A). PAO with 12–13 simple vesicles (Fig. 5C, 6A). Labial type A (sensu Fjellberg 1999) with four papillae, papilla E absent.

Dorsal chaetotaxy. Dorsal chaetotaxy as in Fig. 4B always with some asymmetry. Seta d_0 on the head absent. Body with macro- and meso-microsetae and sensory setae s (slightly distinguished) on head, abdominal terga I, IV and V, their formula per half tergum: 2/000/10012.

Thoracic terga II and III with strong lateral microsensilla (ms). Thoracic tergum I with 4+4 setae. Thoracic terga II and III (Figs 5D, 6B) and abdominal terga I–IV with 1+1 microsetae (a1) along midline. Setae p2 and p3 on abdominal terga I–III subequal. Abdominal tergum V (Figs 5D, 6C) with four long macrosetae (a4, m4, p2 and p5).

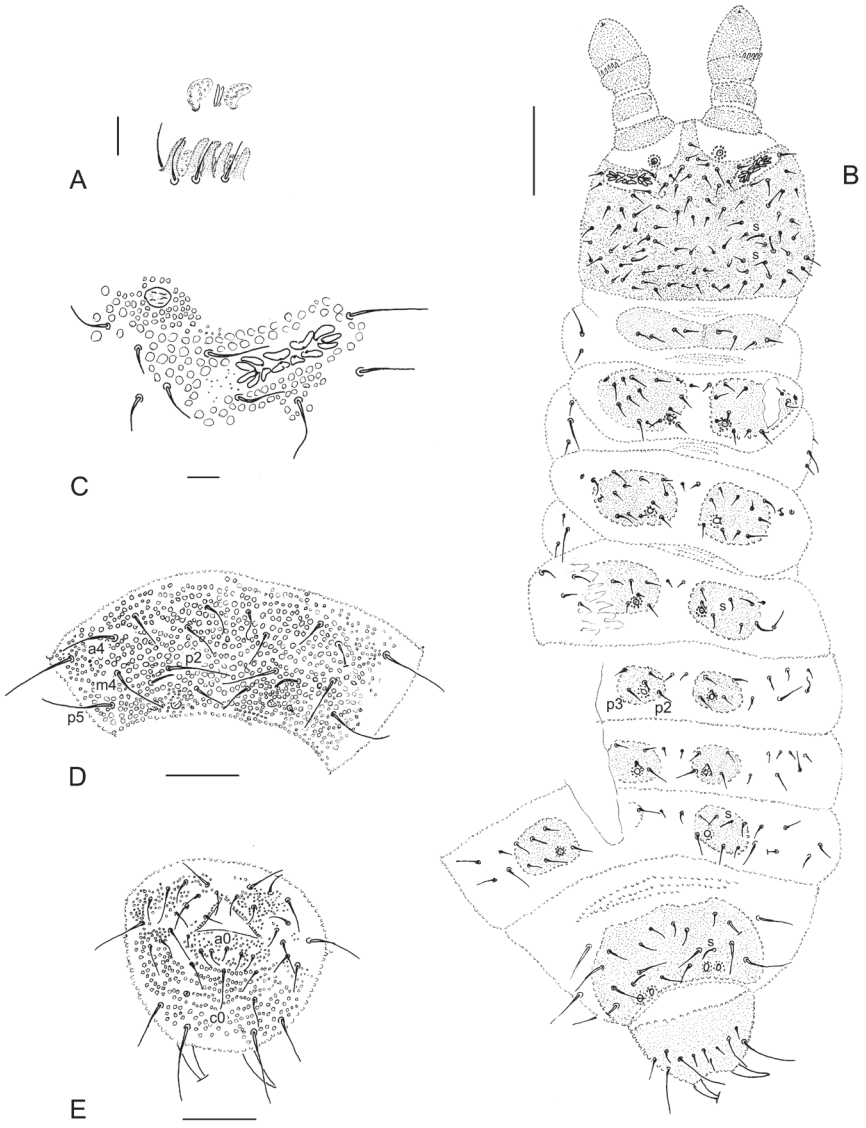

Figure 5. *Hymenaphorura subsimilis* Bagnall, 1948. **A** ant III sensory organ **B** habitus and dorsal chaetotaxy **C** postantennal sensory organ and anterior cephalic pseudocellus **D** abdominal terga V and VI **E** abdominal sternum VI: anal valves. Scale bars: 0.01 mm (**A, C**); 0.1 mm (**B**); 0.05 mm (**D, E**).

Chaetotaxy of anal valves. Each of even anal valves with 3 setae in row a (a1-a0-a1) and five setae in b-row (b2-b1-b0-b1-b2); upper valve with one seta in a-row (a0), four setae in b-row (b2-b1-b0-b1-b2) and with three setae in row c (c2-c0-c2), c0 is distinctly longer than c2 (Fig. 5E).

LEGS. Distal whorl of tibiotarsi with 11 setae. Empodial appendage with small, narrow basal lamella, length of empodium is about 2/3 of inner edge of claw.

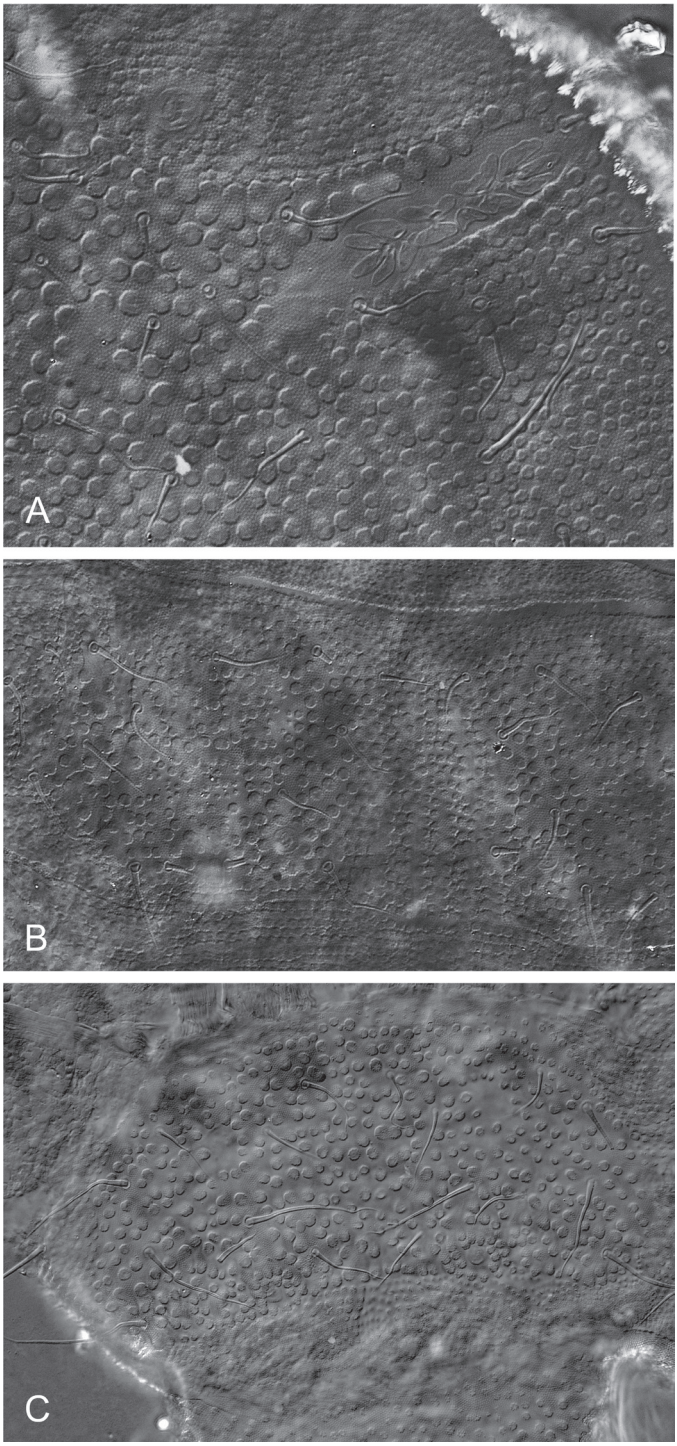

Figure 6. *Hymenaphorura subsimilis* Bagnall, 1948. **A** postantennal sensory organ and anterior cephalic pseudocellus **B** thoracic tergum II **C** abdominal tergum V.

Remarks. In the Collembola collection in the Natural History Museum, London, only a single type microscope slide exists of *Hymenaphorura subsimilis*, which was described by Bagnall (1948). This slide is in a poor condition, with some characters not well visible or completely invisible. Salmon (1959) redescribed the type specimen, but without details of the chaetotaxy. We had an opportunity to study this type specimen, and we found that the description of *H. subsimilis* was probably based on a juvenile or anomalous specimen, because there is only seta a1 in the medial part of terga (Figs 6A, 5D) without m_1 or p_1 and also with only 4+4 setae on Th. I.

Updated key to the known species of *Hymenaphorura*

The key presented below is based on the key by Paśnik and Weiner (2018). Recently described species have been added and some mistakes were corrected. *Hymenaphorura nova* has setae p_2 and p_3 on Abd. terga I–III subequal (not p_2 shorter than p3 as according to Paśnik and Weiner 2018) and *H. anatolii* Pomorski, 2001 has setae p2 longer than p3 (not p2 is four times longer than p3 as described by Paśnik and Weiner 2018).

1 Tibiotarsal distal whorl with 9 setae **2**
– Tibiotarsal distal whorl with 11 setae **6**
2 Base of antenna with 1–2 pso **3**
– Base of antenna with 3 pso ..... ***H. minuta* (Sun, 2014); China**
3 Base of antenna with 1 pso, PAO groove border with 1 or 2 setae **4**
– Base of antenna with 2 pso, PAO groove border with 2 setae **5**
4 Th. I without pso ..... ***H. reducta* Pomorski, 2001; North America**
– Th. I with pso ..... ***H. similis* (Folsom, 1917); USA, Siberia**
5 Granular area on Abd. tergum V with 3+3 macrosetae, Abd. terga I–III with p_2 distinctly longer than p_3, labial palpe of C type ..... ***H. improvisa* Pomorski & Skarżyński, 2000; Poland**
– Granular area on Abd. tergum V with 4+4 macrosetae, Abd. terga I–III with p2 and p3 roughly equal, labial palpe of A type ..... ***H. wusuliensis* Sun & Wu, 2011; China**
6 Base of antenna with 1 pso **7**
– Base of antenna with 2 pso **40**
7 Apex of Ant. IV with cauliflower-like papilla **8**
– Apex of Ant. IV without cauliflower-like papilla **10**
8 Abd. terga I–III with setae p2 and p3 of roughly equal length or p2 slightly longer than p_3 ..... **9**
– Abd. terga I–III with seta p2 about 4 times longer and thicker than p3 ..... ***H. ridibunda* Pomorski, 2001; USA**
9 Granular area on Abd. tergum V with 2+2 macrosetae ..... ***H. cocklei* (Folsom, 1908); North America**
– Granular area on Abd. tergum V with 4+4 macrosetae ..... ***H. decus* (Christiansen & Bellinger, 1980); USA**

10 Th. I with 1 pso **11**
– Th. I without pso **14**
11 PAO groove border with 1 seta, Abd. terga I–III with seta p_2 and p_3 of roughly equal length **12**
– PAO groove border with 2 setae, Abd. terga I–III with seta p_2 about 4 times longer than p_3 ..... ***H. alaskana*** **Pomorski, 2001; USA: Alaska**
12 Claw without inner denticle, granular area on Abd. tergum V with 1–3+1–3 macrosetae **13**
– Claw with inner denticle, granular area on Abd. tergum V with 6+6 macrosetae..... ***H. valdegranulata*** **(Stach, 1954); Europe**
13 Granular area on Abd. tergum V with 1+1 macroseta .... ***H. mystica*** **Pomorski, 2001; USA: Alaska**
– Granular area on Abd. tergum V with 3+3 macrosetae..... ..... ***H. yoshii*** **Paśnik & Weiner, 2018; Japan**
14 PAO with about 7–18 vesicles **15**
– PAO with 30–34 vesicles ..... ***H. reisingeri*** **(Neuherz, 1979); Europe**
15 PAO groove border with 2 setae..... **16**
– PAO groove border with 1 seta **20**
16 PAO with 16–18 vesicles **17**
– PAO with 8–11 vesicles ..... ***H. maoerensis*** **Sun, 2014; China**
17 Seta p2 on Abd. terga I–III longer than p3. ..... **18**
– Seta p_2 on Abd. terga I–III equal or shorter than p_3 ..... **19**
18 Claw with denticle, seta p2 on Abd. terga I–III slightly longer, but thicker than p3 .... ***H. nearctica*** **Pomorski, 2001; USA: Alaska, North-Eastern Asia**
– Claw without denticle, seta p2 on Abd. terga I–III distinctly longer and thicker than p3 .....***H. sensitiva*** **Pomorski, 2001; USA: Alaska**
19 Seta p2 on Abd. terga I–III shorter than p_3 ....***H. superba*** **Pomorski, 2001; USA: Alaska**
– Setae p2 and p3 on Abd. terga I–III roughly equal..... .....***H. granulata*** **Pomorski, 2001; USA: Alaska**
20 Seta p2 on Abd. terga I–III shorter than p3 ..... **21**
– Seta p2 on Abd. terga I–III equal, subequal or longer than p3 ..... **23**
21 Granular area on Abd. tergum V with 4+4 macrosetae..... **22**
– Granular area on Abd. tergum V with 3+3 macrosetae..... ..... ***H. nicolae*** **Barra, 1998; Europe**
22 Claw with denticle, empodial appendage length equals to inner edge of claw, granulated area developed −−type c1 according to Arbea & Jordana (1994).. ..... ***H. dentifera*** **(Stach, 1934); Europe (Carpathians and the Sudetes Mountains)**
– Claw without denticle, empodial appendage length equals ⅔ of inner edge of claw, granulated areas on the body reduced − type a according to Arbea & Jordana (1994)..... ***H. gamae*** **Arbea & Jordana, 1994; Europe: Spain**

23 Seta p2 on Abd. terga I–III distinctly longer than p_3 .....**24**
– Seta p2 and p3 on Abd. terga I–III equal or subequal **25**
24 Two sublobal hairs on the maxillary outer lobe present .....
.....***H. anatolii*** **Pomorski, 2001; North Europe, Siberia**
– Sublobal hairs on the maxillary outer lobe absent.... ***H. inopinata*** **Babenko, 2017 in: Babenko et al. 2017, East European tundra**
25 Claw with inner denticle.....**26**
– Claw without denticle.....**29**
26 Granular on Abd. tergum V area with 1−3+1–3 macrosetae.....**27**
– Granular on Abd. tergum V area with 6+6 macrosetae.....**28**
27 Granular area on Abd. tergum V with 1(2)+1(2) macrosetae.....
.....***H. maiteae*** **Arbea & Jordana, 1994; Europe: Spain**
– Granular area on Abd. tergum V with 3+3 macrosetae.....
.....***H. nova*** **Pomorski, 1990 Europe**
28 Dorsal chaetotaxy with short setae and macrosetae poorly manifested.....
.....***H. sibirica*** **(Tullberg, 1877)*; Siberia**
– Dorsal chaetotaxy with long setae and very distinct macrosetae.....
.....***H. liberta*** **Pomorski, 1990; Crimea**
29 Granular area on Abd. tergum V with 1(2)+1(2) macrosetae.....**30**
– Granular area on Abd. tergum with more macrosetae **32**
30 Granulation of dorsal side of the body coarse, pseudocelli surrounded by 8–11 grains, size 1.3–2 mm **31**
– Granulation of dorsal side of the body with poorly visible granular areas, pseudocelli surrounded by 13–15 grains, empodial appendage length equals ¾ of inner edge of claw, small size 0.8–1.1 mm .....
..... ***H. parva*** **(Skarżyński & Pomorski, 1996); Poland: Sudeten Mts.**
31 Empodial appendage length equals to inner edge of claw, pseudocelli surrounded by 9−11 grains, 1.6–2 mm, males with MVO.....
.....***H. pseudosibirica*** **(Stach, 1954); Europe: Hungary**
– Empodial appendage length equals ½–⅓ of inner edge of claw, pseudocelli surrounded by 8–9 grains, size 1.3–1.8 mm, males without MVO .....
.....***H. hispanica*** **Pomorski, 1992; Europe: Pyrenees**
32 Granular area on Abd. tergum V with 3+3 macrosetae.....**33**
– Granular area on Abd. tergum V with more macrosetae.....**35**
33 Empodial appendage length equals ½–⅔ of inner edge of claw.....**34**
– Empodial appendage length equals to inner edge of claw, small size (0.77–1.1 mm) .....***H. arantiana*** **Weiner & Stomp, 2001; Europe: Luxembourg**

* ***H. sibirica*** − there is a discrepancy in the number of macrosetae on Abd. V given for this species. Pomorski (2001) has given 1+1 macroseta, while Weiner and Fjellberg (1994) in their redescription of *H. sibirica* have given 6 macrosetae on Abd. V.

34 PAO with 10 vesicles, setae on the body rather short, granulation of Abd. tergum V very coarse with cauliflower-like areas .... ***H. polonica*** **Pomorski, 1990*; Europe**

– PAO with 13–15 vesicles, setae on the body rather long, granulation of Abd. tergum V coarse, but without cauliflower-like areas .... ***H. urbana*** **sp. nov. Europe: Romania**

35 Granular area on Abd. tergum V with 4+4 macrosetae..... **36**

– Granular area on Abd. tergum V with 6–8+6–8 macrosetae..... **39**

36 Granular area on Abd. tergum V with three lateral and one submedian macrosetae **37**

– Granular area on Abd. tergum V with two lateral and two submedian macrosetae..... ***H. palaearctica*** **Pomorski, 2001; Siberia**

37 Labial type A **38**

– Labial type 0 ..... ***H. ioni*** **Buşmachiu, Popa, & Weiner, 2014; Europe: Romania, Eastern Carpathians**

38 Abd. V tergum with one seta s (in row p) present, size 1.25 mm..... ..... ***H. subsimilis*** **Bagnall, 1948; Europe: Romania**

– Abd. V tergum with two setae s (in row a and p) present, size 0.81−0.87 mm ..... ***H. kalindera*** **sp. nov. Europe: Romania**

39 Granular area on Abd. tergum V with 6(7)+6(7) macrosetae, granular area on Abd. tergum IV rather small with 10 setae (in row p only p_2 and p_3), empodial appendage length equals ⅔ of inner edge of claw .... ***H. alpina*** **(Stach, 1946); Europe: Alps**

– Granular area on Abd. tergum V with 7(8)+7(8) macrosetae, granular area on Abd. tergum IV rather large with 13 setae (in row p 4–5 setae), empodial appendage length equals 4/5 of inner edge of claw..... ..... ***H. teretis*** **Pomorski, 2001; USA: Alaska**

40 Th. I with pso **41**

– Th. I without pso..... ***H. rafalskii*** **Weiner & Szeptycki, 1997; North Korea**

41 Abd. terga I–III with p2 shorter than p3..... ..... ***H. alticola*** **(Bagnall, 1935); Europe: Alps**

– Abd. terga I–III with p2 and p3 roughly equal..... ..... ***H. strasseri*** **(Stach, 1934); Europe: Slovenia**

Conclusion

As we mentioned in the Introduction, 46 species and the two species newly described here belong to the genus *Hymenaphorura*. European species are the most numerous (28); there are 12 North American species and eight from the Far East. It is possible

* ***H. polonica*** − in the description Pomorski (1990) mentioned 1+1 poorly developed macroseta on Abd. V, while specimens from the type locality and other places have 3+3 macrosetae.

that such this pattern of species distribution is an artefact caused by the intensity of research in these regions. Further studies are needed to confirm.

Six species are insufficiently described: *H. californica* (Coleman, 1941), *H. jugoslavica* (Gisin, 1963), *H. montana* (Handschin, 1921), *H. submontana* (Denis, 1926), *H. troglodytes* Bagnall, 1948, and *H. uzicensis* B.P.M. Ćurčić, Lučić, S.B. Ćurčić & N.B. Ćurčić, 2005, and therefore they are not included in the key.

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RESEARCH ARTICLE

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Taxonomic studies on the genus *Trilacuna* (Araneae, Oonopidae) from Myanmar

Yanfeng Tong[1,2], Shuqiang Li[3], Dongju Bian[4]

1 *Life Science College, Shenyang Normal University, Shenyang 110034, China* **2** *Southeast Asia Biological Diversity Research Institute, Chinese Academy of Sciences, Yezin, Nay Pyi Taw 05282, Myanmar* **3** *Institute of Zoology, Chinese Academy of Sciences, Beijing 100101, China* **4** *CAS Key Laboratory of Forest Ecology and Management, Institute of Applied Ecology, Shenyang 110016, China*

Corresponding authors: Shuqiang Li (lisq@ioz.ac.cn); Dongju Bian (biandongju@163.com)

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Abstract

Six species of the genus *Trilacuna* Tong & Li, 2007 are reported from Myanmar, including four new species: *T. besucheti* Grismado & Piacentini, 2014 (♂♀), *T. changzi* Tong & Li, **sp. nov.** (♂♀), *T. hponkanrazi* Tong & Li, **sp. nov.** (♂♀), *T. loebli* Grismado & Piacentini, 2014 (♀), *T. triseta* Tong & Li, **sp. nov.** (♂), and *T. zhigangi* Tong & Li, **sp. nov.** (♀). Morphological descriptions and photographic illustrations of the new species are given. All types are preserved in the Institute of Zoology, Chinese Academy of Sciences in Beijing (IZCAS).

Keywords

goblin spiders, new species, Oonopinae, taxonomy

Introduction

Of the 1850 spider species of family Oonopidae Simon, 1890 known worldwide (Li 2020), 10 have been previously recorded from Myanmar: *Gamasomorpha inclusa*

(Thorell, 1887), *G. psyllodes* Thorell, 1897, *G. sculptilis* Thorell, 1897, *Kachinia mahmolae* Tong & Li, 2018, *K. putao* Tong & Li, 2018, *Opopaea kanpetlet* Tong & Li, 2020, *O. zhigangi* Tong & Li, 2020, *Promolotra hponkanrazi* Tong & Li, 2020, *P. shankhaung* Tong & Li, 2020, and *Xestaspis parmata* Thorell, 1890. The current article investigates species of the genus *Trilacuna* Tong & Li, 2007 that were collected in Myanmar and includes descriptions and illustrations of four new species.

The spider genus *Trilacuna* was established to accommodate two new species from Southwest China (Tong and Li 2007). Subsequently, additional species have been described: seven from Thailand, Malaysia, and Sumatra (Eichenberger and Kranz-Baltensperger 2011), two from Vietnam (Tong and Li 2013), seven from Bhutan, India, Nepal, and Pakistan (Grismado et al. 2014), one from Iran (Malek-Hosseini et al. 2015), one from Korea (Seo 2017), and 10 from Southwest China (Tong et al. 2018, 2019; Liu et al. 2019). Currently, the genus *Trilacuna* comprises 30 species, all of which are known from Asia (WSC 2020).

Methods

The specimens were examined in 95% ethanol using a Leica M205C stereomicroscope. Details were studied with an Olympus BX51 compound microscope. Photos were taken with a Canon EOS 750D zoom digital camera (18 megapixels) mounted on an Olympus BX51 compound microscope. Vulvae were cleared in lactic acid. Scanning electron microscope images (SEM) were taken in a high vacuum under a Hitachi TM3030 after critical point drying and gold-palladium coating. All measurements were taken using an Olympus BX51 compound microscope and are given in millimeters in the text. The materials are preserved in the Institute of Zoology, Chinese Academy of Sciences in Beijing (**IZCAS**).

The following abbreviations are used in the text and figures:

ab	anterior branch	**glo**	globular structure
ALE	anterior lateral eyes	**lb**	lateral branch
ALE–PLE	distance ALE–PLE	**ldi**	labium deep incision
ap	apodeme	**ls**	long setae
as	anterior sclerite	**mb**	median branch
boc	booklung covers	**ml**	median lobe
bts	bent thick setae	**PLE**	posterior lateral eyes
cmp	clypeus median projection	**PME**	posterior median eyes
cos	comb-like setae	**psp**	posterior spiracle;
db	dorsal branch	**sep**	semicircular plate
ds	dorsal setae	**smb**	small median branch
emb	embolus	**svl**	small ventral lobe
esb	elevated seta base	**tba**	transverse bars

tp	triangular plate	**vb**	ventral branch
tsc	transverse sclerite	**vs**	ventral setae

Taxonomy

Family Oonopidae Simon, 1890

Genus *Trilacuna* Tong & Li, 2007

Trilacuna Tong & Li, 2007: 333; Grismado et al. 2014: 26.

Type species. *Trilacuna rastrum* Tong & Li, 2007

Diagnosis. *Trilacuna* differs from other oonopid genera, except those of the "*Dysderoides* complex" (including *Bannana* Tong & Li, 2015, *Dysderoides* Fage, 1946, *Himalayana* Grismado, 2014, and *Trilacuna*), by the enlarged male palpal femur, the very complex embolus-conductor system, and the notched labium. Males differ from the other genera of the "*Dysderoides* complex" by usually lacking the furrow connecting the posterior tracheal spiracles, and females differ by having a long postgastric scutum covering almost the whole ventral abdomen (Grismado et al. 2014; Tong et al. 2019).

Composition. 34 species, including four described here.

Distribution. Iran to the Korean Peninsula.

Trilacuna besucheti Grismado & Piacentini, 2014

Figs 1–3, 14A–C, 15A, B, 16E, F

Trilacuna besucheti Grismado & Piacentini, in Grismado et al. 2014: 40, fig. 32A–H, 33A–F, 34A–F, 39C–D

Material examined. 3♂1♀, Myanmar, near 1.5 km from the roadside between Kanpetlet and Nat Ma Taung National Park; 21°13.058'N, 93°59.033'E; elevation ca 2420 m; 1.V.2017; Wu J. and Chen Z. leg. (IZCAS AR-25151-25152-25153-25154).

Diagnosis. Males of this species can be recognized by the circular, scale-like structure on the distal part of the bulb (white arrows in Fig. 2E, F) and the cymbium, which has two or three stout, dark setae with large bases (black arrows in Fig. 2G). Females are distinguished by having a darkened band (db) on the posterior margin of the epigastric furrow (Figs 3G, 15A).

Description. See Grismado et al. (2014).

Variation. The specimens from Myanmar have unbranched endites (Fig. 16E, F) and a strongly striated carapace (Figs 1D, F, 3D, F), whereas the specimens from India have distinctly branched endites and a smooth carapace (Grismado et al. 2014: figs 32–34).

Distribution. India (Meghalaya), Myanmar.

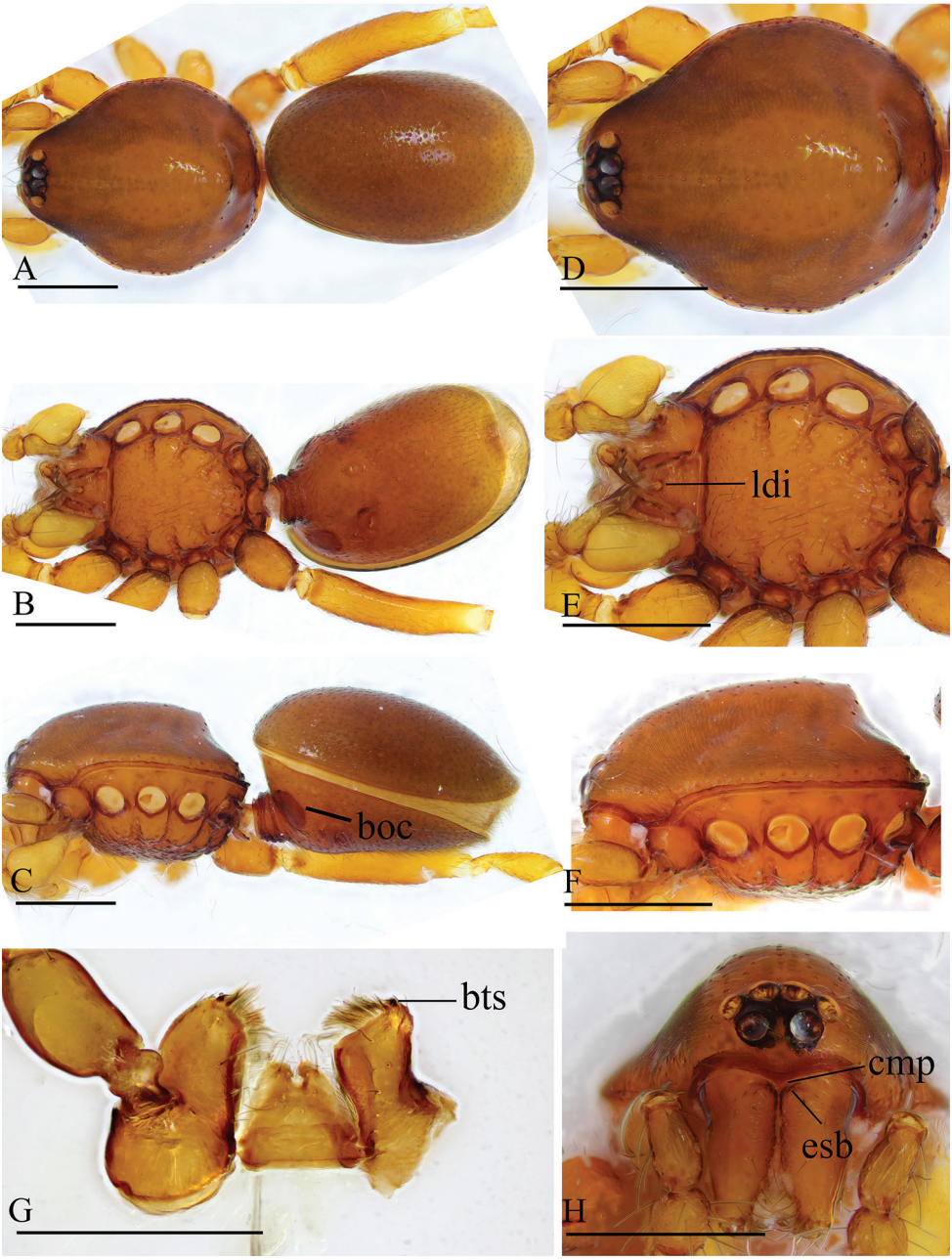

Figure 1. *Trilacuna besucheti*, male (IZCAS AR-25151) **A–C** habitus in dorsal, ventral, and lateral views **D–F, H** prosoma in dorsal, ventral, lateral, and anterior views **G** labium and endites in ventral view. Abbreviations: boc = booklung covers; bts = bent thick setae; cmp = clypeus median projection; esb = elevated seta base; ldi = labium deep incision. Scale bars: 0.4 mm (**A–F, H**); 0.2 mm (**G**).

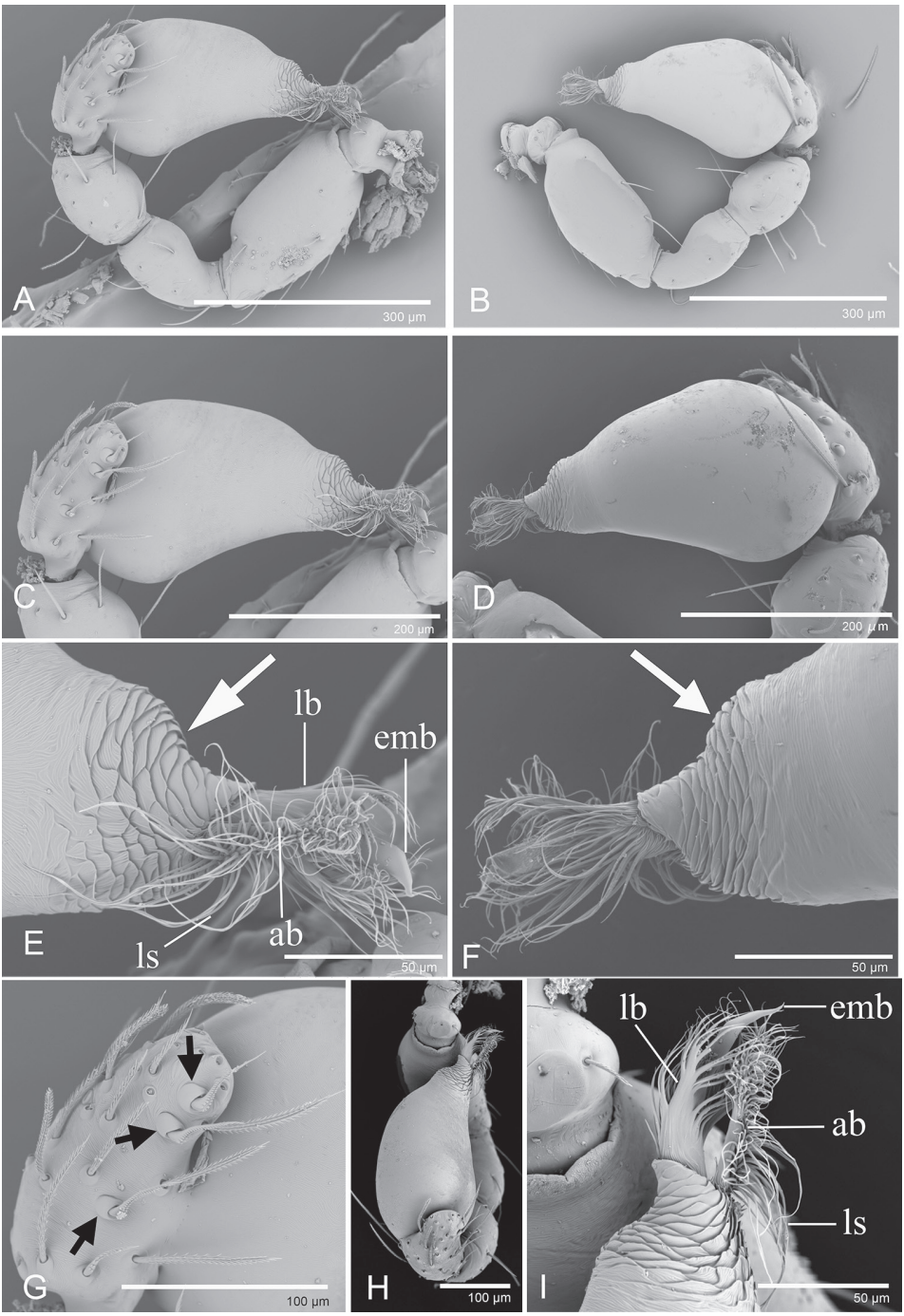

Figure 2. *Trilacuna besucheti*, left male palp, SEM (IZCAS AR-25151) **A, B, H** prolateral, retrolateral, and dorsal views **C, D** palpal bulb in prolateral and retrolateral views **E, F, I** distal part of palpal bulb in prolateral, retrolateral, and dorsal views (white arrows show the circular scale-like structure) **G** cymbium in prolateral view (black arrows show the large setae bases). Abbreviations: ab = anterior branch; emb = embolus; lb = lateral branch; ls = long setae.

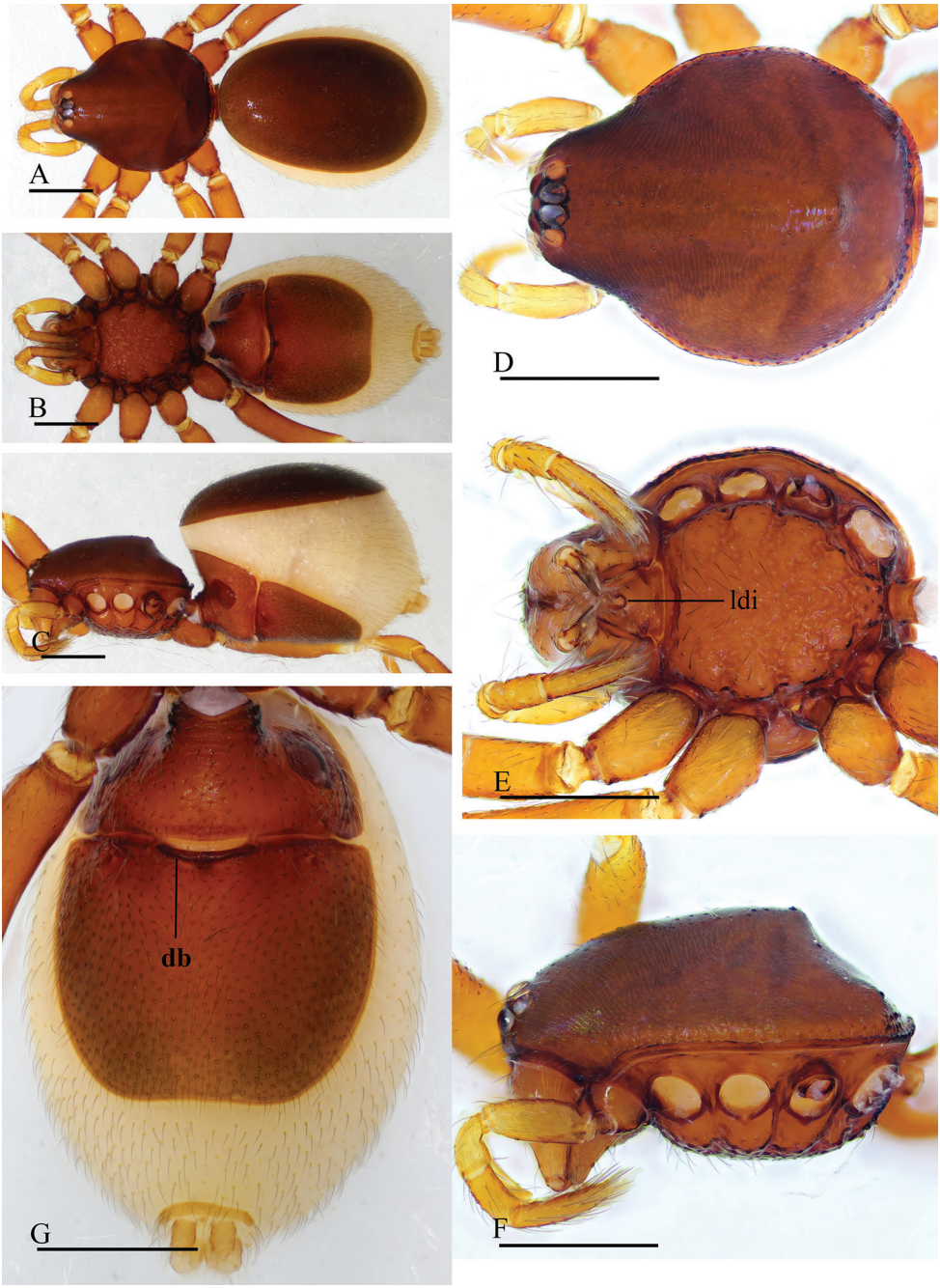

Figure 3. *Trilacuna besucheti*, female (IZCAS AR-25154) **A–C** habitus in dorsal, ventral, and lateral views **D–F** prosoma in dorsal, ventral, and lateral views **G** abdomen in ventral view. Abbreviation: db = darkened band; ldi = labium deep incision. Scale bars: 0.4 mm.

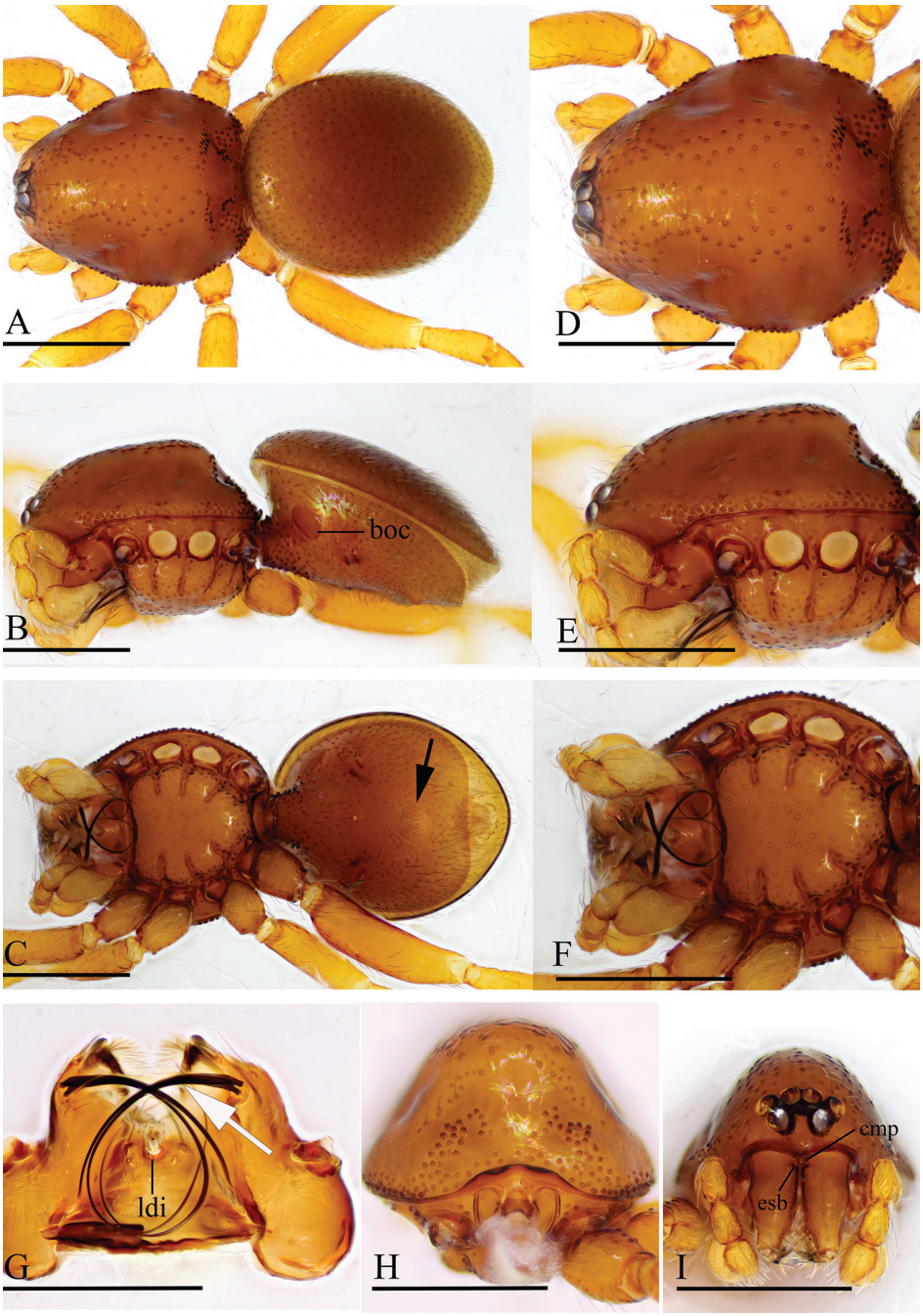

Figure 4. *Trilacuna changzi* sp. nov., male holotype **A–C** habitus in dorsal, lateral, and ventral views; black arrow shows the cluster of densely, short setae **D–F, H, I** prosoma in dorsal, lateral, ventral, posterior, and anterior views **G** labium and endites in ventral view; white arrow shows the long, strongly curved spines. Abbreviations: boc = booklung covers; cmp = clypeus median projection; esb = elevated seta base; ldi = labium deep incision. Scale bars: 0.4 mm (**A–F, H, I**); 0.2 mm (**G**).

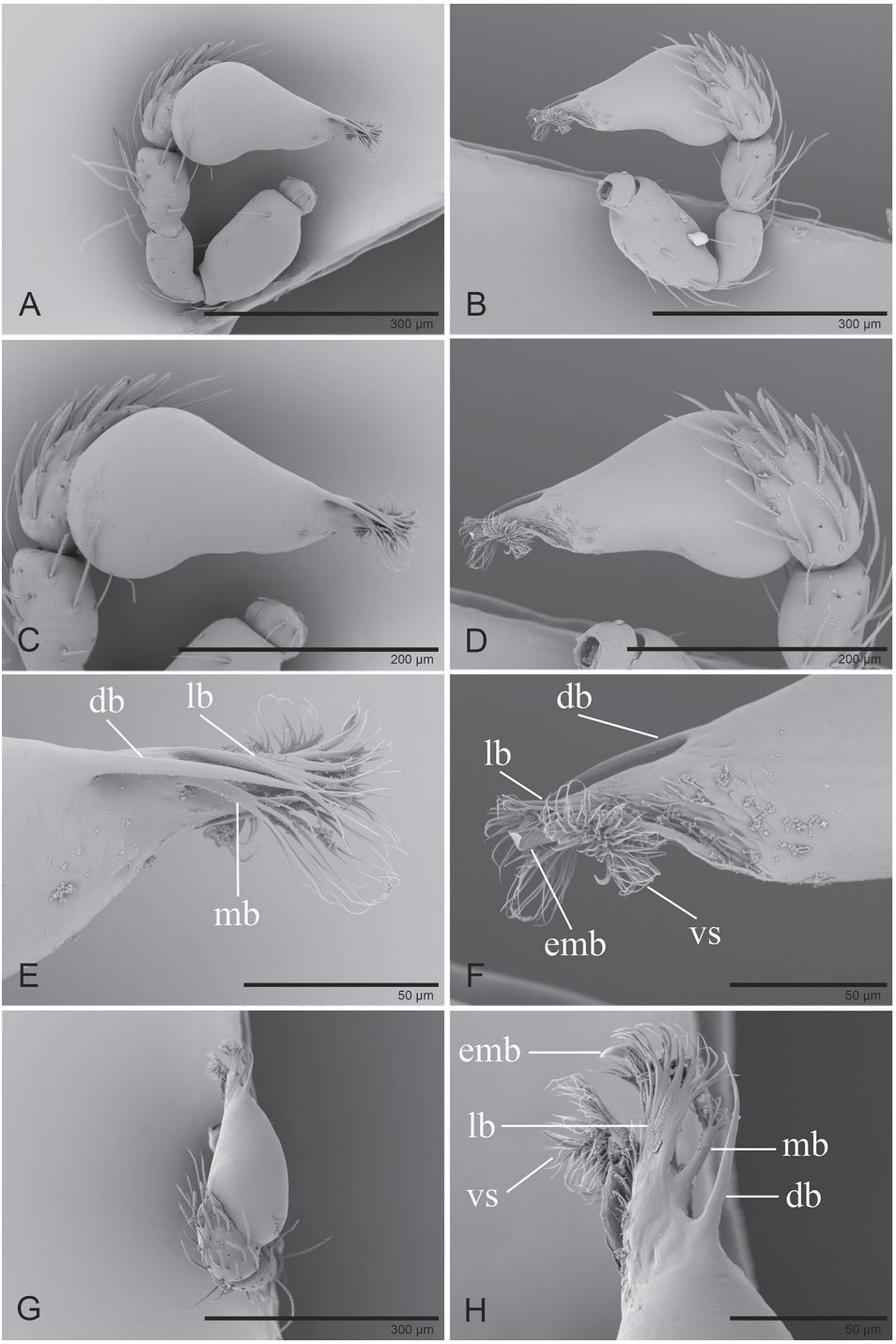

Figure 5. *Trilacuna changzi* sp. nov., male holotype, left palp **A, B, G** prolateral, retrolateral, and dorsal views **C, D** palpal bulb in prolateral and retrolateral views **E, F, H** distal part of palpal bulb in prolateral, retrolateral and dorsal views. Abbreviations: db = dorsal branch; emb = embolus; lb = lateral branch; mb = median branch; vs = ventral setae.

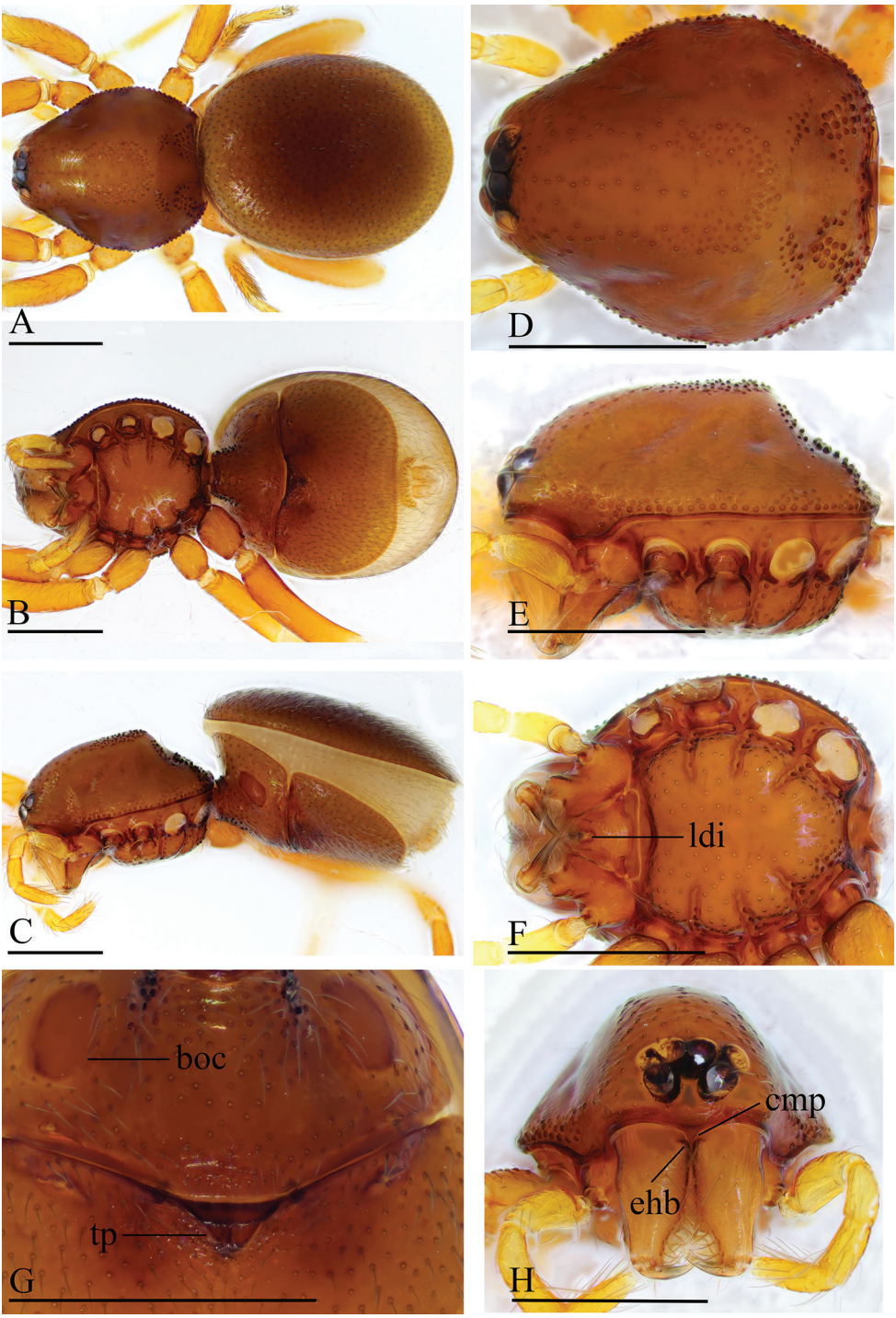

Figure 6. *Trilacuna changzi* sp. nov., female paratype **A–C** habitus in dorsal, ventral, and lateral views **D–F, H** prosoma in dorsal, lateral, ventral, and anterior views **G** abdomen in ventral view. Abbreviations: boc = booklung covers; cmp = clypeus median projection; esb = elevated seta base; ldi = labium deep incision; tp = triangular plate. Scale bars: 0.4 mm.

Trilacuna changzi **Tong & Li, sp. nov.**
http://zoobank.org/8557BE3E-8492-4401-B95E-C4C9D177DFA6
Figs 4–6, 14D–F, 15C, D, 16A, B

Type material. ***Holotype*** ♂: Myanmar, near 1.5 km from the roadside between Kanpetlet and Nat Ma Taung National Park; 21°13.058'N, 93°59.033'E; elevation ca 2420 m; 1.V.2017; Wu J. and Chen Z. leg. (IZCAS AR-25139). ***Paratype*** 1♀: Myanmar, same data as for holotype (IZCAS AR-25140).

Diagnosis. The new species is similar to *T. mahanadi* Grismado & Piacentini, 2014 but can be distinguished by the long, strongly curved spines on the male endites (Figs 4G, 16A, B), the bare dorsal branch (db) of the embolus system (Figs 5E, F, H, 14E), and the triangular plate (tp) of the female epigastric area (Fig. 6G). The male of *T. mahanadi* has unmodified endites and lacks the dorsal branch of the embolus system, and the triangular plate is lacking in the epigastric area of the female (Grismado et al. 2014: figs 36–38).

Description. Male. ***Body*****:** yellow-brown, chelicerae and sternum lighter, legs yellow; habitus as in Figure 4A–C; body length 1.56. ***Carapace*****:** 0.76 long, 0.64 wide; sides smooth, lateral margin rebordered (Fig. 4D); posterior surface with several large setal bases (Fig. 4H). ***Eyes*****:** ALE largest; PLE and PME nearly equal in size; ALE–PLE separated by less than ALE radius; PME touching each other; posterior eye row recurved as viewed from above, procurved as viewed from front (Fig. 4D, I). ***Clypeus*****:** height about 0.7 times of ALE diameter, with a triangular, pointed median projection (cmp). ***Mouthparts*** (Figs 4G–I, 16A, B): endites slender, with two long, strongly curved spines. ***Sternum*****:** (Fig. 4F). ***Abdomen*****:** 0.82 long, 0.66 wide; booklung covers ovoid, surface smooth (Fig. 4I); dorsal scutum not fused to epigastric scutum; apodemes present, posterior spiracles not connected by groove; epigastric region with a cluster of dense, short setae (Fig. 4C). ***Palp*** (Figs 5, 14D–F): orange; 0.48 long (0.15, 0.11, 0.09, 0.13); femur greatly elongated (width/length = 0.65) (Fig. 5A, B); bulb pear-shaped, tapering apically; embolus system (Fig. 5E, F, H) with a bare dorsal branch (db) in prolateral view, and a small median branch (mb) and laterally curved branch (lb) in dorsal view.

Female. Same as male except as noted. ***Habitus*****:** as in Figure 6A–C; slightly larger than male. ***Body*****:** length 1.76. ***Carapace*****:** 0.79 long, 0.67 wide. ***Abdomen*****:** 1.12 long, 0.82 wide. ***Endites*****:** unmodified. ***Epigastric area*** (Figs 6G, 15C): with a large, triangular plate (tp). ***Endogyne*** (Fig. 15D): with narrow, transverse sclerite (tsc), an anterior stick-shaped sclerite (as), and a posterior tortuous, tube-like globular structure (glo); transverse bars (tba) with two lateral apodemes (ap).

Etymology. The specific name is derived from Chinese pinyin, "changzi", which means "long moustache", referring to the long, curved spines on the male's endites; noun in apposition.

Distribution. Known only from the type locality.

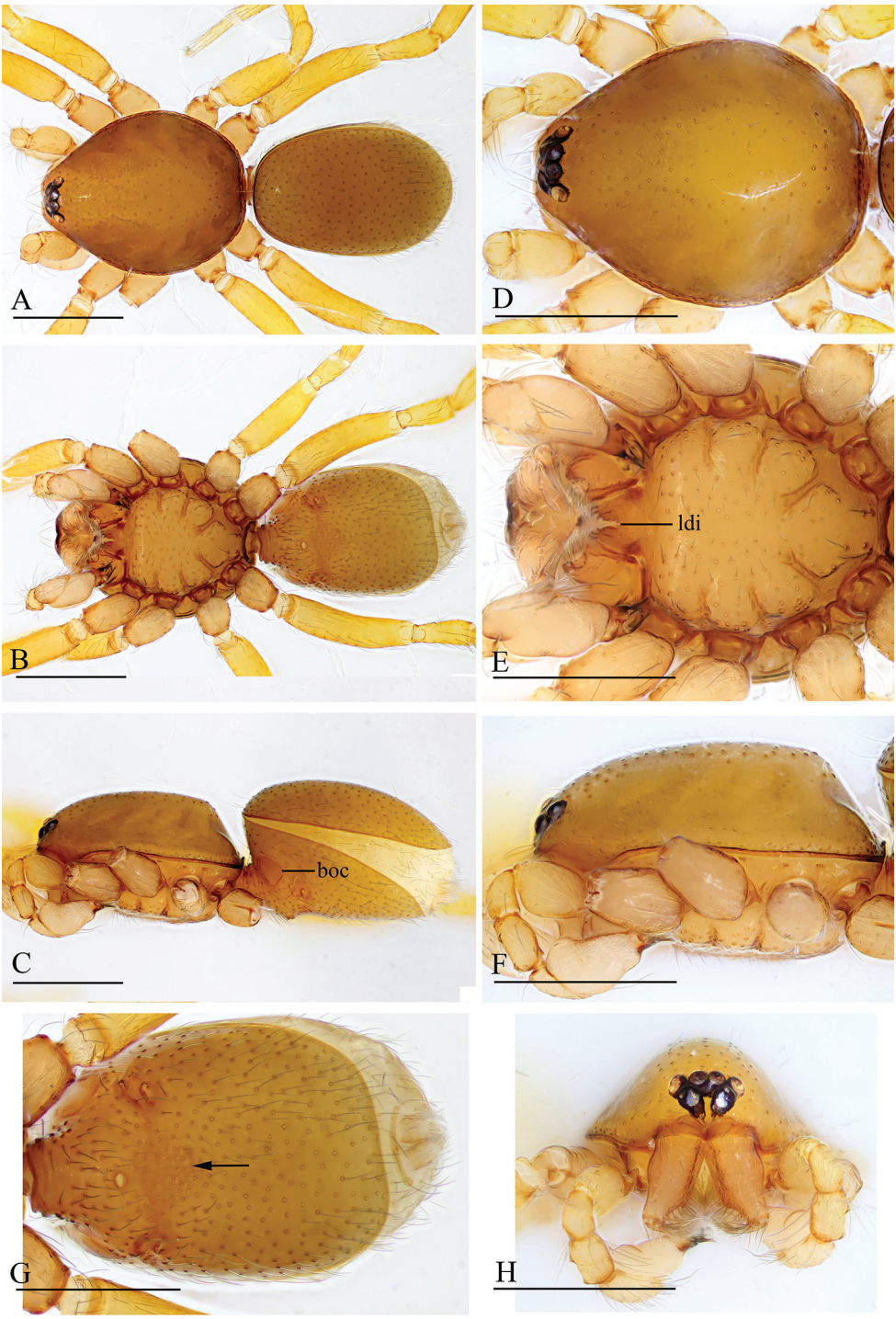

Figure 7. *Trilacuna hponkanrazi* sp. nov., male holotype **A–C** habitus in dorsal, ventral, and lateral views **D–F, H** prosoma in dorsal, ventral, lateral, and anterior views **G** abdomen in ventral view (arrow shows the patches). Abbreviations: boc = booklung covers; ldi = labium deep incision. Scale bars: 0.4 mm.

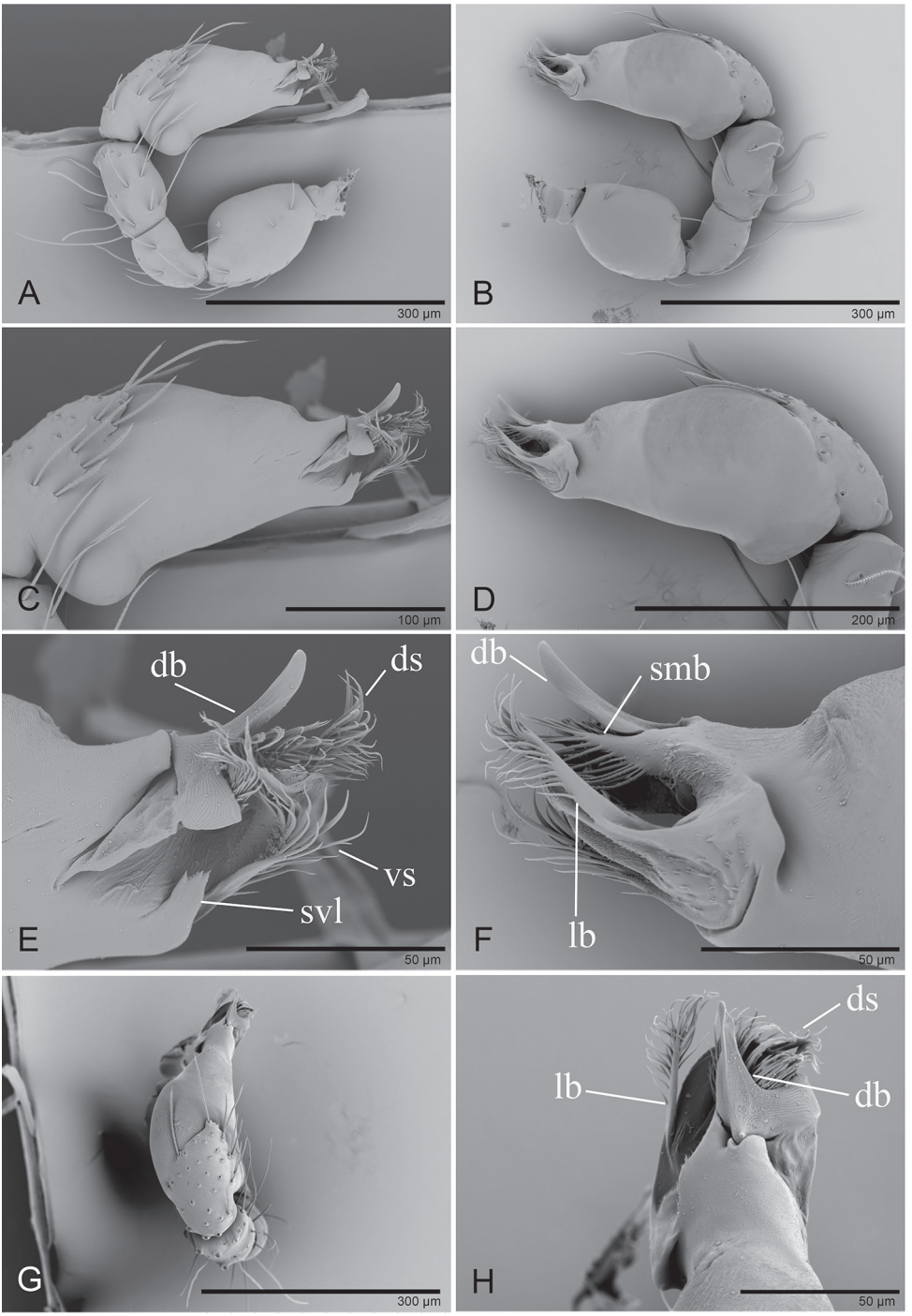

Figure 8. *Trilacuna hponkanrazi* sp. nov., male holotype, left palp, SEM **A, B, G** prolateral, retrolateral and dorsal views **C, D** palpal bulb in prolateral and retrolateral views **E, F, H** distal part of palpal bulb in prolateral, retrolateral, and dorsal views. Abbreviations: db = dorsal branch; ds = dorsal setae; lb= lateral branch; smb= small median branch; svl = small ventral lobe; vs = ventral setae.

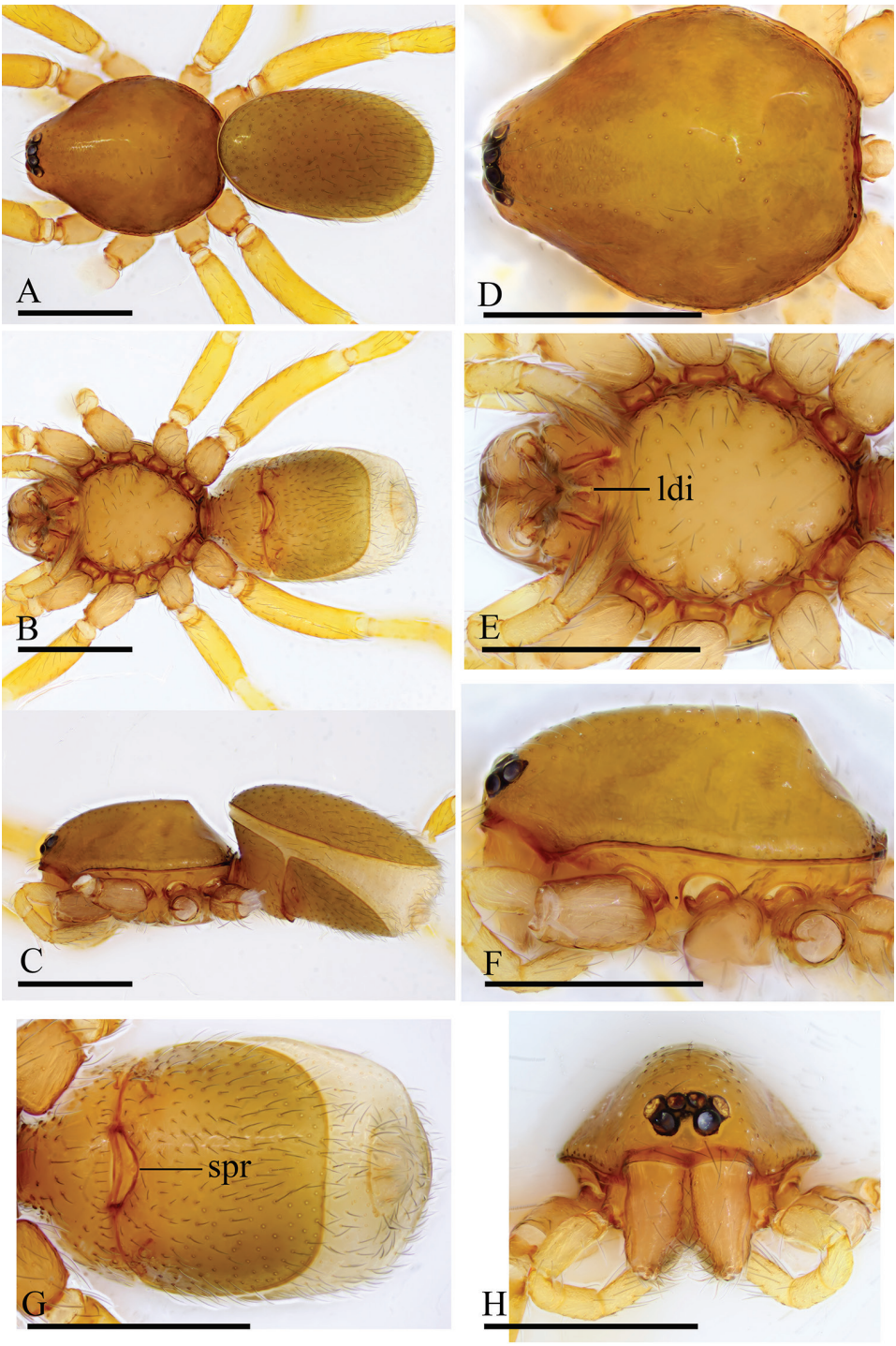

Figure 9. *Trilacuna hponkanrazi* sp. nov., female (IZCAS AR-25147) **A–C** habitus in dorsal, ventral, and lateral views **D–F, H** prosoma in dorsal, ventral, lateral, and anterior views **G** abdomen in ventral view**.** Abbreviation: ldi = labium deep incision; spr = sclerotized posterior ridge. Scale bars: 0.4 mm.

Trilacuna hponkanrazi **Tong & Li, sp. nov.**
http://zoobank.org/13FB4E13-509E-4C85-A8EB-AA4DCD6607BB
Figs 7–9, 14G–I, 15E, F, 16C, D

Type material. ***Holotype*** ♂: Myanmar, Kachin State, Putao, Hponkanrazi Wildlife Sanctuary, around Ziradum; 27°34.499'N, 97°03.546'E; elevation ca 1100 m; 19.XII.2016; Wu J. leg. (IZCAS AR-25141). ***Paratypes*** 1♀: Myanmar, same data as for holotype (IZCAS AR-25142); 2♂1♀: roadside between Wasadum and Ziradum; 27°32.305'N, 97°07.537'E; elevation ca 980 m; 12.XII.2016; Wu J. leg. (IZCAS AR-25143-25144-25145); 1♂: same data as preceding; 27°32.767'N, 97°07.283'E; elevation ca 970 m; 12.XII.2016; Wu J. leg. (IZCAS AR-25146); 3♀: around Ziradum Village; 27°33.465'N, 97°06.580'E; 1051 m; 8.V.2017; Wu J. leg. (IZCAS AR-25147-25148-25149); 1♀: same data as preceding; 27°35.305'N, 97°04.893'E; elevation ca 1140 m; 13.V.2017; Wu J. leg. (IZCAS AR-25150).

Diagnosis. The new species is similar to *T. gongshan* Tong, Zhang & Li, 2019 but can be distinguished by the forked dorsal branch of the embolus system (Fig. 8E), the curved, strongly sclerotized posterior ridge (spr) of the female's epigastric area (Fig. 9G), and the reticulate carapace (Figs 7D, F, 9D, F) of both sexes. *Trilacuna gongshan* has three long, tooth-like lobes in the embolus system, without a curved, strongly sclerotized posterior ridge in the female's epigastric area, and with a granulate carapace in both sexes (Tong et al. 2019: figs 10–12, 24G, H).

Description. Male. ***Body*****:** yellow, chelicerae and sternum lighter; habitus as in Figure 7A–C; body length 1.49. ***Carapace*****:** 0.74 long, 0.60 wide; sides finely reticulate; lateral margin rebordered (Fig. 7C). ***Eyes*****:** ALE largest; PLE and PME nearly equal in size; ALE–PLE separated by less than ALE radius; PME touching each other; posterior eye row recurved as viewed from above, procurved as viewed from front (Fig. 7D, H). ***Clypeus*****:** height about 1.25 times of ALE diameter. ***Mouthparts*** (Figs 7E, H, 16C, D). ***Sternum*** (Fig. 7E). ***Abdomen*****:** 0.63 long, 0.48 wide; booklung covers ovoid, surface smooth (Fig. 7C); dorsal scutum not fused with epigastric scutum; apodemes absent; posterior spiracles not connected by groove; epigastric region with patches between the posterior spiracles (Fig. 7G). ***Palp*** (Figs 8, 14G–I): orange; 0.52 long (0.15, 0.09, 0.13, 0.15); femur greatly swollen (width/length = 0.74) (Fig. 8A, B); bulb oval, stout, tapering apically; embolus system (Fig. 8E, F, H) with a forked dorsal branch (db) and a small ventral lobe (svl) in prolateral view, with a small median branch (mb) and a lateral branch (lb) in retrolateral view.

Female. Same as male except as noted. ***Habitus*****:** as in Figure 9A–C. ***Body*****:** length 1.43. ***Carapace*****:** 0.70 long, 0.57 wide. ***Abdomen*****:** 0.76 long, 0.45 wide. ***Epigastric area*** (Figs 9G, 15E): with a curved, strongly sclerotized posterior ridge (spr). ***Endogyne*** (Fig. 15F): with narrow, transverse sclerite (tsc), an anterior stick-shaped sclerite (as), and a posterior small globular structure (glo); transverse bars (tba) with two lateral apodemes (ap).

Etymology. The specific name is a noun in apposition taken from the type locality.

Distribution. Known only from the type locality.

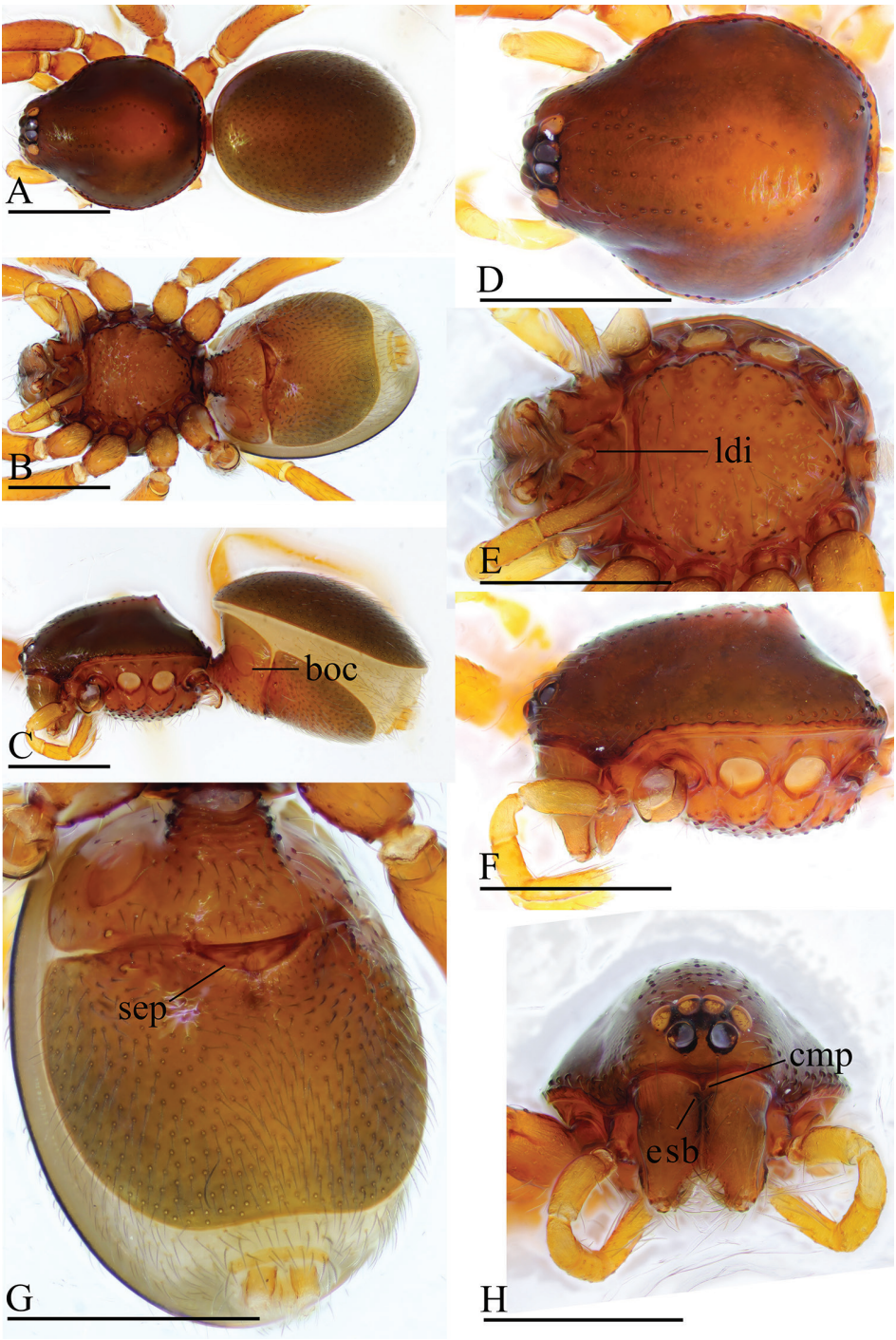

Figure 10. *Trilacuna loebli*, female (IZCAS AR-25156) **A–C** habitus in dorsal, ventral, and lateral views **D–F, H** prosoma in dorsal, ventral, lateral, and anterior views **G** abdomen in ventral view**.** Abbreviations: boc = booklung covers; cmp = clypeus median projection; esb = elevated seta base; ldi = labium deep incision; sep = semicircular plate. Scale bars: 0.4 mm.

Trilacuna loebli **Grismado & Piacentini, 2014**
Figs 10, 15G, 15H

Trilacuna loebli Grismado & Piacentini, in Grismado et al. 2014: 44, fig. 35A–I

Material examined. 1♀, Myanmar, Kachin State, Putao, roadside between Wasadum and Ziradum; 27°32.305'N, 97°07.537'E; elevation ca 980 m; 12.XII.2016; Wu J. leg. (IZCAS AR-25156).

Diagnosis. Females of this species can be distinguished from other congeners by the semicircular plate of the epigastric area and the worm-shaped globular structure of the endogyne (Fig. 15G, H).

Description. See Grismado et al. 2014.

Distribution. India (Assam); Myanmar.

Variation. The specimens from Myanmar have a reticulate carapace and a nearly straight posterior eye row in dorsal view (Fig. 10D). By contrast, the specimens from India have a granulate carapace, and the posterior eye row is slightly recurved in dorsal view (Grismado et al. 2014: figs 35H, I).

Trilacuna triseta **Tong & Li, sp. nov.**
http://zoobank.org/C04150ED-AD13-41F8-A86D-EE9FDD9B02D0
Figs 11, 12, 14J–L, 16G, 16H

Type material. ***Holotype*** **♂:** Myanmar, Kachin State, Putao, Hponkanrazi Wildlife Sanctuary; 27°32.032'N, 97°00.036'E; elevation ca 2010 m; 15.V.2017; Wu J. and Chen Z. leg. (IZCAS AR-25155).

Diagnosis. The new species is similar to *T. bilingua* Eichenberger, 2011 but can be distinguished by the three black, thick setae on the endites of the male (Figs 11G, 16G, 16H) and the slender anterior branch (ab) of the embolus system (Fig. 12E, 12F, 12H). *Trilacuna bilingua* lacks black, thick setae on the endites, and the embolus system has two very short lobes basally (Eichenberger et al. 2011: fig. 5–6).

Description. Male. ***Body*****:** reddish brown, chelicerae and sternum lighter, legs yellow; habitus as in Figure 11A–C; body length 1.97. ***Carapace*****:** 0.95 long, 0.74 wide; sides smooth; lateral margin rebordered (Fig. 11B); posterior surface with several large setal bases (Fig. 11H). ***Eyes*****:** ALE largest; PLE and PME nearly equal in size; ALE–PLE separated by less than ALE radius; PME touching each other; posterior eye row recurved as viewed from above, procurved as viewed from front (Fig. 11D, I). ***Clypeus*****:** height about 0.85 times of ALE diameter, with a triangular, pointed, median projection (cmp). ***Mouthparts*** (Figs 11F, I, 16G, H): endites with three thick, black setae. ***Sternum*** (Fig. 11F). ***Abdomen*****:** 1.05 long, 0.80 wide; booklung covers ovoid, surface smooth (Fig. 11B); dorsal scutum not fused to epigastric scutum; apodemes present; posterior spiracles connected by groove (Fig. 11C). ***Palp*** (Figs 12, 14J–L):

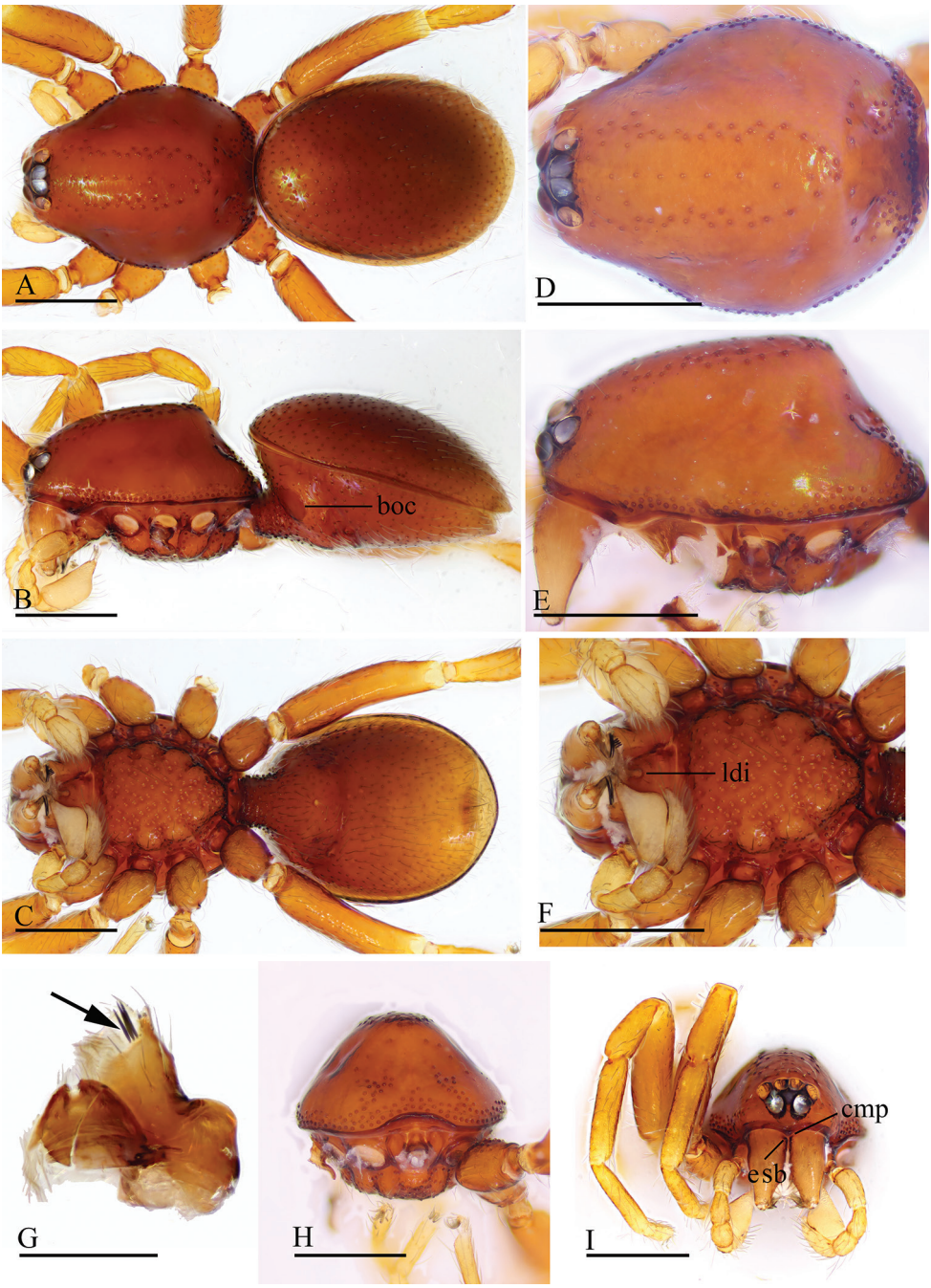

Figure 11. *Trilacuna triseta* sp. nov., male holotype **A–C** habitus in dorsal, lateral, and ventral views **D–F, H, I** prosoma in dorsal, lateral, ventral, posterior, and anterior views **G** labium and endites in ventral view (arrow shows the three black, strong setae). Abbreviations: boc = booklung covers; cmp = clypeus median projection; esb = elevated seta base; ldi = labium deep incision. Scale bars: 0.4 mm (**A–F, H, I**); 0.2 mm (**G**).

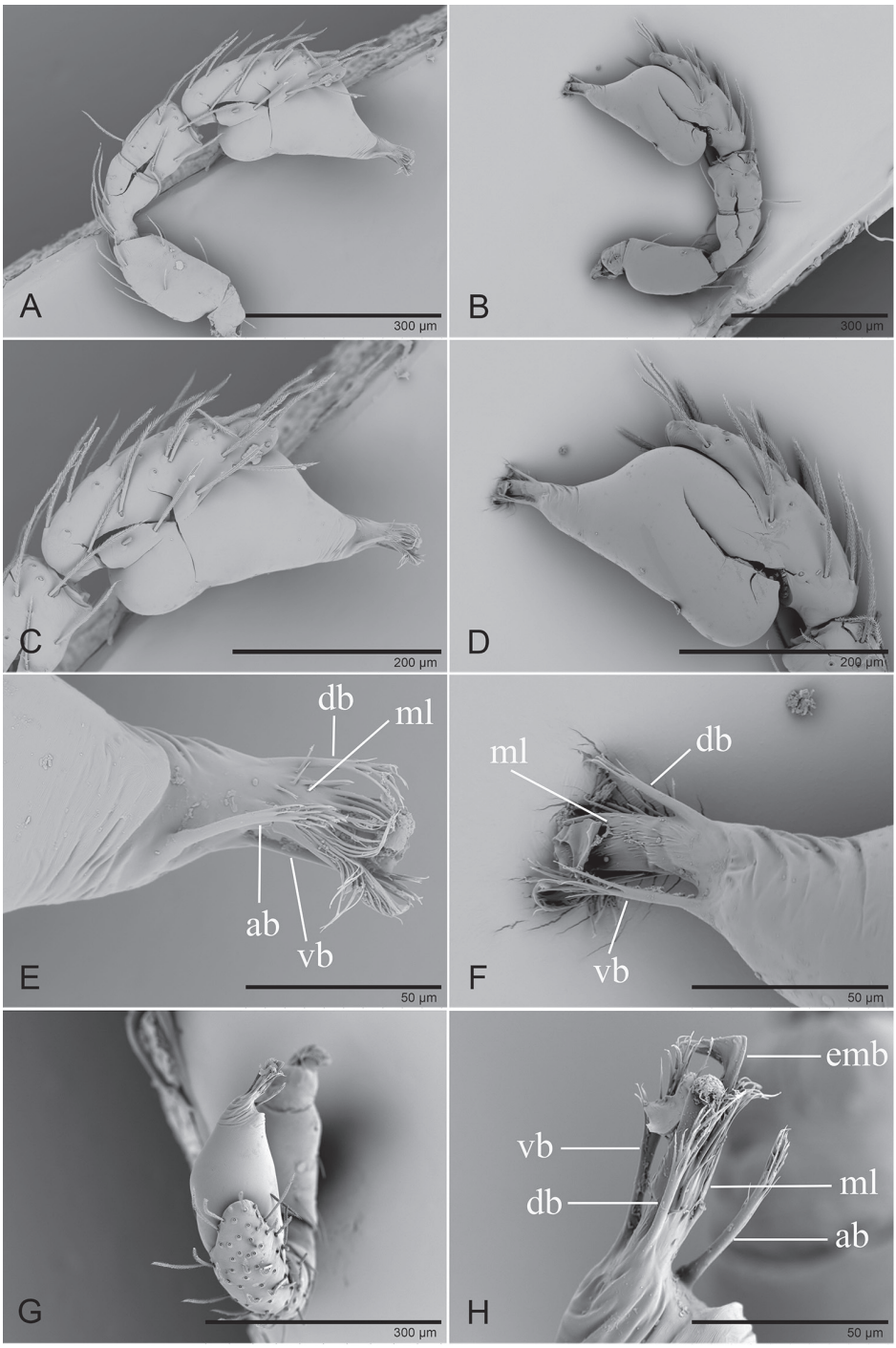

Figure 12. *Trilacuna triseta* sp. nov., male holotype, left palp, SEM **A, B, G** prolateral, retrolateral, and dorsal views **C, D** palpal bulb in prolateral and retrolateral views **E, F, H** distal part of palpal bulb in prolateral, retrolateral, and dorsal views. Abbreviations: ab = anterior branch; db = dorsal branch; emb = embolus; ml = median lobe; vb = ventral branch.

orange; 0.72 long (0.17, 0.11, 0.11, 0.33); femur elongated (width/length = 0.53) (Fig. 12A, B); bulb oval, tapering apically; embolus system (Fig. 12E, 12F, 12H) with an anterior branch (ab), a dorsal branch (db), a ventral branch (vb), and a median lobe (ml) in prolateral view.

Female. Unknown.

Etymology. The species epithet is a noun in apposition composed of the Latin words *tri* (three) and *seta* and refers to the three black, thick setae on the male's endites.

Distribution. Known only from the type locality.

Remarks. There are two species reported from a single female specimen in this study, and one described from a single male: *T. loebli* Grismado & Piacentini, 2014, *T. zhigangi* Tong & Li, sp. nov., and *T. triseta* Tong & Li, sp. nov., respectively. The following characters indicate that neither of the two females are conspecific with *T. triseta* Tong & Li, sp. nov. *T. loebli* is dark brown (Fig. 10A) with a reticulated carapace (Fig. 10D), and *T. zhigangi* has small eyes (Fig. 13A) and lacks the triangular, pointed, median projection of the clypeus (Fig. 13H). The male, *T. triseta* Tong & Li, sp. nov. has a reddish-brown body, a smooth carapace, normal-sized eyes, and a triangular, pointed, median projection (Fig. 11A, D, I).

Trilacuna zhigangi **Tong & Li, sp. nov.**

http://zoobank.org/08344EDB-66A5-4D7F-BC2C-330FE3F2619B
Figs 13, 15I, 15J

Type material. Holotype ♀: Myanmar, Kachin State, Putao, Hponkanrazi Wildlife Sanctuary; 27°31.592'N, 96°58.266'E; elevation ca 2470 m; 15.V.2017; Wu J. and Chen Z. leg. (IZCAS AR-25157).

Diagnosis. The new species is similar to *T. bangla* Grismado & Ramírez, 2014 but can be distinguished by the short, lateral apodemes (they do not reach the groove connecting the posterior spiracles) and the stick-shaped anterior sclerite of the endogyne (Fig. 15J). *Trilacuna bangla* has very long lateral apodemes (they distinctly extend beyond the groove connecting the posterior spiracles), and the anterior sclerite has long arms (Grismado et al. 2014: fig. 48A).

Description. Female. ***Body*****:** yellow, chelicerae and sternum lighter, legs yellow; habitus as in Figure 13A–C; body length 2.02. ***Carapace*****:** 0.86 long, 0.71 wide; sides reticulate; lateral margin rebordered (Fig. 13F). ***Eyes*****:** ALE largest; PLE and PME nearly equal in size; ALE–PLE separated by less than ALE radius; PME touching each other; posterior eye row recurved as viewed from above, procurved as viewed from front (Fig. 13D, H). ***Clypeus*****:** height about 1.2 times of ALE diameter. ***Mouthparts*** (Figs 13E, H). ***Sternum*** (Fig. 13E). ***Abdomen*****:** 1.20 long, 0.87 wide; booklung covers ovoid, surface smooth; postgastric scutum short, covering about 2/3 abdomen length. ***Epigastric area*** (Figs 13G, 15I): surface without external features. ***Endogyne*** (Fig. 15J): with narrow, transverse sclerite (tsc), an anterior stick-shaped sclerite (as), and a posterior small globular structure (glo); transverse bars (tba) with two lateral apodemes (ap).

Male. Unknown.

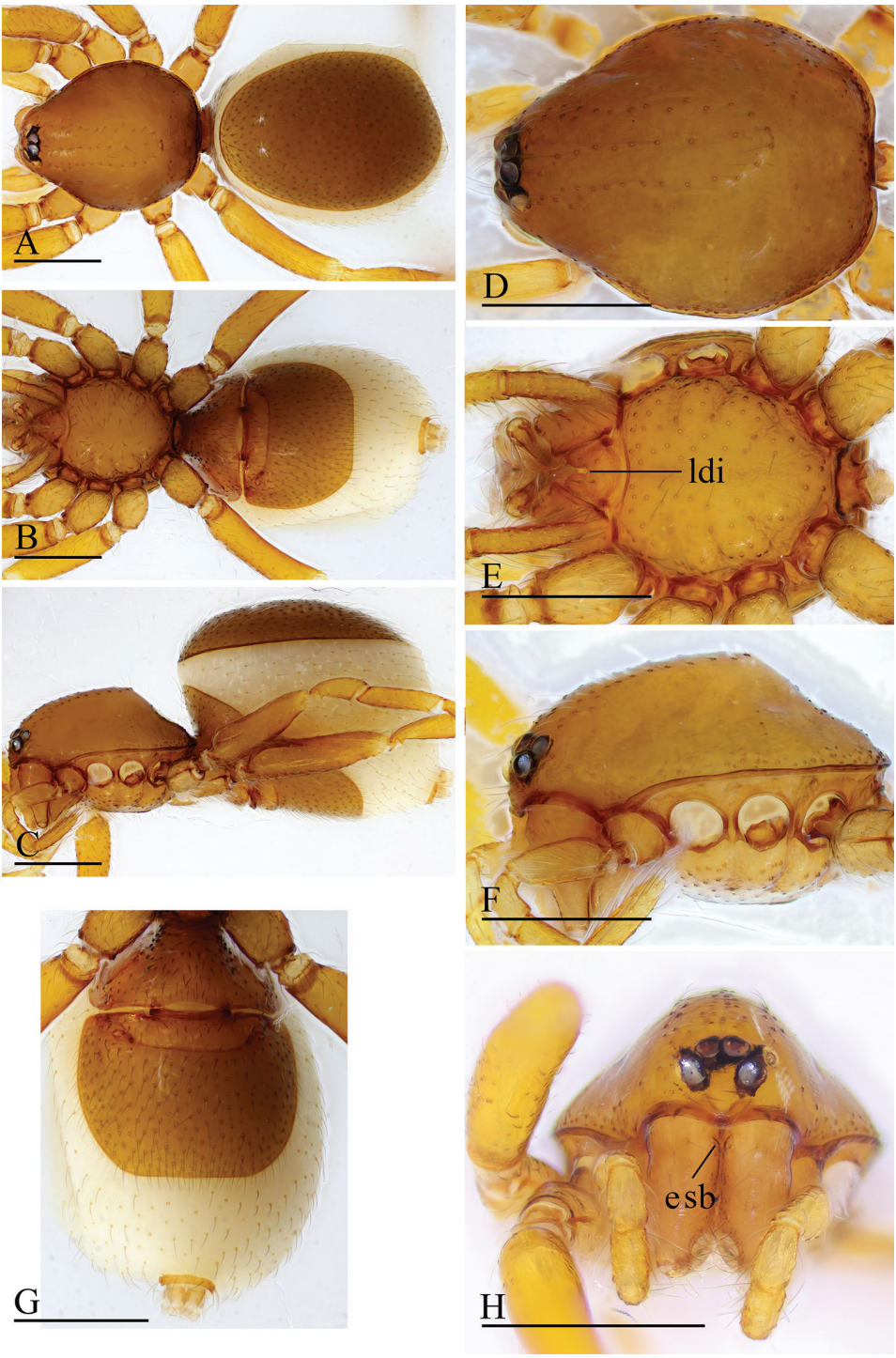

Figure 13. *Trilacuna zhigangi* sp. nov., female holotype **A–C** habitus in dorsal, ventral, and lateral views **D–F, H** prosoma in dorsal, ventral, lateral, and anterior views **G** abdomen in ventral view**.** Abbreviation: esb = elevated seta base; ldi = labium deep incision. Scale bars: 0.4 mm.

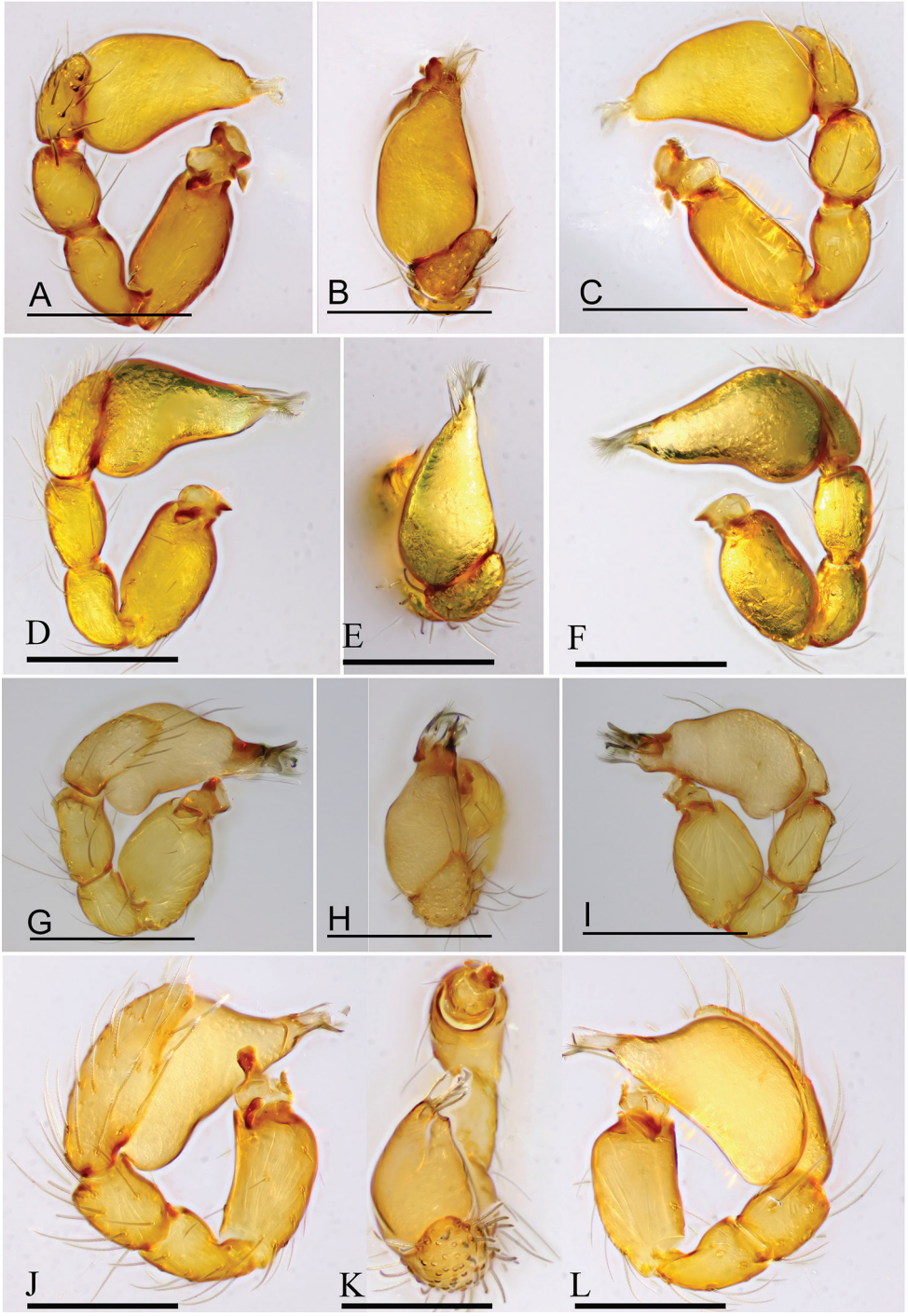

Figure 14. *Trilacuna* spp., left male palp **A–C** *T. besucheti* **D–F** *T. changzi* sp. nov. **G–I** *T. hponkanrazi* sp. nov. **J–L** *T. triseta* sp. nov. **A, D, G, J** prolateral views **B, E, H, K** dorsal views **C, F, I, L** retrolateral views. Scales: 0.2 mm.

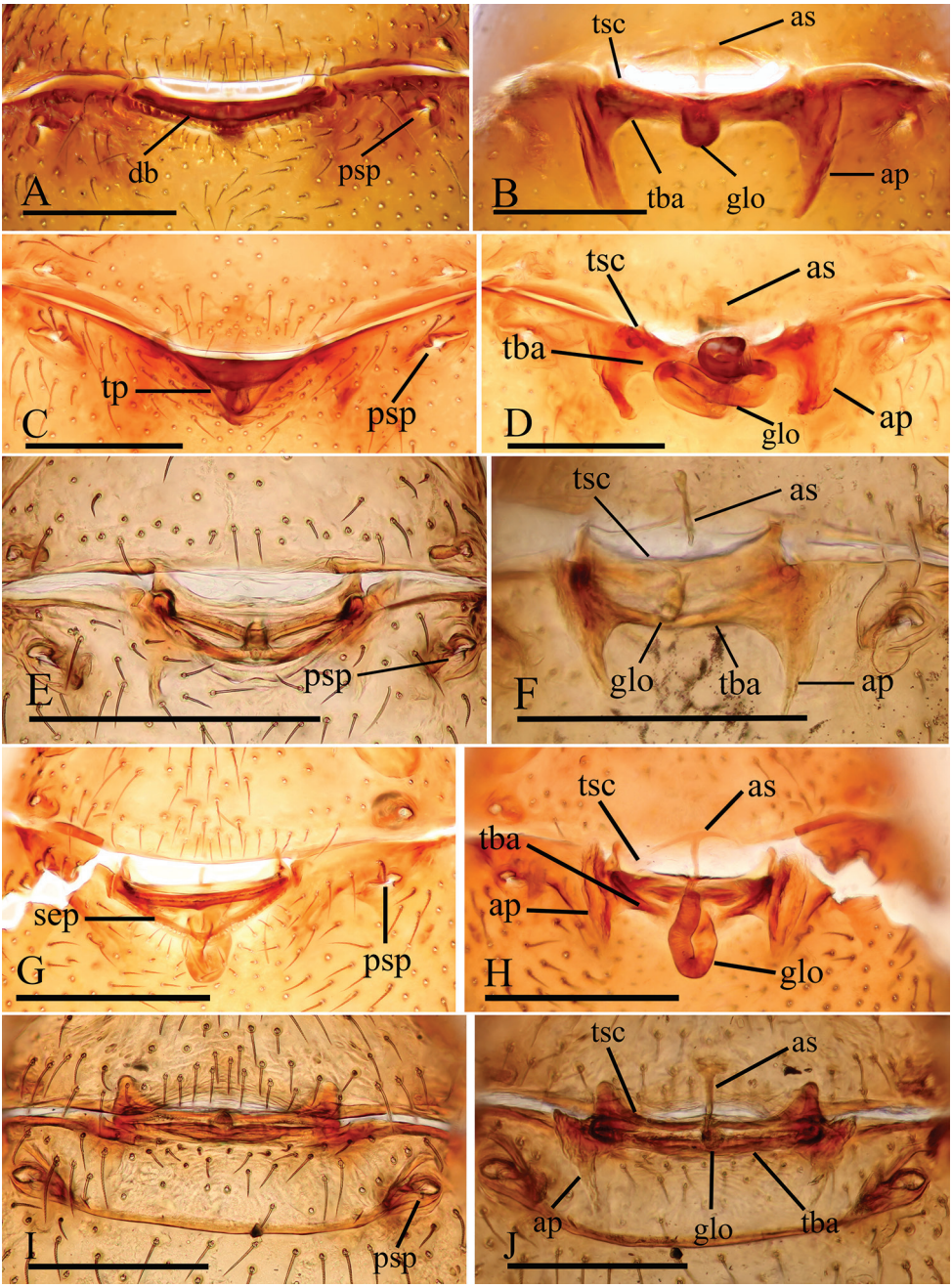

Figure 15. *Trilacuna* spp., female copulatory organ **A, B** *T. besucheti* **C, D** *T. changzi* sp. nov. **E, F** *T. hponkanrazi* sp. nov. **G, H** *T. loebli* **I, J** *T. zhigangi* sp. nov. **A, C, E, G, I** ventral view **B, D, F, H, J** dorsal view. Abbreviations: ap = apodeme; as = anterior sclerite; db = darkened band; glo = globular structure; psp = posterior spiracle; sep = semicircular plate; tba = transverse bars; tp = triangular plate; tsc = transverse sclerite. Scales: 0.2 mm.

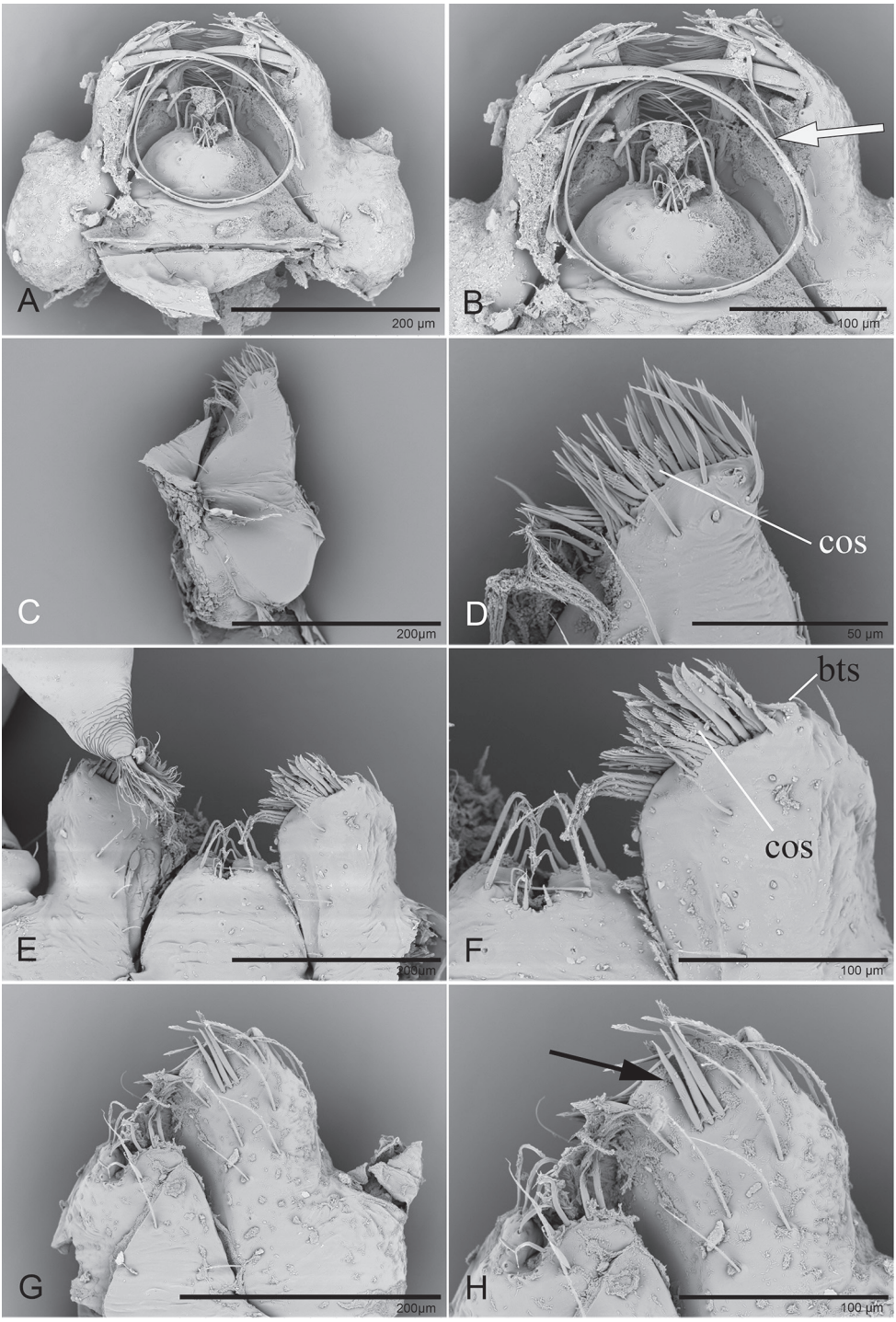

Figure 16. *Trilacuna* spp., male labium and endites, ventral view **A, B** *T. changzi* sp. nov., white arrow shows the long, strongly curved spines **C, D** *T. hponkanrazi* sp. nov. **E, F** *T. besucheti* **G, H** *T. triseta* sp. nov., black arrow shows the three black, strong setae. Abbreviations: bts = bent thick setae; cos = comb-like setae.

Etymology. The species is named after Mr Zhigang Chen, one of the collectors of the holotype.

Distribution. Known only from the type locality.

Acknowledgements

The manuscript benefitted greatly from comments by Yuri Marusik, Alireza Zamani, and Nadine Dupérré. The English was kindly checked by Sarah Crews. This study was supported by the National Natural Science Foundation of China (31750002, 31972867) and the Program for Liaoning Innovation Talents in University to Yanfeng Tong, by the National Natural Science Foundation of China (NSFC-31530067), and the Southeast Asia Biodiversity Research Institute, Chinese Academy of Sciences (2015CASEABRI005, Y4ZK111B01) to Shuqiang Li.

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RESEARCH ARTICLE

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Two new species of the *Exocelina ekari* group from New Guinea with strongly modified male antennae (Coleoptera, Dytiscidae, Copelatinae)

Helena Shaverdo[1], Suriani Surbakti[2], Bob Sumoked[3], Michael Balke[4]

1 *Naturhistorisches Museum Wien, Burgring 7, 1010 Vienna, Austria* **2** *Department of Biology, Universitas Cendrawasih, Waena, Papua, Indonesia* **3** *Walian 2, Tomohon Selatan, N Sulawesi 95439, Indonesia* **4** *SNSB-Zoologische Staatssammlung München, Münchhausenstraße 21, D-81247 Munich, Germany and GeoBioCenter, Ludwig Maximilians University, Munich, Germany*

Corresponding author: Helena Shaverdo (shaverdo@mail.ru)

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Abstract

Two new species of the genus *Exocelina* Broun, 1886: *E. athesphatos* **sp. nov.** and *E. tsinga* **sp. nov.** are described from New Guinea and placed into the *E. ekari* group based on the structure of their male genitalia. The two species are very similar with respect to their external morphology and characterised by almost identical, strongly modified male antennae. However, they can easily be separated by the shape and setation of the median lobe and paramere. Based on morphological similarity and results of a molecular phylogenetic analysis, we suggest these are sister species. Both of them have been collected on the southern slopes of the Central Range (the spine of New Guinea), with a distance of ca. 380 km straight line between the collecting localities.

Keywords

Australasia, distribution, *Exocelina*, systematics, new species

Introduction

Two new species of the genus *Exocelina* Broun, 1886 discovered on the southern slopes of the New Guinea Central Range are introduced. Having a discontinuous outline of the median lobe of the male genitalia, both belong to the largest *Exocelina* species group, *E. ekari* group. To date, this group contains 54 species (including the two new species) endemic to New Guinea (Balke 1998; Shaverdo and Balke 2019; Shaverdo et al. 2005, 2012, 2014, 2016). Including the results of this paper, 142 species of *Exocelina* are now described from New Guinea and 199 species worldwide (Shaverdo and Balke 2019; Shaverdo et al. 2019; Balke and Ribera 2020; Nilsson and Hájek 2020). As in most of our previous papers on the genus, all species data will be presented on the species-id.net portal automatically created by ZooKeys with the publication of this paper.

Materials and methods

The present work is based on material from the following collections:

KSP Koleksi Serangga Papua, at the Biology Department of Universitas Cenderawasih (UNCEN), Waena, Papua, Indonesia;
MZB Museum Zoologicum Bogoriense, Cibinong, Indonesia.

Our methods follow those described in detail in our previous articles (Shaverdo et al. 2012, 2014; Shaverdo and Balke 2014). The terminology to denote the orientation of the genitalia follows Miller and Nilsson (2003). All specimen data are quoted as they appear on the labels attached to the specimens. Label text is cited using quotation marks; comments in square brackets are ours. The following abbreviations were used: TL (total body length), TL-H (total body length without head), MW (maximum body width).

Species descriptions

***Exocelina athesphatos* sp. nov.**
http://zoobank.org/B42F6969-FA5C-48A9-A542-ECDCC0A25CB4
Figures 1, 2, 3, 4, 8A, 9A

Type locality. Indonesia: Papua Province: Pegunungan Bintang Regency, near Ok Bap, 04°49'28.6"S, 140°24'47.0"E, 1,961 m a.s.l.

Type material. ***Holotype*:** male "Indonesia: Papua, nr Ok Bab [sic!], 1961 m, 8.vi.2015, -4.82460033148527, 140.413050251081, Sumoked" (MZB). ***Paratypes*:** 16 males, 9 females with the same label as the holotype (MZB, KSP).

Description. ***Body size and form*:** Beetle medium-sized: TL-H 4.3–4.8 mm, TL 4.85–5.4 mm, MW 2.3–2.5 mm (holotype: TL-H 4.6 mm, TL 5 mm, MW 2.4 mm), with oblong-oval habitus.

***Colouration*:** Dorsally piceous, sometimes with dark brown posterior part of head, middle and lateral parts of pronotum, and usually with dark brown elytral sutural lines; head appendages yellowish red, legs yellowish red to reddish brown (Fig. 1). Teneral specimens paler, reddish brown.

***Surface sculpture*:** Shiny dorsally, with inconspicuous to fine, distinct punctation and weakly impressed microreticulation. Head with dense punctation (spaces between punctures 1–2 times size of punctures), evidently finer and sparser anteriorly; diameter of punctures almost equal to diameter of cells of microreticulation. Pronotum with sparser and finer punctation than head. Elytra with very sparse and fine punctation, sometimes inconspicuous. Microreticulation of elytra weakly impressed, in some specimens slightly stronger. Pronotum and especially head with stronger microreticulation. Metaventrite and metacoxae distinctly microreticulate, metacoxal plates with longitudinal strioles and transverse wrinkles. Abdominal ventrites with distinct microreticulation, strioles, and very fine and sparse punctation.

***Structures*:** Pronotum with distinct, relatively narrow lateral bead. Base of prosternum and neck of prosternal process with distinct ridge, slightly rounded anteriorly. Blade of prosternal process lanceolate, relatively broad, slightly convex, with distinct lateral bead and few setae. Abdominal ventrite 6 broadly rounded or almost truncate, with elongate medial impression.

Male: Antenna strongly modified (Figs 1, 8A): antennomere 2 strongly reduced, antennomeres 3 and 4 strongly enlarged (antennomere 3 the largest), antennomeres 5 and 6 distinctly enlarged, antennomeres 7–10 stout. Pro- and mesotarsomeres 1–3 dilated. Protarsomere 4 slightly dilated, with anterolateral angle shortly expanded (not visible in Fig. 3B due to a wrong angle, but evident for *E. tsinga* sp. nov. in Fig. 7B; the species are similar in this character) and with large, thick, slightly curved anterolateral hook-like seta. Protarsomere 5 ventrally with anterior row of 18 and posterior row of 9 short, thick, pointed setae (Fig. 3B). Median lobe long and slender, with slightly discontinuous outline (see in apical part), enlarged and thickened apex, and with extremely small, fine, sparse setae distally on lateral margins; apex distinctly curved downwards in lateral view and in ventral view, deeply concave, with divergent sides (Fig. 2). Paramere with very deep dorsal notch, separating subdistal part; subdistal part is very large, broad, with fringe of six or seven very broad, flattened setae and more numerous thin, fine setae; proximal setae numerous, dense, thin, much more inconspicuous than subdistal (Fig. 3A). Abdominal ventrite 6 with relatively deep, elongate medial impression forming two small tubercles on both sides subapically and with 14–18 lateral striae on each side (Fig. 9A).

Female: Antennae and pro- and mesotarsi not modified. Abdominal ventrite 6 more rounded apically, with shallow elongate medial impression, without tubercles and lateral striae.

Figure 1. Habitus and colouration of *Exocelina athesphatos* sp. nov., holotype.

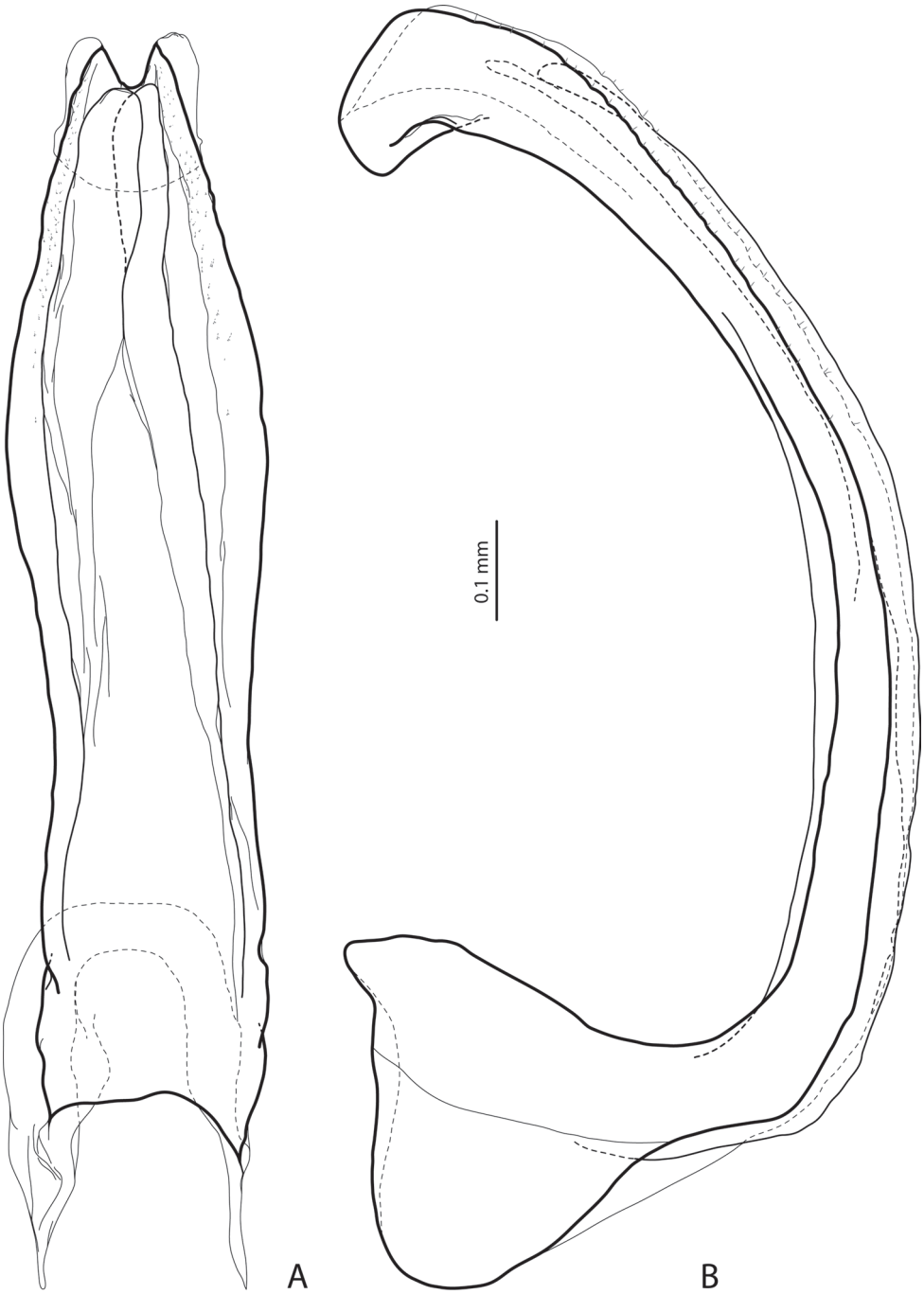

Figure 2. *Exocelina athesphatos* sp. nov., paratype **A** median lobe in ventral view **B** median lobe in lateral view.

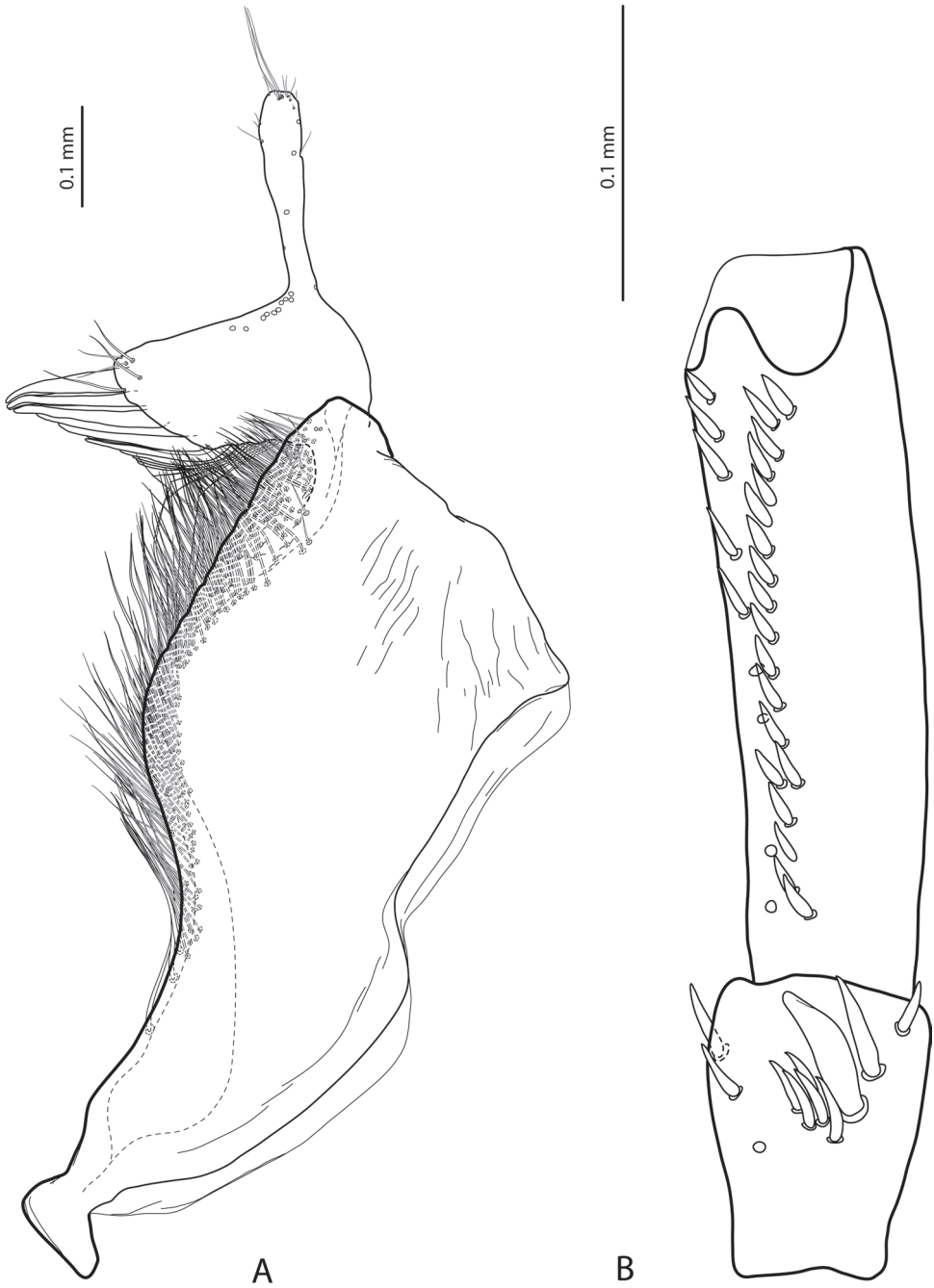

Figure 3. *Exocelina athesphatos* sp. nov., paratype **A** right paramere in external view **B** right male protarsomeres 4–5 in ventral view.

Affinities. Based on shape of the modified male antennae and presence of pronotal bead, the new species can be placed close to the *E. polita* species complex in the identification key. However, this is not a monophyletic group. According to a molecular phylogenetic analysis (Toussaint et al., in preparation), the two new species are sister species, on their own separate branch within the *E. ekari* group.

Exocelina athesphatos sp. nov. is similar to *E. utowaensis* Shaverdo, Hendrich & Balke, 2012 in modifications of the abdominal ventrite 6 and general shape of the median lobe and paramere. But the new species distinctly differs from it in larger size (TL-H 3.4–3.8 mm in *E. utowaensis*), having pronotal bead (absent in *E. utowaensis*) and strongly modified male antennae (simple in *E. utowaensis*). Additionally, in general shape of the median lobe and paramere as well as in the relatively narrow pronotal bead, the new species resembles *E. oceai* Shaverdo, Hendrich & Balke, 2012, which is, however, much smaller (TL-H 3.35–3.8 mm) and has simple male antennae. For comparison with *E. tsinga* sp. nov. see below.

Distribution. Indonesia: Papua Province. The species is known only from the type locality.

Habitat. The specimens were collected from small puddles, in roadside ditches besides a dirt road (in Fig. 4 at the left hand side). The beetles have been presumably been washed into these ditches from small forest creeks during heavy rainfalls.

Figure 4. Dirt road from Ok Sibil to Ok Bap.

Etymology. The species name *αθέσφατος* derives from Greek, meaning "unadulterated, pure". The name is an adjective in the nominative singular.

***Exocelina tsinga* sp. nov.**
http://zoobank.org/F1184304-DE9D-45AA-936E-17300B34EF25
Figures 5, 6, 7, 8B, 9B, 10, 11

Type locality. Indonesia: Papua Province, Mimika Regency, Tsinga Village, Tsingogong River, 04°11.320'S, 137°16.364'E, 1,306 m a.s.l.

Type material. ***Holotype*:** male "Indonesia: Kabupaten [Regency] Mimika, Desa [Village] Tsinga, Sungai [River] Tsingogong", "1306 m, 25–30.v.2017, 04°11.320'S, 137°16.364'E, B. Sumoked" (MZB). ***Paratypes*:** 33 males, 38 females with the same label as the holotype (MZB, KSP). 6 males, 7 females "Indonesia: Kabupaten Mimika, Desa Tsinga, 1381 m, 25–30.v.2017", "04°11.379'S, 137°13.456'E, B. Sumoked" (MZB, KSP).

Description. ***Body size and form*:** Beetle medium-sized: TL-H 4.05–4.8 mm, TL 4.5–5.3 mm, MW 2.15–2.5 mm (holotype: TL-H 4.5 mm, TL 5 mm, MW 2.4 mm), with oblong-oval to elongate habitus (Fig. 5).

***Colouration*:** As in *E. athesphatos* sp. nov.

***Surface sculpture*:** As in *E. athesphatos* sp. nov.

***Structures*:** Pronotum with distinct, relatively narrow anteriorly lateral bead. Base of prosternum and neck of prosternal process with distinct ridge, slightly rounded anteriorly. Blade of prosternal process lanceolate, relatively broad, slightly convex, with distinct lateral bead and few setae. Abdominal ventrite 6 broadly rounded or slightly truncate.

Male: Antenna strongly modified (Figs 5, 8B): antennomere 2 strongly reduced, antennomeres 3 and 4 strongly enlarged (antennomere 3 the largest), antennomeres 5 and 6 distinctly enlarged, antennomeres 7–9 stout. Pro- and mesotarsomeres 1–3 dilated. Protarsomere 4 slightly dilated, with anterolateral angle shortly expanded and with large, thick, slightly curved anterolateral hook-like seta. Protarsomere 5 ventrally with anterior row of 14 and posterior row of 6 short, thick, pointed setae (Fig. 7B). Median lobe relatively long and slender, with slightly discontinuous outline in subapical part (mainly visible in ventral view); in lateral view, apex thin, more or less pointed and curved downwards; in ventral view, apex broad, almost truncate (Fig. 6). Paramere with very deep dorsal notch, separating subdistal part; subdistal part is large, broad, curved downwards and pressed closely to paramere, with fringe of seven very broad, flattened setae; proximal setae numerous, dense, thin, much more inconspicuous than subdistal (Fig. 7A). Abdominal ventrite 6 slightly depressed medially, with 10–12 lateral striae on each side (Fig. 9B).

Female: Antennae and pro- and mesotarsi not modified. Abdominal ventrite 6 without depression and lateral striae.

Affinities. About the placement within the *E. ekari* group, we consider the species in the same way as *E. athesphatos* sp. nov. Both species are very similar in external

Figure 5. Habitus and colouration of *Exocelina tsinga* sp. nov., holotype.

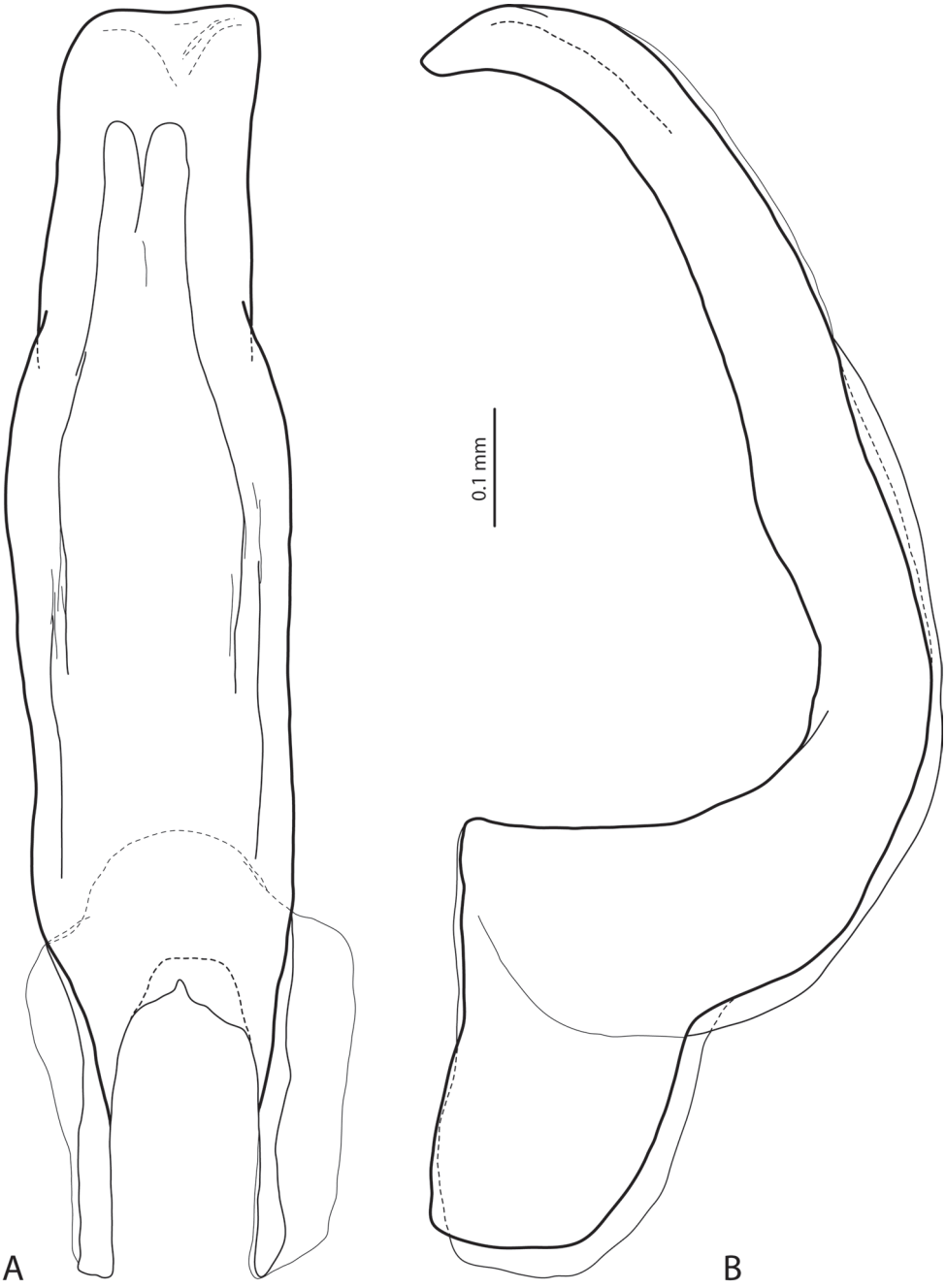

Figure 6. *Exocelina tsinga* sp. nov., paratype **A** median lobe in ventral view **B** median lobe in lateral view.

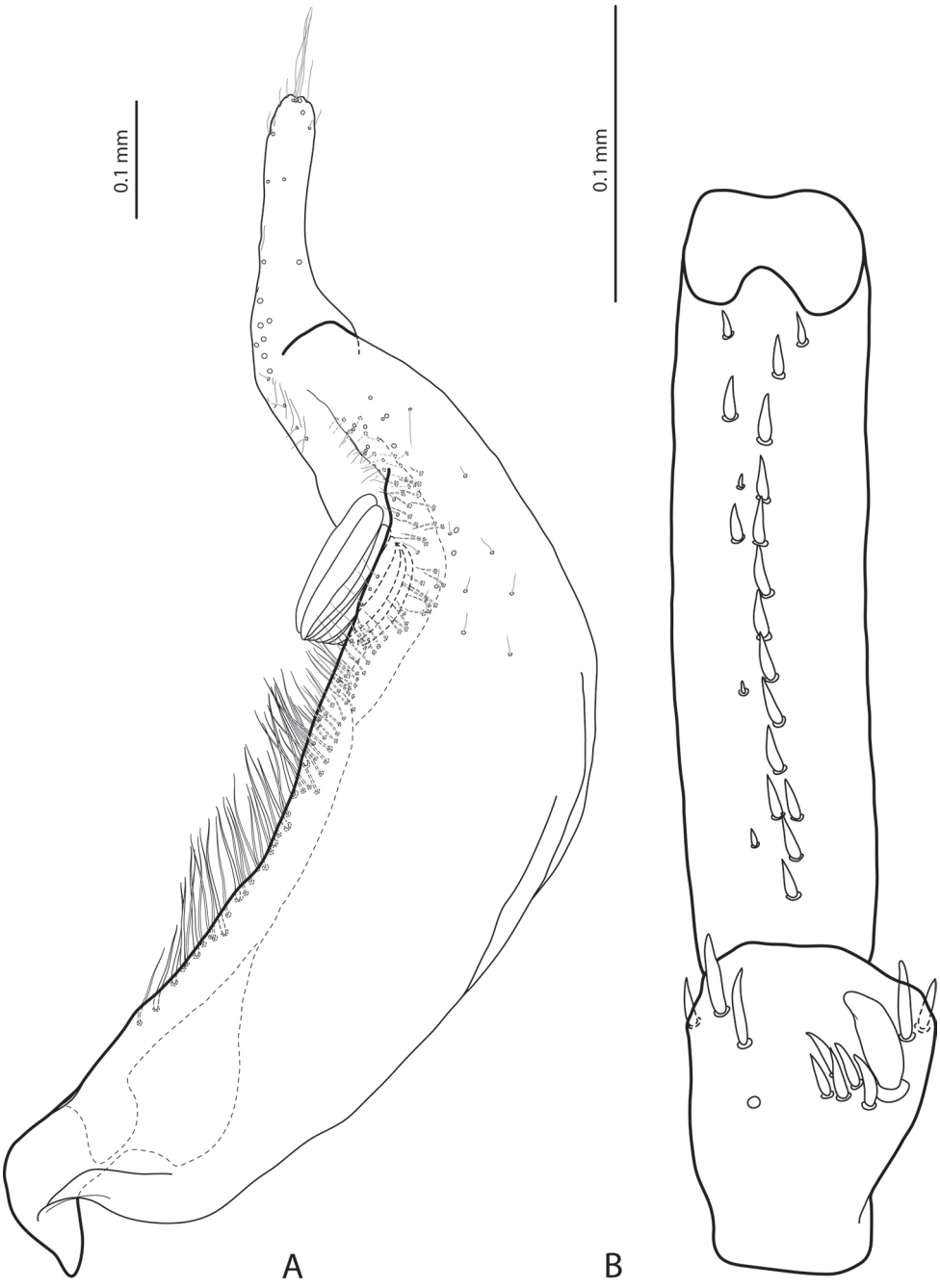

Figure 7. *Exocelina tsinga* sp. nov., paratype **A** right paramere in external view **B** right male protarsomeres 4–5 in ventral view.

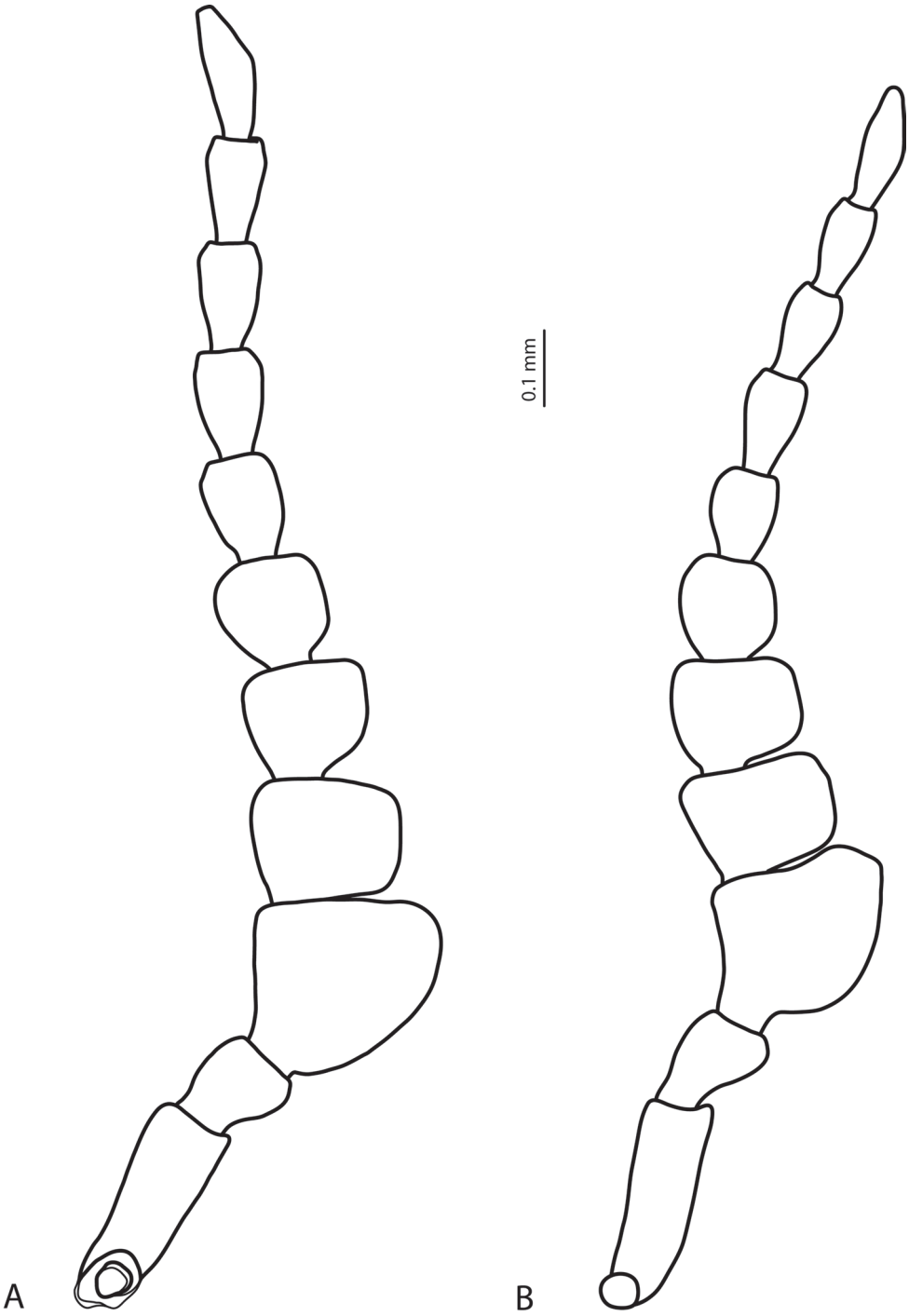

Figure 8. Male antennae **A** *Exocelina athesphatos* sp. nov., paratype **B** *E. tsinga* sp. nov., paratype.

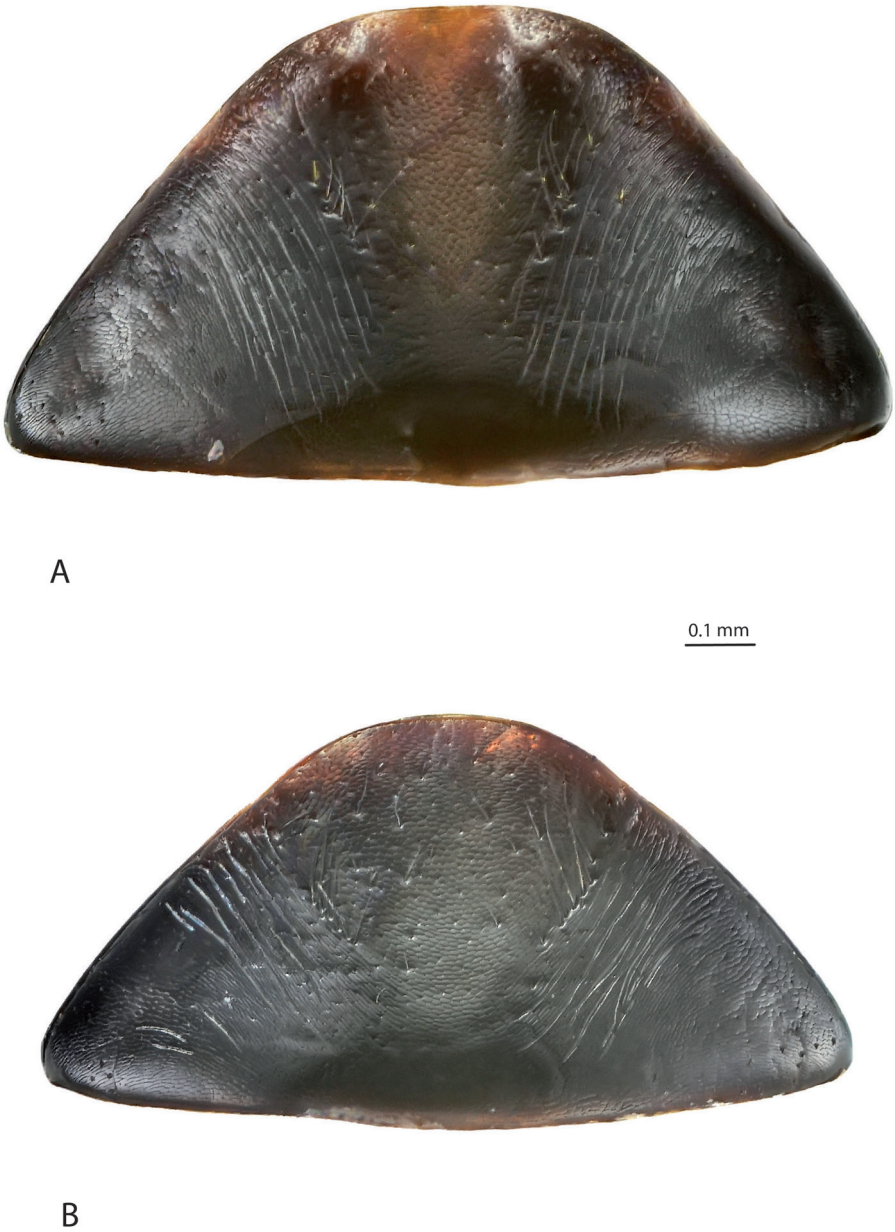

Figure 9. Abdominal ventrite 6 **A** *Exocelina athesphatos* sp. nov., paratype **B** *E. tsinga* sp. nov., holotype.

morphology (colouration, body form and sculpture, shape of male antennae) and, therefore, difficult to distinguish without detailed study (Figs 1, 5). However, males antennomeres of *E. tsinga* sp. nov. are slightly smaller than in *E. athesphatos* sp. nov. and have slightly different form (Fig. 8). The species can be easily separated by the shape of abdominal ventrite 6 (Fig. 9), median lobe and paramere.

Distribution. Indonesia: Papua Province, Mimika Regency. The species is known only from the type locality.

Habitat. The specimens were collected from small puddles on bedrock (Fig. 11), besides fast flowing mountains streams (such as Tsingogong River in Fig. 10).

Etymology. The species is named after Tsinga Village. The name is a noun in the nominative singular standing in apposition.

Figure 10. Tsingogong River.

Figure 11. Small water holes on bedrock besides Tsingogong River.

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RESEARCH ARTICLE

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Contribution to the knowledge of the clown beetle fauna of Lebanon, with a key to all species (Coleoptera, Histeridae)

Salman Shayya[1], Tomáš Lackner[2]

1 *Faculty of Health Sciences, American University of Science and Technology, Beirut, Lebanon* **2** *Bavarian State Collection of Zoology, Münchhausenstraße 21, 81247 Munich, Germany*

Corresponding author: Tomáš Lackner (tomaslackner@me.com)

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Abstract

The occurrence of histerids in Lebanon has received little specific attention. Hence, an aim to enrich the knowledge of this coleopteran family through a survey across different Lebanese regions in this work. Seventeen species belonging to the genera *Atholus* Thomson, 1859, *Hemisaprinus* Kryzhanovskij, 1976, *Hister* Linnaeus, 1758, *Hypocacculus* Bickhardt, 1914, *Margarinotus* Marseul, 1853, *Saprinus* Erichson, 1834, *Tribalus* Erichson, 1834, and *Xenonychus* Wollaston, 1864 were recorded. Specimens were sampled mainly with pitfall traps baited with ephemeral materials like pig dung, decayed fish, and pig carcasses. Several species were collected by sifting soil detritus, sand cascading, and other specialized techniques. Six newly recorded species for the Lebanese fauna are the necrophilous *Hister sepulchralis* Erichson, 1834, *Hemisaprinus subvirescens* (Ménétriés, 1832), *Saprinus* (*Saprinus*) *externus* (Fischer von Waldheim, 1823), *Saprinus* (*Saprinus*) *figuratus* Marseul, 1855, and *Saprinus* (*Saprinus*) *niger* (Motschulsky, 1849) all associated with rotting fish and dung, and the psammophilous *Xenonychus tridens* (Jacquelin du Val, 1853). With the exception of *Hister sepulchralis,* all these taxa belong to the Saprininae subfamily. A most likely undescribed species of *Tribalus* (*Tribalus*) (Tribalinae) has also been collected in detritus at wet places near rivers in Lebanon. Because of the complexity of the genus *Tribalus*, with possible numerous new species present in the circum-Mediterranean area, the Lebanese species is not described herein, pending a revision of the genus. This study advocates further research aimed at improving taxonomic and ecological knowledge of this coleopteran family in Lebanon. The number of Histeridae species currently known from Lebanon stands at 41; a key to all species including images is included.

Keywords
Coleoptera, faunistics, Lebanon, Histeridae, Histerinae, Saprininae, Tribalinae

Introduction

The interesting biodiversity of Lebanon is due to its complex topography and altitudinal diversity and its location at the eastern rim of the Mediterranean Sea (Khater and El-Hajj 2012). According to Khater and El-Hajj (2012), there is a need to complete the assessment of biodiversity in various biological sections, especially invertebrates, which includes in its vast majority the insects. The latter occupy most ecological niches and are considered very important to the dynamics of natural ecosystems' structure and function (Fagundes et al. 2011; Cajaiba et al. 2017). Preserving their abundance and diversity should constitute a prime conservation priority. Coleoptera is the largest hexapodan order with ca. 400,000 described species worldwide, which comprise 40% of all described insect species (Fagundes et al. 2011; Gimmel and Ferro 2018). Carrion, animal droppings, dead wood, bird nests, mushrooms, and ant and termite nests are examples of such microhabitats (Bajerlein 2009; Barbosa and Vasconcelos 2018). The physicochemical conditions of these microhabitats are fleeting and rapidly changing, but they are rich in organic matter and colonized by insects of various guilds: coprophagous or necrophagous species, parasitoids and predators (Bajerlein et al. 2011). Among the beetle fauna associated with cadavers and animal droppings, predation is the main force structuring communities (Goff 2009; Bajerlein et al. 2011). Many Histeridae specialize on these microhabitats and are considered predictable components of carrion and dung communities (Bajerlein et al. 2011). In addition, histerids can be found under bark, in sand, in the galleries of wood-boring insects, and as important predators in stored products (Polat and Yıldırım 2017).

Histeridae may fulfil important practical roles (Kovarik and Caterino 2016). Many Histeridae adults and larvae are necrophilous, feeding mainly on dipteran larvae present on carrion or dung (Caneparo et al. 2017; Szelecz et al. 2018). Some are general predators of mites, insects and insect larvae, while other species are specific feeders on larvae of a single insect species (Szelecz et al. 2018). During carrion decomposition, histerids arrive in large numbers when fly larvae are abundant, i.e., during the active decay and early advanced decay stages (Caneparo et al. 2017; Shayya et al. 2018; Szelecz et al. 2018). Since the predatory taxa are abundant at different stages of decomposition, the knowledge of both their occurrence and the rates of decomposition aids in estimating the minimum postmortem interval PMI_{min} on the basis of entomofaunal succession (Caneparo et al. 2017). The latter method could be the only accessible tool for estimating the PMI_{min} when the PMI is longer than several months or even years (Amendt et al. 2011). Other predatory species of Histeridae have been introduced to augment control of dung-breeding flies (Davis 1994).

Histeridae (clown beetles) contain 4260 species and 400 genera, grouped in nine subfamilies (Mazur 2011; Caterino and Tishechkin 2014; Lackner 2015; Zhou et al. 2020). Our current paper treats only six subfamilies: Abraeinae Macleay, 1819; Dendrophilinae Reitter, 1909; Histerinae Gyllenhal, 1808; Onthophilinae Macleay, 1819; Saprininae Blanchard, 1845 and Tribalinae Bickhardt, 1914. Saprininae and Histerinae contain most forensically-relevant taxa. Saprininae are a moderately large subfamily distributed worldwide (73 genera and subgenera, > 620 species (Mazur 2011; Lackner and Tarasov 2019). In the past ten years, this subfamily has been intensively studied with respect to their phylogeny (Lackner 2014a; Lackner and Tarasov 2019), zoogeographical distribution, taxonomy, morphology, and biology (e.g., Shayya et al. 2018; Lackner et al. 2019). Unfortunately, the rest of the subfamilies present in Lebanon have yet to witness attention from a phylogenetic standpoint. In the Palaearctic Region, 357 species of the Saprininae, 220 of Histerinae, 115 of Dendrophilinae, 101 of Abraeinae, 31 of Onthophilinae, and 31 species of Tribalinae, respectively, have been reported hitherto (Lackner et al. 2015).

Regarding the Saprininae, 23 species are known so far from Lebanon; three belonging to *Chalcionellus* Reichardt, 1932, one to *Gnathoncus* Jacquelin du Val, 1857 one to *Xenonychus* Wollaston, 1864, two to *Hypocacculus* Bickhardt, 1914, one to *Hypocaccus* C.G. Thomson, 1867 and 15 species belonging to *Saprinus* Erichson, 1834 (Lackner et al. 2015; Shayya et al. 2018; present study). Thirteen species of *Saprinus* have been collected on decomposing carrion from Lebanon; eight of them, as well as *Hypocacculus* (*Hypocacculus*) *metallescens* (Erichson, 1834) have only recently been recorded for the fauna of the country (Shayya et al. 2018).

Within the Histerinae, eleven species are currently known from Lebanon; one belonging to *Atholus* Thomson, 1859, one to *Eudiplister* Reitter, 1909, two to *Hister* Linnaeus, 1758, three to *Margarinotus* Marseul, 1853 (all Histerini), one species belonging to otherwise oriental genus *Notodoma* Lacordaire, 1854 (Exosternini), two species of *Platylister* Lewis, 1892, and one species of *Platysoma* Leach, 1817 (Platysomatini) (Lackner et al. 2015; Shayya et al. 2018). *Atholus duodecimstriatus duodecimstriatus* (Schrank, 1781), *Margarinotus* (*Ptomister*) *brunneus* (Fabricius, 1775), and *Margarinotus* (*Grammostethus*) *ruficornis* (Grimm, 1852) were recently newly recorded for the Lebanese fauna (Shayya et al. 2018). Within Dendrophilinae, two species of the genus *Abraeomorphus* Reitter, 1886, are known from Lebanon, while from Abraeinae, only *Stenopleurum rothi* (Rosenhauer, 1856) is recorded from the country. Two species of *Onthophilus* Leach, 1817 are known from Lebanon within Onthophilinae.

No representative of the subfamily Tribalinae has hitherto been recorded from Lebanon, but it was recorded from a geographically close country, Cyprus (two species; Lackner et al. 2015). Unidentified *Tribalus* occur also in neighboring Syria and Israel (Lackner, unpublished). Thus, the occurrence of *Tribalus* in Lebanon is to be expected.

This study is aimed to investigate the diversity of the Histeridae in different Lebanese regions relating to their colonization of ephemeral resources (carrion and dung). We likewise comment on Histeridae that were collected during field trips that are not

necessarily associated to the ephemeral resources. A checklist of species, as well as key to all Lebanese Histeridae (including images of all species) are provided.

Materials and methods

The majority of specimens were collected in pitfall traps (28 cm height and 16 cm width) baited with rotting fish and pig dung. Specimens were collected after one week of placing the pitfall trap in each locality. The localities and their coordinates are mentioned in Table 1. Collection of specimens was also done during field trips in Baissour, Rechmaya, and Tyre. In Baissour and Rechmaya, the specimens were collected from under stones on the riverside and through sifting soil detritus. In Tyre samples were collected through sand cascading on the beach. Quantitative data on *Atholus*, *Margarinotus*, and *Hypocacculus* were recorded from sampling pitfall traps baited by pig carcasses.

General observations and dissections were carried out using stereomicroscope Nikon SMZ1500. Without genital extraction, males of *Saprinus* species can be usually recognized through the examination of the anterior tarsal setae, which are expanded and lamellate, whereas they are unexpanded and pointed in female. Often the males possess a longitudinal depression on the metaventrite and occasionally also a single or two tiny tubercles on the apical metaventral margin. Male genitalia were first macerated in 10% KOH solution for ca. 3 hours, cleared in 80% ethanol, macerated in lactic acid with fuchsine, incubated at 60 °C for another 30 min, subsequently cleared in 80 % ethanol, and then observed in α-terpineol in a small dish. Digital photographs of male genitalia were taken by a Nikon 4500 Coolpix camera and edited in Adobe

Table 1. Sampling localities coordinates and altitude.

District	Locality	Latitude / Longitude	Altitude (m a.s.l.)
Hasbaya	Hasbaya	33°23'52.3"N, 35°41.6'6.6"E	750
	Kfeir	33°25'48.0"N, 35°44'22.8"E	909
	Khalwat El Kfeir	33°25'4.6"N, 35°42'59.2"E	1000
	Mimes	33°25'12.0"N, 35°42'59.2"E	789
Matn	Fanar	33°52'44"N, 35°34'04"E	250
	Naas-Bikfaya	33°54'42.4"N, 35°40'32.7"E	1090
Rashaya	Ain Harcha	33°27'35.2"N, 35°46'45.6"E	994
	Tanoura	33°28'29.1"N, 35°47'58.9"E	985
	Bakifa	33°29'36.5"N, 35°49'8.9"E	994
	Rashaya	33°26'55.7"N, 35°48'58.9"E	1223
	Kfar Qouq	33°32'5.7"N, 35°51'32.6"E	1100
Shouf-Aley	Badghan	33°46'4.5"N, 35°40'11.4"E	1211
	Baissour	33°45'32.9"N, 35°34'1.8"E	850
	Misherfeh	33°45'31.5"N, 35°39'17.9"E	950
	Nabaa Al Safa	33°44'58.7"N, 35°41'41.2"E	959
	Rechmaya	33°44'13.2"N, 35°35'56.7"E	450
	Sawfar	33°48'7.9"N, 35°42'8.4"E	1194
Tyre	Tyre	33°16'19.2"N, 35°12'12.5"E	0

Photoshop CS5. Genitalia drawings based on the photographs or direct observations were produced with the aid of Hakuba klv7000 light box. Habitus photographs were taken by F. Slamka (Bratislava, Slovakia). Specimens were measured with an ocular micrometer. Higher taxa in our paper are arranged according to Mazur (2011); species within higher taxa are aligned alphabetically. For the morphological terminology the reader is referred to Ôhara (1994) and especially Lackner (2010). The general distribution of Histeridae in the Middle East is extrapolated from Lackner et al. (2015). Specimens were identified using the key of Kryzhanovskij and Reichardt (1976) as well as comparing them with reliably identified voucher specimens deposited in the collection of T. Lackner.

The maps of species distribution were made using Google maps and Microsoft Visual Studio Code (Version 1.37).

Results

List of species recorded from Lebanon; their distribution in the Middle East and biology are mentioned. The list records are based on the Palaearctic catalogue (Lackner et al. 2015) and on our sampling efforts from ephemeral resources, viz. pig carrion, pig dung, and other manual collecting. The species distributions across Lebanese localities are presented on geographic maps. In addition, the checklist, a key, and images of all Histeridae species of Lebanon are provided.

Histeridae Gyllenhal, 1808 of Lebanon

Subfamily Abraeinae W.S. Macleay, 1819

Distribution. The subfamily contains five tribes and is distributed worldwide (Mazur 2011). In Lebanon, so far only one species of the tribe Teretriini Bickhardt, 1914 has been recorded.

Biology. Members of the Abraeinae subfamily are often found under bark, in rotting wood, inside galleries of xylophagous insects; in the case of Acritini it is decaying vegetable matter that they frequent the most (Kryzhanovskij and Reichardt 1976).

Tribe Teretriini Bickhardt, 1914

Stenopleurum J. Müller, 1937

Stenopleurum rothi (Rosenhauer, 1856)

Figure 18

Distribution in the Middle East. Cyprus, Lebanon, Syria, Turkey (Lackner et al. 2015).

Biology. This species occurs under the bark of coniferous trees, especially pines, where it presumably preys upon larvae of xylophagous insects (Kryzhanovskij and Reichardt 1976).

Subfamily Dendrophilinae Reitter, 1909

Distribution. This subfamily contains four tribes and is distributed worldwide (Mazur 2011). In Lebanon, so far only two representatives of the tribe Bacaniini Kryzhanovskij, 1976 have been recorded.

Biology. The biology of Dendrophilinae is similar to that of Abraeinae, with most taxa being true dendrophiles and several taxa occurring on dung of herbivore mammals (e.g., *Xestipyge* Marseul, 1862).

Tribe Bacaniini Kryzhanovskij, 1976

Abraeomorphus Reitter, 1886

Distribution. Oriental, Australasian, and Palearctic regions (Mazur 2011).

Biology. *Abraeomorphus* species occur in rotting wood, often under bark (Kryzhanovskij and Reichardt 1976).

Abraeomorphus besucheti Mazur, 1977

Figure 16

Distribution in the Middle East. Israel, Lebanon (Lackner et al. 2015).

Biology. As with the general biology of the genus.

Abraeomorphus minutissimus (Reitter, 1884)

Figure 17

Distribution in the Middle East. Lebanon (Lackner et al. 2015).

Biology. This species is found under bark of oaks (Kryzhanovskij and Reichardt 1976).

Subfamily Tribalinae Bickhardt, 1914

Distribution. Worldwide (Mazur 2011).

Biology. Members of the subfamily are most-commonly found across humid and warm lowland forests, but several taxa are also encountered along streams or rivers.

These beetles are often hidden in decaying vegetable debris, but can also be collected from under bark (Kovarik and Caterino 2016; T. Lackner, pers. obs.). According to P.W. Kovarik (pers. comm. 2019) most of the Tribalinae are associated with rotting tree trunks or leaf litter where the larvae prey on soft-bodied insects and adults feed on fungal spores as well as soft-bodied insects.

Tribalus Erichson, 1834

Tribalus (*Tribalus*) sp.

Figures 3, 120

Distribution. *Tribalus* contains 65 described species divided into two subgenera and is considered a species-rich genus (Lackner and Vienna 2017). The bulk of its representatives occur in Africa, while a smaller number of taxa are present in the Palaearctic and Oriental regions (Mazur 2011). We collected a presumably undescribed species, which represents the first occurrence of this genus for Lebanon, in Baissour, Fanar, and Rechmaya (Figs 120, 126).

Biology. Members of *Tribalus* are found mostly under stones in wetter areas near streams. They can be occasionally collected by sifting forest detritus as well (T. Lackner, pers. obs.). We collected 20 specimens of an unidentified species of *Tribalus* from under stones and tree bark, respectively, in wet areas near rivers of Baissour (8 specimens) and Rechmaya (12 specimens).

Subfamily Histerinae Gyllenhal, 1808

Distribution. Worldwide (Mazur 2011). The subfamily comprises five tribes: Exosternini Bickhardt, 1914; Histerini Gyllenhal, 1808; Hololeptini Hope, 1840; Omalodini Kryzhanovskij, 1972 and Platysomatini Bickhardt, 1914. The tribe Omalodini is almost exclusively Neotropical and no member of the otherwise widely distributed Hololeptini has been recorded from Lebanon hitherto. Regarding the Platysomatini, only the subcortical species *Platylister* (*Popinus*) *simeani* (Mulsant & Godart, 1875) and *Platysoma* (*Cylister*) *cornix* Marseul, 1861 have yet been recorded from Lebanon. On the other hand, likewise subcortical species *Platysoma* (*Platysoma*) *compressum* (Herbst, 1783) and *P.* (*P.*) *inexpectatum* Lackner, 2004 have been recorded from neighboring Syria; their occurrence in Lebanon therefore cannot be ruled out. As mentioned in the introduction, a single member of the otherwise oriental genus *Notodoma* Lacordaire, 1854, *N. lewisi* Reitter, 1910 has been recorded from Lebanon; this species is otherwise also known from Turkey (Lackner and Hlaváč 2002). A strictly myrmecophilous species *Spathochus coyei* Marseul, 1864 is known from neighboring Syria and Israel, as well as Cyprus or Turkey (Lackner 2009), making its occurrence in Lebanon highly likely. We therefore decided to depict this highly charismatic ant inquiline here as well as include it in the key. The tribe Histerini is the most-widely distributed and most species-rich tribe of the subfamily worldwide.

Biology. Members of Histerini are most often encountered on decomposing organic matter, such as manure, dung, compost heaps, decaying vegetables, but are also found on carrion and rotting mushrooms. Inquilinous members are also rather numerous in the subfamily, especially in the Palaearctic, Nearctic and Neotropical regions (Kryzhanovskij and Reichardt 1976). Platysomatini are subcortical as a rule, while Exosternini have varied habits and include fungivores, inquilines and dendrophiles alike (Kovarik and Caterino 2016).

Tribe Exosternini Bickhardt, 1914

Notodoma Lacordaire, 1854

Distribution. *Notodoma* is distributed predominantly in the Oriental region, with a single Palaearctic species, occurring in Lebanon, Syria and Turkey (Mazur 2011).

Biology. Mostly found in and on rotting mushrooms where it preys on Diptera that develop on rotting fungi and basidiomycete mushrooms (Kovarik and Caterino 2016).

Notodoma lewisi Reitter, 1910

Figure 5

Distribution in the Middle East. Lebanon, Syria, Turkey (Lackner et al. 2015). Described from "Hochsyrien, bei Akbes" (Reitter 1910). This locality (Akbès = Meydan Ekbaz) probably does not lie in Lebanon, but in Turkey, right on the Syrian-Turkish border, between the Turkish town Osmaniye and Syrian town of Aleppo. Lackner and Hlaváč (2002) reported a specimen from south-eastern Turkey (Arslanlı, near Erdemli; misspelled as "Arsanli" in their publication) – their locality is actually quite close to the type locality of this species. Most likely, *Notodoma lewisi* does not occur in Lebanon, but since it has been included in all major catalogues of Histeridae (e.g., Mazur 2011) as described from Lebanon, we decided to keep it here pending further investigation.

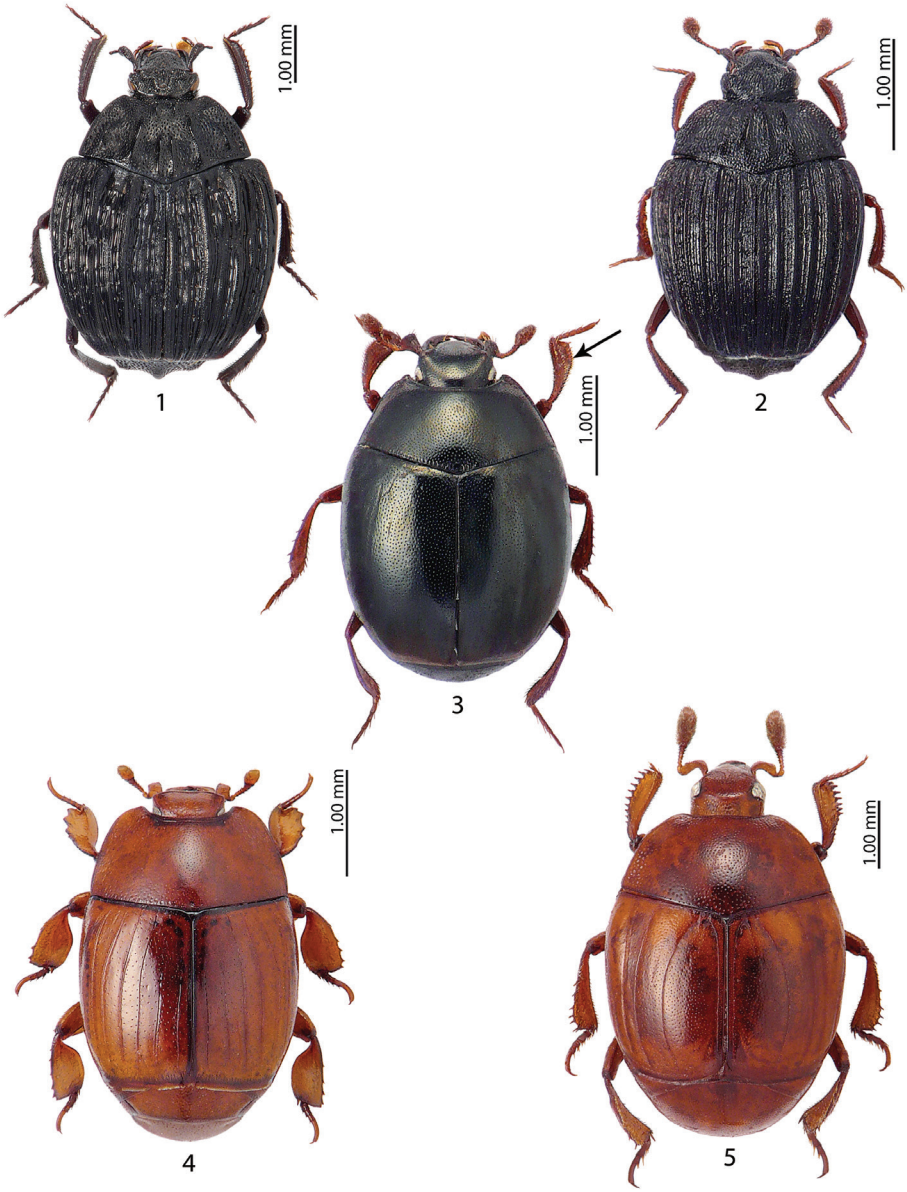
Biology. A fungivorous, extremely rare species (Lackner and Hlaváč 2002).

Tribe Histerini Gyllenhal, 1808

Atholus Thomson, 1859

Distribution. The genus *Atholus* comprises 78 species that inhabit Holarctic, Afrotropical and Oriental regions (Mazur 2011).

Biology. Members of *Atholus* can be found in decomposing carrion and dung, but are commonly found also under stones and in animal burrows (Penati 2009). Members among this genus can be attracted to *Euphorbia* in xeric areas and to rotting roots of Apiaceae and Fabaceae (Kovarik and Caterino 2016).



Figures 1–5. 1 *Onthophilus bickhardti* Reitter, 1909 **2** *Onthophilus striatus inconditus* Reichardt, 1941 **3** *Tribalus* spec. **4** *Spathochus coyei* Marseul, 1864 **5** *Notodoma lewisi* Reitter, 1910.

Atholus duodecimstriatus duodecimstriatus (Schrank, 1781)

Figures 9, 121

Distribution in the Middle East. Iran, Israel, Saudi Arabia, Syria, Turkey (Lackner et al. 2015). Previously reported from Lebanon from Badghan (Shayya et al. 2018) (Fig. 121).

Biology. This species shows a preference for dung that has lost much of its moisture; it has likewise been found in association with various stored products where it likely preys on beetle larvae feeding on these materials (Bajerlein 2009; Kovarik and Caterino 2016; Mazur et al. 2017). In Lebanon, *A. duodecimstriatus duodecimstriatus* was attracted to carrion (Shayya et al. 2018). A very common species in Lebanon.

Eudiplister Reitter, 1909

Eudiplister castaneus (Ménétriés, 1832)
Figure 10

Distribution in the Middle East. Cyprus, Iran, Iraq, Israel, Jordan, Lebanon, Syria, Turkey (Lackner et al. 2015).

Biology. Unknown. Its congeners *Eudiplister peyroni* (Marseul, 1857) and *Eudiplister planulus* (Ménétriés, 1849) were found under plant remains, under stones, under dry excrements, especially in arid places and semi-deserts (Kryzhanovskij and Reichardt 1976).

Hister Linnaeus, 1758

Distribution. *Hister* is the most species-rich genus of the family and comprises 195 species; these can be found in all world regions, with the exception of Antarctica (Mazur 2011).

Biology. *Hister* shows preference for dung, but can also be associated with carrion, while some species feed on dung beetle larvae (Coleoptera: Scarabaeidae) present in dung (Kovarik and Caterino 2016).

Hister limbatus Truqui, 1852
Figure 11

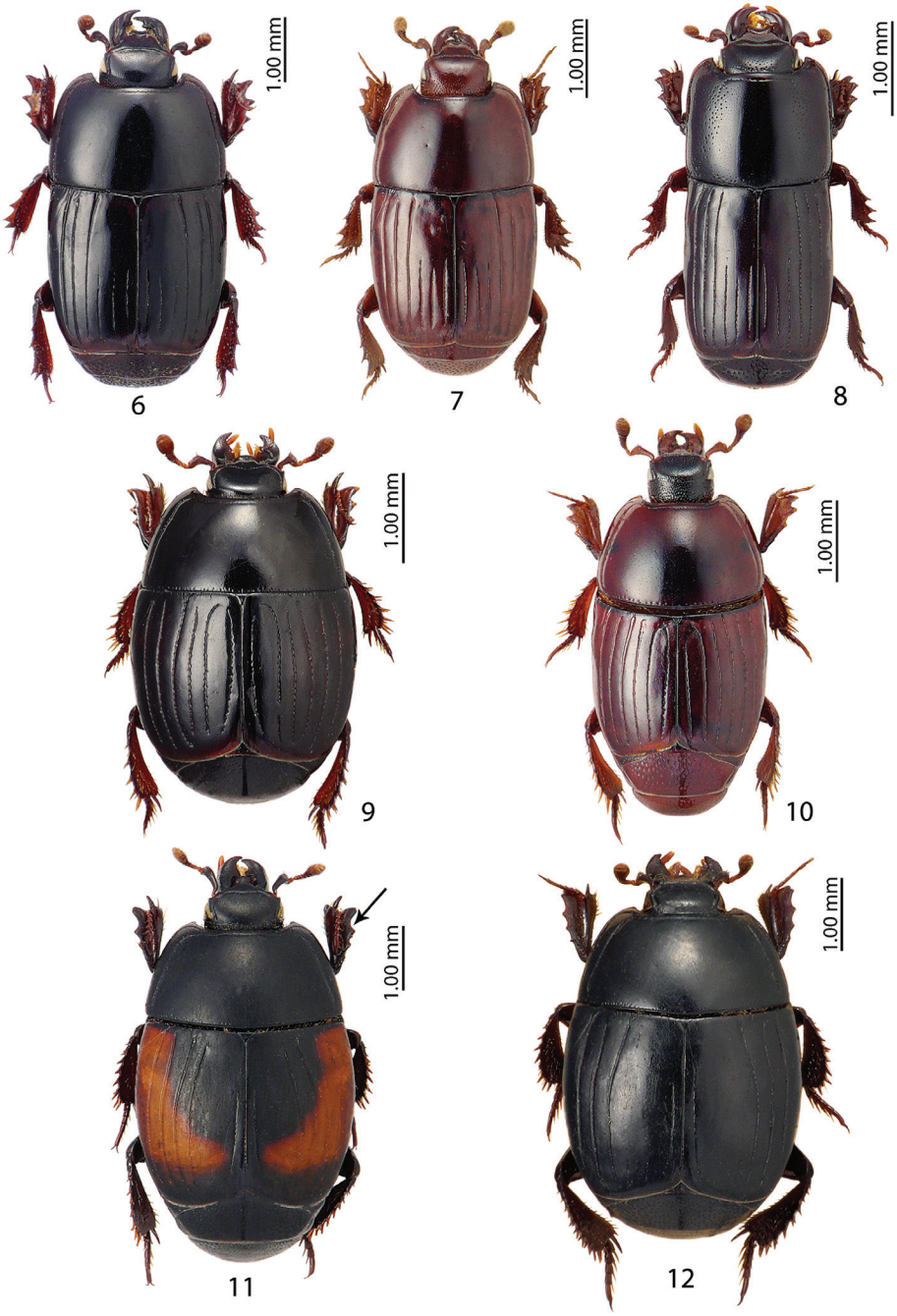
Distribution in the Middle East. Lebanon, Syria, Turkey (Lackner et al. 2015).

Biology. A poorly known species, its biology is unknown.

Hister sepulchralis Erichson, 1834
Figures 12, 121

Distribution in the Middle East. Iran, Jordan, Lebanon, Syria, Turkey (Lackner et al. 2015). Herein it is reported from Lebanon for the first time from Kfar Kouq (Fig. 121, 126).

Biology. *Hister sepulchralis* occurs most often in cattle dung (Rozner 2010) and, like other *Hister* species, it requires liquid fraction from dung to have disappeared to oviposit (Kovarik and Caterino 2016). We collected a singleton of this species from a pig dung-baited pitfall trap. A sporadic and uncommon species in Lebanon.



Figures 6–12. 6 *Platylister* (*Popinus*) *algiricus* (Lucas, 1846) **7** *Platylister* (*Popinus*) *simeani* (Mulsant & Godart, 1875) **8** *Platysoma* (*Cylister*) *cornix* Marseul, 1861 **9** *Atholus duodecimstriatus duodecimstriatus* (Schrank, 1781) **10** *Eudiplister castaneus* (Ménétriés, 1832) **11** *Hister limbatus* Truqui, 1852 **12** *Hister sepulchralis* Erichson, 1834.

Margarinotus Marseul, 1853

Distribution. *Margarinotus* includes ten subgenera containing 109 species altogether, found predominantly in the Holarctic region; several species are likewise autochthonous to the Oriental region (Mazur 2011).

Biology. Taxa grouped in *Margarinotus* are varied in their habitat preferences. Several species are linked to carrion or dung, while others prefer rodent burrows (Caterino 2010; Kovarik and Caterino 2016).

Margarinotus (*Ptomister*) *brunneus* (Fabricius, 1775)

Figures 14, 121, 126

Distribution in the Middle East. Iran, Israel, Turkey (Lackner et al. 2015). Previously found in Lebanon (Shayya et al. 2018). Herein, *M.* (*P.*) *brunneus* is reported from the following Lebanese localities: Fanar, Kfeir, Mimes, Naas, Nabaa Al Safa (Fig. 121).

Biology. This species shows a clear preference for carrion (Kovarik and Caterino 2016), and has previously been reported from pig carcasses (Matuszewski et al. 2008) as well as from dung (Rozner 2010; Mazur et al. 2017). In Lebanon *M.* (*P.*) *brunneus* was collected from carrion during spring in Fanar (50 specimens) and Naas (181 specimens). It was also collected during the same season from rotting fish-baited pitfall traps in Kfeir (1 specimen), Mimes (1 specimen), and Nabaa Al Safa (6 specimens). A very common and widespread species in Lebanon.

Margarinotus (*Grammostethus*) *ruficornis* (Grimm, 1852)

Figures 13, 121

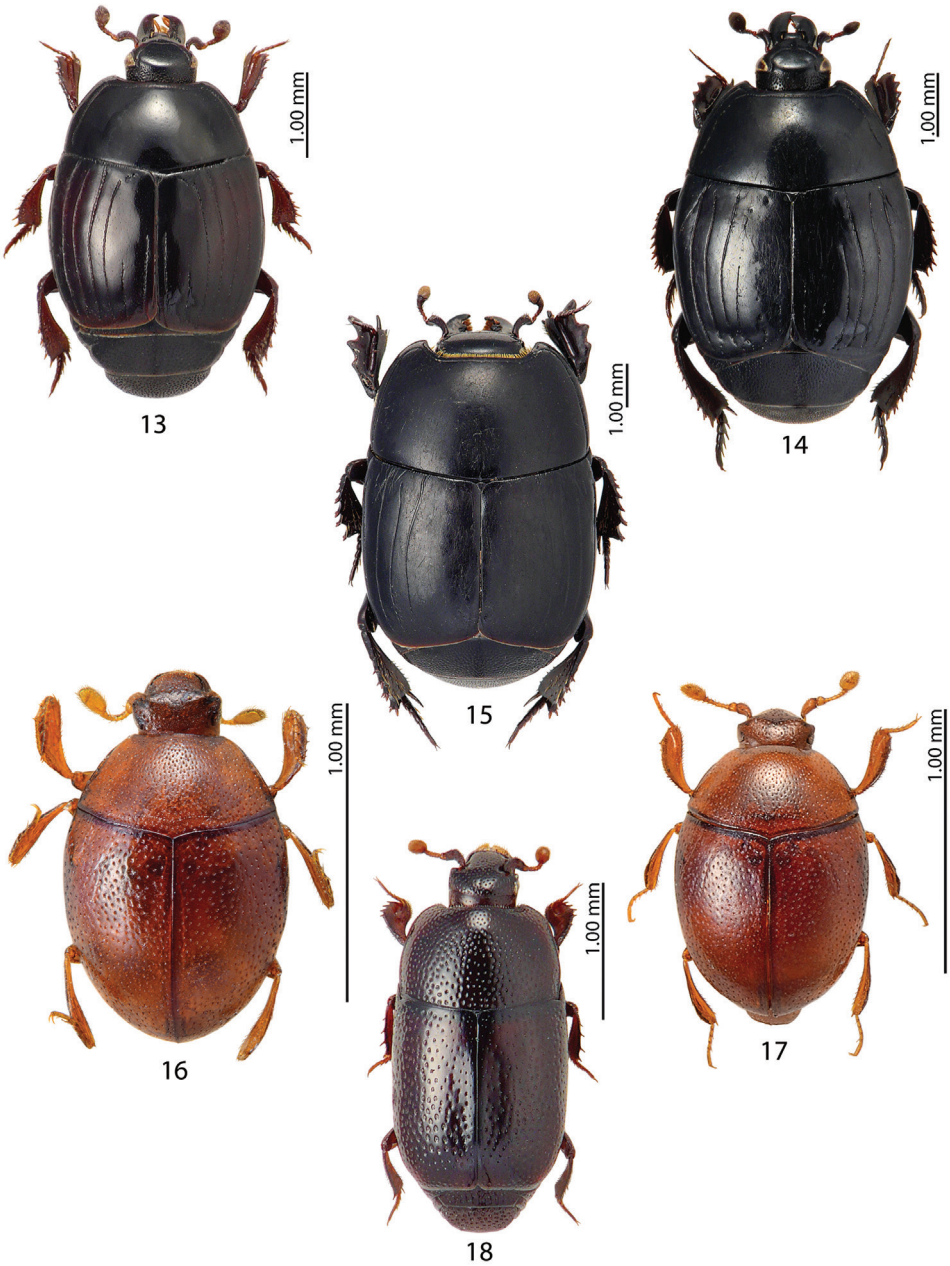
Distribution in the Middle East. Israel, Jordan, Syria and Turkey (Lackner et al. 2015). In Lebanon, previously mentioned from Fanar (Shayya et al. 2018) (Fig. 121).

Biology. Often found in decaying wood in the company of various Formicidae (*Lasius* spp. and *Formica* spp.); it has likewise been known to occur on excrement (Sanchez and Chittaro 2018). In our study, a singleton of *M.* (*G.*) *ruficornis* was collected from carrion during spring in Fanar.

Tribe Platysomatini Bickhardt, 1914

Platylister Lewis, 1892

Distribution. Genus *Platylister* contains three subgenera and is distributed predominantly across Afrotropical, Oriental, and Australasian regions, with two species recorded also from circum-mediterranean area (Mazur 2011).



Figures 13–18. 13 *Margarinotus* (*Grammostethus*) *ruficornis* (Grimm, 1852) **14** *Margarinotus* (*Ptomister*) *brunneus* (Fabricius, 1775) **15** *Margarinotus* (*Stenister*) *graecus graecus* (Brullé, 1832) **16** *Abraeomorphus besucheti* Mazur, 1977 **17** *Abraeomorphus minutissimus* (Reitter, 1884) **18** *Stenopleurum rothi* (Rosenhauer, 1856).

Biology. Members of *Platylister* are collected under bark of trees, where they prey on (the larvae of) subcortical insects (Kryzhanovskij and Reichardt 1976).

Platylister (*Popinus*) *simeani* (Mulsant & Godart, 1875)

Figure 7

Distribution in the Middle East. Lebanon, Turkey, United Arab Emirates (Lackner et al. 2015).

Biology. Attracted to the rotting roots of *Astragalus* (Fabaceae) (Kovarik and Caterino 2016).

Platysoma Leach, 1817

Distribution. *Platysoma* contains three subgenera and is spread across the whole world, albeit only a single species is known from South America (Mazur 2011).

Biology. Associated with bark of trees, where it preys upon members of subcortical insect communities (Kovarik and Caterino 2016).

Platysoma (*Cylister*) *cornix* Marseul, 1861

Figure 8

Distribution in the Middle East. Cyprus, Israel, Lebanon, Syria, Turkey (Lackner et al. 2015).

Biology. Found under bark of pines (Kryzhanovskij and Reichardt 1976).

Onthophilinae Macleay, 1891

Distribution. Worldwide (Mazur 2011).

Biology. Members of Onthophilinae have varied habits. They occur in decaying vegetable matter, on dung, and on rotting mushrooms, but the subfamily likewise contains dendrophilous and nidicolous species (Kovarik and Caterino 2016).

Onthophilus Leach, 1817

Distribution. *Onthophilus* is predominantly Holarctic in distribution, with several species known also from Central America and a single Australian species (Mazur 2011).

Biology. Adults prey on fly eggs (but not larvae) and filter feed on the liquid coating of fresh dung; some are known to prey on Diptera that develop on rotting fungi. Their mouthparts bear modified setae that seem to strain particles from liquid (Kovarik and Caterino 2016).

***Onthophilus bickhardti* Reitter, 1909**
Figure 1

Distribution in the Middle East. Israel, Lebanon, Turkey (Lackner et al. 2015).

Biology. Biology of this rare species is unknown, but most specimens have been collected during November by pitfall traps in higher elevations in Lebanon (Lackner, unpublished).

***Onthophilus striatus inconditus* Reichardt, 1941**
Figure 2

Distribution in the Middle East. Cyprus, Israel, Jordan, Lebanon, Syria, Turkey (Lackner et al. 2015).

Biology. Most commonly encountered under decomposing vegetable matter, at times also on outflowing tree sap, in desiccating manure, under carrion or rotting mushrooms (Kryzhanovskij and Reichardt 1976).

Saprininae C.É. Blanchard, 1845

Distribution. Worldwide (Mazur 2011).

Biology. Saprininae have witnessed a remarkable ecological evolution. They are known as colonizers of different ecological niches: ant-nests, dead termitaria, rodent burrows etc. They even gained fine morphological adaptations and distribution throughout Old World deserts. In addition, members of Saprininae have colonized mammal burrows, nests of birds, ants, termites, and even tortoise burrows. Their life histories are varied, as several lineages exhibit diversity in their terrestrial niches (Lackner 2014a).

***Chalcionellus* Reichardt, 1932**

Distribution. Palearctic, Oriental, and Afrotropical regions; a single Afrotropical species has been introduced into Australia (Mazur 2011).

Biology. Members of *Chalcionellus* are found in manure, in excrements and on carcasses; the genus contains also a single species occupying the rhizosphere of plants (Kryzhanovskij and Reichardt 1976).

***Chalcionellus blanchii blanchii* (Marseul, 1855)**
Figure 20

Distribution in the Middle East. Iran, Iraq, Israel, Lebanon, Syria, Turkey (Lackner et al. 2015).

Biology. Like its congeners, found on carcasses and excrements (Kryzhanovskij and Reichardt 1976; T. Lackner, pers. obs.).

Chalcionellus libanicola (Marseul, 1870)

Figure 21

Distribution in the Middle East. Lebanon, Syria, Turkey (Lackner et al. 2015).

Biology. Unknown, a rare taxon (Lackner 2011).

Chalcionellus aemulus (Illiger, 1807)

Figure 19

Distribution in the Middle East. Iran, Israel, Jordan, Lebanon, Turkey (Lackner et al. 2015).

Biology. Found on carcasses, in excrements etc. (T. Lackner pers. obs.).

Gnathoncus Jacquelin du Val, 1857

Distribution. Predominantly Holarctic in distribution; a single species is known from tropical Africa (Mazur 2011). From the Oriental region a handful of cave-dwelling species have been recorded (Lackner 2020).

Biology. Members of *Gnathoncus* occur predominantly in bird nests or burrows of smaller mammals; occasionally they are found also on carrion or decomposing vegetable matter (Kryzhanovskij and Reichardt 1976).

Gnathoncus disjunctus suturifer Reitter, 1896

Figure 22

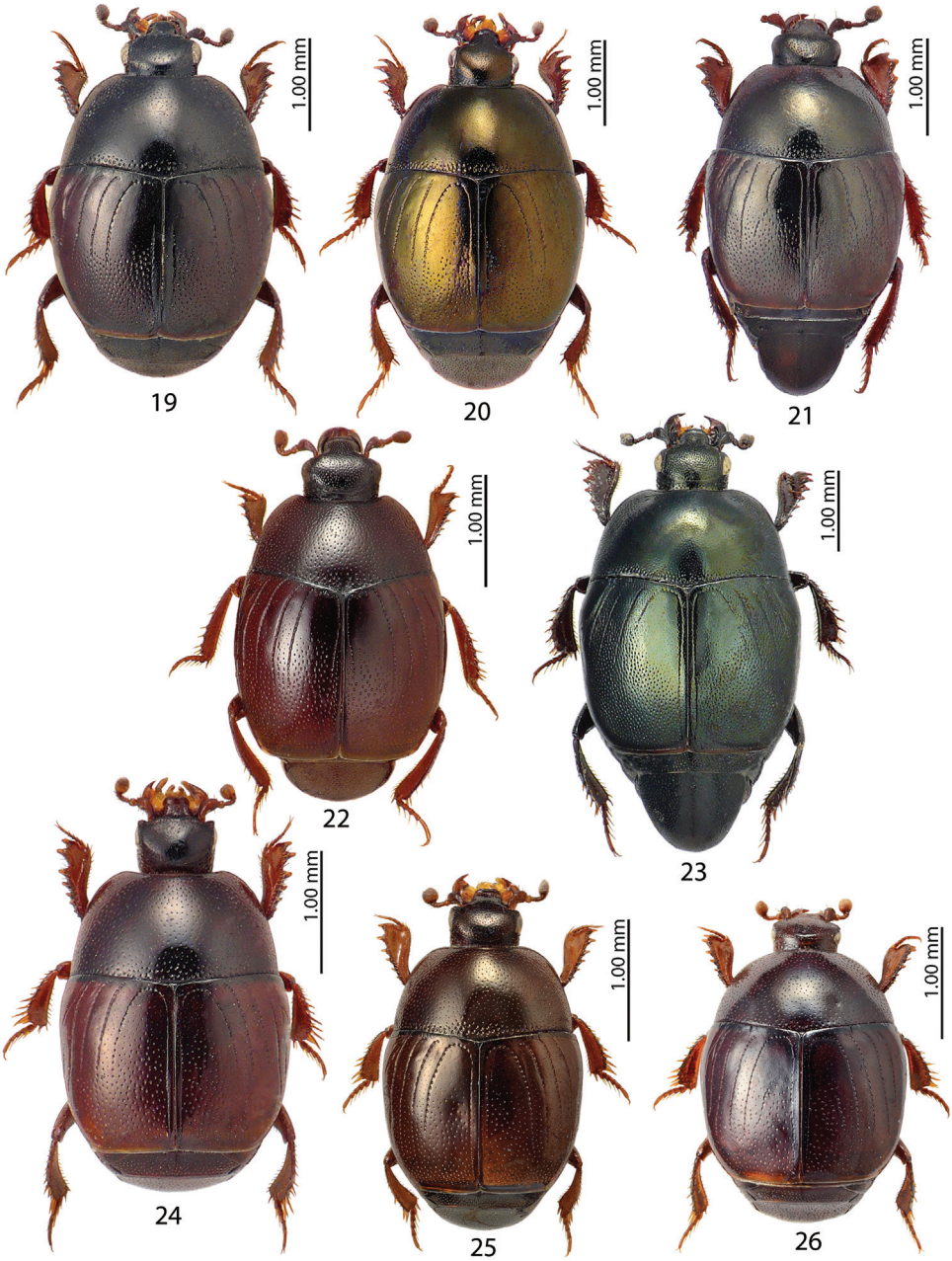
Distribution in the Middle East. Lebanon, Syria, Turkey (Lackner et al. 2015).

Biology. This species is present in burrows of small rodents, e.g., *Citellus* sp. (Kryzhanovskij and Reichardt 1976).

Hemisaprinus Kryzhanovskij, 1976

Distribution. *Hemisaprinus* contains three described Palaearctic species; one species (*H. subvirescens*) marginally enters also the Oriental region (Mazur 2011).

Biology. Members of *Hemisaprinus* are usually associated with carcasses or decomposing vegetable matter (Lackner 2014b).



Figures 19–26. 19 *Chalcionellus aemulus* (Illiger, 1807) **20** *Chalcionellus blanchii blanchii* (Marseul, 1855) **21** *Chalcionellus libanicola* (Marseul, 1870) **22** *Gnathoncus disjunctus suturifer* Reitter, 1896 **23** *Hemisaprinus subvirescens* (Ménétriés, 1832) **24** *Hypocacculus* (*Colpellus*) *praecox* (Erichson, 1834) **25** *Hypocacculus* (*Hypocacculus*) *metallescens* (Erichson, 1834) **26** *Hypocaccus* (*Nessus*) *baudii* (J. Schmidt, 1890).

***Hemisaprinus subvirescens* (Ménétriés, 1832)**
Figures 23, 122, 126

Distribution in the Middle East. Cyprus, Iran, Iraq, Israel, Jordan, Syria, Turkey (Lackner et al. 2015). Newly reported from Lebanon (Bakifa) (Fig. 122).

Biology. Found chiefly on carrion in arid regions (Reichardt 1941; Lackner 2014b); a forensically relevant species (Su et al. 2013). One specimen was found on decomposing fish-baited pitfall trap.

***Hypocacculus* Bickhardt, 1914**

Distribution. Genus *Hypocacculus* contains three subgenera and includes 21 described species, distributed mostly in the Palaearctic and Afrotropical regions (Mazur 2011).

Biology. Taxa included in *Hypocacculus* are typically collected from carrion and animal excrement and usually found in dry and arid regions. Also, they can be collected in open landscapes and some are psammophiles (Lackner 2010).

***Hypocacculus* (*Hypocacculus*) *metallescens* (Erichson, 1834)**
Figures 25, 122, 126

Distribution in the Middle East. Cyprus, Israel, Iran, Iraq, Oman, Saudi Arabia, Syria (Lackner et al. 2015). Already mentioned from Lebanon from Hasbaya (Shayya et al. 2018) (Fig. 122).

Biology. This species is found in association with small animal carcasses, excrements and other decomposing matter. It also found on coastal dunes in the rhizosphere of psammophilous Graminaceae (Penati 2009). It is a generalist predator (Lackner 2014a). Already reported from Lebanon (Shayya et al. 2018).

***Hypocacculus* (*Colpellus*) *praecox* (Erichson, 1834)**
Figure 24

Distribution in the Middle East. Cyprus, Iran, Israel, Lebanon, Oman, Saudi Arabia, Syria, Turkey, United Arab Emirates, Yemen (Lackner et al. 2015).

Biology. *Hypocacculus* (*C.*) *praecox* is a psammo-halobiotic species, which frequents coastal dunes near the roots of halophilous plants and can be attracted to animal carcasses (Penati 2009).

***Hypocaccus* C.G. Thomson, 1867**

Distribution. *Hypocaccus* contains three subgenera: *Hypocaccus* s. str., *Baeckmanniolus* Reichardt, 1926 and *Nessus* Reichardt, 1932 and its members are distributed almost

across the whole world, being poorly represented in South America and Australasia (Mazur 2011).

Biology. Members of *Hypocaccus* s. str. and *Baeckmanniolus* are coastal wrack specialists, occasionally occurring also on banks of rivers and lakes, while members of the subgenus *Nessus* are typical generalist predators with several psammophile or inquiline forms (Kryzhanovskij and Reichardt 1976).

Hypocaccus (*Nessus*) *baudii* (J. Schmidt, 1890)

Figure 26

Distribution in the Middle East. Cyprus, Israel, Lebanon, Syria (Lackner et al. 2015).

Biology. Virtually unknown; a rare species.

Saprinus Erichson, 1834

Distribution. *Saprinus* includes two subgenera *Phaonius* Reichardt, 1941 and *Saprinus* s.str. and 157 species distributed around the world (Mazur 2011). With 116 species in the Palaearctic region and 14 species in Lebanon, it is the most species-rich genus of the Saprininae (Lackner 2010, Lackner et al. 2015, Shayya et al. 2018). Moreover, this study adds three new species records of this genus for the Lebanese fauna. Most of the *Saprinus* species occur in the Palaearctic and Afrotropical regions (Lackner 2010).

Biology. *Saprinus* shows preference to open xeric landscapes and only few are known from mesic biotopes (Lackner 2010). They are frequent on carrion and less so on dung, and prey on larvae and eggs of soft-bodied insects; in some cases they can capture adult flies on dung (Carlton et al. 1996). Some species could also be found on flowers (Lackner 2010; Kovarik and Caterino 2016).

Saprinus (*Saprinus*) *aegialius* Reitter, 1884

Distribution in the Middle East. Iran, Lebanon, Syria, Turkey (Lackner et al. 2015).

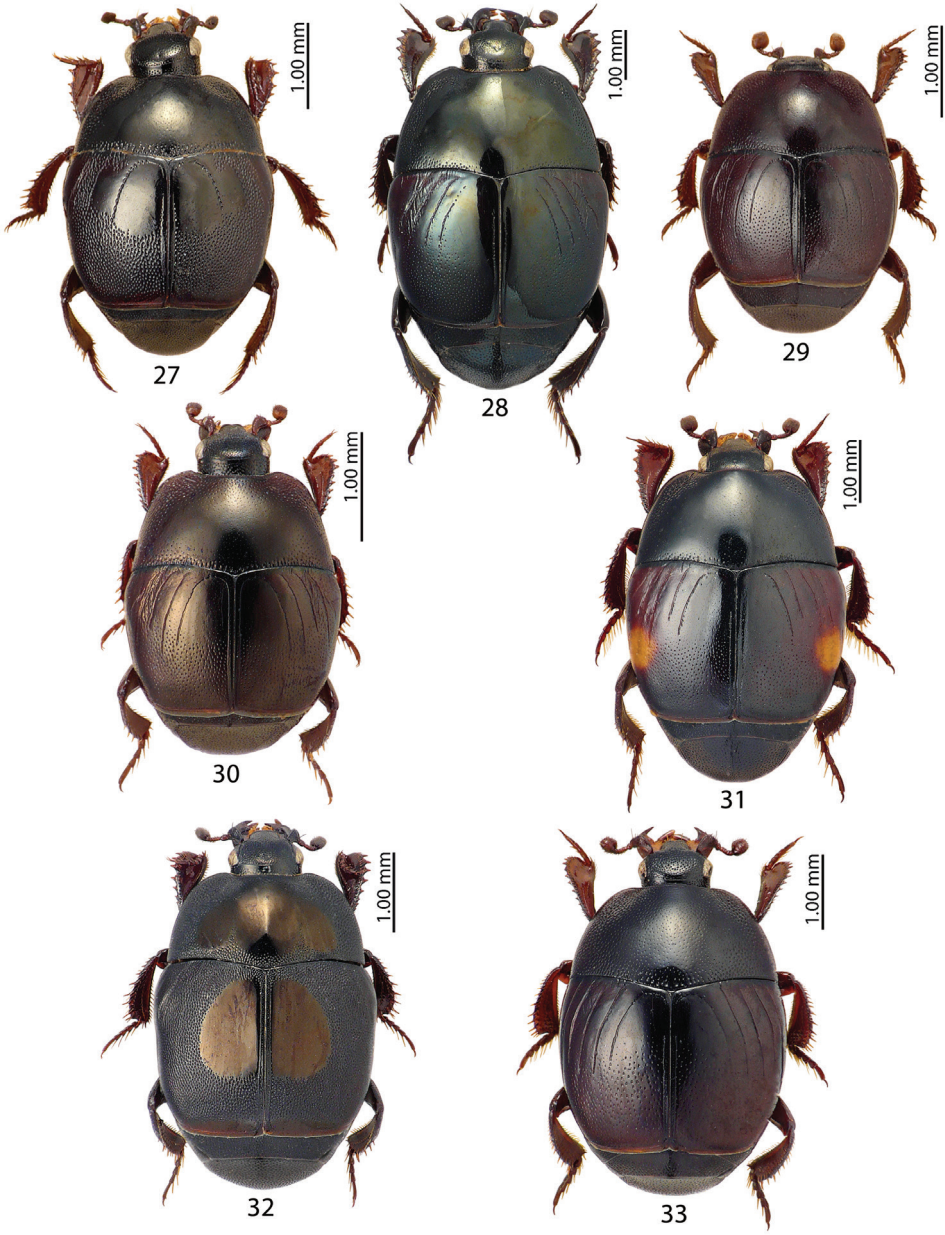
Biology. This species is present on carcasses, in excrements, manure, mammal burrows and occasionally even on flowers (Kryzhanovskij and Reichardt 1976).

Saprinus (*Saprinus*) *calatravensis* Fuente, 1899

Figures 29, 122, 126

Distribution in the Middle East. Iran, Israel, Oman, Saudi Arabia, Turkey (Lackner et al. 2015). Already reported from Lebanon (Deir El-Ahmar, Hasbaya; Shayya et al. 2018) (Fig. 122).

Biology. An essentially necrophilous taxon, attracted to small- and medium-sized carrion (Faria e Silva et al. 2006; Shayya et al. 2018) frequenting xeric landscapes and sandy soils (Kryzhanovskij and Reichardt 1976) with preference to habitats at lower



Figures 27–33. 27 *Saprinus* (*Saprinus*) *aegialius* Reitter, 1884, **28** *Saprinus* (*Saprinus*) *caerulescens caerulescens* (Hoffmann, 1803), **29** *Saprinus* (*Saprinus*) *calatravensis* Fuente, 1899, **30** *Saprinus* (*Saprinus*) *chalcites* (Illiger, 1807), **31** *Saprinus* (*Saprinus*) *externus* (Fischer von Waldheim, 1823), **32** *Saprinus* (*Saprinus*) *figuratus* Marseul, 1855, **33** *Saprinus* (*Saprinus*) *godet* (Brullé, 1832).

elevations and restricted to mesomediterranean holm oak (*Quercus ilex* L.) forests in Spain (Martín-Vega et al. 2015). We report three specimens collected from rotting fish-baited pitfall trap in Kfar Qouq.

***Saprinus* (*Saprinus*) *chalcites* (Illiger, 1807)**
Figures 30, 122, 126

Distribution in the Middle East. Cyprus, Iran, Iraq, Israel, Jordan, Kuwait, Oman, Saudi Arabia, Syria, Turkey, Yemen (Lackner et al. 2015). Already reported from pig carrion in Lebanon (Hasbaya, Fanar, Badghan, Deir El-Ahmar, Naas; Shayya et al. 2018). In our current study it was collected from Badghan, Kfar Qouq, Kfeir, Misherfeh, Nabaa Al Safa and Tanoura (Fig. 122).

Biology. A typical saprobiont, attracted to carrion and mammal dung (Lackner and Vienna 2017), found also on rotting vegetable substances. We found it in rotting fish-baited pitfall traps during spring in Badghan (5 specimens), Misherfeh (1 specimen), Nabaa Al Safa (1 specimen), and Tanoura (6 specimens). We likewise collected this species from pig dung-baited pitfall traps during the same season in Kfar Qouq (1 specimen) and Kfeir (1 specimen).

***Saprinus* (*Saprinus*) *externus* (Fischer von Waldheim, 1823)**
Figures 31, 123, 126

Distribution in the Middle East. Iran, Jordan, Syria, Turkey (Lackner et al. 2015). Newly reported from Lebanon (Kfar Qouq and Rashaya).

Biology. Found among carrion entomofauna at various stages of decomposition, especially in rural areas (Al Tunsoy et al. 2017). *Saprinus* (*S.*) *externus* is an infrequent taxon in Lebanon. According to Reichardt (1941), this species is linked to carrion and dung. In our samplings, a singleton was reported from pig dung-baited pitfall trap in Kfar Kouq and another was collected in decomposing fish-baited pitfall trap in Rashaya (Fig. 123).

***Saprinus* (*Saprinus*) *figuratus* Marseul, 1855**
Figures 32, 123, 126

Distribution in the Middle East. Israel, Jordan, Oman, Saudi Arabia, Syria (Lackner et al. 2015). Newly reported from Lebanon (Ain Harsha and Rashaya).

Biology. *Saprinus* (*S.*) *figuratus* occurs on carrion, with restriction to the meso-mediterranean holm oak forests on basic soils (Reichardt 1941; Martín-Vega et al. 2015). Herein, one specimen was found in a decomposing fish pitfall trap in Rashaya, and another specimen was found in a similar trap in Ain Harsha (Fig. 123).

***Saprinus* (*Saprinus*) *godet* (Brullé, 1832)**
Figures 33, 123, 126

Distribution in the Middle East. Turkey, Saudi Arabia (Lackner et al. 2015). Already mentioned from Lebanon (Fanar, Badghan, Deir El-Ahmar, Hasbaya, Sin El-Fil;

Shayya et al. 2018). We herein report it from Badghan, Kfeir, Mimes, Misherfeh, Nabaa Al Safa, and Tanoura (Fig. 123).

Biology. Occurs on carcasses (Kryzhanovskij and Reichardt 1976; Penati 2009; Shayya et al. 2018). In Lebanon we sampled it from rotting fish-baited pitfall trap during spring in Badghan (1 specimen), Mimes (1 specimen), Misherfeh (2 specimens), Nabaa Al Safa (1 specimen), and Tanoura (1 specimen). In addition, it was sampled from pig dung-baited pitfall traps in Kfeir (2 specimens).

***Saprinus* (*Saprinus*) *niger* (Motschulsky, 1849)**

Figures 36, 123, 126

Distribution in the Middle East. Iran, Iraq, Israel, Jordan, Syria, Turkey (Lackner et al. 2015). New to Lebanon (Kfar Qouq) (Fig. 123).

Biology. A member of the carrion entomofauna (Reichardt 1941). We recorded it from a rotting fish-baited pitfall trap during spring in Kfar Qouq (1 specimen).

***Saprinus* (*Saprinus*) *robustus* Krása, 1944**

Figures 38, 124, 126

Distribution in the Middle East. Cyprus, Iran, Israel, Jordan, Lebanon, Syria, Turkey (Lackner et al. 2015). Already reported from Lebanon from Deir El-Ahmar and Hasbaya (Shayya et al. 2018). We herein add further Lebanese localities: Ain Harsha, Kfeir, Misherfeh and Sawfar (Fig. 124).

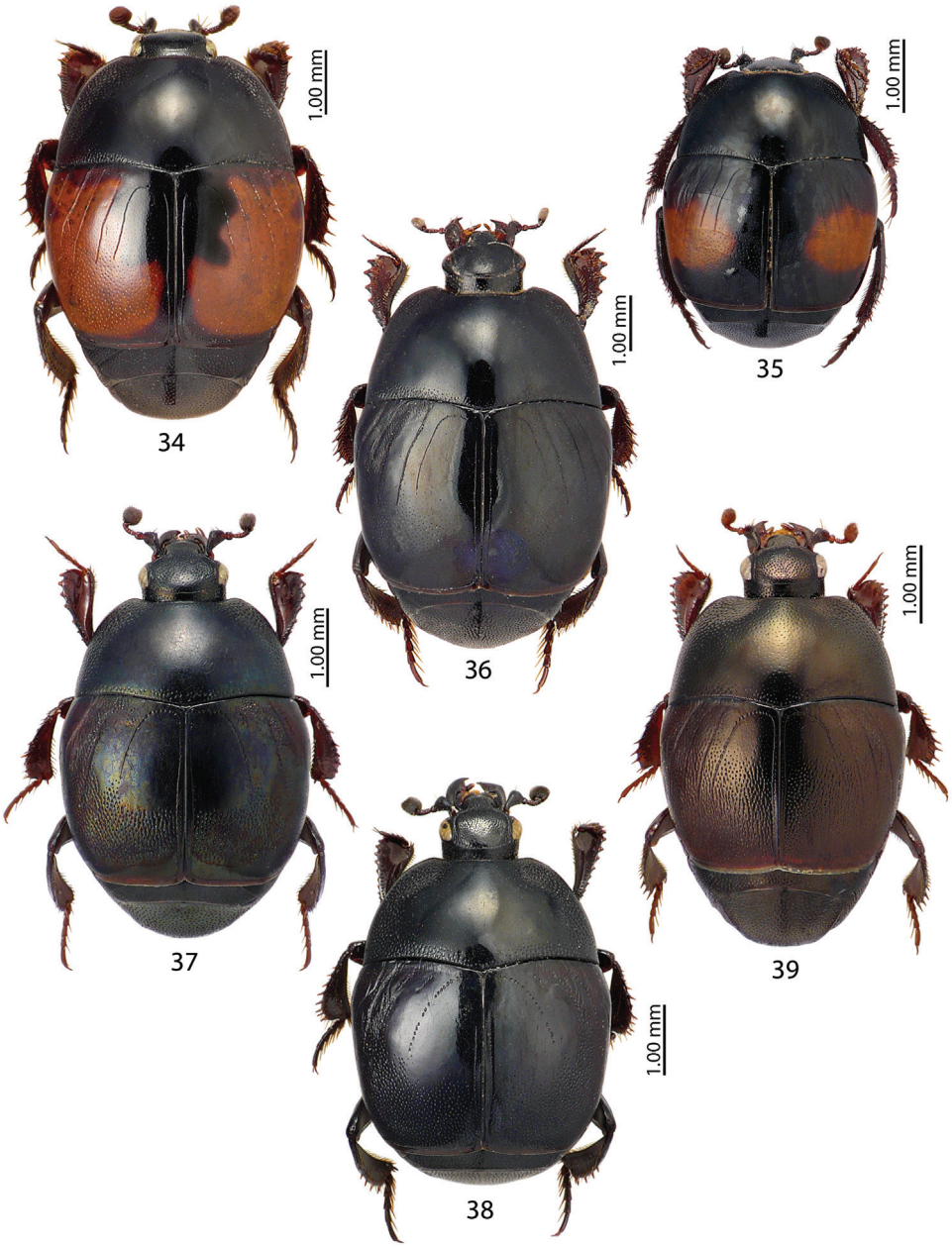
Biology. *Saprinus* (*S.*) *robustus* inhabits dung and carrion alike (Anlaş et al. 2007; Shayya et al. 2018). It was examined in a rotting fish-baited pitfall trap during spring in Ain Harsha (2 specimens), Misherfeh (2 specimens), and Sawfar (3 specimens). A single specimen was attracted to pig dung-baited pitfall trap during spring in Kfeir.

***Saprinus* (*Saprinus*) *strigil* Marseul, 1855**

Figures 39, 124, 126

Distribution in the Middle East. Cyprus, Iran, Iraq, Israel, Oman, Saudi Arabia, Syria, Yemen (Lackner et al. 2015). We already reported it from Lebanon (Hasbaya, Badghan, Fanar, Deir El-Ahmar and Naas; Shayya et al. 2018). New Lebanese localities are: Badghan, Kfar Qouq, Kfeir, Khalwat El Kfeir, Mimes, Misherfeh, Nabaa Al Safa, Rashaya, and Tanoura (Fig. 124).

Biology. *Saprinus* (*S.*) *strigil* was encountered on carrion (Shayya et al. 2018). We collected it from rotting fish-baited pitfall trap during spring in Badghan (12 specimens),



Figures 34–39. 34 *Saprinus* (*Saprinus*) *maculatus* (P. Rossi, 1792) **35** *Saprinus* (*Saprinus*) *magnoguttatus* J. Müller, 1937 **36** *Saprinus* (*Saprinus*) *niger* Motschulsky, 1849 **37** *Saprinus* (*Saprinus*) *prasinus prasinus* Erichson, 1834 **38** *Saprinus* (*Saprinus*) *robustus* Krása, 1944 **39** *Saprinus* (*Saprinus*) *strigil* Marseul, 1855.

Mimes (8 specimens), Misherfeh (25 specimen), Nabaa Al Safa (9 specimens), Rashaya (1 specimen), and Tanoura (8 specimens). It was also found in a pig dung-baited pitfall traps in Kfar Kouq (3 specimens), Kfeir (1 specimen), and Khalwat El Kfeir (5 specimens).

Saprinus (*Saprinus*) *subnitescens* Bickhardt, 1909

Figures 41, 125, 126

Distribution in the Middle East. Cyprus, Iran, Iraq, Israel, Lebanon, Syria, Turkey (Lackner et al. 2015). Already known from Lebanon (Fanar, Badghan, Naas, Deir El-Ahmar and Hammana; Shayya et al. 2018). We herein report this species from the following Lebanese localities: Badghan, Bakifa, Kfeir, Mimes, Misherfeh, Nabaa Al Safa, Rashaya, and Sawfar (Fig. 125).

Biology. *Saprinus* (*S.*) *subnitescens* is a predator without an obvious habitat preference; it has been found on carrion (Özdemir and Sert 2008; Rozner 2010; Al Tunsoy et al. 2017; Shayya et al. 2018; Martín-Vega et al. 2015), and likewise on manure and decaying vegetable matter (Bousquet and Laplante 2006). We collected it from rotting fish-baited pitfall traps during spring in Badghan (1 specimen), Bakifa (1 specimen), Mimes (1 specimen), Misherfeh (20 specimen), Nabaa Al Safa (49 specimen) and Sawfar (2 specimens). Two specimens were found in a pig dung-baited pitfall trap in Kfeir.

Saprinus (*Saprinus*) *tenuistrius sparsutus* Solsky, 1876

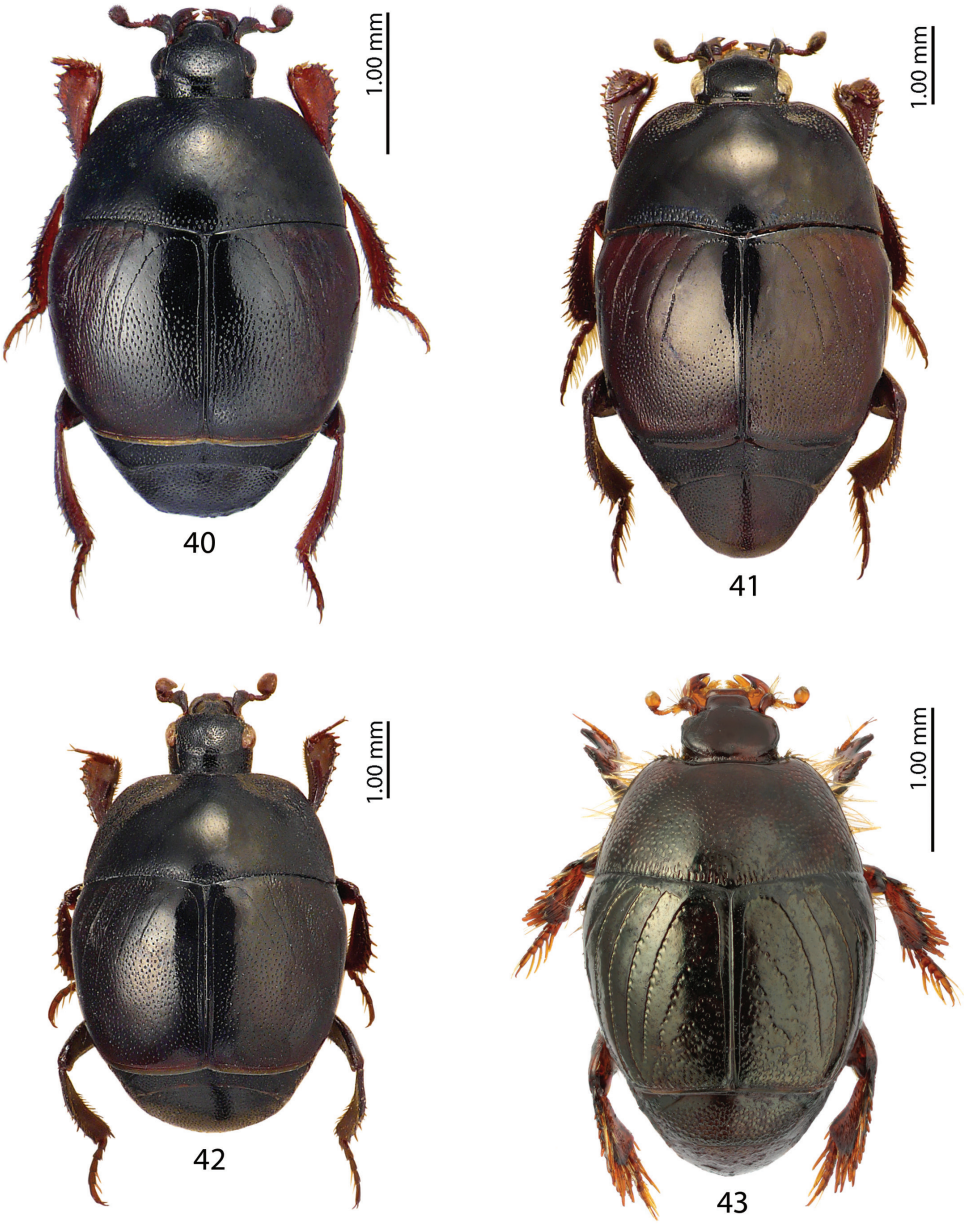
Figures 42, 125, 126

Distribution in the Middle East. Iran, Iraq, Israel, Syria, Turkey (Lackner et al. 2015). According to Rozner (2010) as well as our observations *S.* (*S.*) *tenuistrius sparsutus* is a frequent taxon in the Eastern Mediterranean area. Already known from Lebanon (Deir El-Ahmar, Hasbaya; Shayya et al. 2018). New Lebanese localities: Khalwat El Kfeir, and Rashaya (Fig. 125).

Biology. It is known among the entomofauna of carrion (Al-Tunsoy et al. 2017; Shayya et al. 2018). In Spain, it was found in meso-and supra-Mediterranean forests, which is similar to our findings in Lebanon (Martín-Vega et al. 2015). It is noteworthy to mention that Lebanon shares a similar Mediterranean climate with Spain. We collected it from rotting fish-baited pitfall trap in Rashaya (1 specimen) and from pig dung baited pitfall trap in Khalwat El Kfeir (1 specimen).

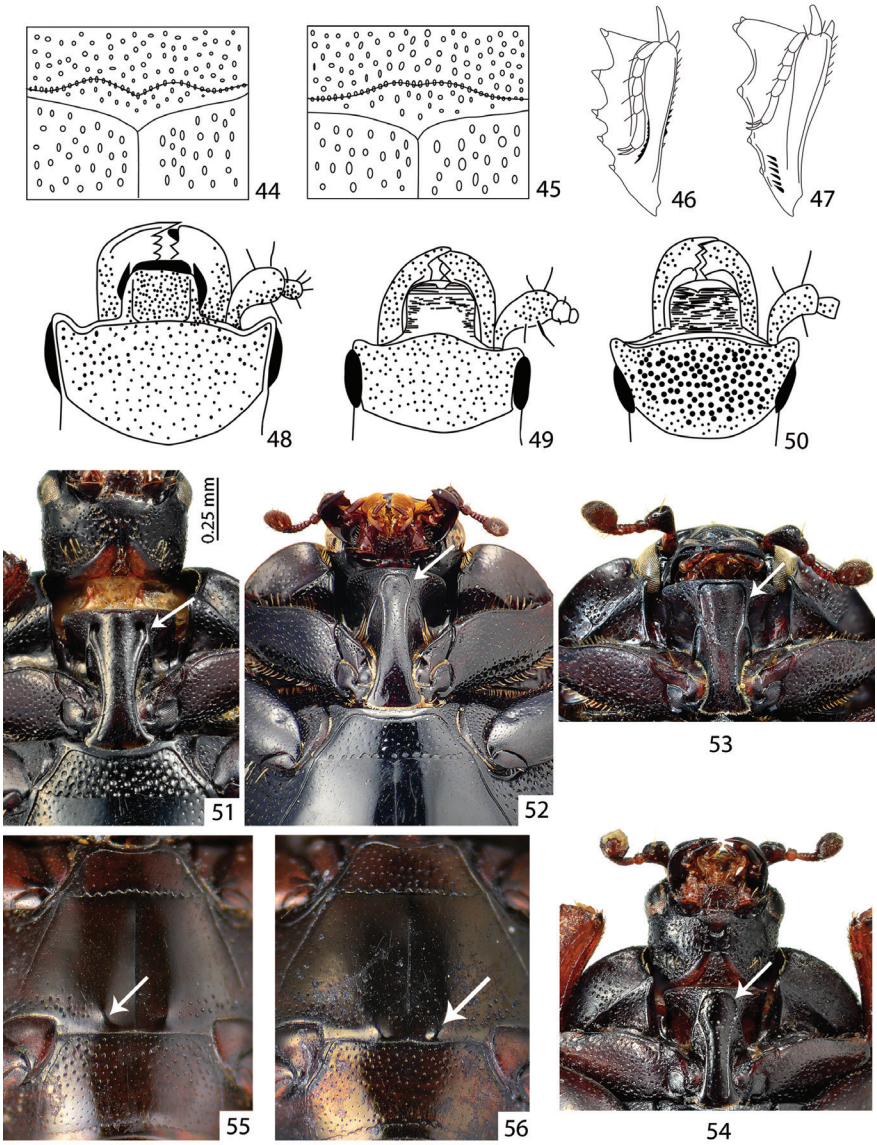
Xenonychus Wollaston, 1864

Distribution. *Xenonychus* contains three described species: *Xenonychus tridens* (Jacquelin du Val, 1853) is distributed from the Cape Verde Archipelago and Canary Islands

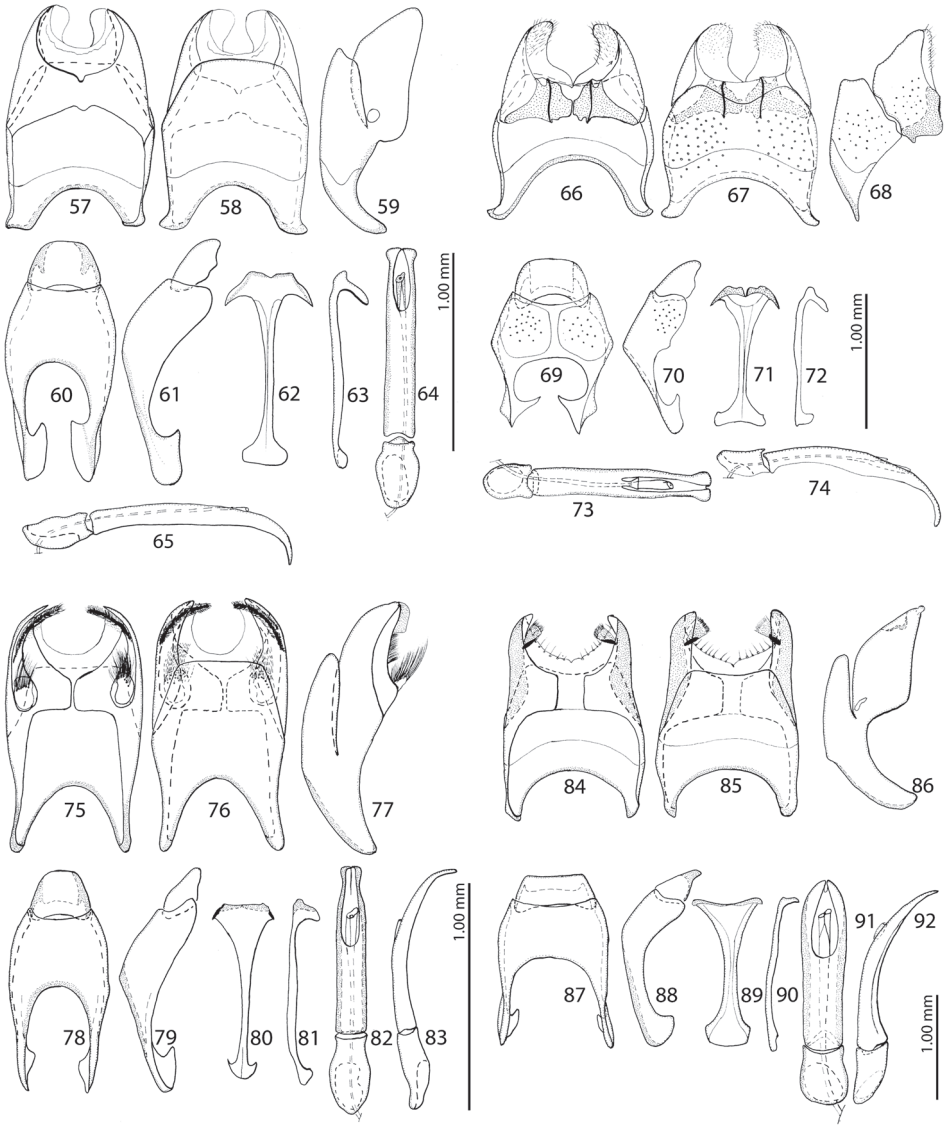


Figures 40–43. 40 *Saprinus* (*Saprinus*) *submarginatus* J. Sahlberg, 1913 **41** *Saprinus* (*Saprinus*) *subnitescens* Bickhardt, 1909 **42** *Saprinus* (*Saprinus*) *tenuistrius sparsutus* Solsky, 1909 **43** *Xenonychus tridens* (Jacquelin du Val, 1853).

in the west through the Sahara Belt along the Mediterranean coast to the Arabian Peninsula in the east. *Xenonychus aralocaspius* Kryzhanovskij, 1976 is found around the Caspian and Aral Seas, and further inland in the middle Asian countries of Kazakh-



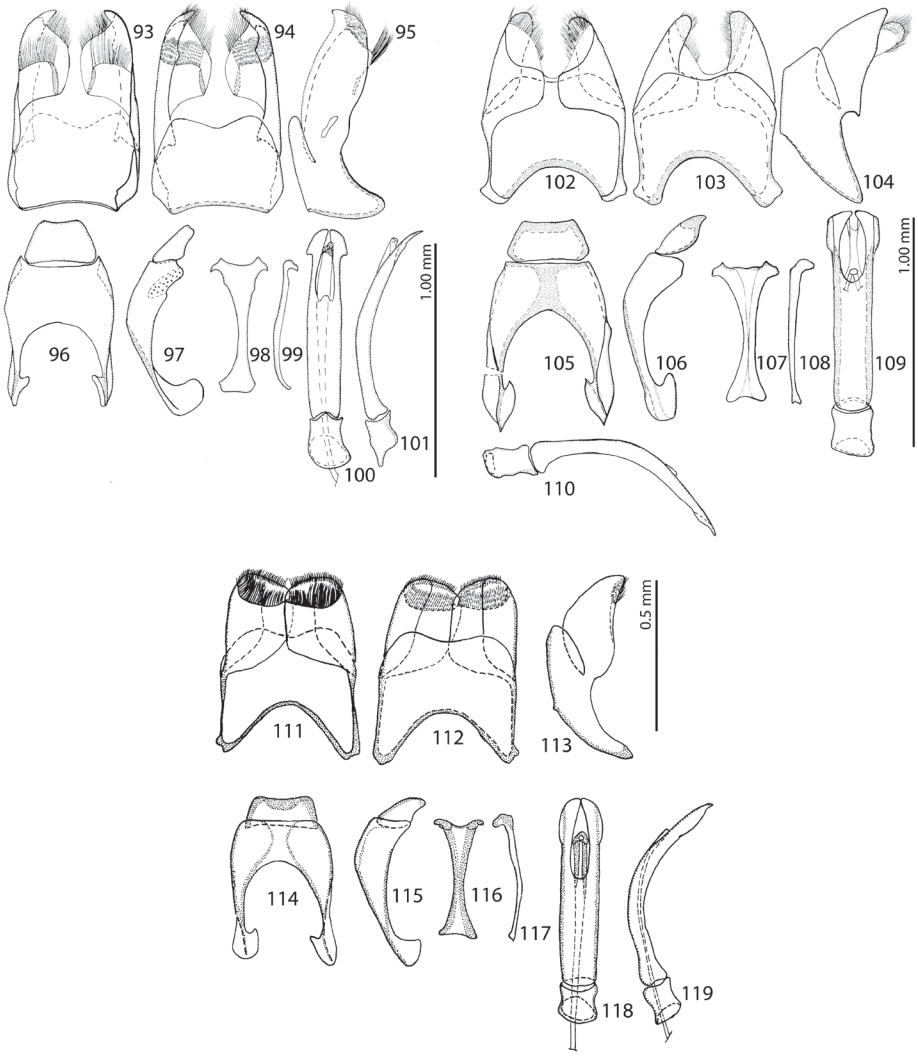
Figures 44–56. 44 *Abraeomorphus besucheti* Mazur, 1977– pronotum (re-drawn from Mazur (1977)) **45** *Abraeomorphus minutissimus* (Reitter, 1884) – pronotum (re-drawn from Mazur (1977)) **46** Platysomatini, protibia (re-drawn from Kryzhanovskij and Reichardt (1976)) **47** Histerini, protibia (re-drawn from Kryzhanovskij and Reichardt (1976)) **48** *Hypocacculus* (*Colpellus*) *praecox* (Erichson, 1834) – frons (re-drawn from Kryzhanovskij and Reichardt (1976)) **49** *Hypocacculus* (*Hypocacculus*) *metallescens* (Erichson, 1834) – frons (re-drawn from Kryzhanovskij and Reichardt (1976)) **50** *Hypocaccus* (*Nessus*) *baudii* (J. Schmidt, 1890) – frons (re-drawn from Kryzhanovskij and Reichardt (1976)) **51** *Hemisaprinus subvirescens* (Ménétriés, 1832) – prosternum **52** *Saprinus* (*Saprinus*) *niger* Motschulsky, 1849 – prosternum **53** *Saprinus* (*Saprinus*) *subnitescens* Bickhardt, 1909 – prosternum **54** *Saprinus* (*Saprinus*) *submarginatus* J. Sahlberg, 1913 – prosternum **55** *Saprinus* (*Saprinus*) *calatravensis* Fuente, 1899 – metaventrite **56** *Saprinus* (*Saprinus*) *chalcites* (Illiger, 1807) – metaventrite.



Figures 57–92. 57–65 *Saprinus* (*Saprinus*) *subnitescens* Bickhardt, 1909 – male genitalia **66–74** *Saprinus* (*Saprinus*) *robustus* Krása, 1944 – male genitalia **75–83** *Saprinus* (*Saprinus*) *godet* (Brullé, 1832) – male genitalia **84–92** *Saprinus* (*Saprinus*) *tenuistrius sparsutus* Solsky, 1909 – male genitalia.

stan, Uzbekistan and Turkmenistan, while *Xenonychus somaliensis* (Thérond, 1963) is, so far, known exclusively from Somalia (Lackner 2012).

Biology. The first two species are inhabitants of arid areas of shifting sand, frequent on sand dunes on beaches and also present inland. The biology of the *X. somaliensis* is unknown, but presumably similar to congeners (Lackner 2012).



Figures 93–119. 93–101 *Saprinus* (*Saprinus*) *submarginatus* J. Sahlberg, 1913 – male genitalia **102–110** *Saprinus* (*Saprinus*) *calatravensis* Fuente, 1899 – male genitalia **111–119** *Saprinus* (*Saprinus*) *chalcites* (Illiger, 1807) – male genitalia.

Xenonychus tridens (Jacquelin du Val, 1853)

Figures 43, 125

Distribution in the Middle East. Cyprus, Israel, Oman, Saudi Arabia, Syria, Turkey, United Arab Emirates (Lackner et al. 2015). New to Lebanon (Tyre) (Fig. 125).

Biology. A typical psammo-halobiotic species, usually found under plants on coastal as well as inland dunes; occasionally found also under carrion on sandy surfaces (T. Lackner, pers. obs. 2012). According to Reichardt (1941), it was examined in dune sands of the sea coast at a depth of 15 to 30 cm of a raw layer of sand and in the vicinity

of plants roots. During sand-cascading at the Tyre beach, 12 specimens were collected in the rhizosphere of various plants.

Key to the Histeridae of Lebanon

We should like to stress that our key contains only species recorded from the territory of Lebanon, with a single exception of *Spathochus coyei*, which has been recorded from the neighboring countries and we strongly suspect it might also occur in Lebanon. If a histerid specimen from Lebanon cannot be identified using our key, we advocate using the monograph of the USSR fauna by Kryzhanovskij and Reichardt (1976; in Russian), which contains keys covering many taxa occurring in the Middle East. Our key will need revision, as the country's fauna becomes better known.

1(4) Taxa of minute size, PEL = max 1.10 mm..... ***Abraeomorphus* Reitter, 1886**

2(3) Metaventrite densely punctate, basal pronotal stria medially not distinctly inwardly angulate (Figs 17; 45) ..... ***A. minutissimus* (Reitter, 1884)**

3(2) Metaventrite sparsely punctate (for fig. see Mazur, 1977 fig. 2); basal pronotal stria medially distinctly inwardly angulate (Figs 16; 44) .... ***A. besucheti* Mazur, 1977**

4(1) Larger taxa, PEL > 1.10 mm **5**

5(8) Elytra and pronotum with costae ..... ***Onthophilus* Leach, 1817**

6(7) Large species, PEL = 4.20 mm; punctures of pronotum not forming elongate rugae; pronotum medially with two interrupted keels (Fig. 1)..... ..... ***O. bickhardti* Reitter, 1909**

7(6) Smaller species, PEL = max 2.50 mm; punctures of pronotum forming elongate rugae; pronotum medially with four complete keels (Fig. 2) .... ***O. striatus inconditus* Reichardt, 1941**

8(5) Elytra and pronotum without costae..... **9**

9(34) Prosternum with prosternal lobe or "presternum" (for fig. see e.g. Ôhara 1994, fig. 11C) **10**

10(11) Labrum with setae; protibia with numerous tiny denticles (Figs 3, 120) .... ***Tribalus* sp.**

11(10) Labrum asetose; protibia usually with several large teeth topped by denticles, never with numerous tiny denticles (Fig. 11) .... **subfamily Histerinae Gyllenhall, 1808**

12(15) Mesoventrite produced into an anterior angle that fits into an angular emargination of the prosternum (for fig. see e.g. Kanaar 1997, fig. 2)..... ..... **tribe Exosternini Bickhardt, 1914**

13(14) Larger species, PEL > 3.00 mm; body strongly convex; elytral stria IV basally connected with complete sutural elytral stria; antennal club larger than antennal funicle (Fig. 5) ..... ***Notodoma lewisi* Reitter, 1910**

14(13) Smaller species, PEL < 3.00 mm; body rather flattened; elytral stria IV basally shortened, not connected with shortened sutural elytral stria; antennal club smaller than antennal funicle (Fig. 4)..... ***Spathochus coyei* Marseul, 1864**

15(13) Mesoventrite not produced into an anterior angle, usually rounded anteriorly (for fig. see e.g. Ôhara 1994, fig. 3C) **16**

16(21) Protarsal groove deep, S-shaped (Fig. 46); body either cylindrical or depressed ..... **tribe Platysomatini Bickhardt, 1914**

17(18) Body cylindrical (Fig. 8) ..... ***Platysoma* (*Cylister*) *cornix* Marseul, 1861**

18(17) Body flattened (Fig. 6) **19**

19(20) Anterior angles of pronotum with dense punctures; pronotum on anterior third only slightly narrowed (Fig. 6) .... ***Platylister* (*Popinus*) *algiricus* (Lucas, 1864)**

20(19) Anterior angles of pronotum with sparse punctures; pronotum on anterior third narrowed more strongly (Fig. 7) .... ***Platylister* (*Popinus*) *simeani* (Mulsant & Godart, 1875)***[*]

21(16) Prosternal groove usually shallow, not S-shaped (Fig. 47); body never cylindrical and usually only slightly flattened..... **tribe Histerini Gyllenhal, 1808**

22(25) Mesoventrite anteriorly outwardly arcuate, rounded (for fig. see e.g. Ôhara 1992, fig. 11D) **23**

23(24) Apical pronotal angles with a single stria; roundly-oval species (Figs 9, 121) ... . ***Atholus duodecimstriatus duodecimstriatus* (Schrank, 1781)**

24(23) Apical pronotal angles with double stria; a depressed taxon (Fig. 10) .... ***Eudiplister castaneus* (Ménétriés, 1832)**

25(22) Mesoventrite deeply emarginate anteriorly (for fig. see e.g. Ôhara 1994, fig. 68C) **26**

26(29) Inner subhumeral stria completely absent (Fig. 12).... ***Hister* Linnaeus, 1758**

27(28) Elytra with red macula (Fig. 11)..... ***Hister limbatus* Truqui, 1852**

28(27) Elytra completely black (Figs 12, 121).... ***Hister sepulchralis* Erichson, 1834**

29(26) Inner subhumeral stria present at least as a short fragment, usually complete (Fig. 14) ..... ***Margarinotus* Marseul, 1854**

30(31) Body large, PEL>7.50 mm, sub-rectangular; elytra usually with only striae I–III complete (Fig. 15) .... ***Margarinotus* (*Stenister*) *graecus graecus* (Brullé, 1834)**

31(30) Body smaller, PEL < 7.50 mm, roundly-oval; elytra with striae I–IV developed **32**

32(33) Pronotum with two lateral striae; a larger species, PEL > 4.50–7.00 mm (Figs 14, 121) ..... ***Margarinotus* (*Ptomister*) *brunneus* (Fabricius, 1775)**

33(32) Pronotum with a single lateral stria; a smaller species, PEL = 2.80–4.00 mm (Figs 13, 121).... ***Margarinotus* (*Grammostethus*) *ruficornis* (Grimm, 1852)**

34(9) Prosternum without prosternal lobe or "presternum" (for fig. see e.g. Ôhara 1994, fig. 12A) **35**

35(36) Tiny (PEL < 2.20 mm), completely black, dorsoventrally flattened subcortical taxon; elytra without striae (Fig. 18) .... ***Stenopleurum rothi* (Rosenhauer, 1856)**

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* According to Y. Gomy (Nevers, France; personal communication, 2019) the two species of *Platylister* are possibly synonyms. This has already been discussed by Kanaar (2008); according to him "A comparison of the type-specimens of both species is needed to solve this question".

36(35) Usually larger (PEL > 2.20 mm), mostly metallic, occasionally with red macula, roundly-oval, not depressed taxa, never subcortical; elytra always striate (Fig. 19)..... **subfamily Saprininae C.É. Blanchard, 1845**

37(38) Frontal and supraorbital striae completely absent, basally between elytral stria IV and sutural elytral stria a short hooked appendix present (Fig. 22)..... .....***Gnathoncus disjunctus suturifer*** **Reitter, 1896**

38(37) At least supraorbital stria always present, frontal stria often interrupted medially, occasionally prolonged onto clypeus; without basal short hooked appendix between elytral stria IV and sutural stria.....**39**

39(54) Prosternal foveae present (Fig. 51) **40**

40(41) Carinal prosternal striae divergent anteriorly, "open", lateral prosternal striae straight, terminating in deep prosternal foveae (Figs 23, 51, 122) .... ***Hemisaprinus subvirescens*** **(Ménétriés, 1832)**

41(40) Carinal prosternal striae usually convergent and united anteriorly; lateral prosternal striae usually convergent anteriorly, occasionally surpassing prosternal foveae, in most cases evading them (for fig. see Lackner 2012, fig. 30)..... **42**

42(43) Underside of body setose, including elytral epipleuron; a very convex taxon; protibia with three large teeth topped by denticle, followed by five short denticles (Figs 43, 125).....***Xenonychus tridens*** **(Jacquelin du Val, 1853)**

43(42) Underside of body usually glabrous, rarely pronotal hypomeron with very short setae (*Hypocacculus* (*H.*) *metallescens*)); elytral epipleuron always glabrous; slightly more flattened taxa; protibia usually with 3–8 short teeth topped by denticle, diminishing in size in proximal direction **44**

44(49) Frontal stria usually interrupted medially, slightly prolonged onto clypeus; if complete (*C. aemulus*) then elytral stria IV basally not united with sutural elytral stria ..... ***Chalcionellus*** **Reichardt, 1932**

45(46) Pronotum with pronotal post-ocular depressions; cuticle metallic, with bronze or slightly greenish hue (Fig. 20) .... ***Chalcionellus blanchii blanchii*** **(Marseul, 1855)**

46(45) Pronotum without post-ocular pronotal depressions; cuticle not metallic, usually dark-brown or black (Fig. 21) **47**

47(48) Frontal stria weakened, but usually complete; elytral stria IV basally not connected with sutural elytral stria (Fig. 19)..... ..... ***Chalcionellus aemulus*** **(Illiger, 1807)**

48 (47) Frontal stria widely interrupted medially and prolonged onto clypeus; elytral stria IV basally connected with sutural elytral stria (Fig. 21) ....***Chalcionellus libanicola*** **(Marseul, 1870)**

49(44) Frontal stria usually complete; elytral stria IV usually basally united with sutural elytral stria.....**genera *Hypocacculus* Bickhardt, 1914 and *Hypocaccus* C.G. Thomson, 1857**

50(53) Frons with sparse minute punctures (Fig. 48)....***Hypocacculus*** **Bickhardt, 1914**

51(52) Frontal stria medially almost straight, forming an acute angle above eyes; supraorbital stria keel-like (Figs 24, 48) .... ***Hypocacculus*** **(*Colpellus*) *praecox*** **(Erichson, 1834)**

52(51) Frontal stria medially outwardly arcuate, not forming an acute angle above eyes; supraorbital stria not keel-like (Figs 25, 49, 122) ....***Hypocacculus* (s.str.) *metallescens* (Erichson, 1834)**

53(50) Frons densely and coarsely punctate, occasionally punctures forming coarse elongate rugae (Figs. 26, 50)....***Hypocaccus* (*Nessus*) *baudii* (Schmidt, 1890)**

54(39) Prosternal foveae absent (Fig. 52).....***Saprinus* Erichson, 1834**

55(60) Elytra bicolored (Fig. 34) **56**

56(57) At least the entire lateral elytral margin orange-red, usually most part of the elytral disk orange-red with only the short band along the elytral suture black (Fig. 34)..... ***Saprinus* (*S.*) *maculatus* (P. Rossi, 1790)**

57(56) Each elytron with a well-defined orange-red macula, never occupying the entire lateral elytral margin (Fig. 35) **58**

58(59) Black without bronze hue; macula reaching into fourth elytral interval (Fig. 35)..... ***Saprinus* (*S.*) *magnoguttatus* Reichardt, 1926**

59(58) Black with bronze hue; macula on elytron reaching into third elytral interval (Figs 31, 123) .....***Saprinus* (*S.*) *externus* (Fischer von Waldheim, 1823)**

60(55) Elytra unicolored, never with red macula (Fig. 36).....**61**

61(62) Pronotal hypomeron setose, fourth dorsal elytral stria strongly reduced, often absent; a large, usually metallic species (PEL = 5.00–7.50 mm) (Fig. 28)..... .....***Saprinus* (*S.*) *caerulescens caerulescens* (Hoffman, 1803)**

62(61) Pronotal hypomeron asetose, fourth dorsal elytral stria usually not reduced, fully developed; smaller species (PEL = 2.50–6.50 mm).....**63**

63(64) Elytra, especially their apical halves with very dense punctation, punctures aciculate and striolate, elytral intervals punctured, third dorsal elytral stria well-developed (Figs 39, 124) .....***Saprinus* (*S.*) *strigil* Marseul, 1855**

64(63) Elytra with variously dense punctation, but punctures usually not aciculate or striolate (some specimens of *S.* (*S.*) *robustus* can have striolate punctures, but then the third dorsal elytral stria is always strongly reduced) (Fig. 38).....**65**

65(70) Elytra with well-defined polished areas 'mirrors', punctation of elytral disk very dense, punctures separated by less than their own diameter, third dorsal elytral stria reduced to absent (Fig. 32) **66**

66(67) Dorsal elytral striae erased by very coarse and dense punctures; pronotum with a well-defined 'mirror' consisting of three interconnected ovals of which the middle one is conspicuously larger than other two (Figs 32, 123) ....***Saprinus* (S.) *figuratus* Marseul, 1855**

67(66) Dorsal elytral striae always visible; pronotum without a well-defined "mirror" (Fig. 27).....**68**

68(69) Elytral 'mirror' with microscopic scattered punctation, light to dark brown species, without greenish or bronze metallic hue, third dorsal elytral stria reduced, but usually discernible; elytral punctation in fourth elytral interval reaches elytral half (Fig. 27) .....***Saprinus* (S.) *aegialius* Reitter, 1884**

69(68) Elytral 'mirror' glabrous, third dorsal elytral stria usually strongly reduced to absent, dorsum with distinct greenish or bronze metallic hue; punctation in

fourth elytral interval does not reach elytral half (Fig. 37) .... ***Saprinus* (*S.*) *prasinus prasinus* Erichson, 1834**

70(65) Elytra without well-defined polished areas ('mirrors'), punctation of the elytral disk less dense, punctures usually separated by their own diameter or more (Fig. 36) **71**

71(72) Apices of carinal prosternal striae convergent anteriorly, rather approximate; large (PEL = 4.50–6.50 mm) entirely black species (Figs 36, 52, 123) .... ***Saprinus* (*S.*) *niger* Motschulsky, 1849**

72(71) Apices of carinal prosternal striae divergent anteriorly (Fig. 53) **73**

73(76) Apices of carinal prosternal striae strongly divergent, laying on lateral sides of the prosternal process (Fig. 53); usually moderately large, brownish species (PEL = 3.50–5.30 mm) **74**

74(75) Pronotal post-ocular depressions deep, third dorsal elytral stria usually not reduced, light to dark brown species with slight bronze metallic hue (Fig. 41), male with deeply depressed metaventrite; male terminalia: apex of 8th sternite (velum) asetose, 8th sternite medially not strongly sclerotized (Figs 57–65, 125) ..... ***Saprinus* (*S.*) *subnitescens* Bickhardt, 1909**

75(74) Pronotal post-ocular depressions shallow, third dorsal elytral stria usually strongly reduced, black species without metallic hue (Fig. 38), male with only shallowly depressed metaventrite; male terminalia: apex of 8th sternite (velum) with dense tiny setae, 8th sternite medially strongly sclerotized (Figs 66–74, 124) ..... ***Saprinus* (*S.*) *robustus* Krása, 1944**

76(73) Apices of prosternal striae divergent, but never laying on lateral sides of the pronotal process (Fig. 54); usually smaller species (PEL= 2.50–3.90 mm)....**77**

77(78) Pronotal post-ocular depressions absent, pronotal disk medially with distinct punctation, humeral elytral stria confluent with inner subhumeral one creating a supplementary dorsal elytral stria parallel to first (Fig. 33); male terminalia: apices of 8th sternite with thin, dense brush of setae, medio-laterally with a bean-shaped setose sclerite, aedeagus strongly constricted before apex (Figs 75–83, 123) ..... ***Saprinus* (*S.*) *godet* (Brullé, 1832)**

78(77) Pronotal post-ocular depressions present, pronotal disk medially with only scattered fine punctation (Fig. 42) **79**

79(80) Entire elytral disk with punctation, punctures separated by twice or more their diameter, dorsal elytral striae thin, impunctate (Fig. 42), antennal club large, light-amber coloured; male terminalia: apices of 8th sternite with tiny triangular accessory sclerite furnished with micro-setae, aedeagus short and stout, not dilated apically (Figs 84–92, 125) .... ***Saprinus* (*S.*) *tenuistrius sparsutus* Solsky, 1876**

80(79) At least the area between united sutural and fourth dorsal elytral striae without punctation (or punctures microscopic), punctures of elytral disk separated usually by less than twice their diameter (Fig. 40), antennal club medium-sized, reddish-brown. The following species are usually only reliably identifiable based on their male terminalia **81**

81(82) Apical margin of metaventrite of male without tubercles. Male terminalia: 8th sternite with two rows of brush-like setae: one situated approximately medially and another apically, aedeagus constricted before apex; apex rounded (Figs 93–101) (Figs 40, 54).....***Saprinus* (*S.*) *submarginatus* J. Sahlberg, 1913**

82(81) Apical margin of metaventrite of male with two distinct tubercles (Fig. 55)....**83**

83(84) Tubercles on the apical margin of metaventrite of male slightly removed from metaventral margin (Fig. 55). Dorsal elytral striae surpassing elytral half; male terminalia: 8th sternite with large setose velum (best seen especially from lateral view), apex of aedeagus rectangularly dilated, truncated (Figs 102–110) (Figs 29, 122) ..... ***Saprinus* (*S.*) *calatravensis* Fuente, 1899**

84(83) Tubercles situated almost on the very apical metaventral margin (Fig. 56); dorsal elytral striae usually not surpassing elytral half; male terminalia: 8th sternite without large setose velum, apex of aedeagus only slightly roundly dilated (Figs 111–119) (Figs 30, 122) ..... ***Saprinus* (*S.*) *chalcites* (Illiger, 1807)**

Checklist of the Histeridae of Lebanon and surrounding countries

This checklist is based on Lackner et al. (2015) as the main reference; other relevant sources of information included Mazur (2011) and Shayya et al. (2018) (Table 2).

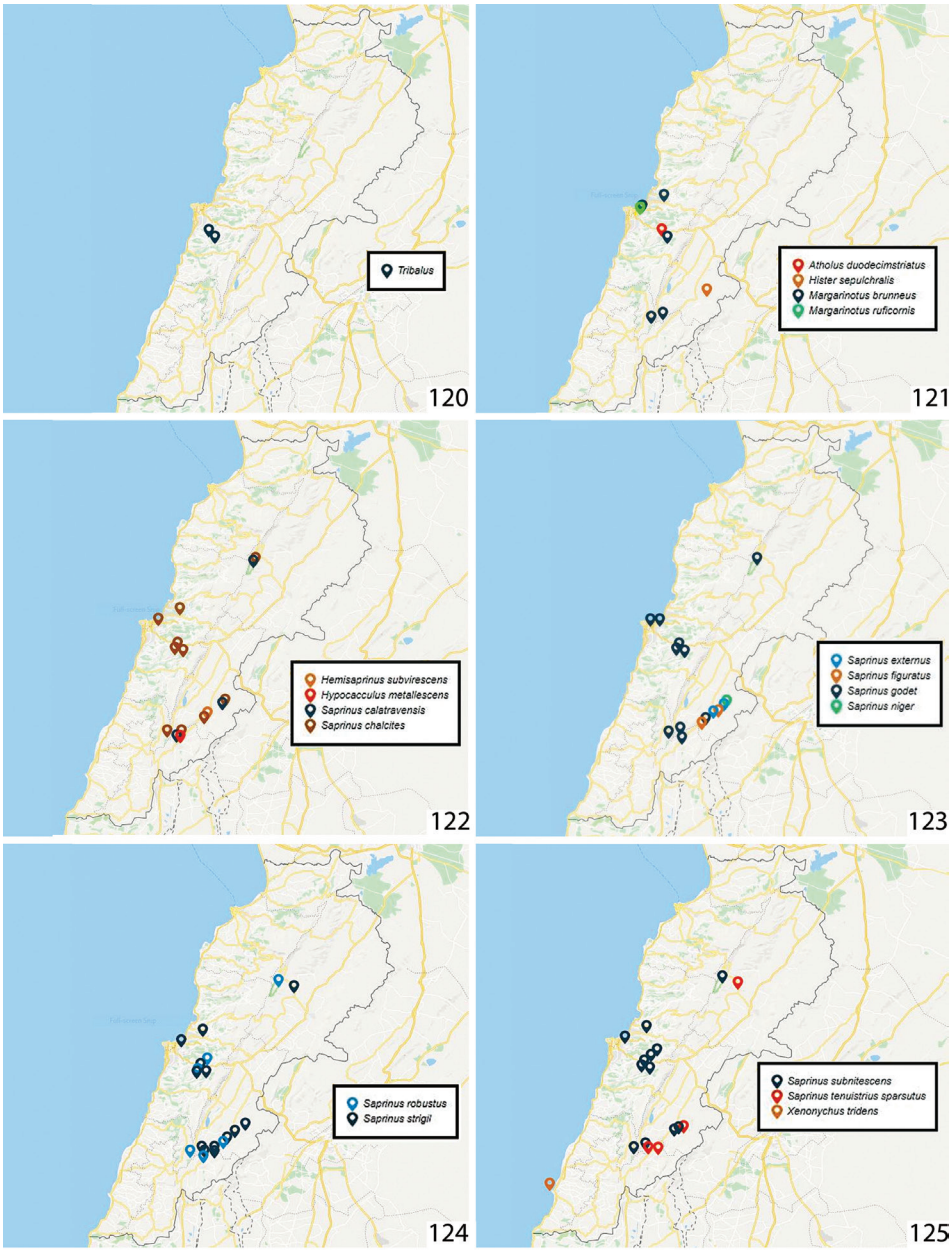
Table 2. Checklist of the Histeridae of Lebanon and surrounding countries.

Species	Lebanon	Syria	Israel	Cyprus
Abraeomorphus besucheti Mazur, 1977	X		X	
Abraeomorphus minutissimus (Reitter, 1884)	X			
Acritus (*Acritus*) *nigricornis* (Hoffmann, 1803)			X	
Acritus (*Acritus*) *minutus* (Herbst, 1791)				X
Acritus (*Pycnacritus*) *homoeopathicus* Wollaston, 1857				X
Alienocacculus vanharteni Kanaar, 2008			X	
Anapleus raddei (Reitter, 1877)			X	
Anapleus wewalkai Olexa, 1982		X		X
Atholus bimaculatus (Linnaeus, 1758)		X	X	X
Atholus corvinus (Germar, 1817)		X	X	
Atholus duodecimstriatus duodecimstriatus (Schrank, 1781)	X	X	X	
Atholus scutellaris (Erichson, 1834)		X	X	X
Carcinops pumilio (Erichson, 1834)				X
Chaetabraeus (*Chaetabraeus*) *lucidus* (Peyerimhoff, 1917)		X		
Chaetabraeus (*Mazureus*) *convexus* (Reitter, 1884)		X	X	
Chalcionellus aemulus (Illiger, 1807)	X		X	
Chalcionellus amoenus (Erichson, 1834)		X		
Chalcionellus blanchii blanchii (Marseul, 1855)	X	X	X	X
Chalcionellus decemstriatus decemstriatus (P. Rossi, 1792)		X	X	X
Chalcionellus libanicola (Marseul, 1870)	X	X		
Chalcionellus mersinae (Marseul, 1857)		X		
Chalcionellus palaestinensis (Schmidt, 1890)		X	X	
Chalcionellus tunisius (Marseul, 1875)		X		
Chalcionellus turcicus (Marseul, 1857)		X		
Chalcionellus tyrius (Marseul, 1857)		X		X

Species	Lebanon	Syria	Israel	Cyprus
Epierus comptus (Erichson, 1834)		X		
Eudiplister castaneus (Ménétriés, 1832)	X	X	X	X
Eudiplister peyroni (Marseul, 1857)		X	X	
Eudiplister planulus (Ménétriés, 1849)		X	X	
Gnathoncus disjunctus suturifer Reitter, 1896	X	X		
Gnathoncus rotundatus (Kugelann, 1792)		X	X	
Hemisaprinus cyprius Dahlgren, 1981				X
Hemisaprinus subvirescens (Ménétriés, 1832)	X*	X	X	X
Hister bipunctatus Paykull, 1811				X
Hister hanka Kapler, 1994				X
Hister illigeri reductus G. Müller, 1960		X	X	
Hister judaicus Mazur, 2008			X	
Hister limbatus Truqui, 1852	X	X		
Hister lugubris Truqui, 1852				X
Hister quadrimaculatus Linnaeus, 1758				X
Hister sepulchralis Erichson, 1834	X*	X		
Hypocacculus (*Colpellus*) *biskrensis* (Marseul, 1876)		X		
Hypocacculus (*Colpellus*) *praecox* (Erichson, 1834)	X	X	X	X
Hypocacculus (*Hypocacculus*) *atrocyaneus* (J. Schmidt, 1888)		X		
Hypocacculus (*Hypocacculus*) *metallescens* (Erichson, 1834)	X	X	X	X
Hypocaccus (*Hypocaccus*) *brasiliensis* (Paykull, 1811)			X	X
Hypocaccus (*Hypocaccus*) *crassipes* (Erichson, 1834)		X		
Hypocaccus (*Nessus*) *baudii* (J. Schmidt, 1890)	X	X	X	X
Hypocaccus (*Nessus*) *interpunctatus interpunctatus* (J. Schmidt, 1885)		X		
Hypocaccus (*Nessus*) *japhonis* (J. Schmidt, 1890)		X	X	
Hypocaccus (*Nessus*) *rubripes* (Erichson, 1834)		X		X
Hypocaccus (*Nessus*) *curtus* (Rosenhauer, 1847)				X
Margarinotus (*Eucalohister*) *kurdistanus kurdistanus* (Marseul, 1857)		X	X	
Margarinotus (*Grammostethus*) *ruficornis* (Grimm, 1852)	X	X	X	
Margarinotus (*Paralister*) *carbonarius carbonarius* (Hoffmann, 1803)		X	X	X
Margarinotus (*Paralister*) *carbonarius macedonicus* (J. Müller, 1937)			X	
Margarinotus (*Paralister*) *purpurascens* (Herbst, 1791)		X		
Margarinotus (*Ptomister*) *brunneus* (Fabricius, 1775)	X		X	
Margarinotus (*Ptomister*) *integer* (Brisout de Barneville, 1866)			X	
Margarinotus (*Stenister*) *graecus graecus* (Brullé, 1832)	X	X	X	X
Margarinotus (*Stenister*) *graecus horni* (Bickhardt, 1912)		X	X	
Margarinotus (*Stenister*) *obscurus* (Kugelann, 1792)		X	X	
Merohister ariasi (Marseul, 1864)		X	X	
Notodoma lewisi Reitter, 1910	X	X		
Onthophilus affinis L. Redtenbacher, 1847		X	X	
Onthophilus bickhardti Reitter, 1909	X		X	
Onthophilus convictor Normand, 1919		X		
Onthophilus punctatus caucasicus Reitter, 1890			X	
Onthophilus punctatus punctatus (O.F. Müller, 1776)		X		
Onthophilus striatus inconditus Reichardt, 1941	X	X	X	X
Pachylister (*Pachylister*) *inaequalis* (Olivier, 1789)		X		X
Pactolinus major (Linnaeus, 1767)		X	X	X
Paravolvulus syphax (Reitter, 1904)		X		
Pholioxenus kodymi Olexa, 1984		X		
Pholioxenus krali Olexa, 1984		X		

Species	Lebanon	Syria	Israel	Cyprus
Platylister (*Popinus*) *simeani* (Mulsant & Godart, 1875)	X			
Platylomalus complanatus (Panzer, 1797)		X		X
Platysoma (*Cylister*) *cornix* Marseul, 1861	X	X	X	X
Platysoma (*Platysoma*) *compressum* (Herbst, 1783)		X		
Platysoma (*Platysoma*) *inexpectatum* Lackner, 2004		X		
Plegaderus (*Plegaderus*) *otti* Marseul, 1856			X	
Plegaderus (*Hemitrichoderus*) *adonis* Marseul, 1876		X		X
Saprinus (*Phaonius*) *pharao* Marseul, 1855		X	X	X
Saprinus (*Saprinus*) *acuminatus acuminatus* (Fabricius, 1798)		X		
Saprinus (*Saprinus*) *aegialius* Reitter, 1884	X	X		
Saprinus (*Saprinus*) *aeneus* (Fabricius, 1775)		X		
Saprinus (*Saprinus*) *caerulescens caerulescens* (Hoffmann, 1803)	X	X	X	X
Saprinus (*Saprinus*) *calatravensis* Fuente, 1899	X	X	X	
Saprinus (*Saprinus*) *chalcites* (Illiger, 1807)	X		X	X
Saprinus (*Saprinus*) *algericus* (Paykull, 1811)				X
Saprinus (*Saprinus*) *concinnus* (Gebler, 1830)		X		
Saprinus (*Saprinus*) *delta* Marseul, 1862		X		
Saprinus (*Saprinus*) *externus* (Fischer von Waldheim, 1823)	X*	X		
Saprinus (*Saprinus*) *figuratus* Marseul, 1855	X*	X	X	
Saprinus (*Saprinus*) *georgicus* Marseul, 1862		X	X	
Saprinus (*Saprinus*) *godet* (Brullé, 1832)	X	X	X	
Saprinus (*Saprinus*) *intractabilis* Reichardt, 1929		X		
Saprinus (*Saprinus*) *maculatus* (P. Rossi, 1792)	X	X	X	X
Saprinus (*Saprinus*) *magnoguttatus* Reichardt, 1926	X	X		
Saprinus (*Saprinus*) *moyses* Marseul, 1862		X		
Saprinus (*Saprinus*) *niger* Motschulsky, 1849	X*	X	X	
Saprinus (*Saprinus*) *ornatus* Erichson, 1834		X	X	
Saprinus (*Saprinus*) *planiusculus* Motschulsky, 1849		X		
Saprinus (*Saprinus*) *politus politus* (Brahm, 1790)		X	X	
Saprinus (*Saprinus*) *prasinus aeneomicans* G. Müller, 1960		X	X	
Saprinus (*Saprinus*) *prasinus prasinus* Erichson, 1834	X	X		X
Saprinus (*Saprinus*) *robustus* Krása, 1944	X	X	X	X
Saprinus (*Saprinus*) *ruber gemmingeri* Marseul, 1864		X	X	
Saprinus (*Saprinus*) *semistriatus* (Scriba, 1790)			X	
Saprinus (*Saprinus*) *sinaiticus* Crotch, 1872		X	X	
Saprinus (*Saprinus*) *strigil* Marseul, 1855	X	X	X	X
Saprinus (*Saprinus*) *stussineri* Reitter, 1909			X	
Saprinus (*Saprinus*) *submarginatus* J. Sahlberg, 1913	X	X	X	
Saprinus (*Saprinus*) *subnitescens* Bickhardt, 1909	X	X	X	X
Saprinus (*Saprinus*) *tenuistrius sparsutus* Solsky, 1876	X	X	X	X
Spathochus coyei Marseul, 1864		X	X	X
Stenopleurum rothi (Rosenhauer, 1856)	X	X		X
Sternocoelis diversepunctatus Pic, 1911				X
Sternocoelis robustus Pic, 1911				X
Teretrius (*Teretrius*) *accaciae* Reitter, 1900			X	
Teretrius (*Teretrius*) *fabricii* Mazur, 1972		X	X	
Teretrius (*Teretrius*) *pulex* Fairmaire, 1877		X		
Tribalus (*Tribalus*) sp.	X*	X	X	
Tribalus (*Tribalus*) *anatolicus* Olexa, 1980				X
Tribalus (*Tribalus*) *scaphidiformis* (Illiger, 1807)				X
Xenonychus tridens (Jacquelin du Val, 1853)	X*	X	X	X
Zorius exilis Reichardt, 1932			X	
Zorius funereus (Schmidt, 1890)			X	

* – newly reported from Lebanon



Figures 120–125. 120 Distribution of *Tribalus* spec. in Lebanon **121** Distribution of *Atholus duodecimstriatus duodecimstriatus*, *Hister sepulchralis*, *Margarinotus* (*Ptomister*) *brunneus* and *Margarinotus* (*Grammostethus*) *ruficornis* in Lebanon **122** Distribution of *Hemisaprinus subvirescens*, *Hypocacculus* (*Hypocacculus*) *metallescens*, *Saprinus* (*Saprinus*) *calatravensis* and *Saprinus* (*Saprinus*) *chalcites* in Lebanon **123** Distribution of *Saprinus* (*Saprinus*) *externus*, *Saprinus* (*Saprinus*) *figuratus*, *Saprinus* (*Saprinus*) *godet* and *Saprinus* (*Saprinus*) *niger* in Lebanon **124** Distribution of *Saprinus* (*Saprinus*) *robustus* and *Saprinus* (*Saprinus*) *strigil* in Lebanon **125** Distribution of *Saprinus* (*Saprinus*) *subnitescens*, *Saprinus* (*Saprinus*) *tenuistrius sparsutus* and *Xenonychus tridens* in Lebanon.

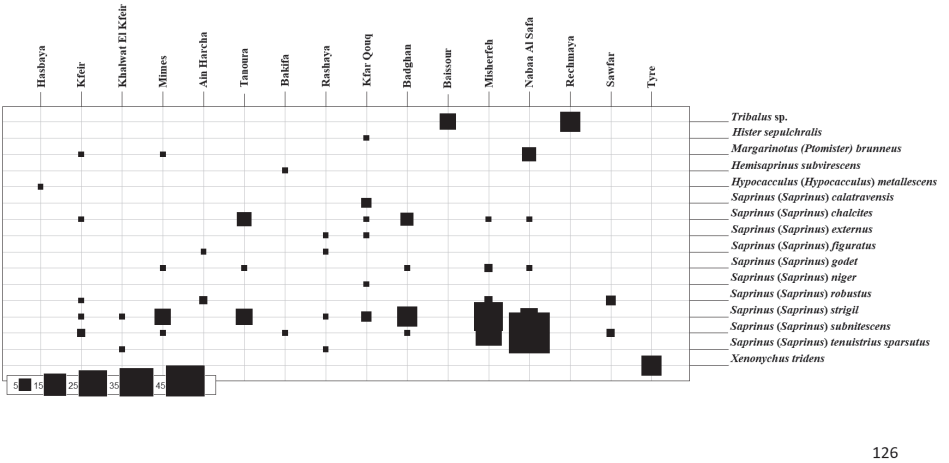


Figure 126. Abundance of Histeridae species collected during this study from different Lebanese localities.

Discussion

In general, faunistic inventories are incomplete since the number of studied species continues to increase with the increase of sampling efforts (Baz et al. 2014). Thus, this paper enriches the knowledge of the fauna of Histeridae in Lebanon as 41 species are currently known from Lebanon. In addition to the knowledge of *Saprinus* of forensic relevance (Shayya et al. 2018), our study lists species and their biology for 17 other genera: *Abraeomorphus*, *Atholus*, *Chalcionellus*, *Eudiplister*, *Gnathoncus*, *Hemisaprinus*, *Hister*, *Hypocaccus*, *Hypocacculus*, *Margarinotus*, *Notodoma*, *Onthophilus*, *Platylister*, *Platysoma*, *Stenopleurum*, *Tribalus*, and *Xenonychus*. It furthermore reports different sampling efforts and mentions six new records for the fauna of the country. The key provided in this study provides a foundation for the identification of histerids from Lebanon for other entomological and ecological studies in the country. The following are comments on species biology and some implications.

Species attracted to ephemeral microhabitats that could be of forensic relevance

Saprinus and *Margarinotus* are dominant genera on ephemeral and unstable microhabitats like carcasses, dung, and decaying plants (Mazur 1981; Bajerlein et al. 2011). Many species belonging to these two genera are considered eurytopic, able to tolerate a wide range of microhabitats (Bajerlein 2011). Species among these genera were found to oviposit their eggs near the carcass, where there is no larval mass and the soil temperature is cooler (Bajerlein et al. 2011; Caneparo et al. 2017). *Saprinus* (*S.*) *subnitescens* was the most abundant species on pig carrion (Shayya et al. 2018). In our samplings, this species was also abundant on rotting fish-baited pitfall traps especially in Shouf-Aley region and it was also present on dung in Kfeir. Also, *Saprinus* (*S.*) *strigil*

was common on decomposing pig carcasses (Shayya et al. 2018). It was also associated with other ephemeral microhabitats used in this study. *Saprinus* (*S.*) *chalcites*, *Saprinus* (*S.*) *godet*, *Saprinus* (*S.*) *robustus*, *Saprinus* (*S.*) *tenuistrius sparsutus* were also attracted to dung, decomposing fish and to carrion (Shayya et al. 2018).

Saprinus (*S.*) *caerulescens* was only attracted to mammalian carrion and it was absent from other baits (rotting fish and dung). This is in accordance with T. Lackner's personal observation that this species is common on large carcasses. However, Kryzhanovskij and Reichardt (1976) collected this species on rotten fish, where it preyed upon dermestids, whereas Anlaş et al. (2007) collected it from cow dung in Turkey. The preference of this species to a specific microhabitat should be further investigated in future studies.

Margarinotus spp. are varied in habits (Caterino 2010). In our samplings (Mediterranean climate), they were present on carrion only in spring; absent in summer. They were less frequent in rotting fish-baited pitfall traps. Despite the differences in climate, this is in accordance with Bajerlein et al. (2011), who found that their abundance was highest in spring, and decreased markedly in summer in a study in West Poland, a temperate climate. Also, Kočárek's (2003) work supported the highest abundance of histerids in spring during a study in the warm and temperate climate of Opava, Czech Republic. *Margarinotus* likewise shows preference to cold and humid forest floor (Bajerlein et al. 2011). The latter condition is common especially in early spring in Lebanon (Abi Saab et al. 2019).

Atholus duodecimstriatus duodecimstriatus was collected from carrion only during summer. Unlike the findings of Bajerlein (2009) and the review of Kovarik and Caterino (2016), which mentioned the preference of this species to dung, it was absent from other ephemeral microhabitats of this study. Similarly, *Hypocacculus* (*H.*) *metallescens* was rare and collected during summer from carrion and absent from other decomposing matter, dung, and sand dunes, which it is normally associated with (Penati 2009). Thus, more sampling efforts should be made to elucidate the habitat preference of these two species. *Hister* is mainly found in cattle and horse dung (Rozner 2010). This is in accordance with our study as *Hister sepulchralis* was absent from carrion and only attracted to pig dung. However, the arrival of *Hister* spp. on carrion during the active decay stage and their presence in the advanced decay and dry stages, as reported by Wolff et al. (2001), was not observed during our sampling from decomposing carrion in Lebanon. *Chalcionellus* spp. were previously recorded from Lebanon, but absent from our collecting. They are usually attracted to excrements and decomposing carcasses (Kryzhanovskij and Reichardt 1976).

According to Nuorteva (1970), histerids, especially those among the genera *Saprinus* and *Hister* are attracted to fish carcasses later than blowflies, predate on fly egg and larvae and even destroy the full-grown fly larvae. Thus, there is a negative correlation between the occurrence of blowflies and histerids on fish carcasses (Nuorteva 1970). In our collections, *Saprinus* (*S.*) *figuratus* was found only on fish carcasses and not on pig ones. In a similar Mediterranean climate, in Spain, this species was found to be rare and restricted to mesomediterranean holm oak forests (Martín-Vega et al. 2015). Un-

like the findings of Reichardt (1941), *Saprinus* (*S.*) *niger* was also collected only from fish carcasses and not from other carrion. In Spain, it was found also on squid carcasses, which are effective for collecting carrion insects and species inventories resemble those from pig studies (Martín-Vega et al. 2015). Al-Tunsoy et al. (2017) suggested that *Saprinus* (*S.*) *externus* is uncommon in Turkey and that carrion is not its primary habitat. Also, Rozner (2010) mentioned that it is very rare. In our samplings we found two specimens on dung and fish but none on pig carrion.

Species collected from humid habitats

The subgenus *Tribalus* s. str. of the genus *Tribalus* is a species-rich group mostly occurring in Africa with smaller number of species found in the Palaearctic and Oriental regions (Mazur 2011; Lackner and Vienna 2017). Similar to the findings Lackner and Vienna (2017), we found this genus under stones in wetter areas on the riverside of Baissour and Rechmaya rivers and also in the soil detritus at Rechmaya riverside. Also, Lackner and Chehlarov (2006) found it in pitfall traps on the right shore of Struma River in Bulgaria. Kovarik and Caterino (2016) mentioned that this genus is attracted to organic material beneath old dead trees and to rotting wood. They likewise mentioned that *Tribalus* (*T.*) *capensis* (Paykull, 1811) shows preference to dung that has lost much of its moisture and that *Tribalus* (*T.*) *cavernicola* Lewis, 1908 occurs in cave entrances. Those two species of *Tribalus* are not found in the Palaearctic region (Lackner et al. 2015). The subgenus contains many undescribed, externally rather uniform species that can be most-reliably separated based on their male genitalia (Lackner and Vienna 2017). It is therefore and due to the lack of reliable taxonomic keys we didn't assign the exact taxonomic identification and we advocate its revision.

Ultra-psammophilic species

The genus *Xenonychus* is an ultra-psammophilic group, which is found exclusively in sand dune systems. They are buried in sand and known as sand-swimmers. They can be found by laborious methods near the roots of plants (Lackner et al. 2019). According to the personal observation of T.L., members of *Xenonychus* could be found on carrion that is on sand or buried in it. Also, *Hypocacculus* (*C.*) *praecox* is a psammohalobiotic species (Penati 2009). We found *Xenonychus tridens* on a sandy beach in Tyre (Lebanon). It is important to study the entomofauna associated with carcasses on the seashore or those buried in sand, which could help in estimating the minimum postmortem interval (PMI_{min}). For instance, in 2018 a murdered woman was found covered with sand in Sidon Rmeileh beach-Lebanon (Zaatari 2018).

Species attracted to decaying plants, trees bark, and fungi

Abraeomorphus minutissimus, *Eudiplister castaneus*, *Margarinotus* (*Grammostethus*) *ruficornis*, *Platysoma* (*Cylister*) *cornix*, and *Platylister* (*Popinus*) *simeani* are often associated

with decaying plant matter and/or bark of trees like pine (Kryzhanovskij and Reichardt 1976; Kovarik and Caterino 2016). *Notodoma lewisi* is a fungivorous species. Fungi can provide insects with nutrients and essential elements, and in recently dead wood they detoxify plant defenses and provide protection (Birkemoe et al. 2018). Such beetles might serve as a dispersal vector for dead-wood-inhabiting fungi. More knowledge on such interaction is detailed in Seibold et al. (2019).

Conclusions

This is considered the first faunistic study of the Histeridae family in Lebanon with a key to all locally recorded species, comments on their biology, and possible implications in the country of study. More ecological research should be performed in different Lebanese regions and more quantitative data are needed to clarify the habitat preference of Histeridae species. Different sampling methods such as sifting, Flight Interception Traps (FIT), pitfall traps, etc. should be also used in the future. Seasonal sampling and replicates are needed to show the peak activity, seasonality, and habitat preferences of members of this family.

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RESEARCH ARTICLE

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Moss-inhabiting flea beetles in the Philippines (Coleoptera, Chrysomelidae, Alticinae)

Albert F. Damaška[1], Dale Joy Mohagan[2], Martin Fikáček[1,3]

1 *Department of Zoology, Faculty of Science, Charles University, Prague, Czech Republic* **2** *Biology Department, Central Mindanao University, University Town, Maramag, 8710 Bukidnon, Philippines* **3** *Department of Entomology, National Museum, Prague, Czech Republic*

Corresponding author: Albert F. Damaška (albert.damaska@natur.cuni.cz)

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Abstract

The Philippine islands are one of the key biodiversity hotspots in the Indo-Pacific area. Knowledge of moss-inhabiting flea beetles (Coleoptera: Chrysomelidae: Alticinae), a diverse and ecologically and morphologically enigmatic group in the Philippines is described. Six species from the Philippines are recorded, belonging to three genera: *Benedictus luzonicus* Sprecher-Uebersax et al., 2009 (recorded from the Philippines previously), *Ivalia antennata* **sp. nov.**, *I. caligulata* **sp. nov.** and *I. postfasciata* (Chen, 1934), **comb. nov.** (transferred from *Chabria* Jacoby, 1887), *Cangshanaltica mindanaoensis* **sp. nov.**, and *C. luzonica* **sp. nov.** Cox1 barcode sequences of *Ivalia antennata* and *Cangshanaltica mindanaoensis* are presented. Biogeography and diversity of moss-inhabiting flea beetles in the Philippines are discussed.

Keywords

Chrysomelidae, Coleoptera, moss-inhabiting flea beetles, new combination, new species, Philippines, taxonomy

Introduction

The Philippine archipelago is one of the world's biodiversity hotspots (Myers et al. 2000). It is characterised by a large number of species and a high level of endemism. The high level of endemism is a consequence of a unique and complex geological history of the archipelago and its current high habitat diversity, although many habitats

are under heavy human exploitation. High endemism is underpinned by the presence of high-mountain sky islands, increasing isolation of populations within and between real islands. These unique, highly isolated, high-altitude areas host many specialised organisms. One of them are moss-inhabiting flea beetles, a specific ecological group of flea beetles (Chrysomelidae: Alticinae) containing many non-related genera worldwide (Konstantinov and Konstantinova 2011, Konstantinov et al. 2013, Ruan et al. 2017). In the Oriental region, the majority of moss-inhabiting flea beetle species diversity is represented by three genera, *Ivalia* Jacoby, 1887, *Benedictus* Scherer, 1969, and *Cangshanaltica* Konstantinov et al., 2013. A single species, *Benedictus luzonicus* Sprecher-Uebersax et al., 2009, is known from the Philippines, contrasting to the high species diversity of other Philippine insect genera. In this study, we show that moss-inhabiting flea beetle fauna is much more diverse in the Philippines. Our review of available material, including the specimens collected during our recent fieldwork, reveals the occurrence of six species, of which five are new to science. In addition to the morphological study of the material, we are also providing cox1 barcodes for the species available in DNA grade, including the first genetic data for *Cangshanaltica*.

Material and methods.

We examined specimens from the museum collections listed below, as well as those collected during the biodiversity survey performed by us in southern Mindanao in 2017. Samples were collected by sifting moss and the surrounding leaf litter in montane cloud forests; specimens were extracted from the samples by AFD and Matyáš Hiřman. Most specimens were dissected for genitalia examination and mounted on mounting cards. Genitalia were mounted on a separate mounting card, embedded in the water-soluble dimethyl hydantoin formaldehyde (DMHF) resin. Photographs were taken by Canon EOS 550D or 70D camera equipped with the Canon MP-E 65 mm f/2.8 1–5× lens, and using an Olympus BX40 microscope. The morphological terminology follows Lawrence et al. (2010); terminology of head structures follows on Ruan et al. (2019).

The complete DNA was extracted by Qiagen DNEasy Blood and Tissue kit or GenAid Genomic DNA Mini kit. Due to the very small size of the specimens, incubation in proteinase K and tissue lysis were conducted in a thermo-shaker, and 50 µl of elution buffer was used in the final step. For better DNA yield and for cleaning the genitalia by proteinase K before dissection, the body wall of the specimens was perforated before the DNA extraction by breaking abdominal tergites. DNA extracts are stored deep-frozen at the Faculty of Science, Charles University, Prague. For PCR reactions, we used a modified protocol with a commercially prepared premix (PPP Mix with $MgCl_2$ added, Top-Bio Czech Republic). We used standard *cox1* barcode primers: forward LCO1490 (5‘-GGTCAACAAATCATAAAGATATTGG-3‘) and reverse HCO2198 (5‘-TAAACTTCAGGGTGACCAAAAAATCA-3‘) (Folmer et al. 1994). PCR was performed in a 13 µl total volume of the mixture, containing 6.25 µl of PPP Mix, 4.75 µl of PCR ddH_2O, 1.0 µl of each primer and 1.0 µl of the DNA extract. The following

PCR program was used: 94 °C for 180 seconds + 35× (94 °C for 30 seconds, 48 °C for 45 seconds, 72 °C for 60 seconds) + 72 °C for 480 seconds. PCR products were purified by adding 0.5 µl Exonuclease 1 [Exo1 (20 U/µL)] (ThermoFisherScientific) and 1.0 µL Thermosensitive Alkaline Phosphatase [FastAP (1 U/µL)] (ThermoFisherScientific); the mixture was incubated in a thermocycler for 37 °C for 15 minutes and 80 °C for 15 minutes. Samples were sequenced by using Sanger sequencing. Raw sequence data were edited by using Geneious 9.1.7 software (Biomatters). Sequences were submitted to GenBank under accession numbers MT654528 and MT654527.

Examined specimens are deposited in the following collections:

ADPC Albert F. Damaška personal collection, Prague, Czech Republic;
IZCAS Institute of Zoology, Chinese Academy of Sciences, Beijing, China (Ming Bai, RuiE Nie);
MHNG Muséum d'Histoire Naturelle, Geneva, Switzerland (Giulio Cuccodoro);
NMPC Department of Entomology, National Museum, Prague, Czech Republic (Lukáš Sekerka).

Results

Cangshanaltica Konstantinov, Chamorro, Prathapan, Ge & Yang, 2013

Type species. *Cangshanaltica nigra* Konstantinov, Chamorro, Prathapan, Ge & Yang, 2013

Type locality. Yunnan, Dali, Cangshan Mt.

Remarks. The genus *Cangshanaltica* is known to be distributed mainly in China and neighbouring areas (Damaška and Aston 2019). Three species have been described so far; descriptions of additional ones are in preparation to date. Here, we describe two new species from Luzon and Mindanao. We place them in this genus based on following characters: (1) round, ovate, and convex body shape; (2) anterior coxal cavities open posteriorly; (3) metatibiae curved in lateral view; (4) metaventrite bearing an anterior, horseshoe-like process reaching mesocoxae and covering the mesoventrite; (5) anterolateral pronotal setiferous pore placed in the middle of the pronotal margin; and (6) antennomere VII bearing a slight distal protrusion.

Cangshanaltica luzonica sp. nov.

http://zoobank.org/0FECE94C-83E4-425A-9F87-DB0538104C92
Figures 1A, 3A, B

Type locality. Philippines: Luzon, Sagada env.

Type material. Holotype ♂ (MHNG): "Philippines: Luzon. env. Sagada. 15.-19. xii.79, Deharveng-Orousset.". **Paratypes** (2♀ 1 MHNG, 1 NMPC): same labels as holotype.

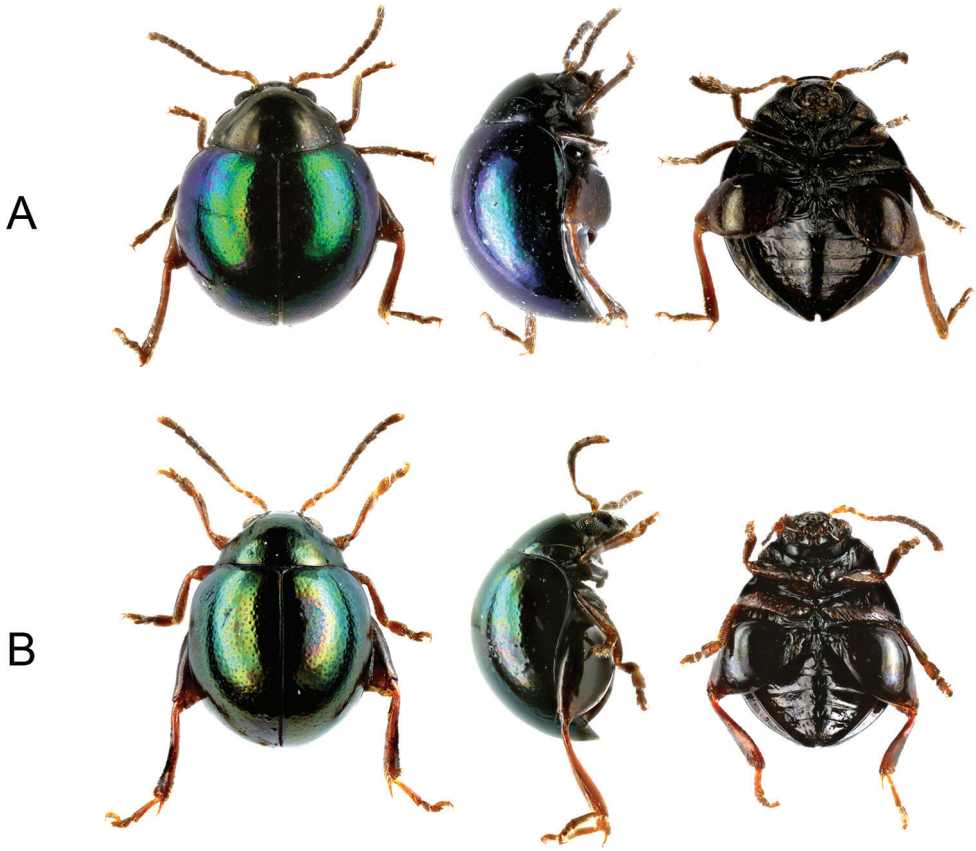

Figure 1. Species of *Cangshanaltica* distributed in the Philippines, dorsal, right lateral, and ventral views **A** *C. luzonica* sp. nov. **B** *C. mindanaoensis* sp. nov.

Differential diagnosis. The species differs from all known species of *Cangshanaltica* except *C. mindanaoensis* by the presence of metallic elytra. It differs from *C. mindanaoensis* in (1) aedeagus slender, elongate (broad and flattened in *C. mindanaoensis*); (2) elytra nearly impunctate (irregularly punctured in *C. mindanaoensis*); (3) head and pronotum with greenish-bronze lustre, elytra with violet-blue lustre (elytra and pronotum of the same greenish lustre in *C. mindanaoensis*,); (4) male pro- and mesotarsomeres I slender (strongly widened and flattened in *C. mindanaoensis*); (5) tibial spur shorter to as long as metatarsomere II (longer than metatarsomere II in *C. mindanaoensis*).

Description. ***Habitus.*** Body round, 2.4–2.6 mm long, 2 mm wide, 1.7 mm high. Head and pronotum black with feeble greenish-bronze metallic lustre, elytra black with violet-blue metallic lustre. Ventral surfaces black, appendages brown to black.

Head nearly hypognathous, triangular in frontal view. Frontal calli nearly indistinct, not surrounded dorsally. Supraorbital, orbital and suprafrontal sulci very deep, supraantennal sulcus forming a deep excavation. Frontal ridge wide, frons with large

punctures bearing white setae. Clypeus impunctate, bearing a row of small white setae. Antennae with 11 antennomeres. Antennomere I as long as antennomeres II–III combined, bulbous; antennomere II small, rounded, antennomere III slightly elongated; antennomeres IV–XI gradually widening and slightly elongating, pilose.

Thorax. Pronotum very convex, twice as broad as long. Anterolateral pronotal margin forming a lobe, anterolateral pronotal setiferous pore in the middle of pronotal margin. Posterior pronotal edges dull. Scutellar shield very small, triangular. Elytra strongly convex, nearly impunctate. Metathoracic wings and humeral calli absent. Pro- and mesotibiae densely pilose on ventral side. Mesotibiae and metatibiae slightly curved laterally. Metatarsus attached to metatibia slightly before its end. Metatibial apical spine shorter or as long as metatarsomere II., metatarsomere I 2× longer than metatarsomere II. Metaventral process horseshoe-like, excavated, with dull apex.

Abdomen. Ventrite I bearing an anterior process reaching metacoxae; with a distinct elevated ridge.

Genitalia. Aedeagus strongly sclerotised, slender, elongate, narrowing towards apex in ventral view; slightly curved in lateral view. Apex of aedeagus dull, rounded. Spermatheca small, with long pump and small, rounded receptacle; spermathecal duct placed laterally, forming two loops.

Etymology. The species name refers to the island of Luzon where the type series was collected.

Biology. Unknown.

***Cangshanaltica mindanaoensis* sp. nov.**
http://zoobank.org/E5686EEC-4A44-46AC-ACE5-F0102AA50745
Figures 1B, 3C, D

Type locality. Philippines: Mindanao, Davao Oriental prov., Mt. Hamiguitan.

Type material. ***Holotype*** ♂ (NMPC): Philippines – Mindanao, Davao Oriental prov., Mt. Hamiguitan; 6°42'52.7"N, 126°11'38.0"E; sifting montane mossy forest; 20.ii.2017; A. F. Damaška lgt. **Paratypes**: (4♂ 1 NMPC, 2 ADPC, 1 USNM), same labels as holotype.

Additional material examined. 1♀ (ADPC): (1) Philippines – Mindanao, Davao City prov., Mt. Malambo, Busay Resort, 1200 m, 7°28'52.83"N, 125°15'43.3" E; sifting montane forest; 23–28.ii.2017, A. Damaška lgt. (2) voucher specimen A. F. Damaška coll., AFD-006.

Differential diagnosis. The species differs from all known species of *Cangshanaltica* except *C. luzonica* by its metallic elytra. For the diagnosis from *C. luzonica*, see the latter species.

Description. ***Habitus.*** Body round, strongly convex; 2.2–2.3 mm long, 1.8 mm wide, 1.4 mm high. Dorsal surface generally black with greenish metallic lustre; ventral surfaces black. Legs chestnut brown, metafemora nearly black.

Head nearly hypognathous, widely triangular. Frontal calli wide, slightly surrounded dorsally by shallow sulci. Supraorbital, orbital and suprafrontal sulci distinct, not extremely deep. Frontal ridge wide, feebly elevated; frons bearing two bunches of small punctures on sides; with scattered long setae. Clypeus impunctate, bearing a row of long setae. Antennae with 11 antennomeres. Antennomere I as long as antennomeres II–III combined, bulbous; antennomere II and III equally long; antennomere IV. small, rounded, antennomeres V–XI gradually widening and elongating, pilose.

Thorax. Pronotum strongly convex, twice as broad as long, bearing small sparsely scattered punctures. Scutellar shield small, triangular. Anterolateral pronotal setiferous pore placed in the middle of pronotal margin. Posterior pronotal edges dull. Elytra strongly convex, irregularly punctate. Metatibiae curved laterally. Pro- and mesotarsomeres I in males widened, flat. Metatarsus attached to metatibia slightly before its end. Metatarsomere I strongly elongate, nearly as long as a third of metatibia. Metatibial spur very long, longer than metatarsomere II. Metaventral process horseshoe-like, excavated, with dull apex.

Abdomen. Ventrite I bearing an anterior process reaching metacoxae; with a distinct elevated ridge. Ventrites III–V distinctly punctate.

Genitalia. Aedeagus slightly curved in lateral view; broad in ventral view, with broadly arrow-like apex.

Etymology. The species name refers to the island of Mindanao, where the type series was collected.

Biology. The species was collected in montane cloud forests (Fig. 4) where it inhabits moss cushions.

Remarks. Type specimens were collected on Mt. Hamiguitan, Davao Oriental, Mindanao. The additional female examined was collected in Mt. Malambo, Davao City, Mindanao, ca. 150 km far from Hamiguitan. This female differs slightly from the type series e.g. in the metallic sheen being different between pronotum and elytra – pronotum has less visible, brownish metallic sheen. Unfortunately, we failed to sequence the type specimens and we cannot compare the morphology of genitalia, because all Mt. Hamiguitan specimens are males. Due to these problems and because of strong isolation of montane flea beetle populations, we decided to exclude the specimen from Mt. Malambo from the type series. The spermatheca of this specimen looks as follows: pump slender, receptacle bulbous, spermathecal duct attached posteriorly, orientated anteriorly, without coils. We also can provide the barcode sequence of the female specimen (GenBank accession number MT654527).

Ivalia Jacoby, 1887

Type species. *Ivalia viridipennis* Jacoby 1887

Type locality. Sri Lanka

For synonymy, see Duckett et al. (2006).

Remarks. The genus includes 79 known species widespread across the Oriental and Australo-Papuan regions. Large proportions of its species diversity are known from Papua New Guinea and from the Himalayan range (Nadein 2013). A bunch of species was recently described from Borneo (Takizawa and Konstantinov 2018) and two species are described from Taiwan. No species has been recorded from the Philippines. *Ivalia* is diagnosed by having convex, oblong-ovate body shape, anterior coxal cavities open posteriorly, strongly curved metatibiae, usually lacking metathoracic wings and humeral calli, anterolateral pronotal setiferous pore placed in anterior half of the pronotal margin, and metaventrite bearing an anterior, dull horseshoe-like process reaching mesocoxae and partially covering the mesoventrite, a character similar to that in *Cangshanaltica*. However, morphological diversity is relatively wide in species described as *Ivalia*, and many known species lack some of the aforementioned diagnostic characters (e.g., strongly ovate body shape or curved metatibiae). The generic placement of the new species described here is discussed below; the generic assignment needs to be re-confirmed by future phylogenetic studies in the case of *I. caligulata* sp. nov.

***Ivalia antennata* sp. nov.**
http://zoobank.org/DA9DE777-74C7-4CC7-885D-43AE6B947B3E
Figures 2A, 3E

Type locality. Philippines: Mindanao – Davao City prov., Mt. Malambo.

Type material. Holotype ♂ (NMPC): (1) Philippines – Mindanao, Davao City prov., Mt. Malambo, Busay Resort, 1200 m, 7°28'52.83"N, 125°15'43.3"E; sifting montane forest; 23–28.ii.2017, A. Damaška lgt.; (2) VOUCHER SPECIMEN A. F. Damaška coll., AFD-014.

Generic assignment. The species is assigned to *Ivalia* on the basis of following characters: (1) metathoracic wings and humeral calli absent; (2) body convex and ovate in shape; (3) metatibiae strongly curved laterally; (4) antennomere VII lacking any process; (5) metaventrite reaching mesocoxae and partially covering the mesoventrite with an anterior process.

Differential diagnosis. The species differs from all known brown-coloured *Ivalia* species by having an unique, club-like shape of antennae.

Description. ***Habitus.*** Body round, convex, 1.9 mm long, 1.4 mm wide, 1 mm high. Colour of ventral and dorsal surfaces chestnut brown, pronotum, head, and antennae somewhat darker than elytra.

Head nearly hypognathous. Frontal calli developed, but indistinctly delimited; surrounded by wide sulcus dorsally. Supraorbital, orbital and suprafrontal sulci developed, indistinct, wide. Frontal ridge wide, feebly elevated; frons short, nearly impunctate. Clypeus straight, developing sharp lateral edges. Antennae short, with 11 antennomeres. Antennomere I bulbous, shorter than antennomeres II and III combined.

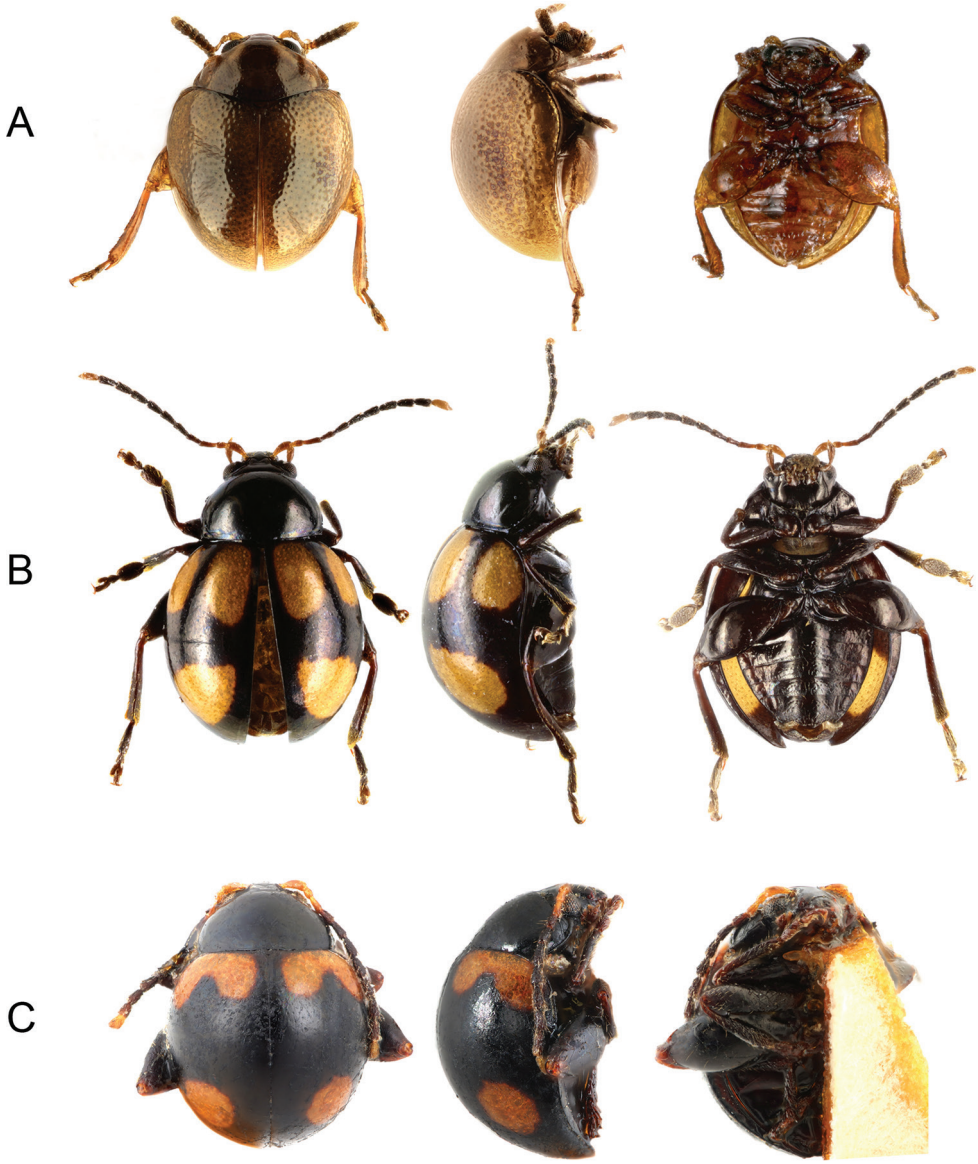

Figure 2. Species of *Ivalia* distributed in the Philippines, dorsal, right lateral, and ventral views **A** *I. antennata* sp. nov. **B** *I. caligulata* sp. nov. **C** *I. postfasciata* (Chen, 1934).

Antennomere II elliptical, antennomere III feebly elongated. Antennomere IV strongly shortened; antennomeres V–XI pilose, short and widened, forming an elongated antennal club. Antennomeres VI–X darkened.

Thorax. Pronotum strongly convex, twice as broad as long, feebly punctured by small, indistinct, scattered punctures. Anterolateral pronotal setiferous pore placed in the

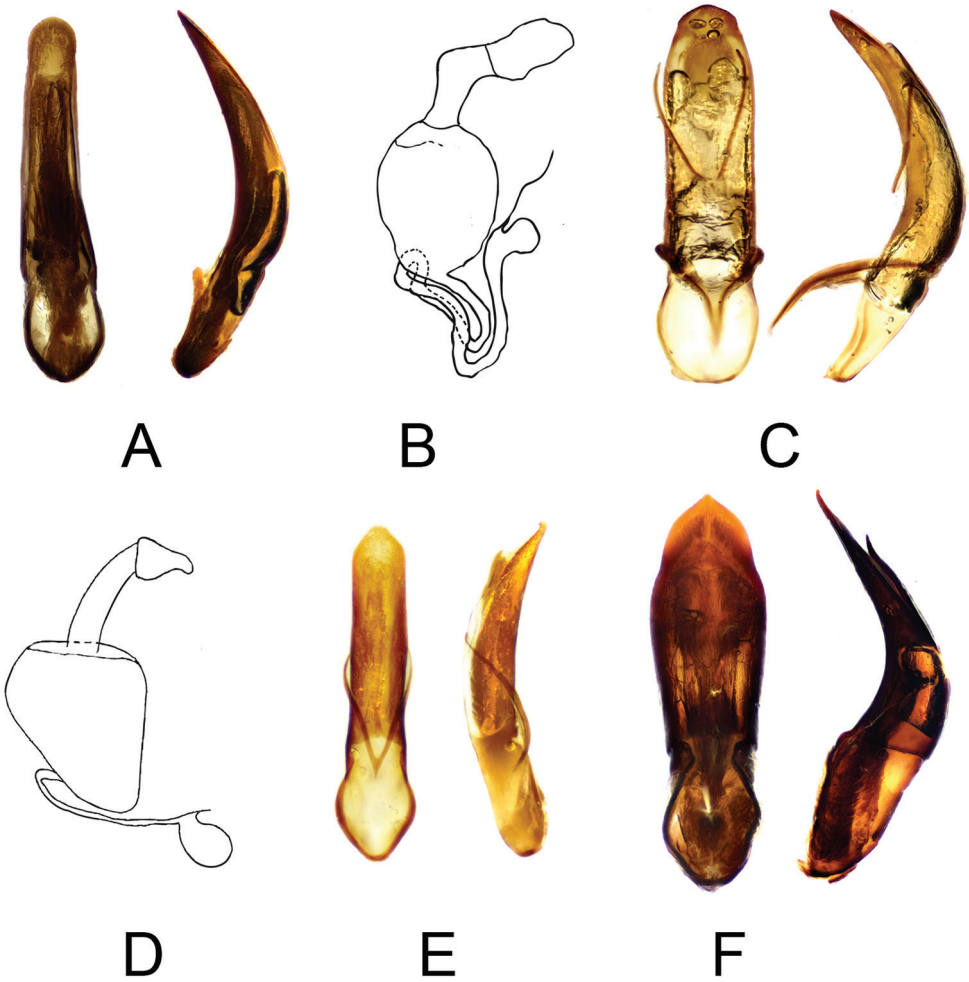

Figure 3. Genitalia *Cangshanaltica luzonica* (**A** aedeagus, **B** spermatheca); *C. mindanaoensis* (**C** aedeagus, **D** spermatheca); *Ivalia antennata* (**E** aedeagus); *I. caligulata* (**F** aedeagus).

anterior half of the pronotal margin; anterior pronotal margin forming a distinct lobe; posterior pronotal edges widely sharp. Scutellar shield small, triangular. Elytra convex, bearing strong and deep irregularly distributed punctures. Pro- and meso-femora and tibiae feebly pilose, metafemora nearly without setae. Metatibiae strongly curved laterally. Metatarsus attached to metatibia slightly before its end. Metatarsomere I feebly elongated.

Abdomen. Ventrites II–V with a distinct row of setiferous punctures.

Genitalia. Aedeagus moderately curved in lateral view; simple, slender in ventral view, with a feebly distinct step-like narrowing in its apical half. Apex of aedeagus long arrow-like, dull pointed. Female spermatheca unknown.

Etymology. The species name refers to the specific club-like shape of its antennae.

Figure 4. Type localities of *Cangshanaltica mindanaoensis* and *Ivalia antennata* **A** montane mossy cloud forest, Mt. Hamiguitan **B** montane forest, Mt. Malambo.

Biology. The only known specimen was collected in a montane forest of Mt. Malambo (Fig. 4B) by sifting moss cushions and surrounding leaf litter. The species is likely moss-inhabiting, but we did not perform the gut dissection.

DNA barcode sequence. GenBank accession number: MT654528.

***Ivalia caligulata* sp. nov.**
http://zoobank.org/07FBA761-2A2E-4794-BC28-7469851F82A0
Figures 2B, 3F

Type locality. Philippines: Luzon – Doline NE Sagada.

Type material. ***Holotype*** ♂ (MHNG): "Philippines: Luzon. Doline NE Sagada, 21. ii.79 Deharveng-Orousset." ***Paratypes*:** 1 ♂ (NMPC): "Philippines: Luzon. Mount Data, 8.I.80 Deharveng-Orousset."

Generic assignment and differential diagnosis. The species assigned to *Ivalia* based on the following characters: (1) lack of metathoracic wings and humeral calli; (2) metaventrite bearing a horseshoe-like process reaching mesocoxae; (3) convex body. The species lacks some characters typical for the majority of *Ivalia* species, especially the round body shape and the metatibiae curved laterally. However, there are species assigned to *Ivalia* which are externally similar to this species, e.g., *I. biasa* Takizawa & Konstantinov, 2018, *I. besar* Takizawa & Konstantinov, 2018, *I. fulvomaculata* Takizawa & Konstantinov, 2018 and *I. kinabalensis* Takizawa & Konstantinov, 2018. The new species can be separated from these four species by aedeagus strongly widening towards the apex and having a pointed apex (all mentioned species have aedeagus slender or less widened towards the apex, and the aedeagus apex is dull). The new species also differs from *I. kinabalensis*, *I. biasa*, and *I. besar* in nearly impunctate elytra (moderately to strongly punctate in the latter species). *Ivalia caligulata* also differs from all mentioned species by having a unique shape of pro- and meso-tarsi in males: widened, flat, and elongate, with a strongly pilose ventral side. The form of the metaventral process is somewhat similar to that in *Ivalia korakundah* Duckett et al., 2006; however, the general body shape and coloration is entirely different in both species.

Description. ***Habitus*.** Body oblong-ovate, 3.1 mm long, 2.2 mm wide, 1.4 mm high. Head and pronotum pitchy black, elytra black with three wide yellow spots on each elytron. Dorsal surfaces and legs black. Antennae black with antennomeres I–III and XI yellow.

Head nearly hypognathous, triangular. Vertex impunctate, frontal calli feebly delimited, not strongly projecting, triangular. Supraantennal, supraorbital, and orbital sulci deep, suprafrontal sulcus forming a sharp angle delimitating frontal calli. Frontal ridge moderately projecting. Clypeus wide, rounded, feebly and widely incised. Antennae long, with 11 antennomeres. Antennomere I long and bulbous, antennomere II elliptical; antennomeres III–XI generally slender and elongated, feebly widening apically.

***Thorax*.** Pronotum rectangular, convex. Anterolateral pronotal setiferous pore placed apically, anterolateral pronotal angle forming a feeble lobe. Posterior pronotal angles sharp. Elytra convex, nearly impunctate. Legs long; pro- and meso-tarsomere I rectangular, strongly widened, flattened and elongated, densely pilose on ventral side. Mesotibiae slightly curved laterally, flattened. Metatibiae only slightly curved laterally, metatarsomere I elongated; longer than the remaining parts of metatarsus. Metaventrite forming a horseshoe-like anterior process reaching mesocoxae, covering only posterior part of mesoventrite; anterior part of mesoventrite visible.

Abdomen. Ventrite I bearing a long, slender anterior process reaching metacoxae; with a distinct elevated ridge not reaching the rest of the ventrite.

Genitalia. Aedeagus strongly sclerotised, broadly thickened in lateral view, strongly widening towards apex in ventral view. Apex of aedeagus paddle-like, pointed. Female spermatheca unknown.

Etymology. The species name is derived from *caligula* (small shoe in Latin), referring to the widened pro- and mesotarsi of the species.

Biology. Unknown.

***Ivalia postfasciata* (Chen, 1934), comb. nov.**
Figure 2C

Chabria postfasciata Chen, 1934: 399, 416 (type locality: Luzon)

Material examined. ***Paratype*** 1 spec. (IZCAS): Luzon.

Remarks. The generic placement of this species is revised based on the following characters: (1) lack of metathoracic wings and humeral calli (*Chabria* species are usually winged and with developed humeral calli); (2) metaventrite forming an anterior horseshoe-like process reaching mesocoxae and covering posterior parts of mesoventrite (the metaventrite of *Chabria* species is simple, without a horseshoe-like process); (3) metatibiae curved laterally (metatibiae not curved in *Chabria*).

Redescription. ***Habitus.*** Body oval, convex, 2.4 mm long, 2 mm wide, 1.7 mm high. Head and pronotum black without metallic lustre, elytra black with large orange spots in humeral area and round orange spots in apical area. Legs black with bases of metatibiae and tarsi brown-orange. Antennae black with antennomeres I–II and XI orange. Ventral surfaces dark brown to black.

Head nearly hypognathous, triangular. Supraantennal and orbital sulci deep. Frontal calli feebly developed, elliptical, surrounded by shallow sulci dorsally. Vertex feebly punctate; frontal ridge wide, feebly projecting. Clypeus bearing one row of short setae. Antennae with 11 antennomeres. Antennomere I bulbous, barely shorter than antennomeres II and III combined. Antennomere II elliptical, shortened; antennomeres III–XI long, not strongly widened, antennomeres IV–XI moderately pilose.

Thorax. Pronotum convex, twice as wide as long; impunctate. Anterior pronotal edge feebly forming a lobe, anterolateral pronotal setiferous pore placed in the anterior part of the pronotal margin. Scutellar shield short, wide, triangular. Elytra convex; impunctate. Legs long, 1 and 2 leg pairs moderately pilose. Metatarsomere I strongly elongated, longer than rest of metatarsus; metatibial apical spine longer than metatarsomere II. Metaventral horseshoe-like process reaching mesocoxae; dull, deeply excavated; brown.

Abdomen. Because of the specimen state, we were not able to study the abdomen in detail.

Genitalia were not studied due to the IZCAS rules on handling type specimens.
Biology. Unknown.

A checklist of flea beetles from moss-inhabiting genera known from the Philippines with their type localities

***Benedictus* Scherer, 1969**

B. luzonicus Sprecher-Uebersax, Konstantinov, Prathapan & Doeberl, 2009 – Luzon (Mt. Data).

***Cangshanaltica* Konstantinov, Chamorro, Prathapan, Ge & Yang, 2013**

C. luzonica sp. nov. – Luzon (Sagada env.).
C. mindanaoensis sp. nov. – Mindanao (Mt. Hamiguitan, Mt. Malambo).

***Ivalia* Jacoby, 1887**

I. antennata sp. nov. – Mindanao (Mt. Malambo).
I. caligulata sp. nov. – Luzon (Doline NE Sagada; Mt. Data).
I. postfasciata (Chen, 1934) – Luzon.

Discussion

Moss-inhabiting flea beetle fauna in the Philippines

Our discovery of three additional *Ivalia* and two additional *Cangshanaltica* species from the Philippines extends the known range of both genera to the Philippines. The *Cangshanaltica* species described here represent the first known *Cangshanaltica* from humid equatorial tropics. Both species are very similar and may be closely related; they may be part of a possibly existing radiation in the Philippine archipelago and its mountain ranges. We expect that more species of *Cangshanaltica* do occur in different islands or mountain ranges. In *Ivalia*, the Philippine species differ greatly from each other, and we hence do not expect them to be closely related. *Ivalia caligulata* strongly resembles several species described from Mt. Kinabalu, Borneo, possibly indicating that *I. caligulata* is a Sundean faunal element. Relationships of the other two *Ivalia* species described here cannot be assumed based on the morphology. Molecular grade material is needed to test the above hypotheses and understand the origin and biogeography of both genera in the Philippines. Additional material is also needed from islands other

than Luzon and Mindanao, especially from the Visayas, and from additional mountain ranges. The list of species presented here is very preliminary and many more moss-inhabiting species may be expected, which is also clearly visible on the distributional map of known moss-inhabiting flea beetles in the Philippines (Fig. 6).

Club-like antennae in moss-inhabiting flea beetles

Some of the newly described species of *Ivalia* show unique morphological characters and suggest morphological trends, which were never discussed before. *Ivalia antennata* has strongly thickened antennae, forming a long, but distinct antennal club. Among known leaf litter and moss-inhabiting flea beetles, fully formed club-like antennae are known only in genera with the strongest morphological specialisation, including also extremely compact body: *Kiskeya* Konstantinov et al., 2009 found in the Neotropics, and *Clavicornaltica* Scherer, 1974, a highly diverse, but enigmatic Oriental genus (Scherer 1974, Konstantinov and Duckett 2005, Konstantinov et al. 2009). Somewhat club-like antennae are also present in various moss-inhabiting flea beetles from the mainly Neotropical *Monoplatus* group, e.g., in *Distigmoptera* Blake, 1943 (Konstantinov and Konstantinova 2011). We do not find a well-formed antennal club in other moss-inhabiting genera; however, we can usually observe at least thickened apical antennal segments, suggesting a trend for club-like antennae (Fig. 5). This is e.g., the case of *Cangshanaltica* Konstantinov et al., 2013, *Mniophila* Stephens, 1831, *Borinken* Konstantinov et al., 2011, *Mniophilosoma* Wollaston, 1854. In *Ivalia*, antennae can be long and filiform (e.g., in *I. caligulata*, *I. besar*, *I. biasa* or *I. kinabalensis*) or more less thickened apically (e.g., *I. uenoi*, *I. korakundah*, *I. lescheni* and *I. iridescens*) (Duckett et al. 2006, Nadein 2013, Takizawa and Konstantinov 2018). *Ivalia antennata* described above has antennal club even more developed, with shortened antennomeres on its basal part, unlike any other *Ivalia* known at the moment. It seems that evolution of the antennal club is a more complex process than the evolution of the compact body, flightlessness, or convex body shape typical for the majority of moss-inhabiting flea beetles.

Comments to future taxonomic work on moss-inhabiting flea beetles

The finding that *Chabria postfasciata* belongs to the genus *Ivalia* indicates that some moss-inhabiting flea beetle species may have been described for a long time but misplaced in other genera, with types hidden in museum collections and never re-examined. Old museum collections also hide vast numbers of undescribed moss-inhabiting flea beetle species. For example, the recently described *Adamastoraltica*, a flightless flea beetle from Africa, was also found in an older collection (Biondi et al. 2020). This study is based on older museum material as well as the newly collected material, which proved to be the ideal approach. Systematic revisional work of ecologically specialised and largely unknown groups should focus not only on field work but on examining forgotten material in museum collections.

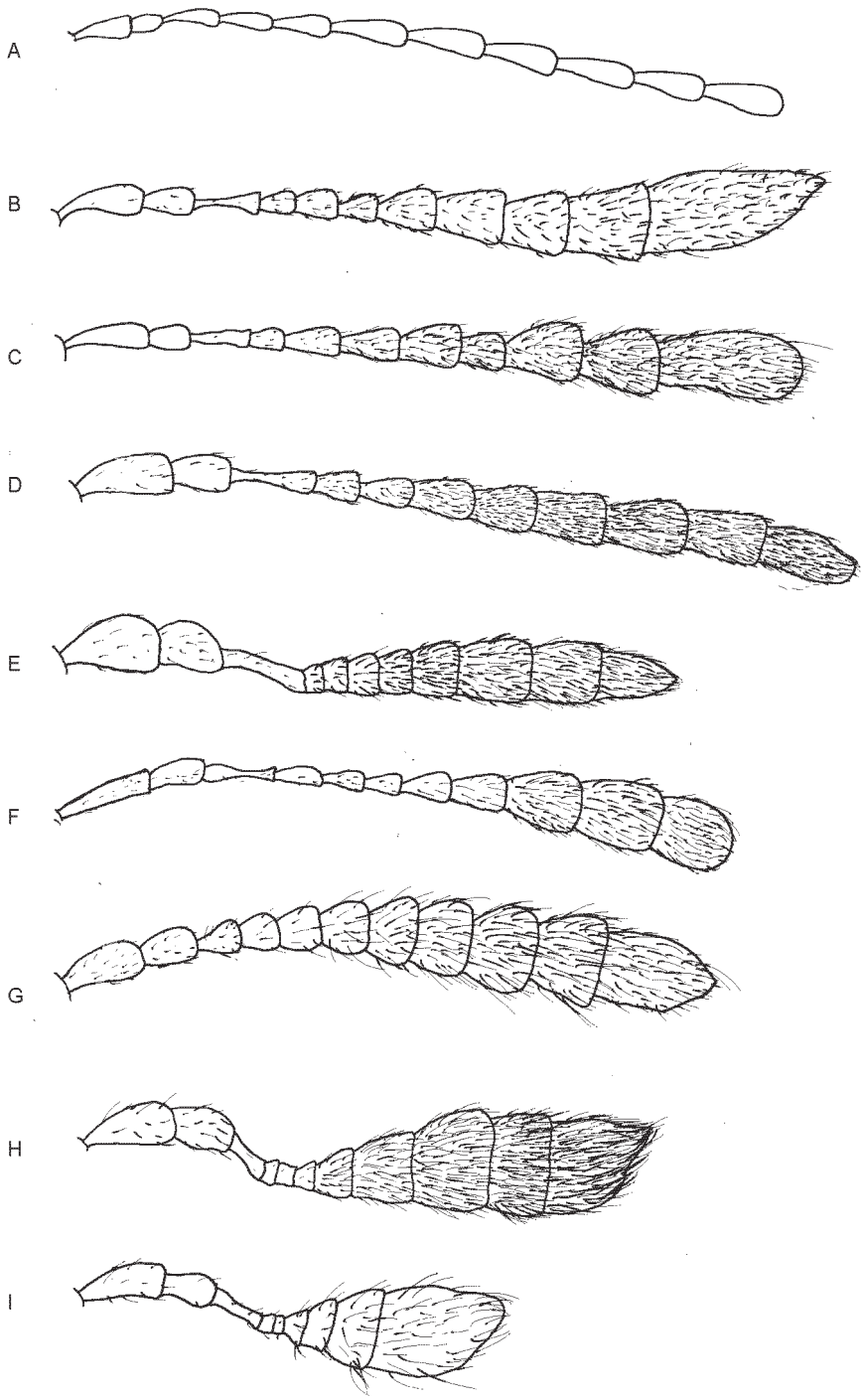

Figure 5. Antennae of various genera and species of moss-inhabiting flea beetles showing various level of antennal club formation **A** *Ivalia besar* **B** *Ivalia lescheni* **C** *Ivalia iridescens* **D** *Ivalia uenoi* **E** *Ivalia antennata* **F** *Mniophilosoma laeve* **G** *Borinken elyunque* **H** *Clavicornaltica doeberli* **I** *Kiskeya baorucae*.

Figure 6 Current knowledge about distribution and diversity of moss-inhabiting flea beetles in the Philippines.

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RESEARCH ARTICLE

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Revision of the genus *Epiparbattia* Caradja, 1925 (Lepidoptera, Crambidae, Pyraustinae), based on morphology and molecular data

Dandan Zhang[1], Kai Chen[2], Lanbin Xiang[2]

1 *School of Ecology, Sun Yat-sen University, Guangzhou, Guangdong 510275, China* **2** *School of Life Sciences, Sun Yat-sen University, Guangzhou, Guangdong 510275, China*

Corresponding author: Dandan Zhang (zhangdd6@mail.sysu.edu.cn)

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Abstract

The genus *Epiparbattia* Caradja, 1925 is revised based on general appearance, including genitalia. A new species, *Epiparbattia multispinalis* Zhang & Chen, **sp. nov.** is described. The external characters and genitalia morphology of all species are figured. The phylogeny of *Epiparbattia* species is investigated using molecular data. Monophyly of the genus is well supported by phylogenetic analysis based on sequence data of *COI*, *16S rRNA*, *EF-1α* and *28S rRNA* gene regions.

Keywords

China, *Epiparbattia*, molecular phylogeny, new species, *Sclerocona*, taxonomy

Introduction

The genus *Epiparbattia* Caradja, 1925 comprises only two species, *E. gloriosalis* Caradja, 1925 and *E. oligotricha* Zhang & Li, 2005, distributed in southern China, India and Bhutan (Munroe and Mutuura 1971; Nuss et al. 2003–2020; Irungbam et al. 2016). These two species are easily recognized by the yellow body and the creamy white wings bearing dark brown markings. Three specimens, having a different colour but similar genitalic morphology, represent a new species of *Epiparbattia*

which is described below. In this paper, we also redefine the genus and summarize the diagnoses of all species based on the external morphological and genitalic characters. The phylogeny of *Epiparbattia* based on sequence data of *COI*, *16S rRNA*, *EF-1*α and *28S rRNA* gene regions is reconstructed.

Material and methods

Morphological studies

The material studied, including the types of the newly described species, are all deposited at the Museum of Biology, Sun Yat-sen University, China (**SYSBM**) except those specified as being in the Insect Collection of the College of Life Sciences, Nankai University, China (**NKU**), the Institute of Zoology, Chinese Academy of Sciences (**IZCAS**) and the National History Museum, London, United Kingdom (**NHMUK**). Slides of genitalic dissections were prepared according to Robinson (1976) and Li and Zheng (1996), with some modifications. Genitalia terms follow Klots (1970), Munroe (1976), Maes (1995) and Kristensen (2003). Images of the specimens at different focal levels were made using a Canon EOS 1DX camera in combination with the Helicon Remote image stacking program; the genitalia pictures were taken using Zeiss Axio Scope.A1 in combination with a Zeiss AxioCam camera and the Axio Vision SE64 programme on a Windows PC; source images were then aligned and stacked on Helicon Focus to obtain a fully sharpened composite image.

Molecular analyses

In total seven species of four genera were included for molecular phylogenetic analyses (Table 1). *Euclasta stoetzneri* (Caradja, 1927) was chosen as the outgroup because the genus *Euclasta* Lederer, 1855 is considered as the basal lineage of the Pyraustinae (Mally et al. 2019). One species of *Sclerocona* and two species of *Crocidophora* were included as closely related groups based on the fovea of the forewing, the minute basal and apical outer spurs of the hindleg in males and the similar genitalic characters. Total DNA was extracted from two legs and, sometimes in addition, from the abdomen of the dry specimens using the TIANGEN DNA extraction kit following the manufacturer's instructions. The nucleotide sequences of two mitochondrial genes, cytochrome c oxidase subunit I (*COI*) and 16S ribosomal RNA (*16S rRNA*), and two nuclear genes, Elongation factor-1 alpha (*EF-1*α) and 28S ribosomal RNA (*28S rRNA*) were selected for study. Primers used in this study are as follow: LCO/Nancy for *COI* and LR-J-12888/ LR-N-13398 for *16S rRNA* (Simon et al. 2006), Oscar-6143/Bosie-6144 for *EF-1*α (Hundsdoerfer et al. 2009) and 28S-f1/28S-r1 for *28S rRNA* (Lee and Brown 2008). All PCRs were performed in 25 µl of solution, containing 2 µl 10×PCR Buffer, 2 µl dNTP (2.5 mM each), 0.6 µl $MgCl_2$ (25 mM), 1 µl of each primer (10 pmol/µl), 0.2 µl Takara Taq DNA Polymerase (Takara Bio Inc., 5 u/µl), 4 µl of template DNA and 14.2 µl ddH_2O for *COI*, *16S rRNA* and *28S rRNA*, and 10 µl 2×PCR Buffer (8 mM $MgCl_2$), 2 µl

Table 1. Species sampled for the molecular phylogenetic analysis.

Genus	Species	Voucher no.	Locality	Genbank accession number				References
				COI	*16S*	*EF-1α*	*28S*	
Euclasta	*stoetzneri*	SYSU-LEP0334	Shaanxi	MT738696	MT734412	MT724335	MT734404	Present study
Crocidophora	*lutusalis*	SYSU-LEP0088	Yunnan	MT738697	MT734413	MT724336	MT734405	
	pallidulalis	SYSU-LEP0090	Yunnan	MT738698	MT734414	MT724337	MT734406	
Epiparbattia	*oligotricha*	SYSU-LEP0243	Sichuan	MT738699	MT734415	N/A	MT734407	
	oligotricha	SYSU-LEP0359	Yunnan	MT738700	MT734416	MT724338	MT734408	
	multispinalis	SYSU-LEP0351	Hubei	MT738701	MT734417	N/A	MT734409	
	multispinalis	SYSU-LEP0378	Hubei	MT738702	MT734418	MT724339	MT734410	
	gloriosalis	SYSU-LEP0244	Guangdong	MT738703	MT734419	MT724340	MT734411	
Sclerocona	*acutella*	SYSU-LEP0152	Macao	MG739577	MG739589	MG739601	MG739612	Chen et al. 2018

dNTP (10 mM each), 1 µl of each primer (10 pmol/µl), 0.4 µl KOD FX DNA Polymerase (TOYOBO CO., LTD., 1 u/µl), 4 µl of template DNA and 6.6 µl ddH_2O for *EF-1α*. PCR cycle conditions were set to an initial denaturation of 5 min at 95 °C, 35 cycles of 30 seconds at 94 °C, 30 seconds at 48 °C (*COI* and *16S rRNA*) or 52 °C (*EF-1α* and *28S rRNA*) and 1 min at 72 °C for amplification, and a final extension at 72° C for 10 min. PCR products were confirmed with 1.5% agarose gel electrophoresis in TAE buffer, then were purified and direct-sequenced at Majorbio Bio-pharm Technology Co., Ltd (Guangzhou), utilizing the same primers used for PCR amplification.

The sequences were aligned using Clustal W (Thompson et al. 1994) in MEGA 6 (Tamura et al. 2013) with default settings. The aligned matrix was corrected by eye. Gaps were treated as missing data. Phylogenetic analyses were inferred using Bayesian inference (BI) method in MrBayes 3.2.6 (Ronquist et al. 2012) and maximum likelihood (ML) in RAxML 8.2.10 (Stamatakis 2014). BI analysis was run with independent parameters for the *COI* and the *16S rRNA* gene partitions under the GTR + G model, the *EF-1α* gene partition under the GTR + I model, and *28S rRNA* gene partition under the GTR + G model, as suggested by jModelTest 0.1.1 (Posada 2008). Two independent runs, each with four Markov Chain Monte Carlo (MCMC) simulations, were performed for 20 million generations sampled every 1000th generation. The first 25% trees were discarded as burn-in, and posterior probabilities (PP) were determined from remaining trees. ML analysis was executed under the GTR + G model for all gene partitions and with 1000 iterations for the bootstrap test. The pairwise Kimura 2-Parameter (K2P) distances between species were calculated from the *COI* gene using MEGA 6 (Tamura et al. 2013).

Results

Epiparbattia Caradja, 1925

Epiparbattia Caradja, 1925: 358.

Type species. *Epiparbattia gloriosalis* Caradja, 1925, by monotypy.

Diagnosis. This genus is related to *Sclerocona* Meyrick, 1890 in the forewings bearing a fovea basally beyond the cell and another fovea between R_{3+4} and R_5, as well as the minute basal and apical outer spurs of the hindlegs in the male, the developed and sclerotized lamella postvaginalis, the coiled and partly sclerotized posterior part of the ductus bursae and the second signum with two almost parallel ridges in the female genitalia, but can be distinguished by the larger body size, the relatively short labial palpi and the prominent markings on the wings. In the genitalia, *Epiparbattia* differs from *Sclerocona* by the relatively broad uncus, the uninflated sacculus, the stout, ventrodistally sclerotized phallus and the broad, nearly elliptical signum.

Redescription. Frons rounded, sometimes weakly flat. Labial palpi obliquely porrect, third segment porrect; exceeding frons by less than the diameter of eyes. Maxillary palpi slightly broadened terminally. Hindlegs of male with basal and apical outer spurs minute. Forewings elongated triangular, costa slightly curved near apex, apex obtuse, termen slightly curved and oblique, tornus rounded; reniform stigma developed and connected with postmedial band, postmedial band comprising of a series of patches and with a broad patch on posterior margin, subterminal band comprising of a series of broad, elliptical patches; length of cell less than half of forewing, male with posterior margin of cell, CuA_2 and 1A basally curved, and forming a fovea, with a scale-tuft on the underside surface at position of fovea, R_3 and R_4 stalked about 1/2–2/3 length of R_4, R_5 basally curved, a fovea present between R_{3+4} and R_5 but without scale-tuft on the underside surface at position of fovea. Hindwings fan-shaped; length of cell less than half length of hindwing; $Sc+R_1$ and Rs anastomosed for 1/3–1/2 length of Rs; subterminal band narrow. **Male genitalia.** Uncus nearly triangular, distally narrowly rounded, with distal half densely setose laterally and dorsally, basal half sparsely setose laterally. Tegumen with dorsal 1/3–1/2 narrow and basal 2/3–1/2 broad. Transtilla connected, arms nearly triangular or trapezoidal, sparsely bearing slender setae, with ventral process extending to juxta. Valvae tongue-shaped, costa nearly straight, ventral margin convex, apex rounded; sella weakly sclerotized and setose, dorsally bearing a large cluster of curved and thick setae or several slender setae forming an editum, ventrally with strongly sclerotized processes; sacculus not inflated; saccus nearly triangular. Juxta with dorsal part divided into two arms. Phallus stoutly cylindrical, distally with ventral part sclerotized. **Female genitalia.** Ovipositor lobes flat, densely setose. Apophyses stout, anterior apophyses about same length of posterior apophyses, 8th tergite with base of anterior apophysis strongly extended forward and connected with lamella postvaginalis. Lamella postvaginalis developed, sclerotized. Antrum reduced. Ductus bursae usually longitudinally wrinkled, about 2–3 times length of corpus bursae; with most of posterior part coiled and partially sclerotized, usually inflated; colliculum elongated hourglass-shaped; ductus seminalis arising closely from anterior end of colliculum. Corpus bursae globular or oval, wrinkled; appendix bursae originating from posterior part; signum broadly rhomboid, nearly elliptical; second signum located between base of appendix bursae and entrance of ductus bursae, plate-shaped and curved, usually with two almost parallel ridges.

Distribution. China, India, Bhutan.

Key to species of *Epiparbattia*

1 Forewings ground colour pale yellow and the covering dark brown scales forming markings in male (Fig. 3), wings pale yellow in female (Fig. 4); ventral processes of sella with rows of densely set spines ventrally, dorsalmost process long and straight (Fig. 7)..... ***E. multispinalis* Zhang & Chen, sp. nov.**

– Wings creamy white bearing dark brown markings; ventral processes of sella with the dorsalmost one curved and with sparse spines ventrally.....**2**

2 Forewings with postmedial band interrupted (Fig. 1); ventral margin and costa of valva approximately parallel, dorsal part of sella densely covered with thick setae forming editum, the setae with apex curved and divided into several filaments, ventral part of sella with dorsalmost process slightly curved and extending inward (Fig. 5)..... ***E. gloriosalis* Caradja, 1925**

– Postmedial band of forewing not interrupted (Fig. 2); valvae gradually widened from base to apex, dorsal part of sella sparsely covered with slender and simple setae forming editum, ventral processes of sella with the dorsalmost one extending dorsad (Fig. 6).....***E. oligotricha* Zhang & Li, 2005**

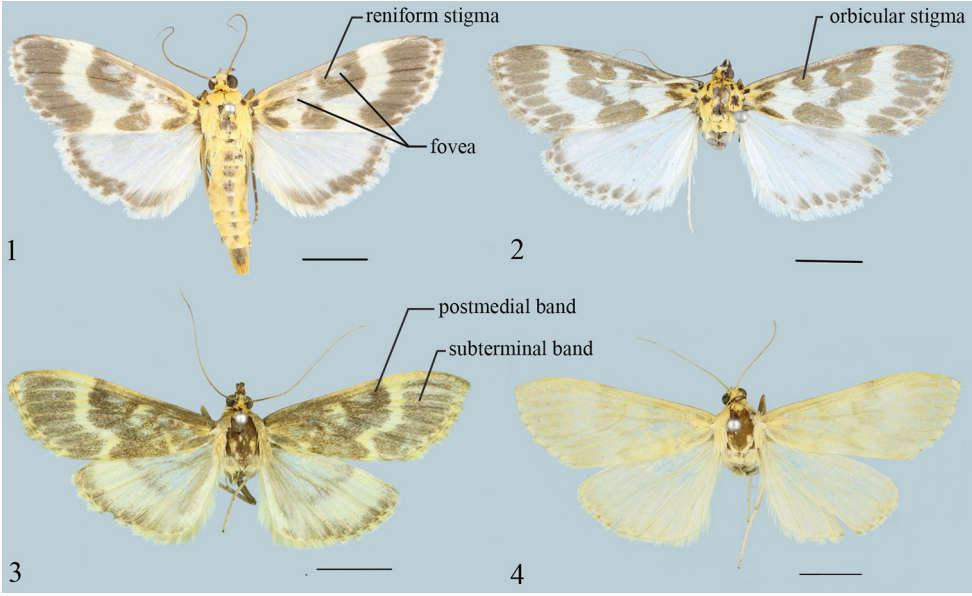
***Epiparbattia gloriosalis* Caradja, 1925**

Figs 1, 5, 8

Epiparbattia gloriosalis Caradja, 1925: 359.
Epiparbattia gloriosalis whalleyi Munroe & Mutuura, 1971: 506.

Type material examined. ***Paratype*** of *Epiparbattia gloriosalis* Caradja, 1925: 1♀, [China: Guangdong]: Lienping [Lianping], 26. April (NHMUK). Types of *Epiparbattia gloriosalis whalleyi* Munroe & Mutuura, 1971: ***holotype*** ♂, [India]: Assam, 5000 ft, Shillong, 19.May.1924, Fletcher coll., Pyralidae Brit. Mus. Slide no. 8708 (NHMUK); ***allotype*** ♀, [India]: Assam, 5000 ft, Shillong, at light, 18.V.[19]28, T. Bainbridge Fletcher, Pyralidae Brit. Mus. Slide no. 8709 (NHMUK); ***paratypes*:** 2♀♀, [India]: Assam, Shillong, at light, H. M. Parish., Pyralidae Brit. Mus. Slide no. 5384 (NHMUK).

Other material examined. China: Fujian: 1♂, Sangang, 15.VIII.1979 (IZCAS); Guangdong: 2♂♂, Mt. Danxiashan, Renhua, alt. 408 m, 15. IV.2008, leg. Wang Fengwei; 1♂, 1♀, Mt. Dinghushan, Zhaoqing, 23.17°N, 112.55°E, alt. 56 m, 8.IV.2013, leg. Li Jinwei, genitalia slide no. CXH12039 (♂), SYSU1036 (♀, molecular voucher no. SYSU-LEP0244); Guangxi: 1♀, Mt. Shiwandashan, 21.91°N, 107.91°E, alt. 352 m, 18.IV.2012, leg. Li Jinwei; Yunnan: 1♂, Lufeng, 22.VI.1982, leg. Song Shimei (IZCAS); 1♀, Kunming, 10.V.1980, leg. Zhong Tiesen (IZCAS); 1♀, Muding, V.1975 (IZCAS); Xizang: 1♀, Pailong, Linzhi, 30.01°N, 95.00°E, alt. 2010 m, 5.VII.2013, leg. Li Jinwei.



Figures 1–4. Adults of *Epiparbattia* spp. **1** *E. gloriosalis*, male (Renhua, Guangdong) **2** *E. oligotricha*, female (Tianquan, Sichuan) **3** *E. multispinalis* sp. nov., holotype, male (Shuangping, Zhuxi, Hubei) **4** *E. multispinalis* sp. nov., paratype, female (Shuangping, Zhuxi, Hubei). Scale bars: 5.0 mm.

Diagnosis. Wingspan 32.0–41.0 mm. This species is similar to *Epiparbattia oligotricha* in appearance, but can be distinguished from it by the tegulae with only one black spot at base, the interrupted postmedial band and the narrower patch on the posterior margin; in male genitalia by the dorsal side of the sella densely covered with thick setae forming editum, and the setae subapically curved and divided into several filaments, the ventral processes of the sella with the dorsalmost curved inward, apically bifurcated, the ventralmost curved ventrad, and by the longer arms of the juxta; in female genitalia by the absence of a U-shaped concave unsclerotized window of the lamella postvaginalis anteriorly and the uninflated posterior part of the ductus bursae.

Distribution. China (Fujian, Hubei, Guangdong, Guangxi, Sichuan, Yunnan, Xizang), India, Bhutan.

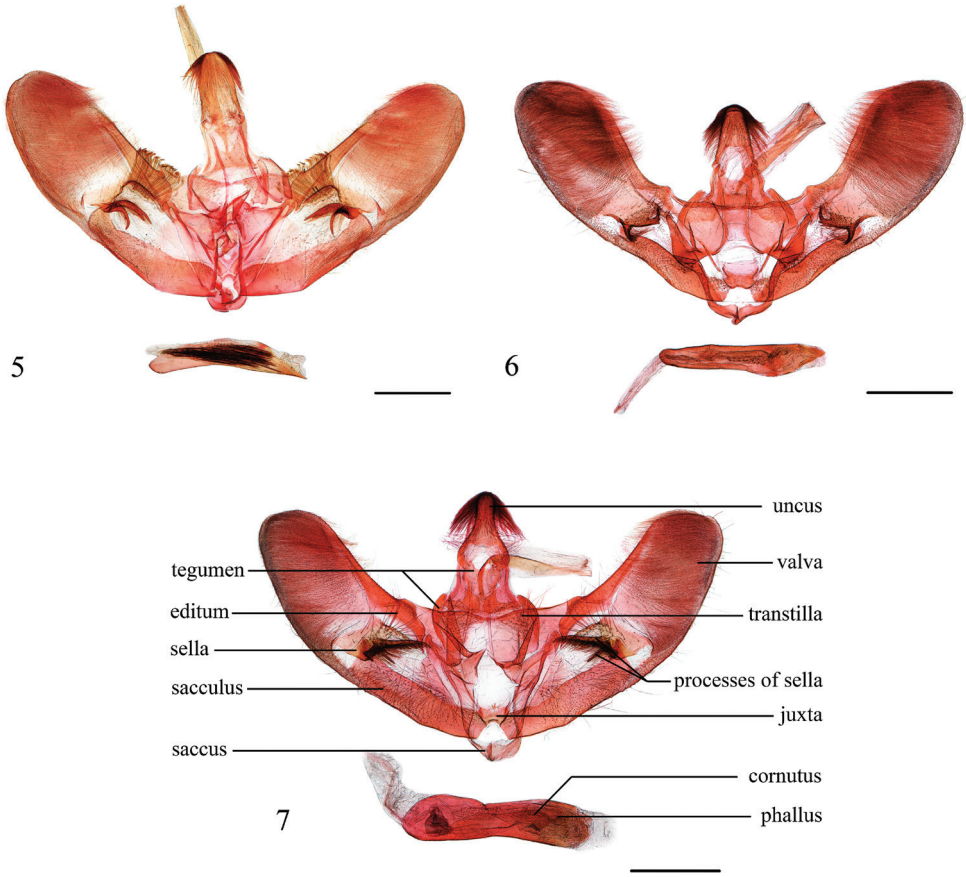
Biology. Larvae bore in the stems of bamboo shoots of *Sinocalamus affinis* (Rendle) McClure (Wang 1980).

Epiparbattia oligotricha Zhang & Li, 2005

Figs 2, 6, 9

Epiparbattia oligotricha Zhang & Li, 2005: 40.

Type material examined. ***Holotype*** ♂, China: Guizhou: Mt. Fanjingshan, 27°33'N, 108°24'E, alt. 1700 m, 1.VI.2002, leg. Wang Xinpu (NKU); ***Paratypes*:** Yunnan:



Figures 5–7. Male genitalia of *Epiparbattia* spp. **5** *E. gloriosalis*, Guangdong (genitalia slide no. CXH12039) **6** *E. oligotricha*, Yunnan (genitalia slide no. ZDD12109) **7** *E. multispinalis* sp. nov., Hubei (genitalia slide no. ZDD12101). Scale bars: 1.0 mm.

2♂♂, 2♀♀, Jinping, 22°28'N, 103°7'E, alt. 1700 m, 9–13.V.1956, leg. Huang Keren (IZCAS).

Other material examined. China: Sichuan: 5♀♀, Labahe, Tianquan, 30.09N, 102.52E, alt. 1860 m, 8.VII.2012, leg. Li Jinwei, genitalia slide no. SYSU1035, molecular voucher no. SYSU-LEP0243, SYSU-LEP0335; Yunnan: 1♂, Qinlangdang Reserve Station, Gaoligongshan Reserve, Nujiang, 27.69°N, 98.27°E, alt. 380 m, 30.V.2017, leg. Teng Kaijian et al., genitalia slide no. ZDD12109, molecular voucher no. SYSU-LEP0359 (NKU).

Diagnosis. Wingspan 32.0–47.0 mm. This species is superficially similar to *Epiparbattia gloriosalis*, but can be distinguished from it by the tegulae bearing a second large black spot in the center, the large orbicular stigma, the uninterrupted postmedial band and the wider patch of the postmedial band at the posterior margin; in male genitalia by the dorsal side of the sella sparsely covered with slender simple setae forming editum, the ventral processes of the sella with the dorsalmost curved dorsad and with

ventral margin sparsely bearing spines, the ventralmost slightly curved inward, as well as the shorter arms of the juxta; in female genitalia by the presence of a deep, U-shaped concave unsclerotized window of the lamella postvaginalis anteriorly and the inflated posterior part of the ductus bursae.

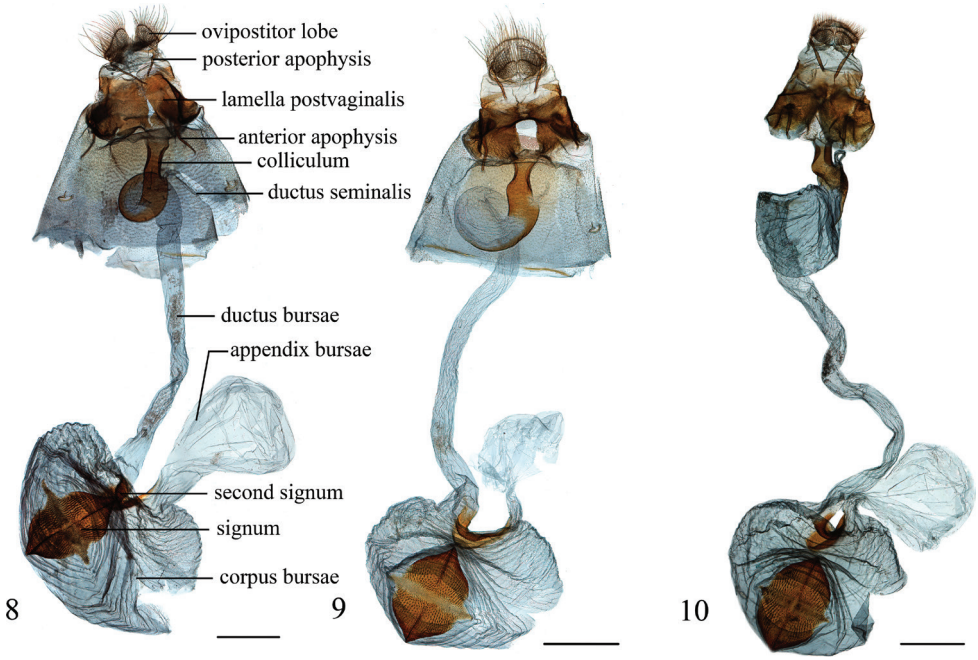
Distribution. China (Sichuan, Guizhou, Yunnan).

***Epiparbattia multispinalis* Zhang & Chen, sp. nov.**
http://zoobank.org/CC9D9746-060F-43D4-A173-50F6AA904464
Figs 3, 4, 7, 10

Material examined. ***Holotype*** ♂, China: Hubei: Shuangping, Zhuxi, 31.57N, 109.87E, alt. 1201 m, 5.VII.2017, leg. Qi Wanding, genitalia slide no. ZDD12101, molecular voucher no. SYSU-LEP0378 (NKU). ***Paratypes*:** 2♀♀, same data as holotype, genitalia slide no. ZDD12074, ZDD12095, molecular voucher no. SYSU-LEP0351 (NKU, SYSBM).

Diagnosis. The new species differs from the other two species by the pale yellow ground colour of forewings with dark brown markings in the male and the pale-yellow wings in the female. In the male genitalia, *Epiparbattia multispinalis* is similar to *E. oligotricha*, but differs from the latter in the concave lateral margin of the uncus, the more convex ventral margin of the valva, the ventral processes of the sella with the dorsalmost straight and long, narrowly triangular, with rows of spines ventrally, transversely extending inward, and by the large drop-shaped cornutus. In the female genitalia, this species is different from *E. gloriosalis* and *E. oligotricha* by the prominently inflated posterior part of the ductus bursae, approximately 2–3 times the width of the remainder of the ductus bursae.

Description. Wingspan 29.0–33.0 mm. **Male** (Fig. 3). ***Head.*** Frons flat or round, brown. Vertex brown. Labial palpi brown, pale yellow at base beneath. Maxillary palpi brown, paler at apex. Basal scales of proboscis pale brown. Antennae yellowish brown. ***Thorax.*** Pale brown dorsally, tegulae bearing scales pale yellow with pale brown apex; greyish white ventrally. Legs yellowish brown, hindlegs of male with basal and apical outer spurs minute, about 1/5 length of inner spurs. Forewings ground colour pale yellow, with area from base to postmedial band densely covered with dark brown scales, only with a diffuse pale yellow medial area between wing base and postmedial band; reniform stigma dark brown, nearly triangular; postmedial band dark brown, from costal 2/3 to middle of posterior margin; subterminal band broad, brown, with veins pale yellow; termen with brown spots at veins end; fringe pale yellow, scattered with dark browns scales. Forewings with a fovea beyond posterior margin of cell and another outside of cell. Hindwings pale yellow, with basal half sparsely scattered with dark brown scales and a narrow pale brown postmedial line as outer demarcation; subterminal band dark brown, with inner margin suffusing and irregular; termen and fringe same as forewing. ***Abdomen.*** Brown, dorsally with posterior margin of



Figures 8–10. Female genitalia of *Epiparbattia* spp. **8** *E. gloriosalis*, Guangdong (genitalia slide no. SYSU1036) **9** *E. oligotricha*, Sichuan (genitalia slide no. SYSU1035) **10** *E. multispinalis* sp. nov., Hubei (genitalia slide no. ZDD12074). Scale bars: 1.0 mm.

each segment pale yellow. ***Male genitalia*** (Fig. 7). Uncus laterally strongly concave and with distal end narrowly rounded. Valvae slightly curved, costal margin slightly concave and ventral margin convex; width of basal half relatively even and slightly tapering from middle towards bluntly rounded apex; sella nearly rhombic and weakly sclerotized, dorsal part sparsely bearing slim setae and several thick setae forming editum, ventral processes of sella with the dorsalmost sclerotized, straight and long, narrowly triangular, transversely extending inward and densely bearing rows of spines ventrally, another process of sella spine-shaped and small. Juxta small, nearly inversely trapezoidal, dorsal arms weak and widely separated. Phallus slightly narrowed in middle, with a large drop-shaped, weakly sclerotized cornutus. **Female** (Fig. 4). Head and thorax yellow, antennae pale brown. Forewings yellow, with a pale yellow band indistinct, wider than that in male; termen with pale brown spots at veins end; fringe pale yellow. Hindwings pale yellow; subterminal band indistinct; termen and fringe as in forewing. Abdomen brown. ***Female genitalia*** (Fig. 10). Lamella postvaginalis densely covered with minute spines, strongly extended dorsad and connected dorsally, with dorsal part forming a pair of closely associated rounded sclerites. Ductus bursae about three times diameter of corpus bursae, with posteriormost part prominently inflated, about 2–3 times width of the remainder; colliculum hourglass-shaped. Corpus bursae globular, length of signum about 2/3 of diameter of corpus bursae, ends of the long

axis approximately right-angled, ends of the short axis (perpendicular to long axis) produced into short acute-angled tips.

Etymology. The specific name is derived from the Latin *multi-* (= many) and *spinalis* (= spine) corresponding to the ventral processes of the sella bearing many spines.

Distribution. China (Hubei).

Phylogenetic relationships

The concatenated dataset of four genes consisted of 2510 nucleotide positions (658 for *COI*, 468 for *16S rRNA*, 619 for *28S rRNA*, and 765 for *EF-1α*). Both BI and ML analyses of the concatenated dataset inferred congruent topologies with only subtle differences in posterior probability and bootstrap values (Fig. 11). The monophyly of *Epiparbattia* is robustly supported (PP = 1.00, BS = 99), the genus *Sclerocona* and *Epiparbattia* are sister groups with moderate support. The results of the current phylogenetic analyses support the placement of *E. multispinalis* sp. nov. in *Epiparbattia*, with *E. oligotricha* as its sister species, with strong support in the BI analysis (PP = 0.98, BS = 75).

Pairwise distances of the barcoding region (*COI*) are given in Table 2. The genetic distances between *Epiparbattia* and other genera range from 8.5% (*Crocidophora*) to 15.5% (*Euclasta*). Interspecific genetic distances within *Epiparbattia* range from 5.6% (*E. oligotricha* to *E. multispinalis*) to 7.9% (*E. oligotricha* to *E. gloriosalis*), while intraspecific genetic distances range from 0.2% (*E. multispinalis*) to 1.9% (*E. oligotricha*).

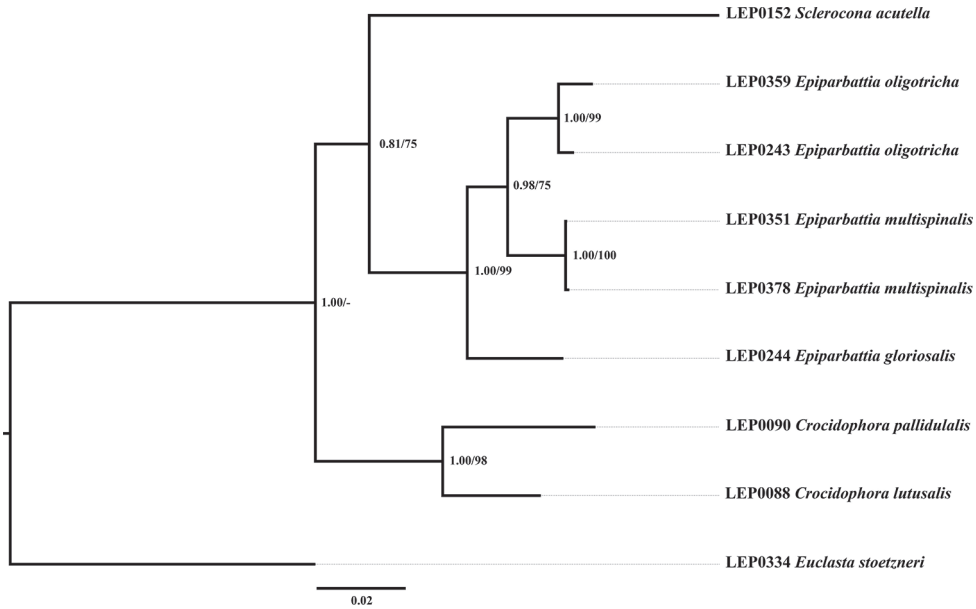


Figure 11. Phylogenetic hypothesis inferred from Bayesian inference. Numbers on branches indicate Bayesian posterior probabilities and ML bootstrap values respectively.

Table 2. Pairwise distances of the *COI* barcode region based on Kimura-2-parameter model (intraspecific distances are highlighted in bold).

		1	2	3	4	5	6	7	8
1	SYSU-LEP0334 *Euclasta stoetzneri*								
2	SYSU-LEP0088 *Crocidophora lutusalis*	0.133							
3	SYSU-LEP0090 *Crocidophora pallidulalis*	0.136	0.077						
4	SYSU-LEP0243 *Epiparbattia oligotricha*	0.138	0.098	0.085					
5	SYSU-LEP0359 *Epiparbattia oligotricha*	0.133	0.101	0.089	**0.019**				
6	SYSU-LEP0351 *Epiparbattia multispinalis*	0.153	0.103	0.098	0.056	0.070			
7	SYSU-LEP0378 *Epiparbattia multispinalis*	0.155	0.105	0.099	0.058	0.071	**0.002**		
8	SYSU-LEP0244 *Epiparbattia gloriosalis*	0.135	0.098	0.089	0.072	0.079	0.067	0.069	
9	SYSU-LEP0152 *Sclerocona acutella*	0.118	0.113	0.092	0.092	0.103	0.087	0.089	0.096

Discussion

The monophyly of *Epiparbattia* is robustly supported by the results of the molecular analysis. Three species can be recognized as members of *Epiparbattia* by a series of external and genital characters provided above in the diagnosis of the genus. As is apparent from the tree topology (Fig. 11), *E. multispinalis* is more closely related to *E. oligotricha* than to *E. gloriosalis* which makes good sense with respect to the similar hair-like editum in male genitalia (Figs 6, 7). According to the tree topology (Fig. 11), *Epiparbattia* is more colsely related to *Sclerocona*. Species of *Epiparbattia* and *Sclerocona* have two foveae on the forewing in males, a developed and sclerotized lamella postvaginalis, and a weakly developed, almost reduced antrum in females.

Additionally, several pyraustine genera, *Anamalaia* Munroe & Mutuura, 1969, *Lepidoplaga* Warren, 1895, *Limbobotys* Munroe & Mutuura, 1970 and *Torulisquama* Zhang & Li, 2010, are similar to *Epiparbattia* and *Sclerocona* by bearing fovea (at least one fovea) on the forewing, minute basal and apical outer spurs of hindleg in males, as well as a developed and sclerotized lamella postvaginalis in females, but can still be distinguished from each other by the number and position of the fovea and other genital characters. The relationships among all these genera need to be further studied.

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