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# Sea cucumbers of the genus *Stichopus* Brandt, 1835 (Holothuroidea, Stichopodidae) in Straits of Malacca with description of a new species

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## Abstract

Five sea cucumber species including one new species of the genus *Stichopus* are reported from the shallow coral reefs of Straits of Malacca. The new species *Stichopus fusiformiossa* has unusual fusiform spicules in the tentacles, which are not found in the other species of the genus. Pseudo-tables and large perforated plates are newly recorded for *Stichopus hermanni* Semper, 1868 and *Stichopus vastus* Sluiter, 1887, respectively.

## Keywords

Echinodermata, sea cucumbers, *Stichopus*, Malaysia, taxonomy, spicules, shallow reef

## Introduction

Recent revisions on the holothuroid taxonomy have resulted in some taxonomical changes and introduction of several new species in the genus *Stichopus* Brandt, 1835 of the family Stichopodidae (Rowe and Gates 1995; Massin 1999; Massin et al. 2002;

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Byrne et al. 2010). Outer morphology of *Stichopus* is somehow very deceptive and similar interspecifically (Clark 1922; Massin et al. 2002), and variable intraspecifically. Field identification by their external appearances proved to be difficult and identification using spicules is essential (Clark 1922; Clark and Rowe 1971; Massin et al. 2002; Massin 2007). To enhance the understanding of classification within the family Stichopodidae, Moraes et al. (2004) introduced chemotaxonomic approach while Byrne et al. (2010) and Uthicke et al. (2010) have employed molecular sequence data.

One of the earliest comprehensive records on the diversity and distribution of holothurians in Malaysian waters was done by Ridzwan and Che Bashah (1985). Then, Zulfigar et al. (2008) produced a field guide to sea cucumbers in shallow water and coral reefs in Malaysia. However, taxonomic studies of the genus *Stichopus* in Malaysia were scarce and done only at the southern part of the South China Sea (Siti et al. 1999; Massin et al. 2002). Massin et al. (2002) described two new species, *Stichopus rubermaculosus* and *Stichopus ocellatus* there. The genus *Stichopus* is one of the dominant genera in tropical shallow waters which is an important fishery commodity. Although Straits of Malacca is a major area for stichopodid fisheries, there has not been a comprehensive taxonomic study done on stichopodids in that area. Furthermore, the genus *Stichopus* is taxonomically very confusing due to their similarity between each species in outer appearance and the presence of variations (Massin et al. 2002). In this study, detailed morphological descriptions were done on the species of the genus *Stichopus* including a new species found from the shallow reefs of the Straits of Malacca.

## Material and methods

Sea cucumbers were collected from the shallow coral reef areas of Pulau Payar (6°26'2.7"N, 99°40'54.8"E), Pulau Songsong (5°48'31.2"N, 100°17'38.0"E) and Pulau Sembilan (4°1'46.8"N, 100°32'39.7"E) in the Straits of Malacca as shown in Figure 1. The sampling areas were situated in highly sedimented waters of the Straits of Malacca (Chua et al. 2000) with poor reef framework formation (Pillai and Scheer 1974). All sampling areas exhibited similar shallow reef flat at depths about 10-15m with gradual slope of sandy substrate extending to 30m depth. SCUBA diving was employed in collecting specimens using wandering transect covering an area of about 150–200 $m^2$, .up to 30 m water depth during day and night. The sea cucumber specimens were fixed in absolute ethanol for two weeks and stored in 70% ethanol. Spicules were extracted from the tissues of the dorsal body, tip of the papillae, tentacles, and tube feet. The tissue were dissolved using commercial bleach and spicules were then washed several times with distilled water before transferring them to a glass slide to be observed under microscope. Pencil drawing of the spicules were done using a drawing tube attached to the microscope. The pencil drawings were then traced on a tracing paper using fine technical pens and digitized by scanning. All specimens were deposited at Marine Science Laboratory, Universiti Sains Malaysia (USM/MSL).

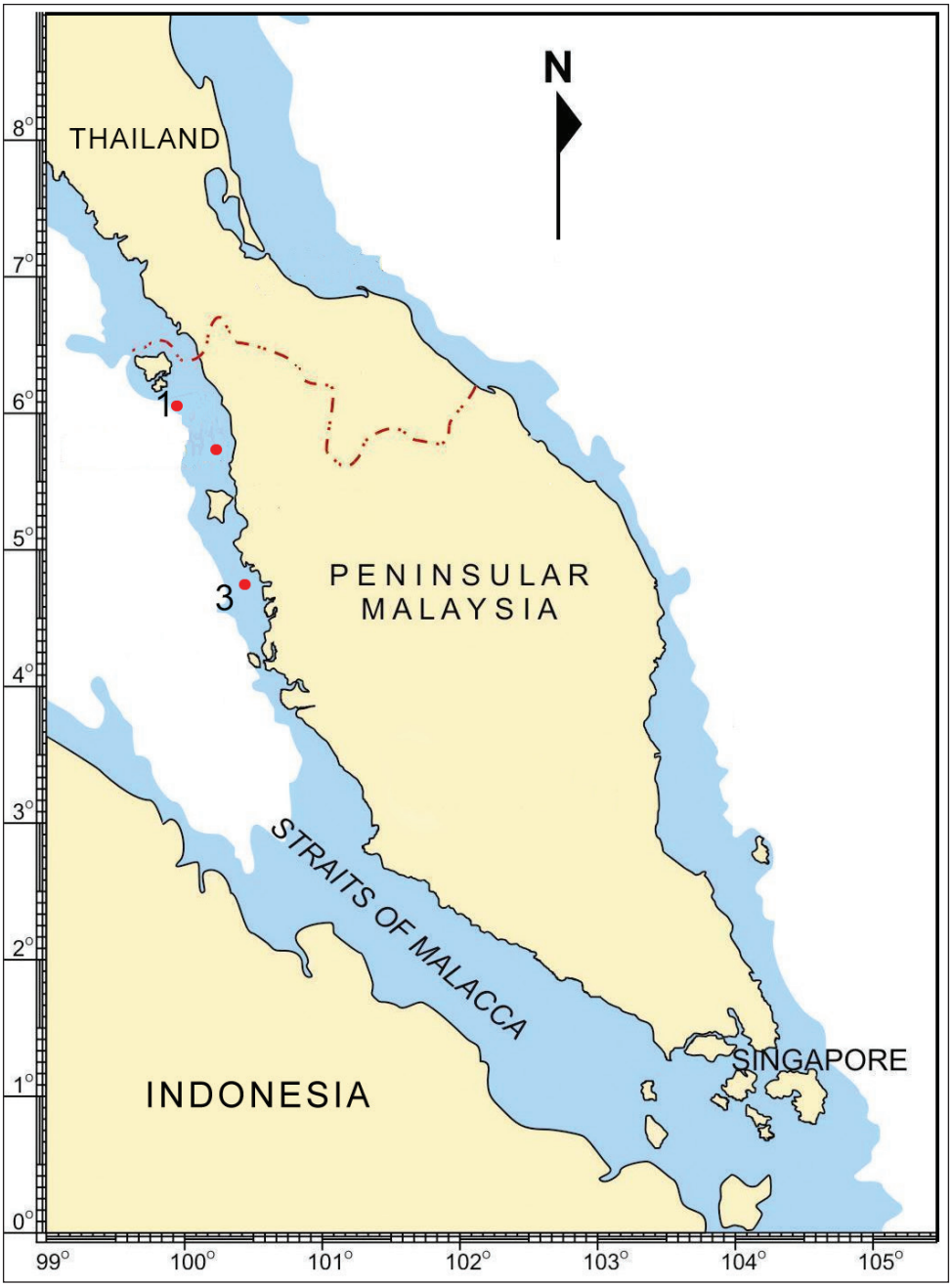


**Figure 1.** Map of study area in the Straits of Malacca: **1** Pulau Payar **2** Pulau Songsong **3** Pulau Sembilan.

## Results

### Systematics

### Stichopodidae Haeckel, 1896

*Stichopus* Brandt, 1835

**Type species.** *Stichopus chloronotus* Brandt, 1835

**Diagnosis.** Peltate-shaped tentacles at ventral mouth with quadrangular shaped body. Flattened ventral sole with tube feet in ambulacra area. Papillae conspicuous. No cuvierien tubules and no anal teeth or traceable papillae around the cloacal opening. Gonads in two tufts, one at each sides of the dorsal mesentery. Spicules primarily tables, branched rods and C-shaped rods (Clark and Rowe 1971).

**Species composition.** This genus consists of 14 species. *Stichopus chloronotus* Brandt, 1835; *Stichous ellipes* Clark, 1938; *Stichopus herrmanni* Semper, 1868; *Stichopus horrens* Selenka, 1867; *Stichopus ludwigi* Erwe, 1913; *Stichopus monotuberculatus* (Quoy & Qaimard, 1834); *Stichopus naso* Semper, 1868; *Stichopus noctivagus* Cherbonnier, 1967; *Stichopus ocellatus* Massin, Zulfigar, Hwai & Boss, 2002; *Stichopus pseudohorrens* Cherbonnier, 1967; *Stichopus quadrifasciatus* Massin, 1999; *Stichopus rubermaculosus* Massin, Zulfigar, Hwai & Boss, 2002; *Stichopus fusiformiossa* sp. n. Woo; *Stichopus vastus* Sluiter, 1887

**Remarks.** The common characteristics of this genus include gonads with two branching tufts (which is a taxonomic character for the family Stichopodidae) and the presence of tables, C-shaped, and S-shaped rod spicules in the tissue (Clark and Rowe 1971). The distribution of the genus *Stichopus* was throughout the tropical and subtropical waters of the Indo-West Pacific region (Clark and Rowe 1971).

### *Stichopus chloronotus* Brandt, 1835

Figs 2–3

*Holothuria (Holothuria) quadrangularis* Lesson, 1830: 90, pl 31, fig. 1.
*Stichopus* (*Perideris*) *chloronotus* Brandt, 1835: 250.
*Stichopus chloronotus*; Selenka 1867: 315, pl. 17, figs 20–24; 18, fig. 25; Pearson 1903: 204; Panning 1944: 30, fig. 3a–e; Loi and Sach 1963: 238, pl. 1, fig. A, pl. VI, fig. 1; Clark and Rowe 1971: 178, pl. 27, fig. 18; Mary Bai 1980: 16, fig. 101; Tan Tiu 1981: 65, pl. 7, figs 1–3; Clark 1984: 99; Féral and Cherbonnier 1986: 94; Cannon and Silver 1986: 27, fig. 4h; Cherbonnier 1988: 146, fig. 60A–O; James and James 1994: 12, pl. VI; Kerr 1994: 163; Rowe and Gates 1995: 323; Massin et al. 2002: 74, figs 1–2, pl. 1A.
*Stichopus cylindricus* Haacke, 1880: 47.
*Stichopus chloronotus* var. *fuscus* Pearson, 1903: 204.

*Stichopus hirotai* Mitsukuri, 1912: 161.
*Holothuria viridis* Cherbonnier, 1952: 19–21, fig. 7.

**Material examined.** Five specimens: USM/MSL/PB004, USM/MSL/PB005, USM/MSL/PB006, USM/MSL/PB007, USM/MSL/PP005.

**Type locality.** Lugunor Islands, Guam.

**Description.** External morphology: Body quadrangular in cross-section with four distinctive sides; smooth, firm, and hard, indicating thick integument; dark blue in colour underwater and almost black out of water (Fig. 2). Large and long papillae at dorso-lateral edge running from collar of tentacles toward anus in two rows; similar papillae at ventro-lateral edge but in one single row; tip to base of papillae yellow to ochre in colour. Ambulacral areas with tube feet and narrow interambulacra; central ambulacrum wider compared to other two ambulacra. Oral opening with 20 peltate tentacles on ventral side; anus at terminal.

Spicules: Dorsal body wall with tables, C-shaped rods, and S-shaped rods (Fig. 3A–C). Tables abundant in dorsal body wall; base smooth with four large central perforations and 4–10 smaller peripheral holes; four pillars forming spires, joined with one crossbeam; tip of each pillar spiny. C-shaped rods smooth with sharp endings; some being irregular in form. S-shaped rods derived from C-shaped rods present. Dorsal papillae bearing C-shaped rods, S-shaped rods, elongated rods, and tables (Fig. 3D–G). Tables in dorsal papillae with large disc, four central perforations, and multiple peripheral holes; pillars joined by one, sometimes incomplete, crossbeam; tip of pillars with multiple large spines. Ventral tube feet bearing plates, thick rods, tables, and C-shaped rods (Fig. 3H–J). Large plates in ventral tube feet having distinctive larger central perfo-

**Figure 2.** *Stichopus chloronotus* Brandt, 1835 (USM/MSL/PB004), dorsal (**A**) and ventral (**B**) views.

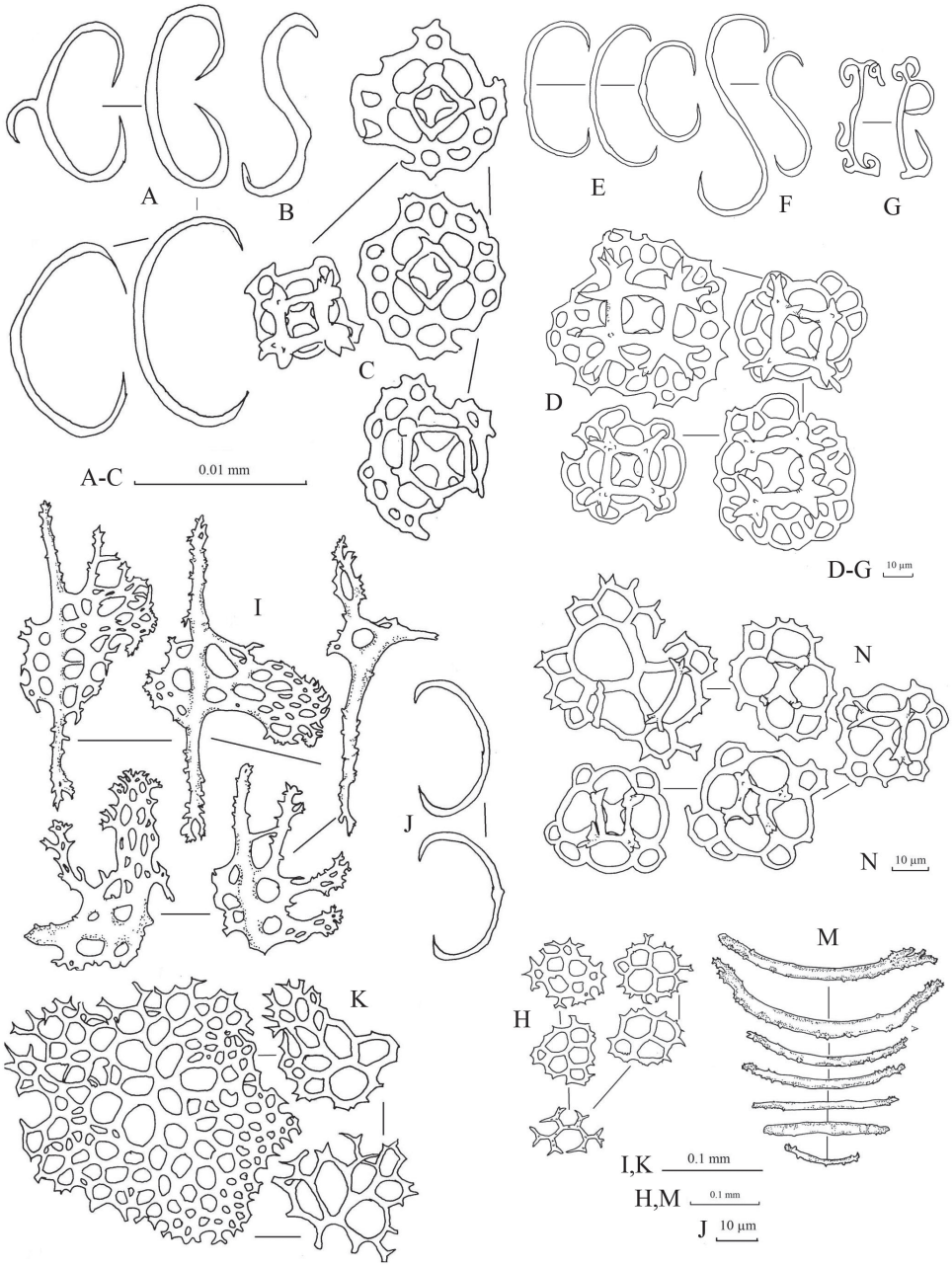


**Figure 3.** Spicules of *Stichopus chloronotus* Brandt, 1835 (USM/MSL/PB004). **A** C-shaped rods from the dorsal body **B** S-shaped rods from the dorsal body wall **C** tables from the dorsal body wall **D** table with large base from the dorsal papillae **E** C-shaped rods form the dorsal papillae **F** S-shaped rods from the dorsal papillae; G rosettes from the dorsal papillae **H** tables from the tube feet **I** large rods with central perforations from the tube feet **J** C-shaped rods from the tube feet **K** perforated plates from the tube feet **L** reduced tables from the tube feet **M** rods from the tentacles **N** tables from the tentacles.

rations; numerous smaller peripheral holes distributed over plates. Other smaller plates in ventral tube feet having perforations similar in size to each other. Edges of plates in ventral tube feet jagged but less pointy and sharp. Tables in ventral tube feet having reduced pillars or no pillar; one crossbeam incompletely joining all pillars; four central perforations with less peripheral holes compared to tables from dorsal body. Rods in ventral tube feet with 0–3 (mostly one) perforation(s) at central extension (Fig. 3I). Tentacles with tables and rods. Tables in tentacles reduced to only disk without pillars, with four central perforations surrounded by smaller peripheral holes; similar to tables in dorsal body wall (Fig. 3F). Rods in tentacles in various sizes, with spiny and rough surface; smaller rods straight while larger rods slightly curved (Fig. 3L).

**Remarks.** *Stichopus chloronotus* is fairly easy to be identified in situ due to the bright, distinctive green-blue colouration on the body with yellowish coloured papillae (Fig. 2A), although there are some colour variations in the papillae across different localities (Massin et al. 2002). This species is distinguished from the other congeneric species also by its smooth body.

Large spicules with elaborated sculpted surface in the tentacles reported from Madagascar by Cherbonnier (1988) were not found in our specimens. This type of spicule is also missing from other descriptions by Théel (1886), Massin (1996) and Massin et al. (2002).

**Distribution.** This is a common species found throughout the Indo-West Pacific area (Clark and Rowe 1971).

### ***Stichopus herrmanni*** **Semper, 1868**

Figs 4–5

*Stichopus variegatus Herrmanni* Semper, 1868: 73.
*Stichopus variegatus*; Cherbonnier 1947: 187–189, fig. a–c; Féral and Cherbonnier 1986: 98.
*Stichopus herrmanni*; Massin 1999: 63, fig. 52.

**Material examined.** Four specimens: USM/MSL/PSEM 001, USM/MSL/PSEM002, USM/MSL/PSEM003, USM/MSL/PP004.

**Type locality.** Philippines.

**Description.** External morphology: Large body with quadrangular cross-section with four distinctive sides; firm, rugose, and having thick folding surfaces. Uniformly greyish brown on dorsal side; light brown to yellowish on ventral body with an orange patch spreading from mid ventral body to anterior ventral body. Two rows of small and short papillae on dorso-lateral edges; papillae absent on ventro-lateral edges; tip of papillae brown; base grey-coloured. Numerous, smaller, brown-tipped papillae spreading across dorsal body. Laterally, papillae being lesser in number and density. Ring of minute papillae surrounding oral opening. Tube feet numerous in ambulacra areas. Central ambulacrum occupying more rows of tube feet compared to other two am-

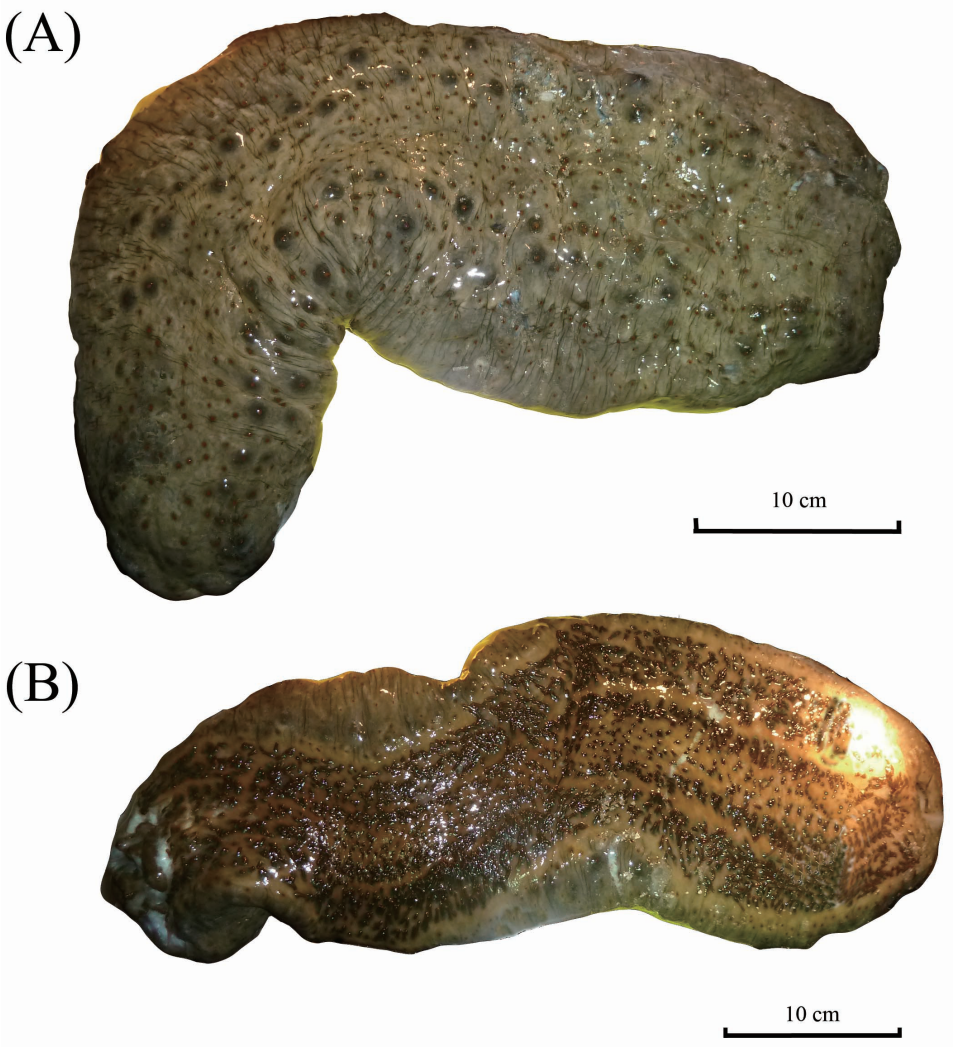


**Figure 4.** *Stichopus herrmanni* Semper, 1868 (USM/MSL/PSEM004), dorsal (**A**) and ventral (**B**) views.

bulacra areas. Narrow interambulacra areas without tube feet. Twenty peltate-shaped tentacles. Anus terminal.

Spicules: Dorsal body mainly tables, C-shaped rods, rosettes, and pseudo tables (Fig. 5A–D). Table spicules in dorsal body have rounded to quadrangular in shape bases, with four central perforations and numerous peripheral holes; three or four short pillars forming spires connected by a cross beam; tip of pillars with thorny crown endings (Fig. 5A). Rosettes in dorsal body abundant with various shapes and sizes; simple to complex bifurcation on both ends (Fig. 5C). Pseudo tables in dorsal body have four pillars extending from reduced base; no disk formed at base (Fig. 5D). Papillae consist of tables, C-shaped rods, and rosettes (Fig. 5E–G). Base of tables in papillae with rough

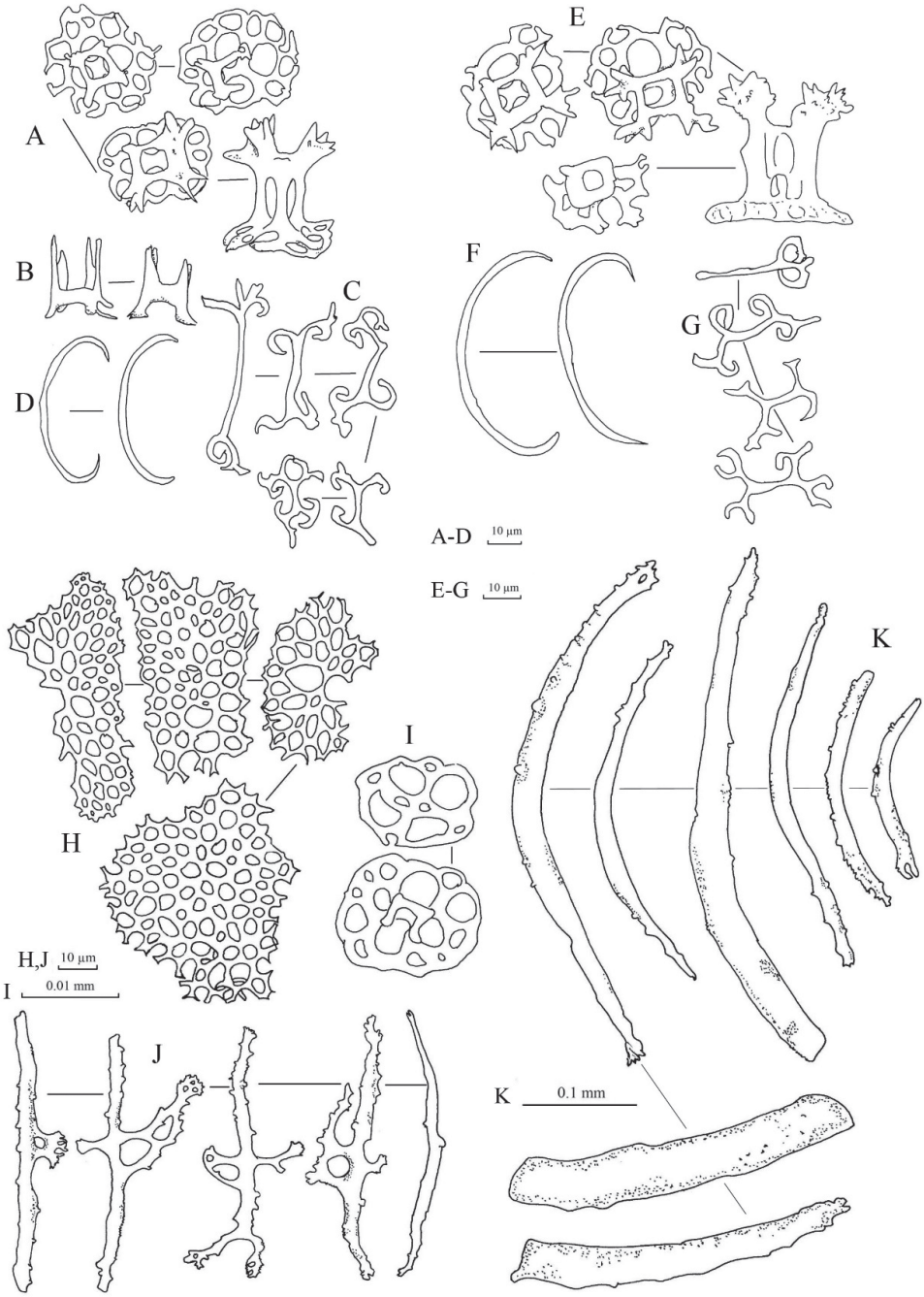


**Figure 5.** Spicules of *Stichopus herrmanni* Semper, 1868 (USM/MSL/PSEM004). **A** tables from the dorsal body **B** pseudo tables from the dorsal body wall **C** rosettes from the dorsal body wall **D** C-shaped rods from the dorsal body wall **E** tables from the dorsal papillae **F** C-shaped rods from the dorsal papillae **G** rosettes from the dorsal papillae **H** large multiperforated plates from the tube feet **I** reduced tables from the tube feet **J** rods with central perforations from the tube feet **K** rods of different sizes from the tentacles.

rims; four pillars with multiple spines on the tip erected from disc; four central holes on the disc with 2–3 peripheral holes. C-shaped rods and rosettes in papillae similar to those in dorsal body. Tube feet have large perforated plates, rods, and reduced tables (Fig. 5H–J). Perforated plates in tube feet in rectangular and square shapes, jagged and pointy rims (Fig. 5H). Rods in tube feet with central extended perforations (Fig. 5J); surface covered with spinelets. Reduced tables of tube feet have base with four central perforations and 5–8 peripheral holes; reduced pillars liken knobs formed at central of base; rim of base being smooth (Fig. 5I). Tentacles containing rods of different sizes with rough surfaces covered with spinelets; slightly bended (Fig. 5K).

**Remarks.** *Stichopus herrmanni* is originally described as a subspecies of *Stichopus variegatus* before Rowe and Gates (1995) reclassify and accorded *S. herrmanni* a species status. *Stichopus herrmanni* is closely related to *Stichopus monotuberculatus* (Quoy & Gaimard, 1833) but the papillae of *S. herrmanni* are clearly smaller and less conspicuous than those of *S. monotuberculatus*. Massin et al. (2002) noted that rosette spicules in *S. herrmanni* were highly variable in size and abundance. The presence of pseudo-tables found in the dorsal body of our *S. herrmanni* specimens was the first to be reported for the genus *Stichopus*. Pseudo-tables has only been found in *Thelenota* within the family Stichopodidae (Cherbonnier and Féral 1984; Cherbonnier 1988; Massin and Lane 1991; Massin 1999). It is not certain whether this spicule is commonly occurring in this species of different localities. Pseudo-tables can be used to distinguish *S. herrmanni* from other congeners if they are consistently present in specimens from other localities.

**Distribution.** Throughout the Indo-West Pacific (Clark and Rowe 1971).

### ***Stichopus horrens*** **Selenka, 1867**

Figs 6–7

*Stichopus horrens* Selenka, 1867: 316; Panning 1944: 35; Loi and Sach 1963: 238, pl. 1, fig. B, C, pl. VI, Fig. 2; Cannon and Silver 1986: 27, figs 2d, 7g; Féral and Cherbonnier 1986: 96; Cherbonnier 1988: 147, fig. 61A–P; Rowe and Gates 1995: 324; Gosliner et al. 1996: 281, fig. 1033; Byrne et al. 2010: 1077, fig. 2A–D, fig. 3B–D.

*Stichopus godeffroyi* Semper, 1868: 75, pl. 30, fig. 4; Sluiter 1901: 31.

*Stichopus godeffroyi* var. *pygmaeus* Semper, 1868: 75; Lampert 1885: 105; Ludwig 1888: 812.

*Stichopus tropicalis* Fisher, 1907: 676, pl. 70, fig. 1a–i.

**Material examined.** Four specimens: USM/MSL/PP001, USM/MSL/PP002, USM/MSL/PP003, USM/MSL/PP006.

**Type locality.** Society Islands, French Polynesia

**Description.** External morphology: Body slightly sub quadrangular in cross-section, with firm and rough surface; wrinkles on mid-dorsal area. Dominantly dark brown and yellowish in colour, with sporadic whitish-brown patches (Fig. 6). Papillae

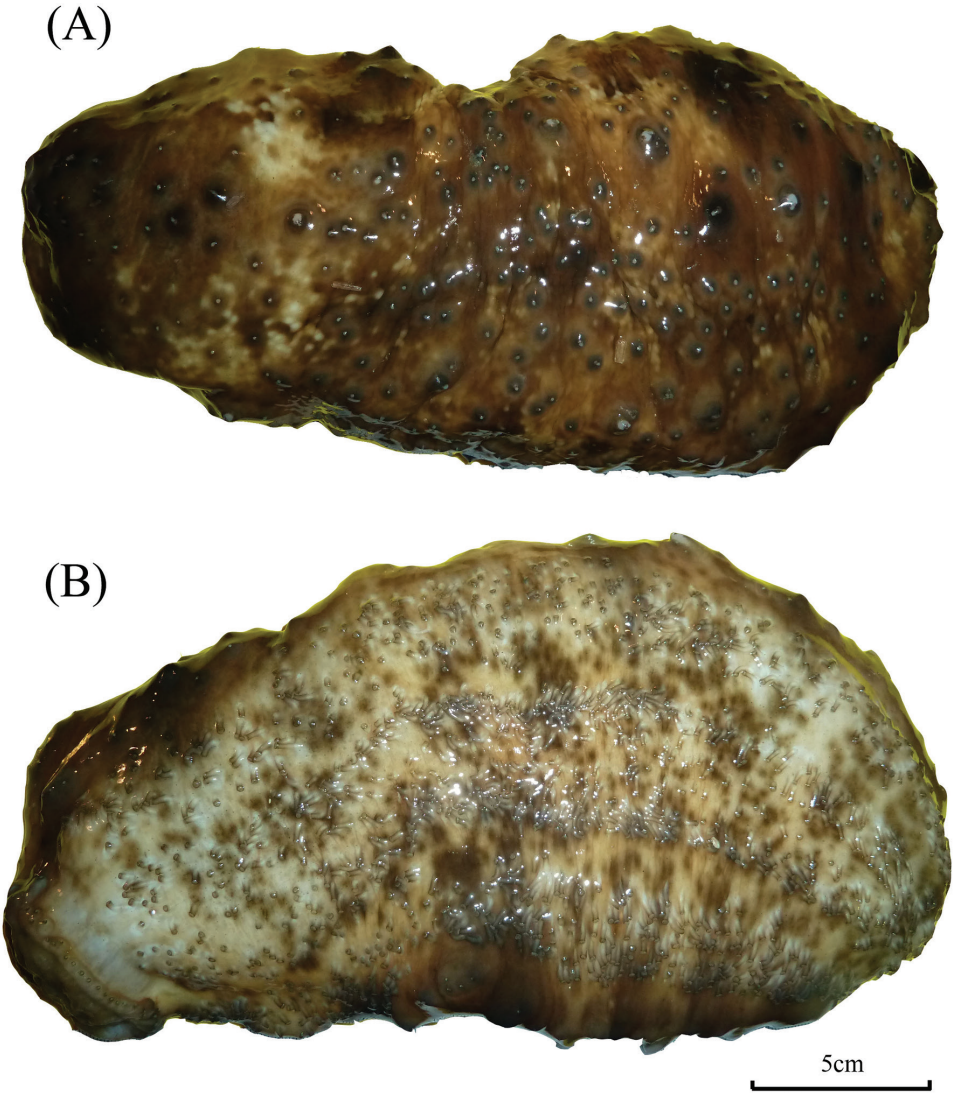


**Figure 6.** *Stichopus horrens* Selenka, 1867 (USM/MSL/PP001), dorsal (**A**) and ventral (**B**) views.

scattered across dorsal surface with larger papillae along dorso- and ventro-lateral areas; base of papillae dark grey, apex white. Ring of small papillae surrounding oral opening. Tube feet restricted in three ambulacra areas, with mid ambulacrum being wider with more rows of tube feet but a gap of lesser tube feet density in middle area of mid ambulacrum. Cream-white background colour with patches of brown dots across ventral body. Twenty peltate tentacles. Anus terminal.

Spicules: In dorsal body, numerous tables and C-shaped rods spicules. Tables in dorsal body with four central perforations, 9–21 peripheral holes around smooth-surfaced

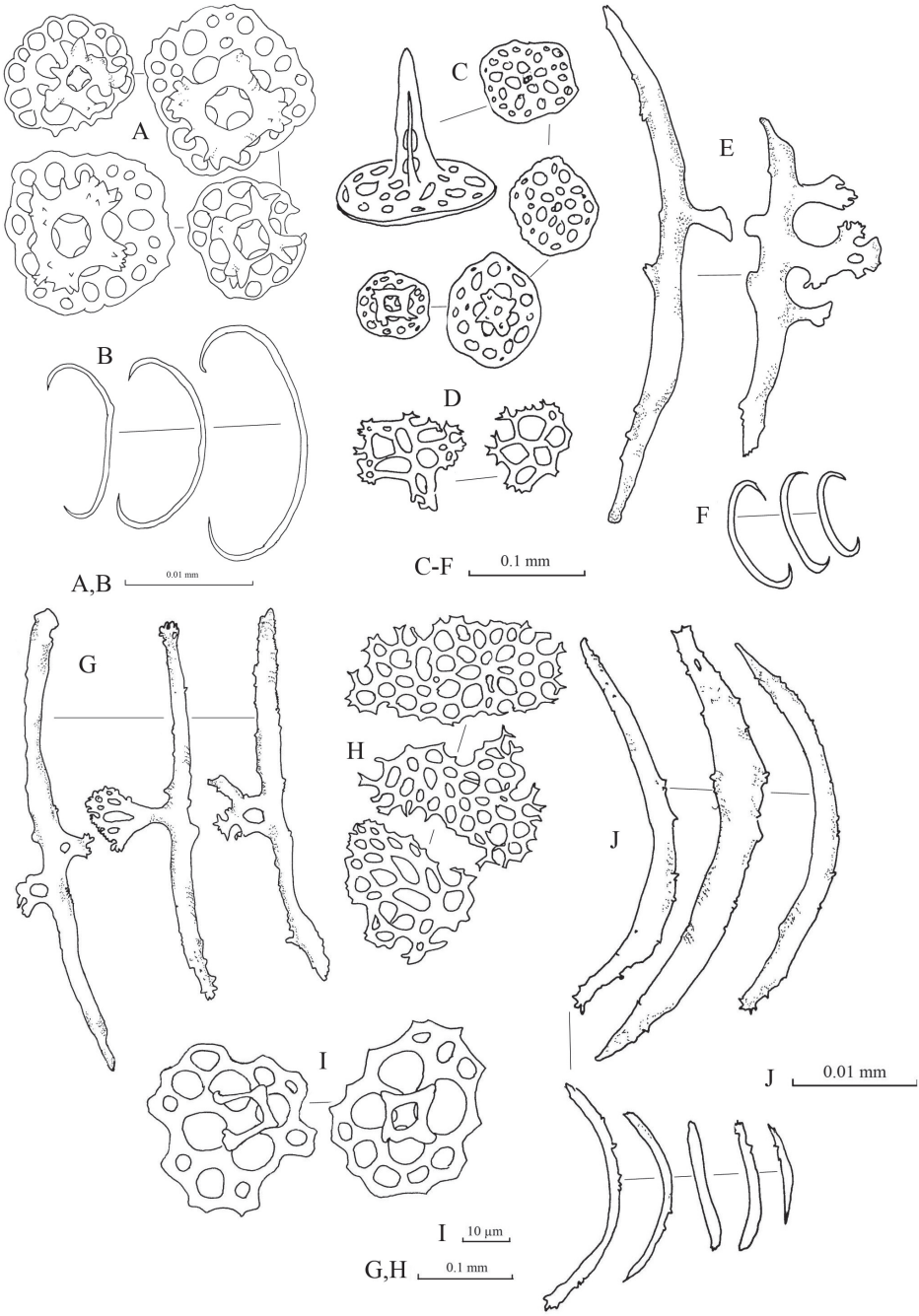


**Figure 7.** Spicules of *Stichopus horrens* Selenka, 1867 (USM/MSL/PP001). **A** tables from the dorsal body wall **B** C-shaped rods from the dorsal body wall **C** tack-liked tables from the dorsal papillae **D** perforated plates from the dorsal papillae **E** dorsal papillae rods from the dorsal papillae **F** C-shaped rods from the dorsal papillae **G** large rods from the tube feet **H** multiperforated plates from the tube feet **I** tables from the tube feet **J** Rods of different sizes from the tentacles.

base; four pillars with moderate heights forming spires joined with one crossbeam, tip of spires with large spines (Figure 7A–B). Spicules in dorsal papillae comprised of tack-liked tables, rods, C-shaped rods, and perforated plates (Fig 7C–F). Four pillars erected and fused at tips forming tall spire from middle of base (Fig. 7C). Large rods have rough surface and tiny spines on surface, especially at both ends; central perforations can be elaborate or simple (Fig. 7E). Perforated plates in papillae have jagged rims and 6–12 irregular holes; smaller in size than those of tube feet. Tube feet with large rods, multi-perforated plates, and tables (Fig. 7G–I). Large rods have central plate with perforations; rod surfaces rough and covered with spinelets (Fig. 7G). In tentacles, spicules consist of rods in different size and thickness (Fig. 7J). All rods have rough surface and spinelets; slight curves in larger rods while smaller appeared straight.

**Remarks.** This species exhibits diverse body colours in specimens from different localities. Clark (1922) noted specimens from the Hawaiian Islands were dark olive-green, mottled with deep brownish-green in colour, which were not seen in specimens from the Torres Strait. Domantay (1953) remarked that the colour of this species changes with age. The species *S. horrens* look very similar to *S. fusiformiossa* sp. n. but are readily distinguishable by the presence of tack-like spicules on the papillae of *S. horrens* and the absence of fusiform spicules on the tentacles in *S. horrens.* Detailed characters distinguishing these species are provided in the section describing *S. fusiformiossa* sp. n.

**Distribution.** Society Islands, Galapagos, Indian Ocean, Bay of Bengal, South China Sea, Southern Japan, Papua New Guinea, Philippines, Australia, Hawaii to New Caledonia.

### ***Stichopus vastus*** **Sluiter, 1887**

Figs 8–9

*Stichopus vastus* Sluiter, 1887: 198, pl. 2, figs 46–48; Rowe and Gates 1995: 326; Massin 1999: 71, figs 57a–l, 58a–m, 29a–g, 60a–d, 61, 112d,e; James 1998: 13, fig. 1; Massin et al. 2002: 92, pl. 2E, F, figs 12, 13.

*Stichopus* spec; Colin and Arneson 1995: 262, fig. 1242; Gosliner et al. 1996: 282, fig. 1039.

*Stichopus "variegatus"*; Colin and Arneson 1995: 262, fig. 1240.

**Material examined.** One specimen, USM/MSL/PLAN001.

**Type locality.** Java, Indonesia.

**Description.** External morphology: Body slightly quadrangular in cross-section, without distinct edges. Body surface smooth and tough. Black deep depression lines on dorsal body; dorsal background brown colour with numerous darker brown strips transverse and encircles the base of papillae. Two rows of large papillae with very low protrusion on dorsal body. Tube feet only in ambulacral areas; median tube feet twice wider than those in other two ambulacral areas; narrow interambulacral areas clearly

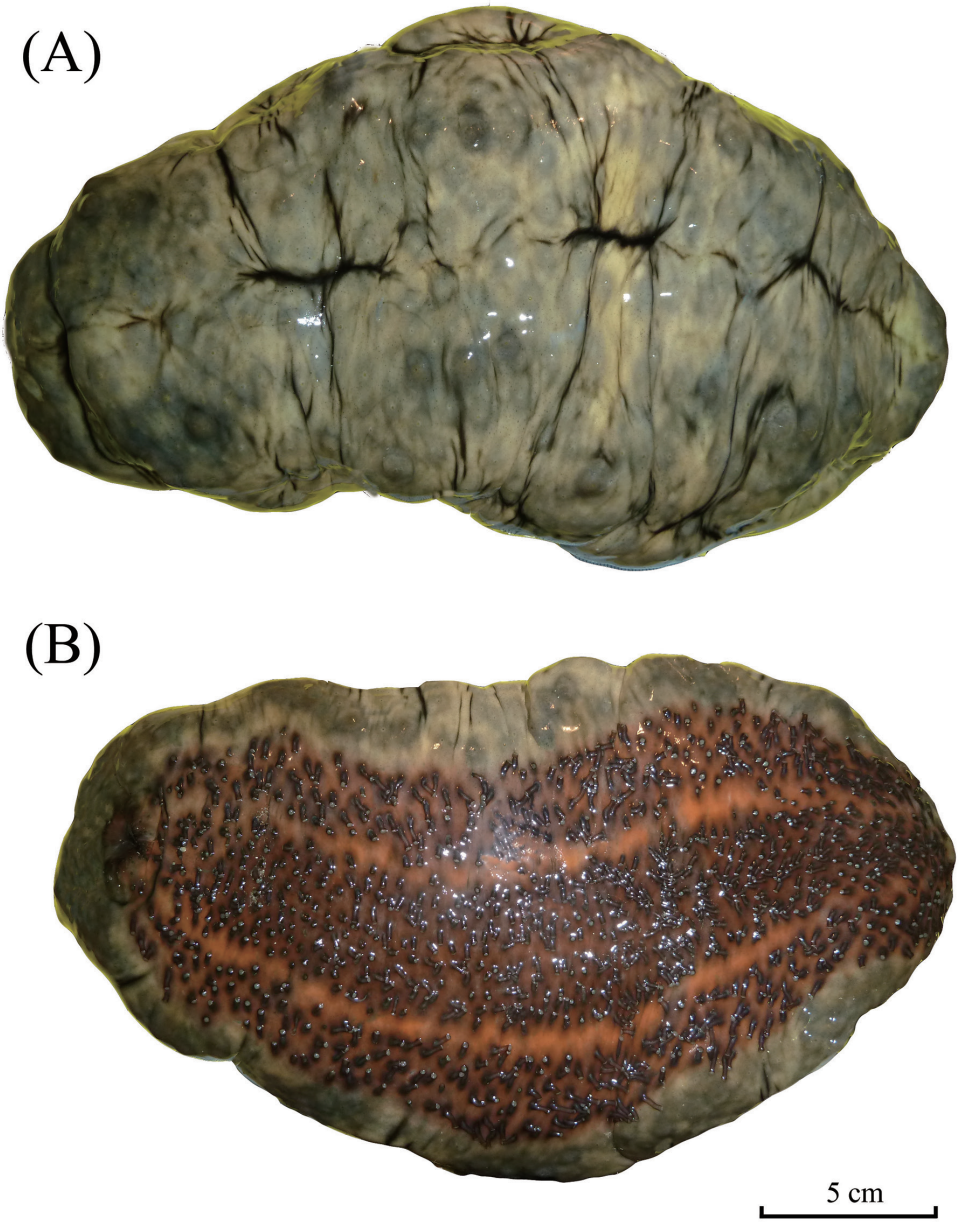


**Figure 8.** *Stichopus vastus* Sluiter, 1887 (USM/MSL/PLAN001), dorsal (**A**) and ventral (**B**) views.

separates each ambulacrum area. Reddish brown background colour on ventral side with lighter yellowish-brown on interambulacral areas. Ventral mouth with 18–20 peltate tentacles surrounded by ring of minute papillae at oral opening (Fig. 8).

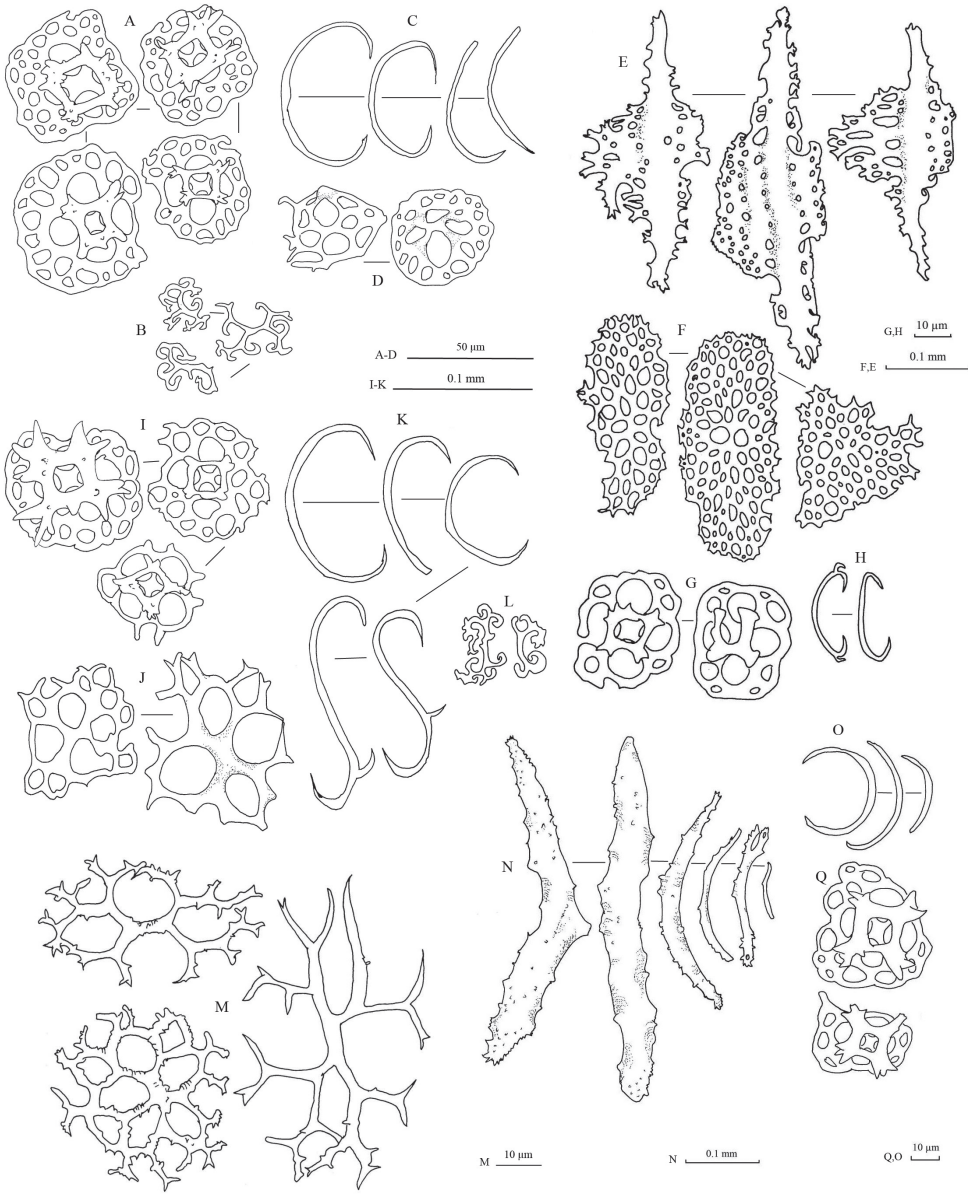


**Figure 9.** Spicules of *Stichopus vastus* Sluiter, 1887 (USM/MSL/PLAN001). **A** Large tables from the dorsal body wall **B** rosettes from the dorsal body wall **C** C-shaped rods from the dorsal body wall **D** reduced tables from the dorsal body wall **E** rods with large perforated central plate from the tube feet **F** multiperforated plates from the tube feet **G** tables from the tube feet **H** C-shaped rods from the tube feet **I** tables from the dorsal papillae **J** large reduced tables from the dorsal papillae **K** C-shaped and S-shaped rods from the dorsal papillae **L** rosettes found from the dorsal papillae **M** large perforated plates from the dorsal papillae **N** rods from the tentacles **O** C-shaped rods from the tentacles **Q** tables from the tentacles.

Spicule: Tables, C-shaped rod, and rosette spicules present in dorsal body (Fig. 9A–D). Tables in dorsal body with large quadrangular base, four central perforations, and 15–27 smaller peripheral holes; four pillars forming spire from the central of the base with a cross beam connecting them; tip of pillars with multiple thorny spines (Fig. 9A). Reduced tables in dorsal body having similar structure to the base of tables but lack pillars; slightly raised surface on the central (Fig. 9D). Spicule of papillae consists of tables, reduced tables, C-shaped rods, rosettes, and perforated plates (Fig. 9I–M). Tables in papillae similar to those in dorsal body; some with larger thorns on pillar apexes (Fig. 9I). Some C-shaped rods were modified liken S-shaped rods with protrusion at the middle body (Fig. 9K). In ventral tube feet, centrally-perforated rods, perforated plates, tables, and C-shaped rods (Fig. 9E–H) present. Centrally-perforated rods in tube feet have conspicuous large central plate and multiple perforations of different sizes; surface rough and covered with spinelets (Fig. E). Oval- to square-shaped perforated plates; rim were not smooth and jagged (Fig. 9F). Tables in tube feet have small base disc with four main central holes and 5–8 peripheral holes; four pillars erected from central of base with thorny crowns on the tip, but do not extend out of base (Fig. 9G). Small C-shaped rods in tube feet (Fig. 9H). Spicules of tentacles consists of rods, perforated plates, tables, and C-shaped rods (Fig. 9N–Q). Curved rods in tentacles in multiple different sizes; rough surface covered with spinelets especially dense at both ends. Perforated plates in tentacles spiny, rough surface covered with spinelets; some likens dichotomous rods (Fig. 9M). Tables and C-shaped rods in tentacles similar to ones found in the papillae (Fig. 9O, Q).

**Remarks.** *Stichopus vastus* is the only species in *Stichopus* that have elaborate reticulated stripes covering the dorsal body with different density and intensity (Fig. 8). Massin (1999) and Massin et al. (2002) demonstrated this coloration varies for specimens from across different localities. The black transverse line in the area between bulges is also unique to this species. Massin et al. (2002) mentioned S-shaped rods were found in the dorsal body in small specimens, and the absent in larger specimens (>160 mm in body length). C-shaped rods in the tentacles of the present specimens were also mentioned by Cherbonnier and Féral (1984) but not by Massin (1999) and Massin et al. (2002). Prominent large perforated plates found in the dorsal papillae have not been reported from this species and they look like dichotomous branching rods found in the tentacles.

**Distribution.** Indian Ocean, Andaman Islands, South China Sea, Indonesia, Thailand, Flores Sea, Great Barrier Reef Australia, Micronesia, Palau, Papua New Guinea (Clark and Rowe 1971; Massin et al. 2002).

### ***Stichopus fusiformiossa*** **Woo, sp. n.**

http://zoobank.org/76607F6A-8FF8-4FDA-A5AD-DA0BD359381C
Figs 10–14

**Material examined.** Three specimens: Holotype, USM/MSL/PSS001, collected from Pulau Songsong (5°48'31.2"N, 100°17'38.0"E ), Kedah, Malaysia, 6m depth, on sand,

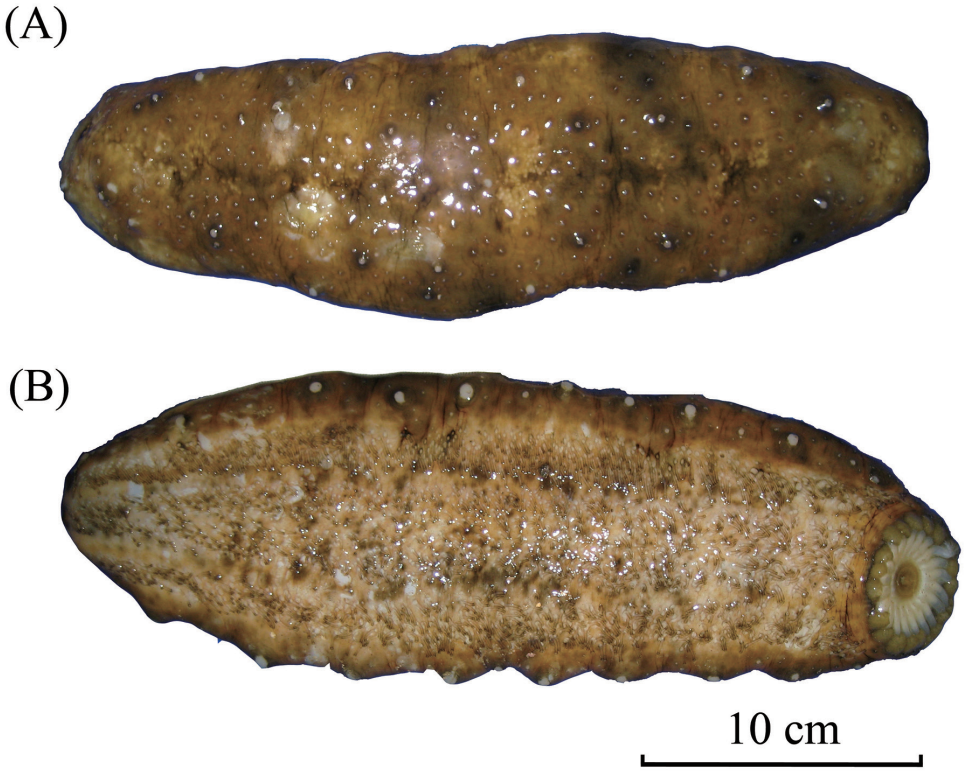


**Figure 10.** *Stichopus fusiformiossa* sp. n. (USM/MSL/PSS001), dorsal (**A**) and ventral (**B**) views.

fixed in 99% ethanol. Paratype 1, USM/MSL/PSS002, collected from Pulau Songsong (5°48'31.2"N, 100°17'38.0"E ), Kedah, Malaysia, 8m depth, on sand, fixed in 99% ethanol. Paratype 2, USM/MSL/PP003, collected from Pulau Songsong (5°48'31.2"N, 100°17'38.0"E ), Kedah, Malaysia, 7m depth, on sand, fixed in 99% ethanol.

**Type locality.** Straits of Malacca, Malaysia: Pulau Songsong, Kedah, 05°48'31.2"N, 100°17'38.0"E, on sandy substrate adjacent to a reef area, at a depth of 6–8 m, collected by Woo SP and Zulfigar Y.

**Description.** External morphology: Body quadrangular in cross-section with slight rounded four sides. Body wall firm, rugose, and wrinkled surface; variously-sized tiny warts regularly-arranged on dorsal body (Fig. 10). Dorsal body brown in background colour, with patchy beige areas and black patches; latter usually running from anterior to posterior ends and concentrated in middle part of body, and absent in some specimens. Ventral body wall light beige background with two orange, narrow lines spreading from oral to aboral. Large dorsal papillae 0.5–1.0 cm in width at base in the holotype, but highly variable between specimens, more or less arranged in two continuous rows; smaller dorsal papillae scattered on dorsal body; colour of dorsal papillae black, with apex always white. Two rows of large (about 2 cm), white-coloured papillae aligned and arranged in straight line along ventro-lateral edges. Minute pa-

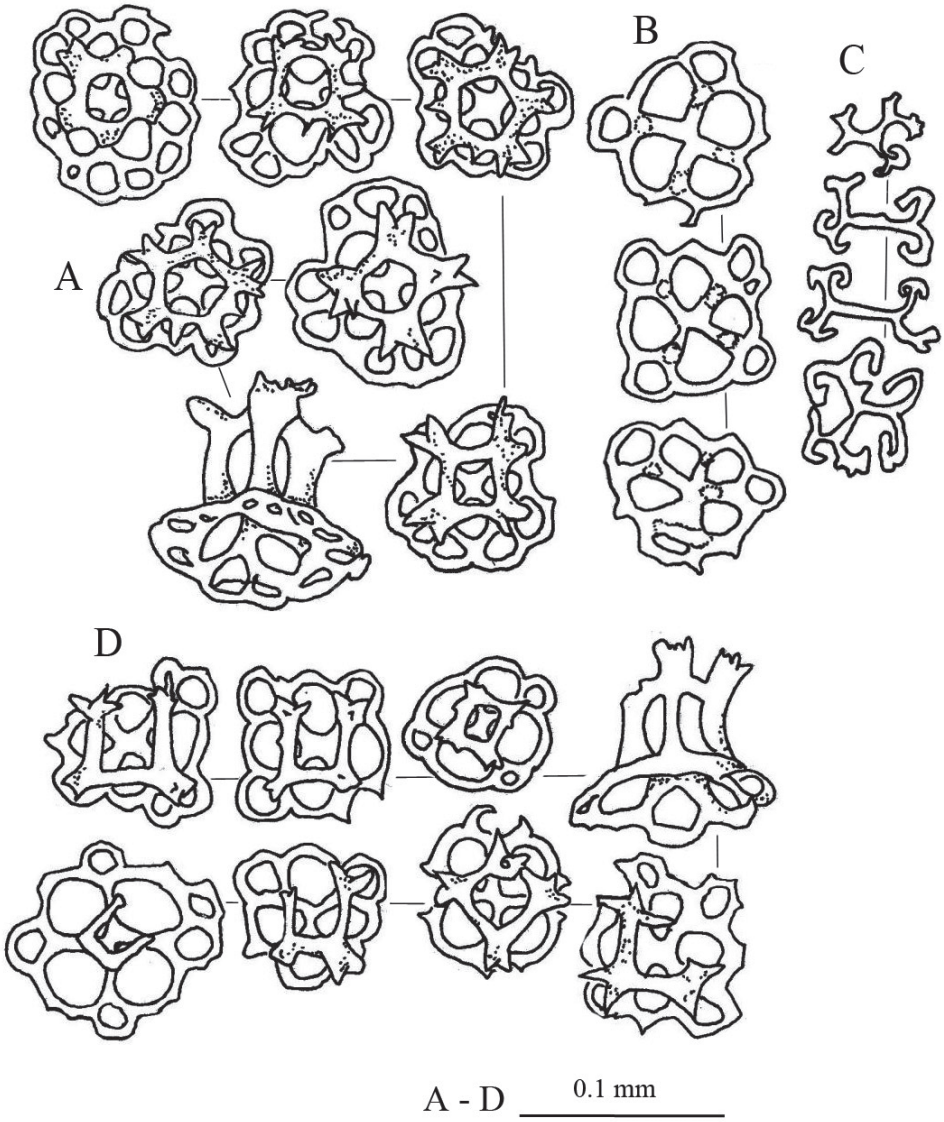


**Figure 11.** Spicules from the dorsal body wall of *Stichopus fusiformiossa* sp. n. (USM/MSL/PSS001). **A** tables with multiple perforations from the base of the dorsal body wall **B** reduced tables **C** rosettes **D** tables with limited number of perforations from the base of the dorsal body wall.

pillae forming ring surrounding oral opening. Tube feet in ambulacral areas, more numerous in central ambulacral areas than in lateral ones. Two interambulacral areas very narrow, with lesser number of tube feet. Tube feet fairly long, 3–5 mm in length. All specimens examined having 20 peltate-shaped tentacles. Anus terminal.

Spicules: Spicules in dorsal body consisting tables and rosettes (Fig. 11A–D). Many tables in dorsal body having large base with four central perforations and mul-

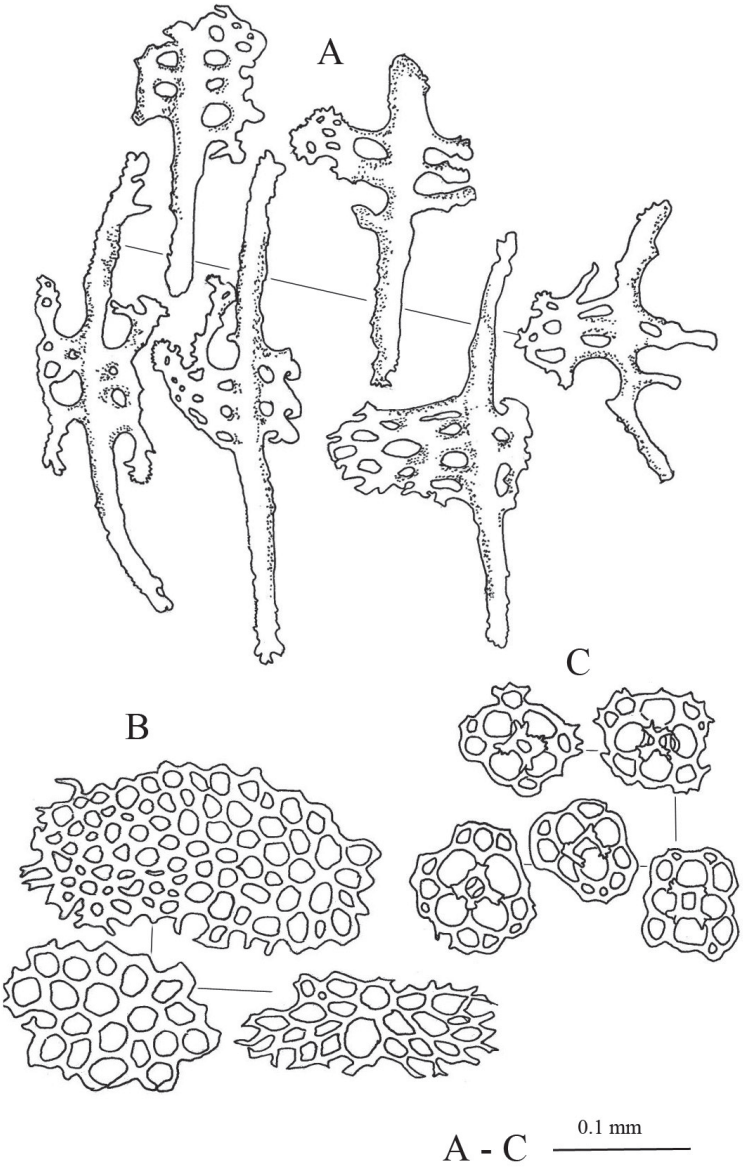


**Figure 12.** Spicules from the tube feet of *Stichopus fusiformiossa* sp. n. (USM/MSL/PSS001). **A** rods with large central perforated plates **B** large perforated plates **C** tables.

tiple peripheral perforations; four pillars erected from base forming a spire connected by a cross beam, with spines at the tip (Fig. 11A). Some tables in dorsal body having smaller base with less peripheral perforations; pillars connected incompletely with a crossbeam, tip of spire without crown of spines (Fig. 11D). Tables in dorsal body sometimes with pillars reduced to knobs and disc with four central perforations and limited peripheral perforations (Fig. 11B). Papillae consisting large tables, reduced

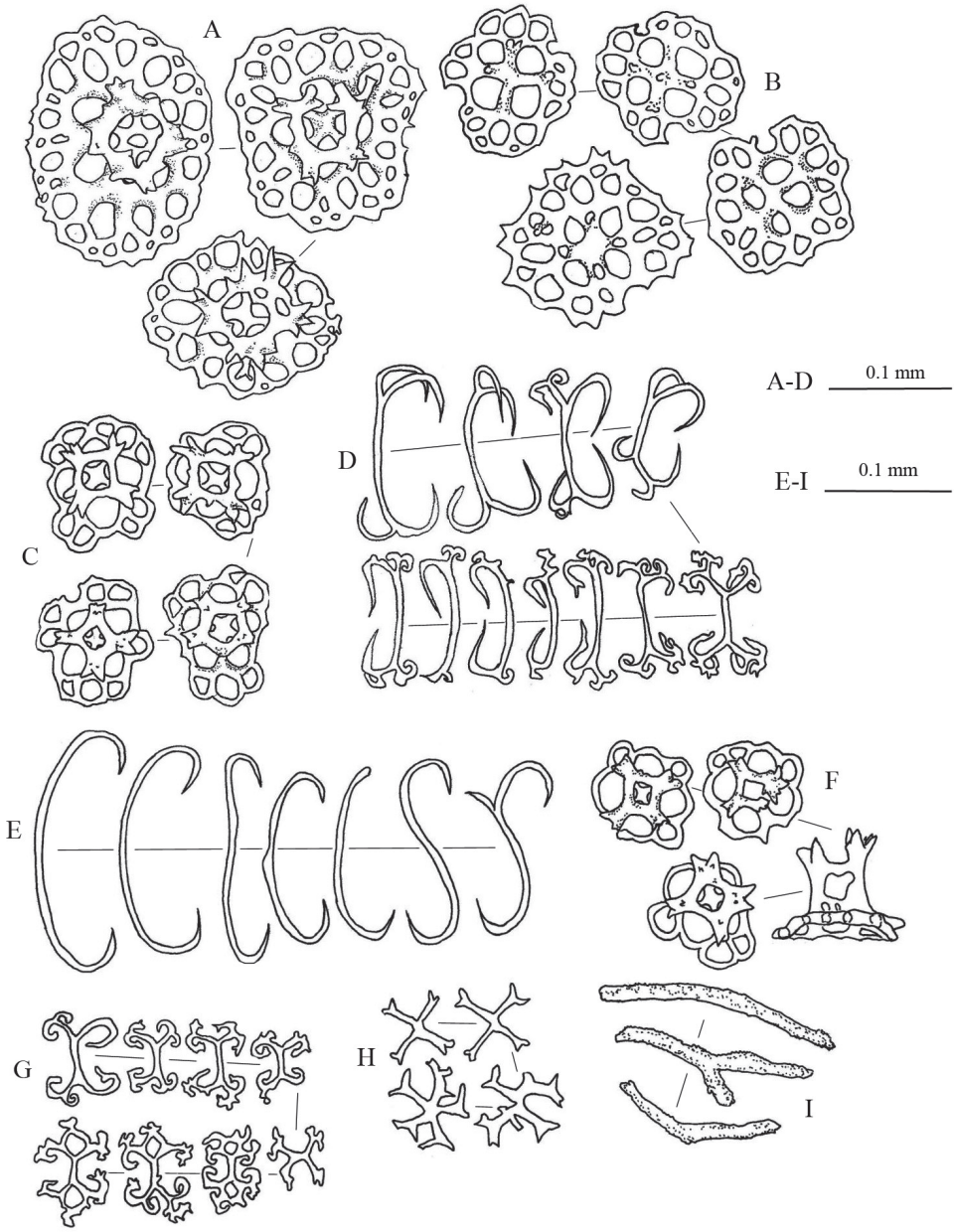


**Figure 13.** Spicules from papillae of *Stichopus fusiformiossa* sp. n. (USM/MSL/PSS001). **A** table with large base plates **B** reduced tables **C** tables **D** modified C-shaped rods **E** C-shaped rods **F** tables with smaller base plates and number of perforations **G** rosettes **H** X-shaped rods **I** rods.

tables, rosettes, C-shape rods, X-shaped rods, and rods (Fig. 13A–I). Large tables in papillae with multiperforated base disc; four pillars forming spire connected with a cross-beam, tip of pillar very spiny (Fig. 13A). Reduced tables in papillae larger compared to

reduced tables in dorsal body (Fig. 13B). Rosettes in papillae form simple curving to extensive bifurcations at both ends (Fig. 13D); smaller rosettes more complex in bifurcations (Fig. 13G). C-shaped rods in papillae simple, some modified to S-shaped rods (Fig. 13E). X-shaped rods in papillae have bifurcate endings in each arms; some with five arms (Fig. 13H). Rods in papillae with rough surface (Fig. 13I). Spicules in tube feet mainly large rods with perforated central plate, multiperforated plates, and tables (Fig. 12E–G). Surface of rods in tube feet rough, covered with spinelets; numbers and sizes of perforations on central plates of tube feet vary between rods. Tables in tube feet simpler compared to tables in dorsal body and papillae; tip of pillars less spinous and forming small crowns. Spicules in the tentacles consisting of fusiform spicules and rods (Fig. 11A, B). Fusiform spicules spindle-like in shape with dense spines interconnected to each other forming some hollow spaces in between (Fig. 14B). Rods in tentacles rough, slightly curved, and densely covered with spinelets at both ends.

**Remarks.** This new species looks very much like *S. horrens* in its body colouration. They both have similar, grey-brown background with irregular grey and black spots in colour. The live specimens of this species do not have very long papillae as observed in *S. horrens* reported by Rowe and Gates (1995) and Massin et al. (2002). *Stichopus fusiformiossa* also lacks tack-like table spicules in the papillae which are the definitive taxonomic feature for *S. horrens*. The prominent white and black colour of the papillae is distinctive to separate *S. fusiformiossa* from *S. rubermaculosus* with the red-coloured papillae, *S. quadrifasciatus* that has brown to red papillae tip, and from *S. chloronotus* with yellow-coloured papillae. Furthermore, *S. quadrifasciatus* has four transverse black-grey bands on the dorsal body wall, which are not seen in *S. fusiformiossa*. The sporadic arrangement of papillae on the dorsal body of *S. fusiformiossa* do not have consistent nor specific patterns as similarly observed in *S. horrens* in this study. However, the two rows of large, black papillae with white tip, arranged in a straight line along ventro-lateral edges are not seen in any other species.

*Stichopus fusiformiossa* lacks C-shaped rods in the dorsal body, which is commonly seen in the other *Stichopus* species. Reduced tables are found in the dorsal body in *S. fusiformiossa* and *S. herrmanni*, but the former lacks rosettes and C-shaped spicules that are present in the dorsal body of *S. herrmanni*. The C-shaped rods in the papillae of *S. fusiformiossa* are strongly modified and do not resemble to any spicules observed in the other *Stichopus* species except the C-shaped rods of *S. chloronotus* (Theel 1886; Sluiter 1887; Ludwig 1887; Mitsukuri 1912). But the colouration and arrangement of papillae easily separate *S. fusiformiossa* from *S. chloronotus*.

The X-shaped rods in the papillae of *S. fusiformiossa* have been only found in *S. variegatus* (now *S. herrmanni*) by Cherbonnier (1988). The X-shaped rods of *S. variegatus* (now *S. herrmanni*) are derived from rosettes (Cherbonnier 1988). Careful examination of his drawings (Cherbonnier 1988: fig. 62H) suggested that X-shaped rods of *S. fusiformiossa* were more rigid and angled compared to the curvy and slender ones of *S. variegatus* (now *S. herrmanni*).

The thick rods with rough surfaces seen in *S. fusiformiossa* are commonly found in the tentacles of any other species of *Stichopus.* Fusiform and spindle-liked spicules

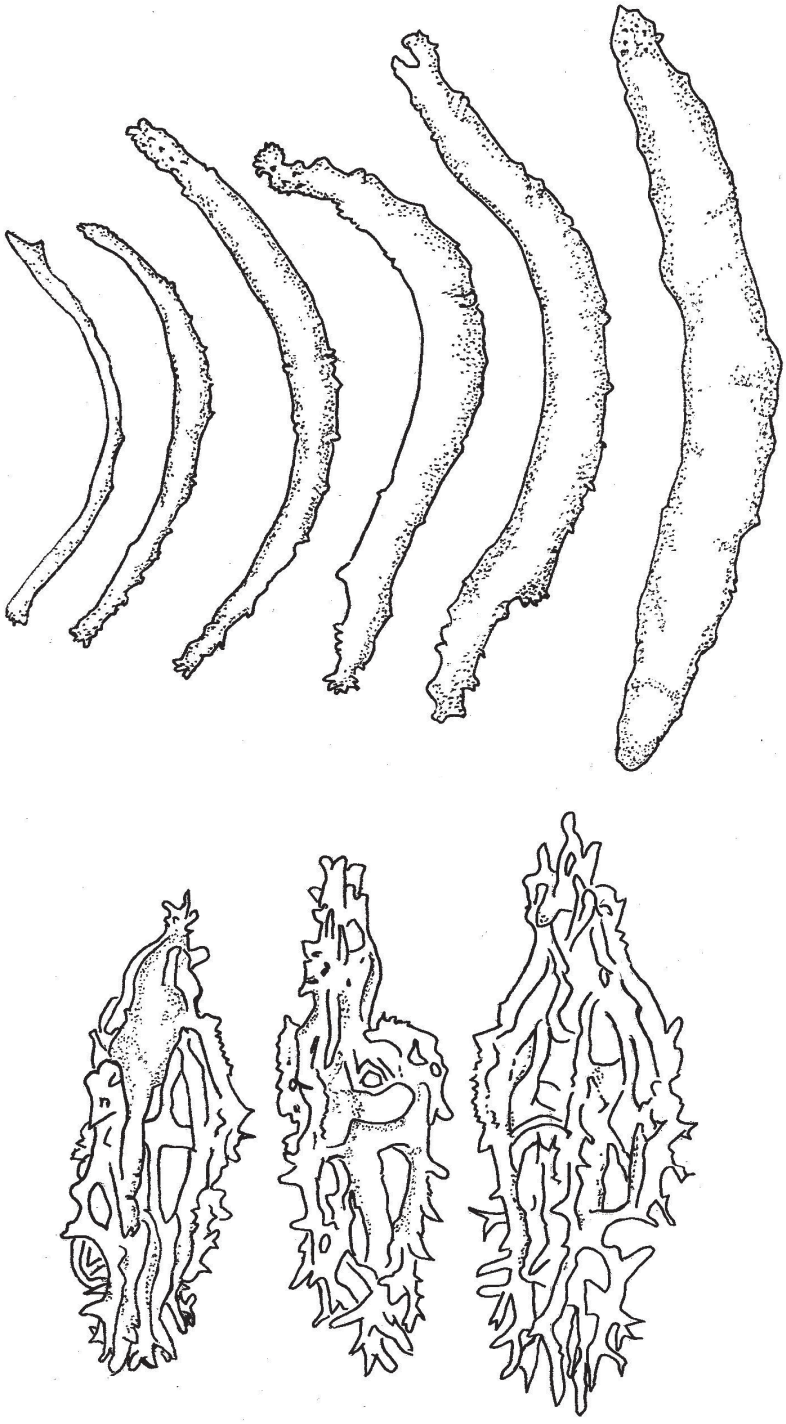

**Figure 14.** Spicules from the tentacles of *Stichopus fusiformiossa* sp. n. (USM/MSL/PSS001). **A** curved rods **B** fusiform spicules.

instead are rare and only shared with *S. variegatus* (now *S. herrmanni*) (Cherbonnier 1947, fig. C). Since *S. variegatus* had been separated to either *S. herrmanni* and *S. monotuberculatus* by Rowe and Gates (1995), the presence of fusiform and spindle-like spicules can be accorded to *S. fusiformiossa* as a character differentiating it from both *S. herrmanni* and *S. monotuberculatus* because both *S. herrmanni* and *S. monotuberculatus* lack the presence of this spicule. A reexamination of specimens of Cherbonnier (1947) collected from the Gulf of Oman, Madagascar, and the Red Sea are necessary to establish the correct species name of those specimens.

**Etymology.** The new specific name is a compound descriptive name from the combination of adjective-noun derived from the Latin words of fusiform (fusiformis) and bone (ossa). The name is nominative, neuter, and plural; referring to the distinctive fusiform and spindle-liked spicules found in the tentacles.

**Key to the species of *Stichopus* in Straits of Malacca**

| | | |
|---|---|---|
| 1 | Tack-liked tables present in dorsal papillae ..... | ***Stichopus horrens*** |
| – | Tack-liked tables absent in dorsal papillae..... | **2** |
| 2 | Fusiform spicules present in tentacles..... | ***Stichopus fusiformiossa*** |
| – | Fusiform spicules absent in tentacles..... | **3** |
| 3 | Uniform blue green colouration on dorsal body wall .... | ***Stichopus chloronotus*** |
| – | Beige, brownish to yellowish colouration on dorsal body. ..... | **4** |
| 4 | Elaborate reticulated stripes on the dorsal body wall ..... | ***Stichopus vastus*** |
| – | No stripy body wall ..... | ***Stichopus herrmanni*** |

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# A new species of *Amphictene* (Annelida, Pectinariidae) from the northern South China Sea

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## Abstract

Pectinariids are a family of polychaetes commonly found in shallow coastal waters around the world, but their diversity is poorly known along the coasts of Asia. Here we describe *Amphictene alata* **sp. n.** (Pectinariidae), based on 15 specimens collected from the coastal waters of Guangdong in the northern South China Sea. This new species can be distinguished from all other 13 described species and one described subspecies of *Amphictene* by having a pair of dorsolateral lobes on segment 3, a pair of large lateral lobes on segment 21, and more scaphal hooks (26 to 37 pairs).

## Keywords

Polychaete, taxonomy, systematics, Guangdong

## Introduction

Pectinariids, commonly called ice cream cone worms, are morphologically unique polychaetes with a cone-shaped tube which they build from sand grains, and a set of golden opercular paleae which they use for digging into soft sediment (Hartman 1941; Wolf 1984; Hutchings 2000; Rouse and Pleijel 2001). Currently five genera (*Amphictene*, *Pectinaria*, *Cistenides*, *Lagis* and *Petta*) are recognized in the family Pectinariidae (Fauchald 1977; Wolf 1984; Hutchings and Peart 2002).

*Amphictene* can be distinguished from other genera of Pectinariidae by having a cirrate dorsal opercular rim. Currently this genus has 13 recognized species and one recog-

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nized subspecies (Hutchings and Peart 2002; García-Garza and de León-González 2014). Among them only three species have been described from Asia: *A. moorei* (Annenkova, 1929) from the east coast of Russia, *A. japonica* (Nilsson, 1928) from Japan and *A. leioscapha* (Caullery, 1944) from Indonesia. The diversity of Pectinariidae is poorly known along the coasts of China, with only seven recorded species, some of which are South African or European species whose identities should be confirmed (Yang and Sun 1988; Sun and Qiu 2012). Here we describe a new species of *Amphictene* based on specimens collected from the coastal waters of Guangdong in the northern South China Sea.

## Material and methods

Specimens were collected during benthic ecology surveys conducted in Daya Bay and Honghai Bay of the northern South China Sea (Table 1). Sediment samples were collected using a 0.05 $m^2$ or 0.1 $m^2$ van Veen grab, and washed through a sieve with a 0.5 mm mesh size. Specimens were picked up from the sieve, fixed in 5% formalin and later transferred to 70% ethanol. Specimens were observed under a Carl Zeiss Stemi 2000-C dissecting microscope fitted with an AxioCam ICc 1 camera. Two paratypes were dehydrated using a Xiangyi CFD-10D freeze-dryer, gold coated with an EDT SC-150, and observed under a TESCAN CEGA 3 scanning electron microscope. Types are deposited in the following institutions: the Australian Museum, Sydney, Australia (AM); The Marine Biological Science Museum of the Chinese Academy of Sciences, Qingdao, China (MBM); The South China Sea Institute of Oceanology of the Chinese Academy of Sciences, Guangzhou, China (SCSMBC). The taxonomic terms defined by Hutchings and Peart (2002) are used for describing the species.

The following abbreviations are used in figure legends: op, opercular palea; or, opercular rim; cv, cephalic veil; pp, peristomial palp; tc, tentacular cirrus; br, branchia; dll, dorsal lateral lobes (segment 3); c1, chaetiger 1 (segment 5); c4, chaetiger 4 (segment 8); c10, chaetiger 10 (segment 14); sc, scaphe; sh, scaphal hooks; al, anal lobe; s21, segment 21.

## Results

**FAMILY Pectinariidae de Quatrefages, 1866**
**GENUS *Amphictene* Savigny in Lamarck, 1818**
**Type species. *Amphitrite auricoma* Müller, 1776**

***Amphictene alata* sp. n.**
http://zoobank.org/0DE5D0F9-FCF9-4FDF-A300-786BC1A0F88C
Figs 1–3, Table 1

**Material examined.** 15 type specimens, all collected from the silt-clay bottom of Daya Bay and Honghai Bay, Guangdong Province, China at 6 to 22.5 m depth (Table 1).

**Holotype:** MBM283388. **Paratypes:** MBM283389, MBM283390, MBM283391 and MBM283392, SCSMBC006677, SCSMBC006678, SCSMBC006679 (prepared for SEM), SCSMBC006680, SCSMBC006681, SCSMBC006682, SCSMBC006683 (prepared for SEM), AMW.48292, AMW.48293 and AMW.48294. Among them, SCSMBC006681 and SCSMBC006682 are incomplete with 14 anterior segments and 12 anterior segments, respectively. SCSMBC006679 and SCSMBC006683 are each broken into two fragments. Others specimens are complete.

**Etymology.** The specific name *alata* is derived from *ala*, a Latin word for wing. It refers to the pair of wing-shaped dorsal lateral lobes on segment 3, a distinctive feature for this species.

**Diagnosis.** Cephalic veil completely free from operculum forming dorsal semicircle around numerous peristomial palps. Rim of cephalic veil with 11 to 16 long cirri. Dorsal operculum raised with 20–25 marginal cirri. Comb-like branchiae present on segments 3 and 4. A pair of dorsal lateral lobes present on segment 3. Chaetigers 1 to 3 (segments 5 to 7) with notopodia and notochaetae only. Chaetigers 4 to 16 (segments 8 to 16) biramous with notopodia, neuropodia, notochaetae and neurochaetae. Notochaetae winged capillaries. Neurochaetal uncini with major teeth arranged in two to three rows. Segment 21 with a pair of large lateral lobes but without chaetae. Scaphe distinctly separated from abdomen, with 26–37 pairs of short hooks with a slightly curved tip.

**Description.** Preserved specimens pale cream to grey in colour. Body length of intact specimens including scaphe 16.0 to 50.7 mm, and greatest width at cephalic region 2.2 to 6.9 mm (Table 1). Cephalic veil completely free from operculum, forming dorsal semi-circular lobe surrounding numerous peristomial palps. Rim of cephalic veil with 11 to 16 long smooth cirri; cirri basally triangular, tapering to form terminal filament (Figs 1A, 2E, 3B). Doral opercular margin raised, crenulated with 8 to 13 triangular dorsal lappets and 5 to 6 pairs of short smooth lateral cirri (Figs 1B, 2D, 3A). Operculum with 8 to 11 pairs of golden paleae, fan-shaped on each side with ventral ones longer than lateral ones, curved dorsally with extended tips (Figs 1B, 2B, 3A).

Tentacular cirri subulate, annulate, tapering to apex (Figs 1A, B). First pair of tentacular cirri arises on ventral posterolateral margin of segment 1 (Figs 1B, 2F, 3C). Second pair of tentacular cirri present laterally on segment 2 with dorsal and ventral ear-shaped lobes at the base (Figs 1B, 2F, 3C). Segment 2 with an incised ventral ridge, forming glandular lobes (Fig. 1B). Segment 2 without anterodorsal lobe (Figs 1B,2D, 3A).

Segment 3 with a large midventral lobe (Figs 1A, 2E, 3B), a pair of dorsolateral lobes with crenulated margin (Figs 1B, 2D, 2F, 3A, 3D), and a pair of lateral lamellate branchiae (Figs 1B, 2F, 3C).

Segment 4 with a small midventral lobe (Figs 1A,2E, 3B), a pair of larger lateral ventral lobes (Figs 1A, 2E, 3B), and a pair of lateral lamellate branchiae (Figs 1B, 2F, 3C). Large subquadrate glandular lobes arise ventrally at base of branchiae (Fig. 1A). Segment 4 with smooth dorsum (Figs 1B, 2B, 3A).

Segments 5 to 7 (chaetigers 1 to 3) with notopodia and notochaetae only (Figs 1B, 2F); anteroventral lobe large and broad (Figs 1A, 2E, 3B). Segment 5 with a small mid-

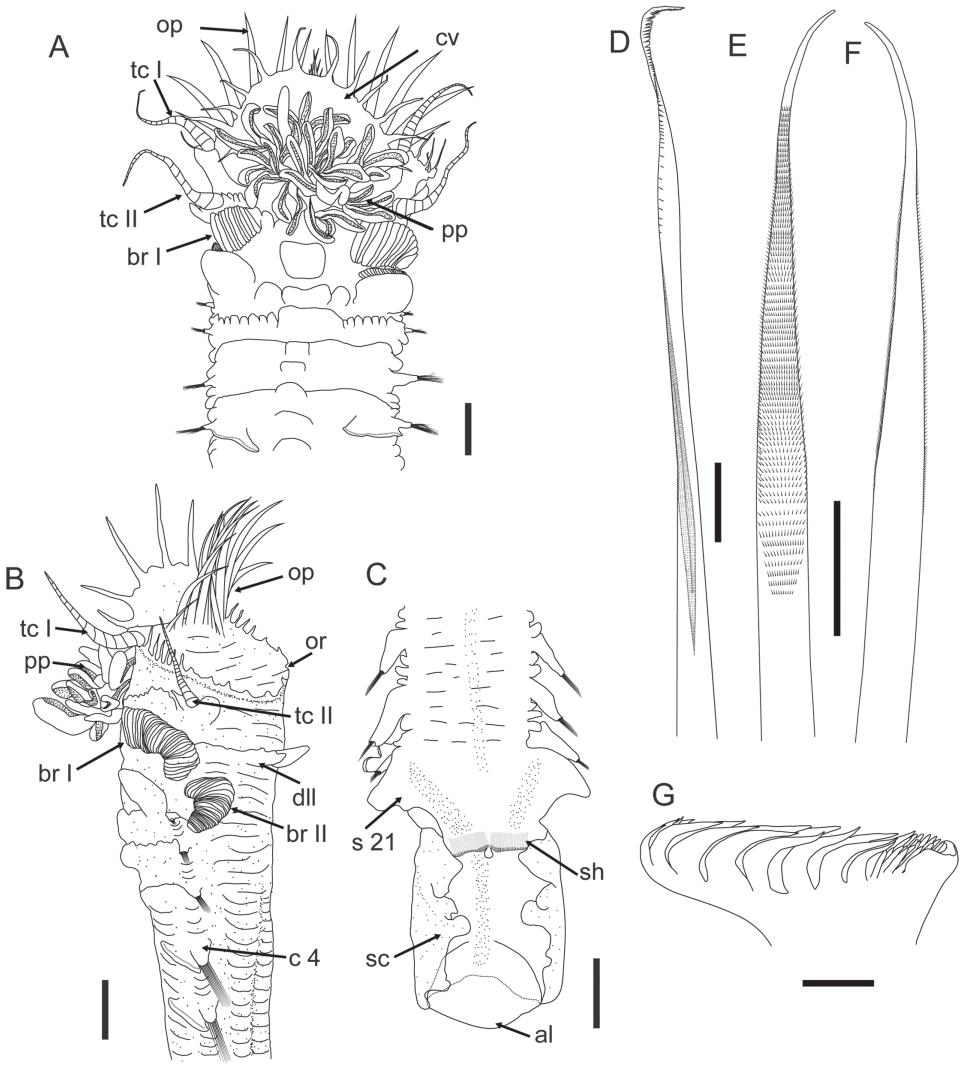


**Figure 1.** *Amphictene alata* sp. n., drawn from holotype MBM283388. **A** ventral view of anterior end **B** lateral view of anterior end **C** dorsal view of posterior end **D** ventral view of notochaeta 1 **E** ventral view of notochaeta, chaetiger 2 **F** dorsal view of notochaeta, chaetiger 2 **G** lateral view of neurochaeta uncinus. Scale bars: 1 mm (**A–C**); 50 μm (**D–F**); 5 μm (**G**). Abbreviations for morphological characters have been defined in Material and methods.

ventral lobe, and a pair of huge lateral ventral lobes covering much of the venter. Segment 6 with a small midventral lobe, and a pair of larger lateral ventral lobes. Segment 7 with a raised ventral lobe running through the venter. Segments 8 to 20 (chaetigers 4 to 16) biramous with wedge-shaped notopodia and lobe-shaped neuropodia. Notopodia with two kinds of simple chaetae: one slender, with sub-distal serrations along one side (Figs 1D, 3F–I); the other stout, with finely hirsute surface on one side, tapering

**Table 1.** Major morphological characters and collection information for the type specimens of *Amphictene alata* sp. n.

| Catalogue number | Body length (mm) | Anterior body width (mm) | Number of cirri on cephalic veil | Pairs of paleae | Pairs of scaphal hooks | Number of lappets on opercular rim | Collection date (yyyy/mm/dd) | Location | | Water depth (m) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | N(°) | E(°) | |
| **Holotype** | | | | | | | | | | |
| MBM283388 | 27.9 | 4.6 | 15 | 9 | 26 | 22 | 2013/12/24 | 22.52333 | 115.09167 | 22.5 |
| **Paratype** | | | | | | | | | | |
| SCSMBC006677 | 29.4 | 5.3 | 11 | 10 | 26 | 24 | 2013/5/20 | 22.5880 | 114.5886 | 14.5 |
| SCSMBC006678 | 36.1 | 3.9 | 13 | 8 | 29 | 22 | 2013/5/20 | 22.5880 | 114.5886 | 14.5 |
| SCSMBC006679 | 34.5 | 4.7 | 13 | 8 | 37 | 24 | 2013/5/20 | 22.57611 | 114.68444 | 14.5 |
| SCSMBC006680 | 38.8 | 5.8 | 15 | 9 | 39 | 24 | 2013/10/25 | 22.5880 | 114.6786 | 15.0 |
| AMW.48292 | 33.0 | 4.0 | 14 | 10 | 32 | 21 | 2013/9/27 | 22.5914 | 114.5539 | 12.0 |
| MBM283389 | 50.7 | 6.7 | 13 | 11 | 35 | 22 | 2013/9/27 | 22.55940 | 114.61190 | 20.0 |
| MBM283390 | 48.8 | 6.9 | n.r. | 9 | 36 | 22 | 2013/9/27 | 22.5594 | 114.6119 | 20.0 |
| MBM283391 | 30.8 | 4.0 | 13 | 9 | 34 | 20 | 2013/10/24 | 22.5914 | 114.5539 | 13.0 |
| MBM283392 | 26.3 | 5.0 | n.r. | 9 | 33 | n.r. | 2013/8/28 | 22.55942 | 114.61192 | 16.0 |
| SCSMBC006681 | 14.0 | 2.2 | 13 | 11 | n.r. | 20 | 2014/1/23 | 22.5914 | 114.5539 | 12.0 |
| SCSMBC006682 | 10.2 | 2.4 | n.r. | 11 | n.r. | 20 | 2014/8/21 | 22.6247 | 114.6719 | 13.0 |
| AMW.48293 | 25.0 | 4.0 | 16 | 10 | 26 | 25 | 2014/8/21 | 22.6083 | 114.7288 | 12.0 |
| AMW.48294 | 16.0 | 2.8 | 16 | 9 | 25 | 22 | 2014/8/19 | 22.54550 | 114.87067 | 6.0 |
| SCSMBC006683 | 45.2 | 5.8 | 16 | 10 | 32 | 22 | 2015/3/20 | 22.5930 | 114.5532 | 10.0 |

n.r.: character not recorded due to specimen damage.

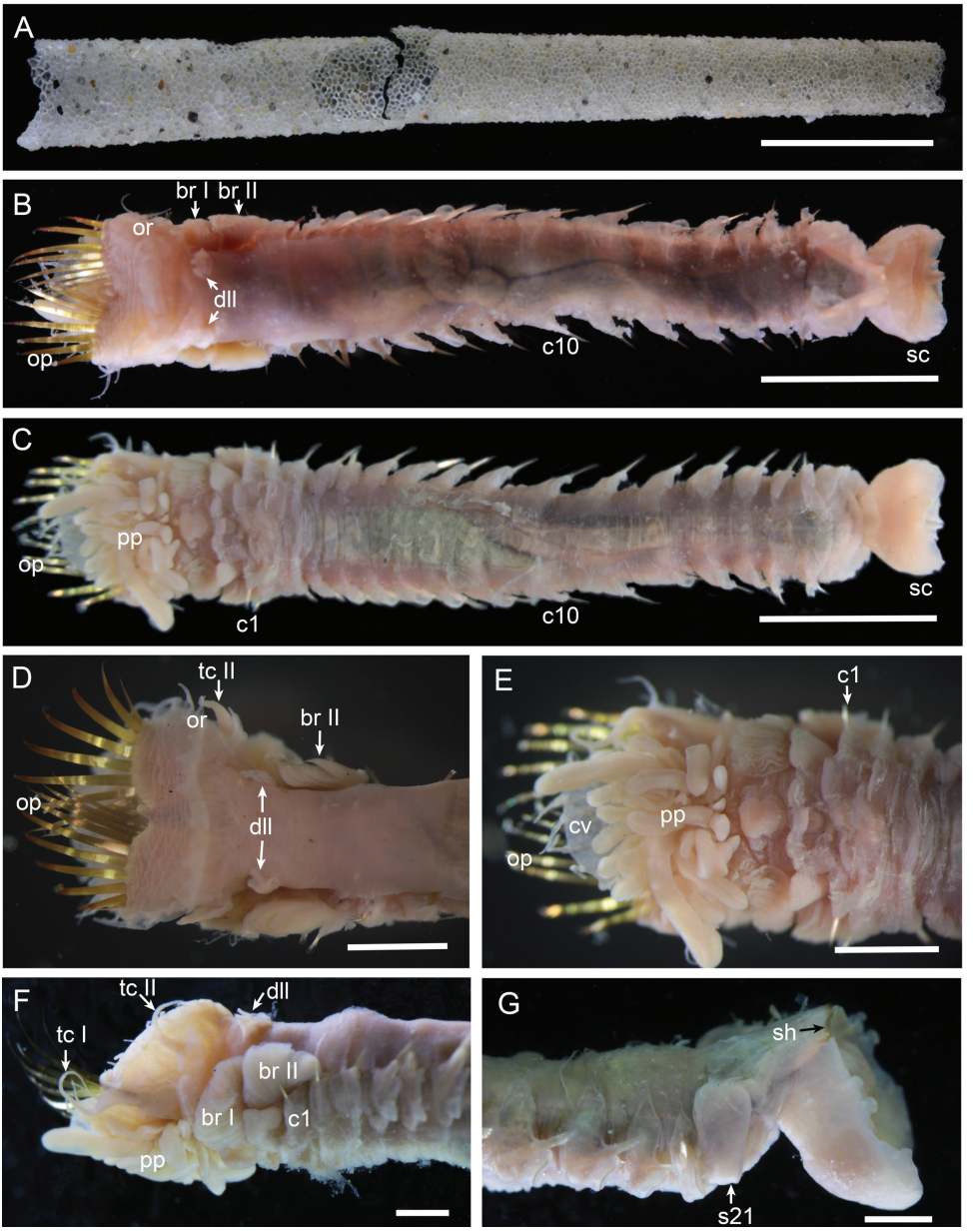


**Figure 2.** *Amphictene alata* sp. n. paratypes W.48293. **A** tube, broken in the middle **B** dorsal view of the whole worm **C** ventral view of the whole worm **D** dorsal view of anterior end **E** ventral view of anterior end **F** lateral view of anterior end **G** lateral view of posterior end. Scale bars: 1 cm (**A**); 5 mm (**B, C**); 2 mm (**D, E**); 1 mm (**F, G**). Abbreviations for morphological characters have been defined in Material and methods.

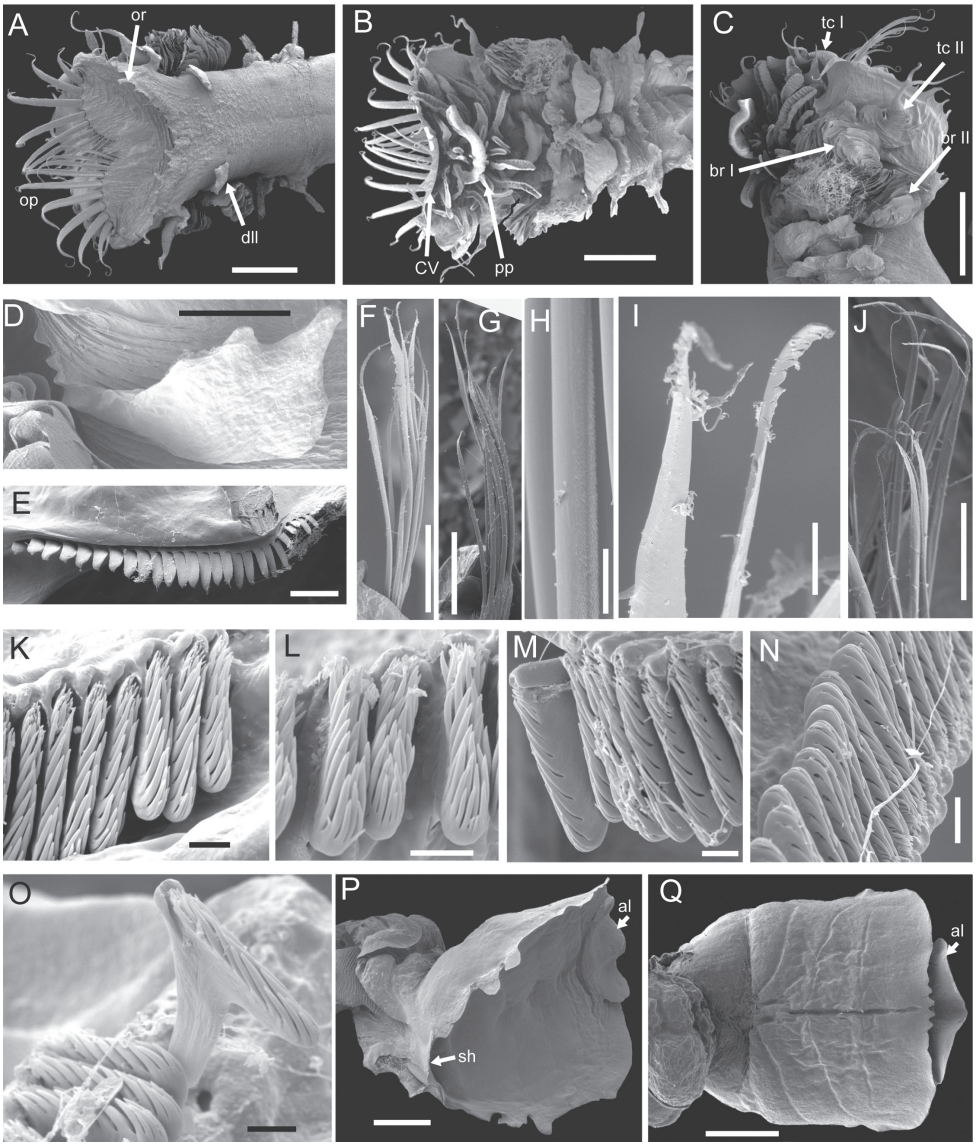


**Figure 3.** *Amphictene alata* sp. n. Scanning electron micrographs of paratype SCSMBC006683. **A** dorsal view of anterior end **B** ventral view of anterior end **C** lateral view of anterior end **D** left dorsal lateral lobe on segment 3 **E** some examples of the scaphal hooks **F, H, I** ventral view of notochaetae from chaetiger 2 **G** dorsal view of notochaetae from chaetiger 2 **J** ventral view of notochaetae from chaetiger 4 **K, L** and **M** ventral neurochaetae from chaetiger 4, 6 and 13, respectively **N** and **O** dorsal neurochaetae from chaetiger 5 and 16, respectively **P** dorsolateral view of scaphe **Q** ventral view of scaphe. Scale bars: 2 mm (**A–C**); 500 µm (**D**); 100 µm (**E, J**); 200 µm (**F, G**); 20 µm (H, I); 5 µm (**K–M, O**); 10 µm (**N**); 1 mm (**P, Q**). Abbreviations for morphological characters have been defined in Material and methods.

to an acute tip (Figs 1E, 1F, 3J). Neuropodia with uncini arranged in one row along raised ridge of the tori. Uncini with two or three longitudinal rows of teeth, each row with 7 to 9 major teeth (Figs 1G, 3K–O).

Segment 21 achaetous, with a pair of large lobes covering much of the lateral sides of the body (Figs 1C, 2G, 3P).

Scaphe formed by fusion of 5 posterior segments, distinctly separated from abdomen (Fig. 3Q). Scaphe ovoid, slightly convex dorsally, with two pairs of lappets on lateral margin (Figs 1C, 1D, 2G, 3P), and four small triangular lappets on distal margin (Fig. 3Q). Scaphal hooks 26 to 39 pairs, short, with a slightly bent tip (Fig. 3E). Anal tongue oval, with smooth margin extending beyond posterior scaphal margin (Figs 1C, 3P, 3Q).

Tube yellowish, conical, straight, composed of sand grains and shell fragments held together by cement (Fig. 2A).

**Variation in morphological characters.** A number of morphological characters exhibit variations (Table 1). Specifically, the body length ranges from 10.2 to 50.7 mm, the widest width of anterior body ranges from 2.2 to 6.9 mm, the numbers of cephalic veil cirri range from 11 to 16, the pairs of paleae range from 8 to 11, the number of triangular lappets on the raised opercular rim varies from 20 to 25, and the number of pairs of scaphal hooks ranges from 25 to 37. The widest width of anterior body (BW) and body length (BL) are positively correlated: BL = 0.7469BW - 3.6038, $R^2 = 0.8252$, $P < 0.001$, n = 15. Correlational analysis between BW, which is considered to be less affected by fixation than BL, and other quantitative parameters in Table 1 shows that BW had significant positive correlation only with the number of scaphal hooks (SH): SH = 2.3185BW + 20.213, $R^2 = 0.3419$, $P = 0.036$, n = 13.

**Type locality and distribution.** Currently only known from Daya Bay and Honghai Bay, Guangdong in the northern South China Sea.

## Discussion

*Amphictene alata* sp. n. can be distinguished from other currently recognized species in the genus by several features. First, it has a pair of dorsolateral lobes with crenulated margins on segment 3. None of the other species has dorsolateral lobes. Second, segment 21of *A. alata* sp. n. has a pair of large lateral lobes but has no chaetae. Among the reported species of *Amphictene*, *A. japonica* is also achaetous in segment 21, but it does not have large lateral lobes. Third, *A. alata* sp. n. has more scaphal hooks (26-37 pairs) than other species of *Amphictene* (4 to 25 pairs). Forth, the scaphal morphology of *A. alata* sp. n. is unique among *Amphictene* spp. in having 2 pairs of lateral lappets, four small triangular terminal lappets, and an oval anal plate with a smooth margin.

According to the generic diagnosis of Hutchings and Peart (2002), *Amphictene* has 17 chaetigers, with chaetigers 1 to 3 (segments 5 to 7) having notopodia and notochaetae only; chaetigers 4 to 16 (segments 8-20) biramous with notopodia, neuropodia, notochaetae and neurochaetae; and chaetiger 17 (segment 21) with notopodia and no-

tochaetae only. However, *Amphictene alata* sp. n. has 16 chaetigers only, with the last chaetiger having notopodia, neuropodia, notochaetae and neurochaetae; and segment 21 is achaetous. *Amphictene japonica* also has 16 chaetigers, with the last chaetiger being biramous with notopodia, neuropodia, notochaetae and neurochaetae (Nilsson 1928; Okuda 1934; Nishi et al. 2014). *Amphictene helenae* has 15 chaetigers, followed by three achaetous segments anterior to the scaphe (García-Garza and de León-González 2014). Therefore the generic diagnosis should be amended to change that members of this genus can have 15 to 17 chaetigers.

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RESEARCH ARTICLE

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# Annotated checklist of the leech species diversity in the Maloe More Strait of Lake Baikal, Russia

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## Abstract

In this paper, the very first checklist of the freshwater leeches of Maloe More Strait, a special part of Lake Baikal, is presented. It includes 14 free-living and parasitic species, of which four species belong to endemic Baikal genera – two species from *Baicalobdella* and one species each from *Baicaloclepsis* and *Codonobdella*. The checklist highlights six potentially new morphological species recorded for the first time in the area. The exact systematic position is stated for all leech species. Each species from the list is provided with information on taxonomic synonymy, data on its geographic distribution, and ecological characteristics. New species records are additionally provided with brief morphological characteristics and photos of their external morphology.

## Keywords

Hirudinea, checklist, endemic, Maloe More Strait, Lake Baikal

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## Introduction

The Baikal leeches (Hirudinea) are one of the least studied groups of invertebrates due to underestimation of their role in aquatic ecosystems and intractability of their taxonomy. In fresh and brackish waters, some leeches serve as invertebrate predators while others are infamous for their ability to feed on the blood of either invertebrates or vertebrates. The first group includes macrophagous leeches. These leeches have a large size relative to other freshwater invertebrates and a high density in the littoral zone of reservoirs and lowland streams making them critical to fish nutrition. This role is obviously underestimated at present. This may be attributed to peculiarities of their habitation and consequently of their sample collection. Macrophagous leeches are rarely found in hydrobiological collections; therefore, their abundance has not been taken into account and their role in ecosystems has often been undervalued. The second group consists of parasitic forms, which constitute the main part of the leech diversity, and their role in ecosystems is absolutely different. Being epizoic parasites, they have relevance to transmission of bacterial and viral infections (e.g. Faisal and Schulz 2009, Faisal et al. 2011), as well as hematozoa including trematodes, cestodes and nematodes (Demshin 1975), and parasitic flagellates (Khan 1976, Khamnueva and Pronin 2004, Burreson 2007), which are considered to be pathogenic organisms for aquatic animals.

An exploration of the Baikal parasitic leech diversity was begun by pioneering 19$^{th}$ century German zoologist Adolf Eduard Grube. *Clepsine echinulata* Grube, 1871 (now *Baicaloclepsis echinulata* (Grube, 1871)), *Piscicola torquata* Grube, 1871 (now *Baicalodbella torquata* (Grube, 1871)) and *Codonobdella truncata* Grube, 1873 may have been the first freshwater leeches recorded from Lake Baikal, but their host relationships had not been identified. Non-parasitic leeches of Lake Baikal were excluded from any scientific interest for a long time due to their belonging to the common Siberian faunal assemblage, and the scientific pursuit of unique endemic elements. Later, the famous Russian scientist Nikolai Livanow, studying Baikal samples, described the species *Protoclepsis tesselatoides* Livanow, 1902, which has some morphological differences from the Palaearctic *Protoclepsis tessulata* (Müller, 1774) (now *Theromyzom tessulatum*) parasitizing waterfowl. Next, the endemic "flat" leech *Torix baicalensis* Shchegolew, 1922 (now *Paratorix baicalensis*) was discovered by Shchegolew (1922) in collections from 1916, but the host remains unknown. No publications on Baikal leeches appeared for the subsequent 35 years until the description of a new endemic genus and species *Baicalobdella cottidarum* (Dogiel and Bogolepova 1957), found on cottoid fish. Subsequently, Lukin and Epstein (1960a) described a new genus (*Baicaloclepsis*) and a new species (*B. grubei*), the first leech record from the Maloe More Strait. The same authors then created a new subfamily (Toricinae), which included the genus *Baicaloclepsis* Lukin et Epstein, 1960 and newly established *Paratorix* (Lukin and Epstein 1960b). Since, in addition to the above, the following papers on the Baikal leeches have been published: Dogiel et al. 1949; Epstein 1961, 1973, 1987; Lukin 1967, 1976; Finigenova and Snimschikova 1991; Kozhova and Izmest'eva 1998; Rusinek

2007. In order to revise the Lake Baikal leech fauna, the most recent target investigations have worked towards clarifying the taxonomic status of various species as well as adding to the species list with new records (Kaygorodova 2012, 2013; Kaygorodova and Natyaganova 2012; Kaygorodova and Utevsky 2012; Kaygorodova and Pronin 2013, Kaygorodova et al. 2013, Kaygorodova and Mandzyak 2014, Kaygorodova and Sorokoivikova 2014, Kaygorodova and Petryaeva 2014). Despite a recent surge of interest, the study of Baikal hirudinids is still in its infancy and, at the very least, there is a need for a provisional checklist as a starting point for further study. The present paper aims to provide such a list for the Maloe More Strait, a special part of Lake Baikal.

The data included here are based on previously published records and additional field investigations from 2002–2014. Collected material has been deposited in the laboratory of Molecular Systematics, Limnological Institute SB RAS, Irkutsk, Russia. The list provides morphologic and taxonomic notes where needed, as well as distribution ranges of genera and species. The accepted modern names of the type species of genera are provided. The systematic arrangement at family and more inclusive levels is based on the currently accepted classification system. Within this paper, family, subfamily, genus and species names are arranged alphabetically. The checklist includes 14 species and subspecies along with several new distribution records, including four endemic species, and six potential new species.

## Materials and methods

Previously published information and an extensive collection of specimens, collected by the author in the period from 2002 to 2014 were used in this paper. Most of the specimens came from the task-oriented expedition on the Maloe More Strait which was undertaken in 2013. All sampling locations are shown in Fig. 1. Since the usual hydrobiological equipment (sweep net, dredge, scraper, bottom grab, etc.) is often less effective in procuring leeches than searching for many other aquatic invertebrates in order to catch parasitic and predatory leeches we inspected various aquatic plants and animals as well as different underwater objects (rotten wood, driftwood, snags, stones, etc.), to which hirudinids can be attached. Some leeches were picked out from zoobenthic samples. In most cases piscine and endemic flat leeches (glossiphoniids) were gathered directly in captured living hosts. Fish, molluscs and amphipods were collected by scuba divers at a depth of 2–42 m and by dredge or fishing gear at 30–200 m.

Newly collected specimens were photographed alive, placed in separate vials, fixed and kept in 80% ethanol solution. Current systematic keys (Lukin 1976, Epstein 1987, Nesemann and Neubert 1999) and several original taxonomical descriptions (Lukin and Epstein 1960a,b; Dogiel and Bogolepova 1957) were used for species identification. Morphological analysis was conducted using a stereomicroscope MSP-2 var. 2 (LOMO). All images were taken with a camera NIKON D700. All voucher specimens were deposited at the Laboratory of Molecular Systematics, Limnological Institute, Russia.

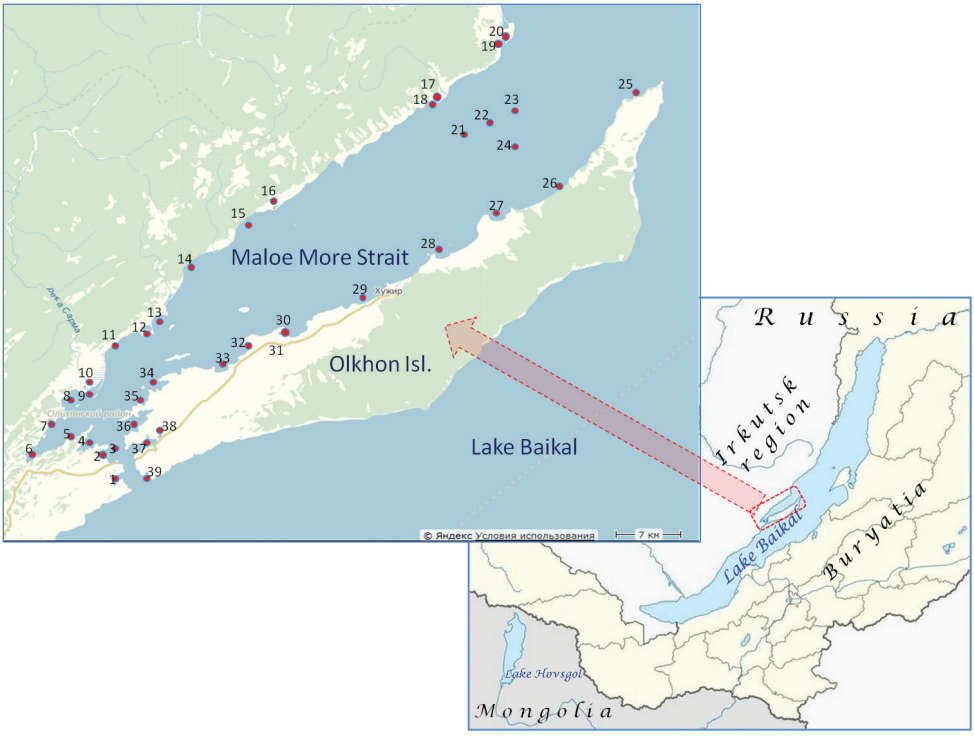


**Figure 1.** Map of the Maloe More Strait of Lake Baikal. Red dots indicate leech sampling localities: **1** Tutay Bay **2** Sakhurte Bay **3** Olkhon Gates Strait **4** Kurkut Bay **5** Ulirba Bay **6** Mukhor Bay **7** Shide Bay **8** Khuzhir-Nugho Bay **9** Khuzhir-Nugho Bay against of Sarma village) **10** Sarma River **11** Mukhor-Khale Bay **12** Khagden-Khale Bay **14** Kurma Bay **15** Otto-Khushun Bay **16** Lake Surkhaytor-Hur **17** Lake Zunduk **18** Zunduk Bay **19** Codoviy Bay **20** Lake Zama **21–24** Northern transit of the Maloe More **25** Cape Khoboy **26** Nyurgon Bay **27** Kharansa Bay **28** Odonim Bay **29** Khuzhir Bay **30** Elgay Bay **31** Lake Khankhoy **32** Shibetey Bay **33** Semisosennaya Bay **34** Khargoy Bay **35** Kharin Irgi Bay **36** Khul Bay **37** Zagli **38** Lake Nur **39** Ushun Bay.

## Systematics

**Phylum Annelida Lamarck, 1809**
**Class Clitellata Michaelsen, 1919**
**Subclass Hirudinea Lamarck, 1818 (synonym Hirudinida)**
**Order Rhynchobdellea Blanchard, 1894**
**Family Glossiphoniidae Vaillant, 1890**
**Subfamily Glossiphoniinae Autrum, 1939**

### Genus *Alboglossiphonia* Lukin, 1976

**Geographic distribution.** Holarctic.

**Type species.** *Alboglossiphonia heteroclita* (Linnaeus, 1761).

### ***Alboglossiphonia heteroclita*** **(Linneaus, 1761)**

*Hirudo heteroclita*: Linnaeus 1761; *Hirudo papillosa*: Braun 1805; *Hirudo trioculata*: Carena 1820; *Clepsine caranae*: Moquin-Tandon 1826; *Clepsine striata*: Apáthy 1888; *Clepsine polonica*: Lindenfeld and Pietruszynski 1890; *Glossiphonia heteroclita*: Blanchard 1894; *Glossiphonia heteroclita*: Harding and Moore 1926.

**Geographic distribution.** Holarctic species.

**Subspecies.** *papillosa* (Pawlowski, 1936)

**Geographic distribution,** widespread in the Holarctic region.

Maloe More: Tutay Bay, Kurkut Bay, Zagli Bay, Mukhor Bay, Kurma Bay, Lake Zunduk, Lake Zama, Codoviy Bay, Lake Khuzhir.

**Ecological characteristics.** *A. heteroclita* lives in various types of flowing and stagnant waters (Nesemann and Neubert 1999). It has been recorded from brackish water, up to 3% in the Baltic Sea by Koli (1960). It occurs from the lowlands to mountainous regions. *Alboglossiphonia heteroclita* is a suctorial freshwater sit-and-wait predator; it preys on small invertebrates – mainly on gastropods, isopods and oligochaetes. It inhabits sor zones and warm bays of Lake Baikal. As a typical glossiphoniid, it shows touching parental care.

### ***Alboglossiphonia hyalina*** **(Müller, 1774)**

*Hirudo hyalina*: Müller 1774; *Clepsine hyalina*: Moquin-Tandon 1826; *Glossiphonia hyalina*: Blainville 1827; *Glossiphonia heteroclita* f. *hyalina*: Pawlowski 1936.

**Geographic distribution.** Palaearctic region.

Maloe More: Kharin Irghi Bay, Kurma Bay, Shide Bay, Lake Khuzhir, Lake Khankhoy, Lake Surkhaytor-Nur, Lake Zunduk, Lake Zama, Codoviy Bay.

**Ecological characteristics.** This species is a benthic ectoparasite of snails. It was found in the mantle cavity of representatives of Lymnaeidae, for instance *Lymnaea stagnalis* (Linnaeus, 1758) and *Stagnicola corvus* (Gmelin, 1791). In Baikal, *A. hyalina* feeds on Planorbidae, Lymnaeidae, and Valvatidae.

### **Genus *Glossiphonia* Johnson, 1817**

**Geographic distribution.** Palaearctic and Nearctic.

**Type species.** *G. complanata* (Linnaeus, 1758).

### *Glossiphonia* sp. 1

**New species records.** Kurma Bay, Lake Surkhaytor-Nur, Lake Zunduk, Lake Zama.

**Morphological characteristics.** Length is up to 25 mm. Three pairs of eyes. On the dorsal side there are longitudinal rows of dark pigmentation (Fig. 2). Central pair of stripes is always brighter in comparison with the more lateral ones.

**Ecological characteristics.** Specimens were collected in the littoral zone. Life cycle is typical for majority of the genus. It prefers to sit on the rocks, or slowly crawl. This leech feeds almost exclusively on molluscs, and sometimes on worms or larvae of insects. With its elastic proboscis, it pierces the delicate covers of the victim and sucks its blood. The Maloe More *Glossiphonia* sp. 1, like other glossiphoniids, takes care of its young.

### *Glossiphonia* sp. 2

**New species records.** Kurma Bay, Lake Zama.

**Morphological characteristics.** The size varies from 7 to 12 mm. This leech has a bright amber colour due to tiny pale brown pigment cells uniformly strewn along the body dorsally and one pair of dark longitudinal median rows (Fig. 3).

**Ecological characteristics.** *Glossiphonia* sp. 2 occupies the same ecological niche as the previous *Glossiphonia* species, parasitizing small invertebrates preferentially molluscs.

## Genus: *Helobdella* Blanchard, 1876

**Geographic distribution.** Cosmopolitan.

**Type species.** *Helobdella stagnalis* (Linnaeus, 1758)

### *Helobdella stagnalis* (Linnaeus, 1758)

*Hirudo stagnalis*: Linnaeus 1758; *Hirudo pulligera*: Daudin 1800; *Glossiphonia perata*: Johnson 1816; *Erpobdella bioculata*: Lamark 1818; *Clepsine bioculata*: Savigny 1822; *Glossobdella pulligera*: Blainville 1827; *Clepsine stagnalis*: Fillipi 1837; *Glossiphonia bioculata*: Maquin-Tandon 1846; *Glossiphonia circulans*: Maquin-Tandon 1846; *Clepsine modesta*: Verrill 1972; *Glossiphonia modesta*: Vaillant 1890; *Glossiphonia stagnalis*: Blanchard 1894; *Glossiphonia* (*Helobdella*) *stagnalis*: Moore 1922; *Bakedebdella gibbosa*: Sciacchitiano 1939.

**Geographic distribution.** Cosmopolitan.

Maloe More: Tutay Bay, Zagli Bay, Mukhor Bay, Shide Bay, Lake Khankhoy, Lake Surkhaytor-Nur, Lake Zunduk, Codoviy Bay.

**Figure 2.** *Glossiphonia* sp. 1 (below) and *Alboglossiphonia heteroclita* (above) from Kurma Bay of the Maloe More Strait (Lake Baikal). Scale bar 10 mm.

**Figure 3.** *Glossiphonia* sp. 2 from Kurma Bay of the Maloe More Strait (Lake Baikal). Scale bar 1 mm.

**Ecological characteristics.** This species is considered one of the most common freshwater leeches in the world. Within Baikal, *H. stagnalis* inhabits shallow bays and salinas. This *Helobdella* species cannot swim; it crawls on aquatic plants and other objects, using its suckers as organs of attachment. Most suck the haemolymph of freshwater invertebrates such as oligochaetes, larvae of insects, and freshwater snails (Kozhova and Izmest'eva 1998). Freshwater jawless leeches are remarkable for their parental care. They produce a membranous bag or cocoon to hold the eggs, which are then carried on the ventral surface. The young attach to the parent's belly after hatching and are thus ferried to their first meal.

**Genus: *Hemiclepsis* Vejdovský, 1884**

**Geographic distribution.** Palaearctic region.

**Type species.** *H. marginata* (Müller, 1774)

***Hemiclepsis marginata* (Müller, 1774)**

*Hirudo marginata*: Müller 1774; *Hirudo variegates*: Braun 1805; *Hirudo cephalota* Carena 1820; *Hirudo oscillatoria*: Saint-Amas 1825; *Piscicola tesselata*: Maquin-Tandon 1826; *Piscicola linearis*: Kollar 1842; *Glossobdella cephalota*: Blainville 1827; *Haemoharis marginata*: Filippi 1837; *Glossiphonia marginata*: Maquin-Tandon 1846; *Hirido flava*: Dalyell 1953; *Glossiphonia flava*: Johnston 1865; *Glossiphonia marginata*: Blanchard 1892.

**Geographic distribution.** Palaearctic region. A closely related taxon *Hemiclepsis marginata asiatica* Moore, 1924, is known from Cashmere to Sumatra. Its relationship to the nominate subspecies is still doubtful.

Maloe More: Kurma Bay, Mukhor Bay, Khuzhir-Nugho Bay, Lake Khankhoy, Lake Surkhaytor-Nur, Lake Zunduk.

**Ecological characteristics.** This species inhabits Europe and Asia. In Central Europe, however, it is rare, whereas in Eastern Siberia it is widespread. As a sanguivorous ectoparasite it feeds on fishes and amphibians. *Hemiclepsis marginata* is able to move actively. When not on a host, *H. marginata* usually is found beneath large stones in shallow water or on submerged macrophytes. It can be found in all types of freshwater habitats and often thrives in stagnant water, weedy ponds, and, less often, in streams.

**Subfamily Theromyzinae Sawyer, 1986.**

**Genus *Theromyzon* Philippi, 1867**

**Geographic distribution.** Holarctic.

**Type species.** *T. pallens* Philippi, 1867

### *Theromyzon tessulatum* (Müller, 1774)

*Hirudo tessulata*: Müller 1774; *Hirudo tesselata*: Bosc 1802; *Nephelis tesselata*: Savigny 1822; *Erpobdella tesselata*: Fleming 1822; *Ichthyobdella tesselata*: Blainville 1828; *Erpobdella vulgaris* var. *tesselatum*: Blainville 1828; *Clepsine tessulata*: Müller 1844; *Glossiphonia tessulata*: Maquin-Tandon 1846; *Glossiphonia aecheana*: Thompson 1846; *Hirudo vitrina*: Dalyell 1853; *Glossiphonia vitrina*: Johnston 1865; *Theromyzon tessulatum*: Philippi 1867; *Hemiclepsis tesselata*: Vejdovsky 1883; *Glossiphonia tesselata*: Blanchard 1892; *Protoclepsis tesselata*: Livanow 1902.

**Geographic distribution.** Palaearctic and Nearctic regions. A closely related taxon *Protoclepsis tesselatoides* Livanow, 1902 was synonymised in *T. tessulatum* (Lukin 1976). This pooling into the nominate species is still doubtful.

Maloe More: Lake Zunduk, Lake Zama.

**Ecological characteristics.** This is a widespread but rare species. It can be found in warm bays of Baikal and adjacent freshwater reservoirs. It prefers stagnant water. Feeds on the blood of vertebrates. Most likely hosts might be fishes, water birds or amphibians.

### *Theromyzon* sp.

**New species records.** Ulirba Bay.

**Morphological characteristics.** Specimens are 12 mm in length and about 2 mm in width and can stretch up to 15-17 mm, becoming 1 mm in width. It has four pairs of eyes as do all representatives of the genus. A special colouration of the body sets them apart from all other known species (Fig. 4).

**Ecological characteristics.** Representatives of this genus are known as bloodsuckers of birds (Sawyer 1986, Lukin 1976, Nesemann and Neubert 1999). The host for the Maloe More *Theromyzon* is unknown, since these specimens were found free-living.

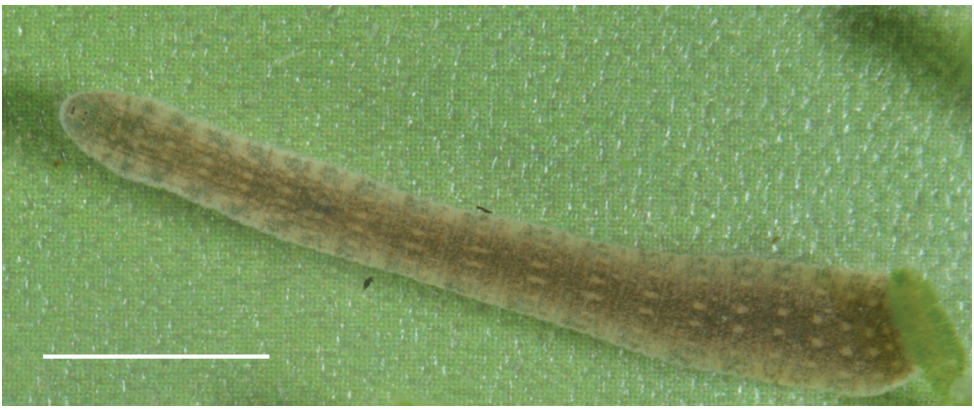

**Figure 4.** *Theromyzon* sp. individual inhabiting Ulirba Bay of the Maloe More Strait (Lake Baikal). Scale bar 5 mm.

**Subfamily: Toricinae Lukin & Epstein, 1960**

**Genus *Baicaloclepsis* Lukin & Epstein, 1960**

**Geographic distribution.** Endemic to Lake Baikal.

**Type species.** *Baicaloclepsis echinulata* (Grube, 1871)

***Baicaloclepsis grubei* Lukin & Epstein, 1960**

*Clepsine echinulata* (part.): Grube 1871; *Haementeria echinulata*: Dogiel & Bogolepova 1957.

**Geographic distribution.** Endemic to Lake Baikal.

Maloe More: Zagly Bay, Khargoy Bay, Semisosennaya Bay, Elgay Bay.

**Ecological characteristics.** Endemic to Lake Baikal. Large leeches (length of 30-40 mm, width of 10-15 mm). *Baicaloclepsis grubei* were found only within the Maloe More Strait at relatively shallow depths of 14-40 m. This leech cannot swim and apparently can move only slowly. Since *B. grubei* has a comparatively small posterior sucker, it is unlikely that it can provide a strong fastening to a host. In addition, this species probably spends a significant part of its life in a free-living state. All specimens were collected from benthic samples. The question of a potential host of this bloodsucking leech remains open.

**Family Piscicolidae Johnston, 1865 (synonym Ichthyobdellidae Leuckart, 1863)**
**Subfamily Piscicolinae Caballero, 1956**

**Genus *Baicalobdella* Dogel & Bogolepova, 1957**

**Geographic distribution.** Endemic to Lake Baikal.

**Type species.** *Baicalobdella torquata* (Grube, 1871).

***Baicalobdella cottidarum* Dogiel, 1957**

*Trachelobdella torquata* (part.): Epstein 1959; *Trachelobdella torquata* (part.): Epstein 1959; *Trachelobdella torquata* (part.): Kozhov 1962; *Trachelobdella torquata* (part.): Lukin 1963; *Baicalobdella torquata* (part.): Lukin 1976.

**Geographic distribution.** Endemic to Lake Baikal.

Maloe More: Kurma Bay; Olkhon Gates Strait; Kharansa Bay.

**Ecological characteristics.** This species inhabits the littoral zone of Lake Baikal (0–200 m). This species is less abundant in the Maloe More area than its sister species, *B. torquata*. In contradistinction to *B. torquata*, it parasitizes only Baikal cottoid fishes. *Baicalobdella cottidarum* can be found directly on a host or in a free-living state on the surface of benthic substrates.

### ***Baicalobdella torquata*** **(Grube, 1871)**

*Piscicola torquata* Grube, 1871; *Trachelobdella torquata* (part.): Epstein 1959; *Trachelobdella torquata* (part.): Kozhov 1962; *Trachelobdella torquata* (part.): Lukin 1963.

**Geographic distribution.** Endemic to Lake Baikal.

Maloe More: Khagden-Khale Bay; Otto-Khushun Bay; Nyurgon Bay; Odonim Bay; Ulirba Bay; Mukhor Bay; Sakhurte Bay; Khul Bay; Ushun Bay.

**Ecological characteristics.** This is a typical component of the littoral zone of open water in Baikal. This species was found at depths of 0.5–10 m. These small leeches are 5-8 mm in length, with a width of 2-3 mm. Body colour varies from light green to pale rust, retaining a characteristic mosaic pattern on the dorsal side of the urosome. *Baicalobdella torquata* feed on Baikal endemic amphipods.

### **Genus *Codonobdella* Grube, 1873**

**Geographic distribution.** Endemic to Lake Baikal.

**Type species.** *C. truncata* (Grube, 1873).

### ***Codonobdella*** **sp.**

**New species records:** Northern transit of Maloe More Strait, Nyurgon Bay, Kharansa Bay, opposite the Cape Khoboy, Shibetey Bay.

**Morphological characteristics.** Body length of 8–10 mm. It differs from the type species, *Codonodbella truncata*, by the existence of a distinctive pigmentation on the dorsal side and the representative shape of the body (Fig. 5). There is a monotonous gray-green coloration of the dorsal side and a lighter colour on the ventral surface. A striped pattern is located laterally on each side of the body. Formerly, this leech was mistaken for *Piscicola geometra* (Kozhova and Izmest'eva 1998, Rusinek 2007) because of the similarity in colour patterns, the piscicola-like body shape and the lighter coloration of the ventral surface.

**Ecological characteristics.** This leech is an inhabitant of open waters. Within the Maloe More, it was recorded in the northern part of the strait at a depth of 30–140 m.

**Figure 5.** *Codonobdella* sp. on its host amphipod. The sample was found in the northern transit of the Maloe More Strait.

**Order Arhynchobdellea Blanchard, 1894**
**Suborder Erpobdelliformes Sawyer, 1986**
**Family Erpobdellidae Blanchard, 1894**

**Genus *Erpobdella* de Blainville, 1818**

**Geographic distribution.** Palaearctic and Nearctic regions.

**Type species.** *Erpobdella octoculata* (Linnaeus, 1758).

***Erpobdella* sp. 1**

**New species records.** Kurkut Bay, Kurma Bay, Zagli Bay, Shide Bay, Kharin Irghi Bay, Tutay Bay, Ulirba Bay.

**Morphological characteristics.** The leeches are about 25–35 mm in length and 3–4 mm in width. Eight eyes. The leech has a pale pink body tinge. Dorsal pigmen-

**Figure 6.** *Erpobdella* sp. 1 from Zagli Bay of the Maloe More Strait (Lake Baikal). Scale bar 5 mm.

tation is almost absent. There are only a few dark spots irregularly scattered on the dorsal surface (Fig. 6).

**Ecological characteristics.** This freshwater ribbon leech is common in the sor zone of Lake Baikal (Kaygorodova 2012). It was found mainly in the south-western part of the Maloe More. This is a non-parasitic leech. With a powerful pharynx *Erpobdella* completely or partially ingests different aquatic animals, including small annelids, crustaceans, insect larvae, molluscs, and even young fishes. In addition, it has been known to feed on dead animals and smaller specimens of its own species.

### *Erpobdella* sp. 2

**New species records.** Lake Zama, Lake Zunduk, Codoviy Bay.

**Morphological characteristics.** These large sized leeches are up to 90 mm in length and 4.5–5.0 mm in width. The leeches have dark green or brown dorsal pigmentation flecked with yellow. Ventral pigmentation is almost absent (Fig. 7).

**Ecological characteristics.** This non-parasitic macrophagous leech species has a restricted distribution even within the Maloe More. It was found only in lakes and bays of the most north-western coast of the strait.

**Figure 7.** *Erpobdella* sp. 2 from Codoviy Bay (Maloe More Strait, Lake Baikal). Scale bar 5 mm.

## Conclusions

This is the first comprehensive checklist of the Baikal leech species inhabiting the Maloe More Strait. At present, 14 species are documented. This species diversity includes both widespread Holarctic and Palaearctic leeches and also endemic leech species from two different orders (Rhynchobdellida and Arhynchobdellida), three families (Glossiphoniidae, Piscicolidae, and Erpobdellidae) and nine genera. The most diverse is the group of glossiphoniid leeches, which consists of nine species belonging to six genera (*Alboglossiphonia* – 2 spp., *Glossiphonia* – 2 spp., *Helobdella* – 1 sp., *Hemiclepsis* – 1 sp., *Theromyzon* – 2 spp., *Baicaloclepisis* – 1 sp.). The Maloe More piscine leeches include representatives of two endemic genera (*Baicalobdella* – 2 spp. and *Codonobdella* – 1 sp.). Among the Arhynchobdellida, two species of the genus *Erpobdella* were found in the Maloe More. Six species in the checklist, including both representatives of *Erpobdella*, two of *Glossiphonia*, as well as one each from *Theromyzon* and *Codonobdella* were referred in this paper, with caution, to unidentified species since their morphology differed from all currently described species. With high probability, these six non-identified species are potentially new to science. All six of these, for the first time were recorded within the Maloe More. Some of these new morphotypes had previously been found in other parts of Lake Baikal. Thus, leeches similar to *Erpobdella* sp. 1 had already been reported from Chivyrkuy Bay (Kaygorodova 2012, 2013; Kaygorodova and Pronin 2013), whereas unidentified piscicolids *Codonobdella* sp. had been found throughout the lake (Kaygorodova 2012, 2013).

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# Synopsis of *Poeciloderrhis* Stål, 1874, with the description of three new species, and a redescription of the male and female of *Poeciloderrhis ferruginea* (Brunner von Wattenwyl, 1865) from southeast Brazil (Blattodea, Blaberidae, Epilamprinae)

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**Citation:** da Silva LCO, Lopes SM (2015) Synopsis of *Poeciloderrhis* Stål, 1874, with the description of three new species, and a redescription of the male and female of *Poeciloderrhis ferruginea* (Brunner von Wattenwyl, 1865) from southeast Brazil (Blattodea, Blaberidae, Epilamprinae). ZooKeys 545: 53–65. doi: 10.3897/zookeys.545.6172

## Abstract

*Poeciloderrhis* Stål (1874) was first described without reference to the included species and without morphological details. The genus was described in a key for the American *Epilampra*, which left only Asian-Australian species in the genus. Roth (1970) was the first to separate *Poeciloderrhis* from *Epilampra* with strong morphological characters. In this contribution, three species of *Poeciloderrhis* are described and a new record from Minas Gerais State is added. The genitalia of the female of *P. ferruginea* are described for the first time. The genital plates were removed after dissection of the posterior part of the abdomen of males and females, using traditional dissection techniques. The parts were dissected on slides containing glycerin for examination under the stereoscopic microscope. Habitus images, and images of the pronotum, head and genitals were obtained with the help of a camera coupled to a stereomicroscope. The studied material is stored in glycerin inside microvials, and is deposited in the collection of the Museu Nacional. Three new species, *P. caracensis* **sp. n.**, *P. minoris* **sp. n.** and *P. tijucana* **sp. n.** are described and compared with the holotypes of previously described species, together with a redescription of the male and female of *P. ferruginea* (Brunner von Wattenwyl, 1865).

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**Keywords**
Epilamprinae, morphology, *Poeciloderrhis*, taxonomy

## Introduction

*Poeciloderrhis* Stål (1874) is a genus that was insufficiently described. The author did not name its constituent species or a description of their morphological details (Stål 1874). The genus was created to separate species of *Epilampra* Burmeister, 1838 that occurred in the Americas from those occurring in Asian and Australian regions.

Kirby (1903) allocated one Australian species to *Heterolampra*, while maintaining *Epilampra* for the American species. He designated *E. brasiliensis* as the type species of *Epilampra* and *Epilampra verticalis* as the type of *Poeciloderrhis*, defining those (*Poeciloderrhis*) geographically as individuals from South America. Shelford (1910) and Princis (1967) placed *Poeciloderrhis* as a synonym of *Epilampra*. However, according to Roth (1970), the tergal modification in the abdomen of *Epilampra* does indeed distinguish it from *Poeciloderrhis* as these modifications would probably lead to mating incompatibilities between the two groups. Roth (1970) also presented the genitalia of six species he considered as *Poeciloderrhis*.

Roth (1970) separated both genera using a key in which only male characters were employed: the presence (*Poeciloderrhis*) or absence (*Epilampra*) of a tergal modification; apex of the dorsal sclerite of the medio-ventral phallomere (L2d) pointed and solidly fused with the median sclerite (L2vm) (*Poeciloderrhis*) or not fused (*Epilampra*); prepucium membranous and setose (*Epilampra*), or not clearly defined and with dense setae (*Poeciloderrhis*); hook (R2) small and robust, without sub-apical incision (*Poeciloderrhis*) or slender and tapering with subapical incision (*Epilampra*) and left phallomere always (L1) without a tuft of setae and fused sclerotized clefts (*Poeciloderrhis*) or setal tufts sometimes present and cleft not fused (*Epilampra*) These traits characterize the genus *Poeciloderrhis*.

Based in the configuration of the tergal modifications of the abdomen, Roth (1970) defined six species, *P. catharina* Shelford, 1910, *P. atriventris* (Saussure, 1895), *P. ferruginea* (Brunner von Wattenwyl, 1865), *P. proxima* (Brunner von Wattenwyl, 1865), *P. verticalis* (Burmeister, 1838) and *P. cribrosa* (Burmeister, 1838).

Pellens and Grandcolas (2008) cited *Epilampra basistriga* (Walker, 1868) as belonging to *Poeciloderrhis*. However, Roth (1970) had already presented the genital structures of that species, making it clear that its configuration is typical of those belonging to *Epilampra* as the apex of the right phallomere is hooked and very elongated; thus being entirely different from those belonging to *Poeciloderrhis.* Lopes Oliveira and Khouri (2010) revalidated the status of *Epilampra basistriga* based on specimens from the Museu Nacional Collection, confirming Roth (1970), which we reaffirm in this paper.

Beccaloni (2015) catalogued 13 species that occur in Brazil, four of which occur in the southeast: P. *bicolorata* Rocha e Silva & Lopes, 1977, *P. boraceiana* Lopes &

Oliveira, 2006, *P. imperialis* Rocha e Silva & Jurberg, 1978, *P. paulistensis* Lopes & Oliveira, 2006) and one in Argentina (*P. verticalis* Burmeister, 1838).

Three new species are added to the genus and for the first time, the female genitalia of *P. ferruginea* are described.

## Materials and methods

The genital plates were removed after dissection of the posterior part of the abdomen, using traditional dissection techniques, as described by Lopes and Oliveira (2000). After analysis, the genital plates and genital pieces were stored in microvials containing glycerin and attached to the respective exemplar, a technique developed by Gurney et al. (1964). The terminology for the genitalia and the taxonomic classification follows Roth (2003). The new species were compared with other known species of *Poeciloderrhis* and species of *Epilampra* and deposited in the Blattodea Collection of the Museu Nacional of Rio de Janeiro (MNRJ). Digital images of the habitus, pronotum, head and genital sclerites were taken with a camera mounted on a stereoscope. The holotypes were deposited in the collection of the Department of Entomology at the Museu Nacional of Rio de Janeiro (MNRJ).

## Results

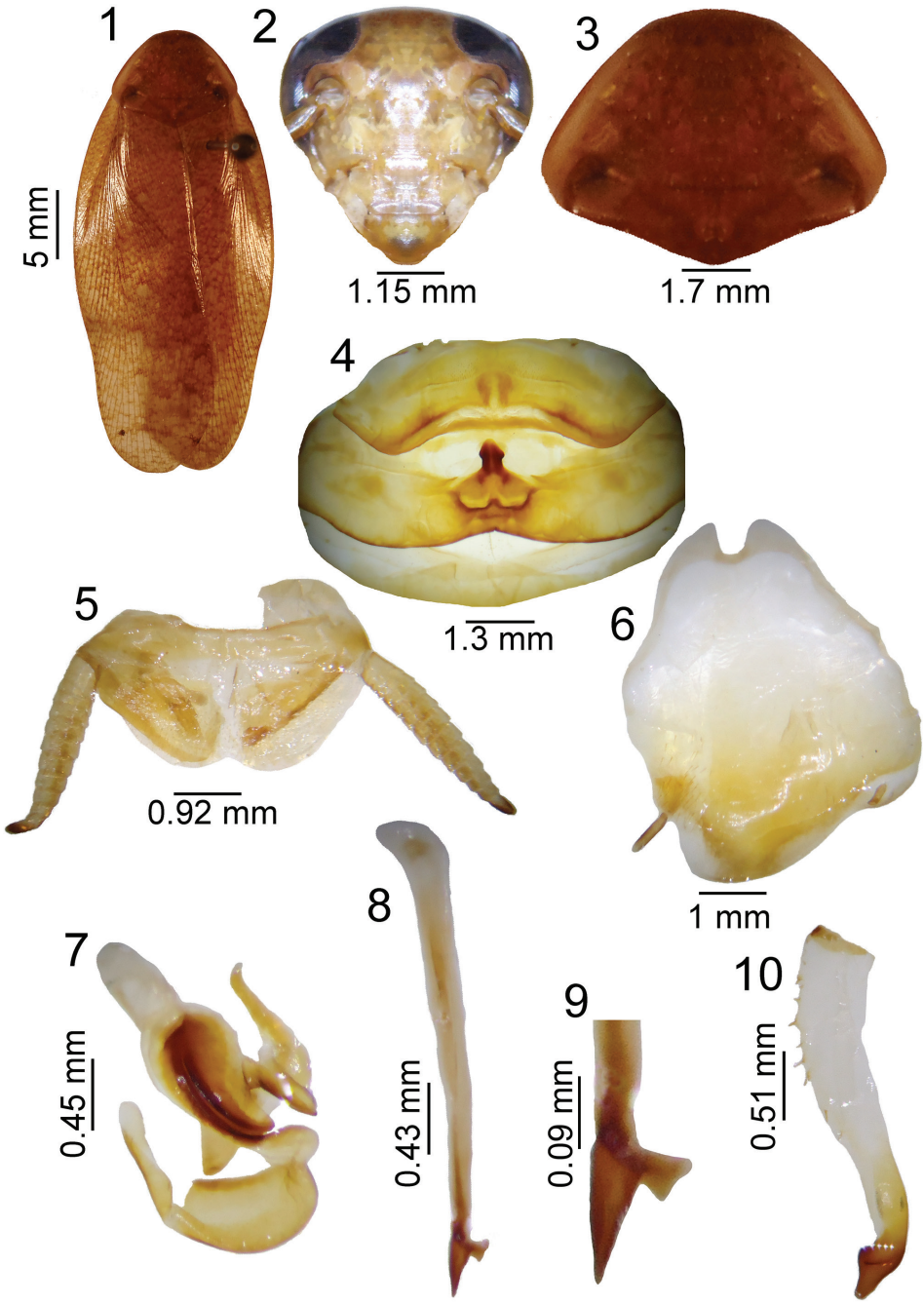
***Poeciloderrhis ferruginea* (Brunner von Wattenwyl, 1865)**
Figures 1–16

**General coloration.** Shiny dark brown (Figs. 1 and 11). Head with vertex, interocular space between ocellar fenestra and antennae brown. Two brown spots below ocellar fenestra. Maxillary palps with brown apical segment, with golden cilia. Eyes black (Fig. 2). Pronotum semi-transparent with dark brown punctuation (Fig. 3). Tegmen semi-transparent, light brown, bearing dark brown spots. Legs light brown with spines, arolia and claws brown. Abdomen light brown with brown punctation.

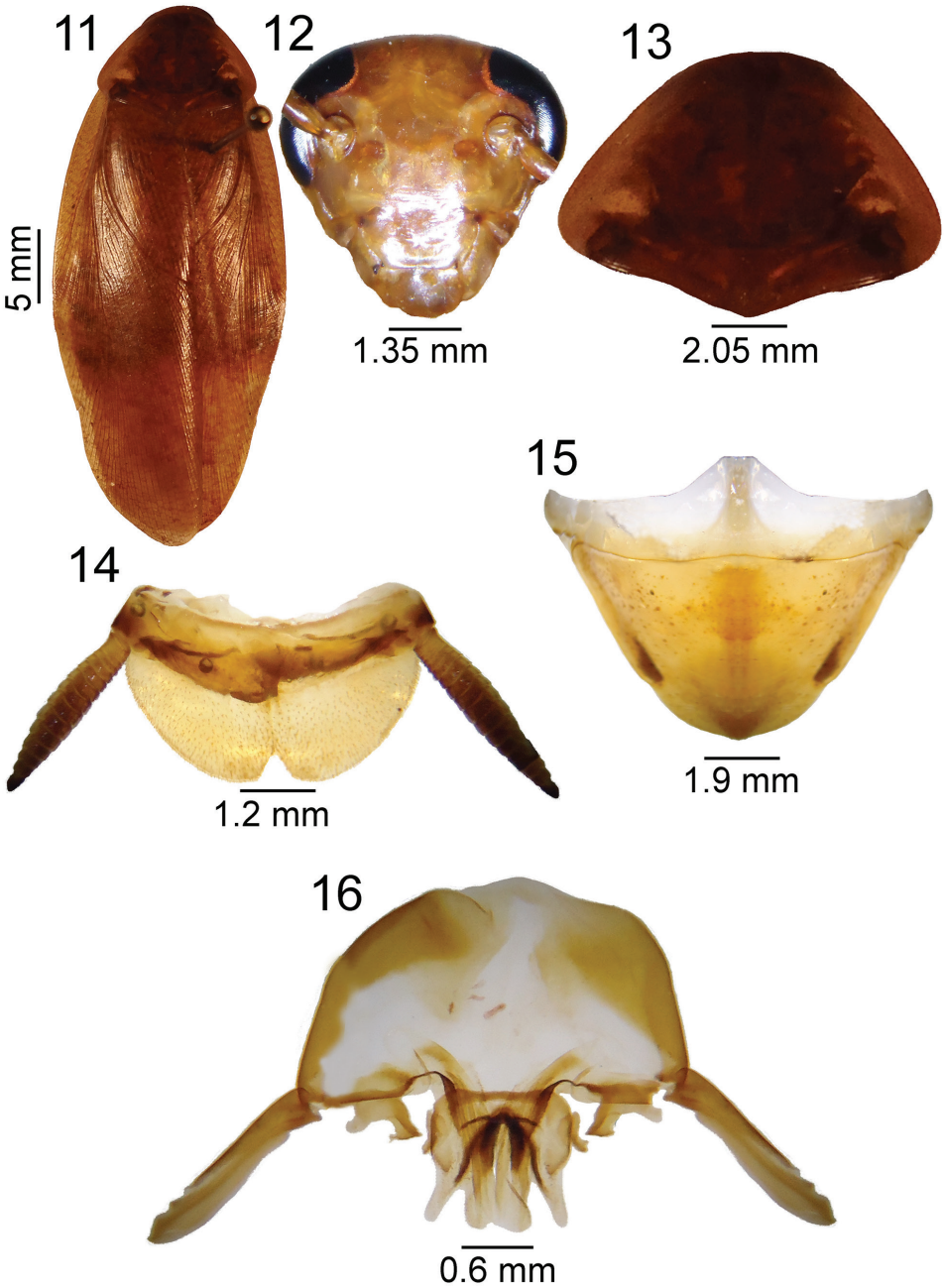
**Dimensions (male) (mm).** Total length: 32; total length of pronotum: 6.57; width of pronotum: 7.5; length of tegmen: 27.1; width of tegmen: 6.1.

**Head.** Triangular with rounded angles, vertex hidden in dorsal view; interocular space measuring about 1 mm; antennae long, slender and tomentose, reaching beyond apex of cerci. Eyes antero-lateral in position; maxillary palps with first and second segments reduced, the second measuring 0.41 mm, third segment 25% longer than fourth and 25% shorter than fifth segment, which is a little more dilated and very tomentose.

**Thorax.** Pronotum wide, pentagonal, convex, with curved margins, base with small median projection. Legs developed, half of femur I with anteroventral surface bearing four strong spines, followed by series of small spines towards apex, where two strong apical spines are present; posteroventral surface with three strong spines, one




**Figures 1–10.** *Poeciloderrhis ferruginea* (Brunner Von Wattenwyl, 1865) male **1** habitus **2** head, ventral view **3** pronotum, dorsal view **4** tergal modification in 1th tergite and 2th **5** supra-anal plate, dorsal view **6** subgenital plate, ventral view **7** left phallomere, dorsal view **8–9** median sclerite, dorsal view **10** right phallomere.




**Figures 11–16.** *Poeciloderrhis ferruginea* (Brunner Von Wattenwyl, 1865) female. **11** habitus **12** head, ventral view **13** pronotum, dorsal view **14** supra-anal plate, dorsal view **15** subgenital plate, ventral view; **16** valves, dorsal view.

apical; femora II and III showing strong spaced spines on their ventral surfaces. Pulvilli present on fourth tarsal segment, claws symmetrical and specialized, with two rows of small spines on ventral surface. Tegmen reaching beyond apex of abdomen. Marginal field wide, slightly concave, convex, curved, discoidal field convex and short at apex, anal field convex and well-marked.

**Abdomen.** Tergal modification pyramid-shaped, tall, with cilia, located on first tergite and depression followed by curved stalk on second tergite (Fig. 4). Supra-anal plate round with cerci reaching beyond the plate (Fig. 5). Subgenital plate asymmetric, with two slender styles, one long, and one short; larger style with sharper lateral tomentosity (Fig. 6). Left phallomere with median structure shaped as sclerotized cleft (Fig. 7). Median apical sclerite spiniform with intense sclerotization, with membranous sclerotized structure bearing lateral shaft and slender pre-apical structure (Figs. 8, 9). Right phallomere with straight apex and a small spine next to apex; lateral portion of phallomere with spines (Fig. 10).

**Dimensions (female) (mm).** Total length: 33.5; total length of pronotum: 7.7; width of pronotum: 9.45; length of tegmen: 29.3; width of tegmen: 7.8. Female larger than male; brown color of vertex extending to frons (Fig. 12); pronotum brown; in the abdomen, anal plate enlarged with indistinct slit medially, cerci poorly developed reaching apex of plate (Fig. 14); subgenital plate triangular (Fig. 15); female genitalia in three pairs of valves, of which the first is the most developed and widens toward apex, the second is the smallest and most sclerotized, and the third is more slender apically and slightly smaller in length than the first. Valvifers tapered and very small (Fig. 16).

**Material examined.** 1 ♂ Brazil, Minas Gerais, Catas Altas, RPPN Serra da Caraça, collected at 1490 m; 3 to 7/XII/ 2013. J. P. Botero, A. Carelli & G. C. Queiroz cols; 1 ♀ Brazil, data the same as for male.

**Diagnosis.** The male of *P. ferruginea* differs from the male in the size of the body, brown color of the vertex extending to the frons; enlarged supra-anal plate with indistinct median indentation, cerci poorly developed reaching apex of the plate; subgenital plate triangular; female genitalia with 3 pairs of valves; valvifers slender and small.

### ***Poeciloderrhis caracensis*** **sp. n.**

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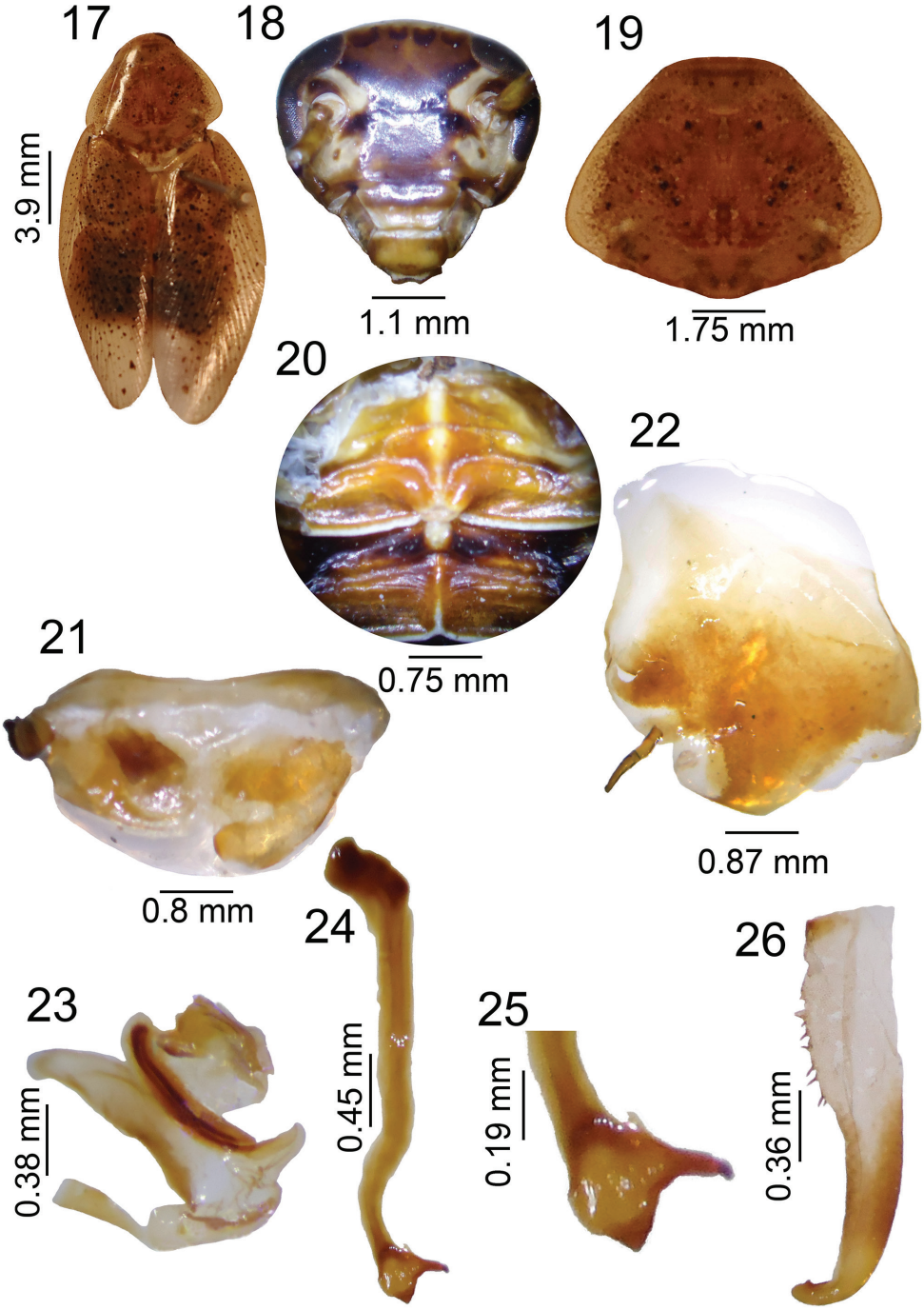
Figures 17–26

**General coloration.** Shiny light brown (Fig. 17). Head with apex light brown; ocelli and region above ocelli and below antennal insertions brown. Eyes dark brown (Fig. 18). Pronotum light brown, semi-transparent with dark brown punctations and symmetrical spot centrally (Fig. 19); tegmina light brown, semi-transparent with dark brown spots. Legs light brown and pulvilli with spines, arolia and claws dark brown. Abdomen dark brown.

**Dimensions (mm).** Total length: 21.3; total length of pronotum: 6.2; width of pronotum: 8.1; length of tegmen: 8.1; width of tegmen: 6.5.




**Figures 17–26.** *Poeciloderrhis caracensis* sp. n. male. **17** habitus **18** head, ventral view **19** pronotum, dorsal view **20** tergal modification in 1st tergite and 2nd **21** supra-anal plate, dorsal view **22** subgenital plate, ventral view **23** left phallomere, dorsal view **24–25** median sclerite, dorsal view **26** right phallomere.

**Head.** Triangular with rounded edges, vertex slightly exposed in dorsal view; interocular space measuring about 1 mm. Eyes positioned antero-laterally; maxillary palps with first and second segments reduced, the latter 0.45 mm, third segment the largest, 25% longer than the fourth, which is equal to fifth and a little more dilated and very tomentose.

**Thorax.** Pronotum wide, pentagonal, convex, with curved margins, base bearing small median projection. Legs developed, femur I bearing 3-6 strong spines up to the middle, followed by series of small spines towards apex, where two apical strong spines are present; posteroventral surface with three strong spines, one apical; femora II and III with strong spaced spines on ventral surfaces. Pulvilli present on four tarsal segments, claws symmetrical and specialized, with two rows of small spines on ventral surface, similarly to those of legs. Tegmen not exceeding apex of abdomen.

**Abdomen.** Tergal modification a tall structure on second segment, first segment with three median humps (Fig. 20). Supra-anal plate round with cerci short and tomentose dorsally (Fig. 21). Subgenital plate asymmetric, with left style in ventral view slender, filiform and well sclerotized; right style absent (Fig. 22). Genitalia with left phallomere bearing median structure shaped as sclerotized cleft (Fig. 23); median sclerite with quadrangular apex and a curved, well-developed spine (Fig. 24, 25). Right phallomere with curved apex bearing one small spine; prepucium with spines (Fig. 26).

**Material examined.** Holotype ♂, Brazil, Minas Gerais, Serra do Caraça, XI/1969. F. M. Oliveira col. Paratype ♂ Brazil, Mato Grosso, Sinop, X/1974, Alvarenga & Roppa col. Paratype ♂ without locality data.

**Diagnosis.** *P. caracensis* sp. n. is similar to *Poeciloderrhis verticalis* (Burmeister, 1838) in coloration and habitus (in Roth, 1970 fig. 50), but differs in size (*P. verticalis* is 38,8 mm). *P. caracensis* sp. n. also differs from *Poeciloderrhis santosi* (Rocha e Silva & Lopes, 1976) in size (*P. santosi* is 19,6 mm). The tergal modification also differentiates *P. verticalis* and *P. caracensis*. In *P. verticalis* the first segment has one raised medial ridge and in the second segment has two projections; one hooked (basal) and one pyramidal (apical).

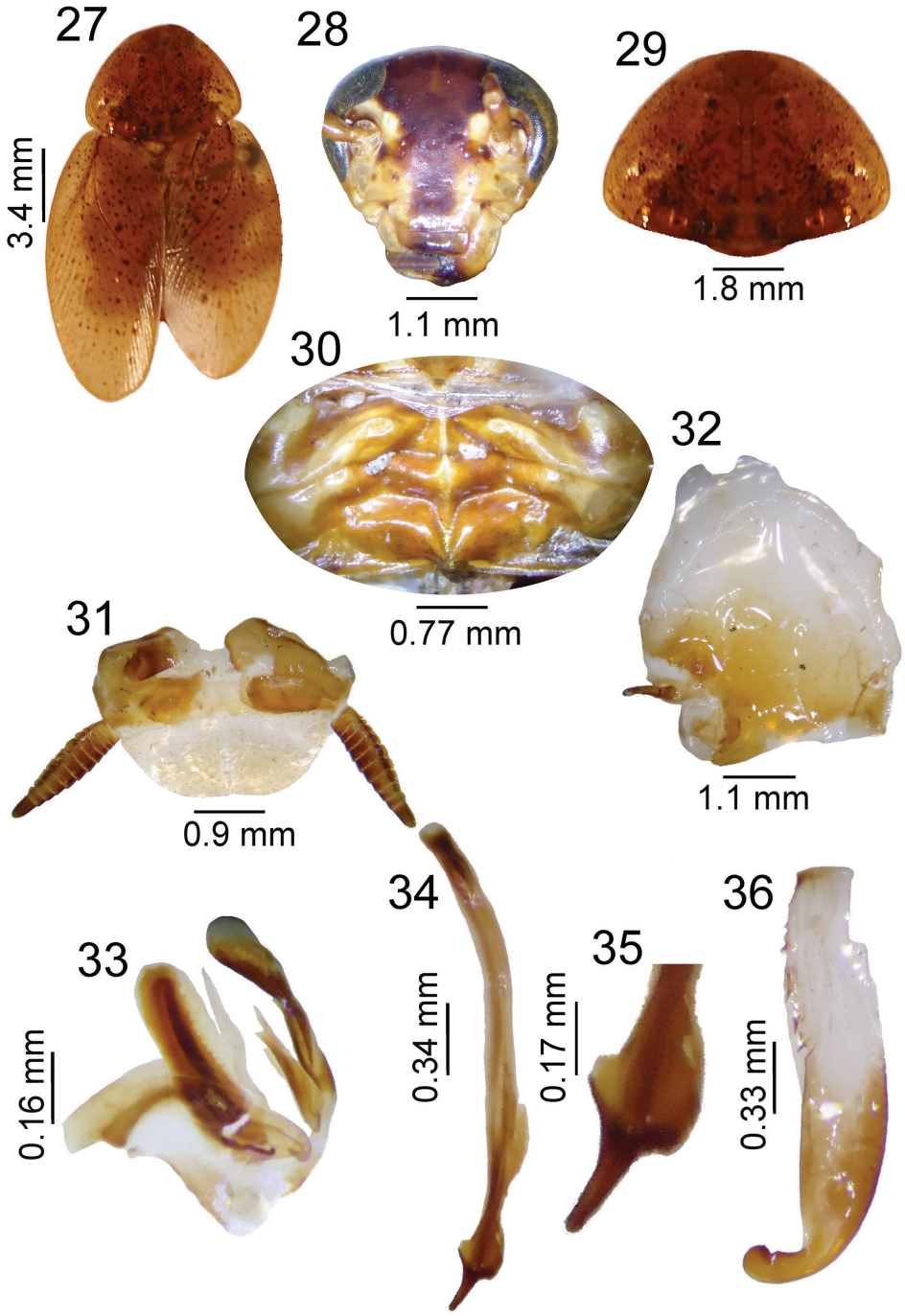
**Etymology.** The species epithet refers to the locality where it was collected.

### ***Poeciloderrhis minoris*** **sp. n.**

http://zoobank.org/FAEB84A1-9D28-444A-9DF6-123F794BE25C
Figures 27–36

**General coloration.** Shiny light brown (Fig. 27). Head with vertex light brown; interocular space between ocelli and antennal insertions brown; other regions light brown with brown stripe from between antennae to the tip of the clypeus. Ocelli brown; maxillary palps with apical segment brown, cilia golden. Eye black (Fig. 28). Pronotum light brown, semi-transparent with dark brown punctations (Fig. 29); tegmen light brown, semi-transparent with dark brown spots. Legs light brown with spine, pulvilli, arolia and claws dark brown. Abdomen light brown with brown punctations.

**Dimensions (mm).** Total length: 17.1; total length of pronotum: 5.4; width of pronotum: 7.1; length of tegmen: 12.8; width of tegmen: 5.3.




**Figures 27–36.** *Poeciloderrhis minoris* sp. n. male. **27** habitus **28** head, ventral view **29** pronotum, dorsal view **30** tergal modification in 1st tergite and 2nd **31** supra-anal plate, dorsal view **32** subgenital plate, ventral view **33** left phallomere, dorsal view **34–35** median sclerite, dorsal view **36** right phallomere.

**Head.** Triangular with rounded edges, vertex slightly exposed in dorsal view; interocular space 1.4 mm. Eyes positioned antero-laterally; maxillary palps with first and second segments reduced, the latter 0.43 mm, third segment 25% of fourth, and smaller than fifth segment, which is a little more dilated and very tomentose.

**Thorax.** Pronotum wide, pentagonal, convex, with curved margins, base bearing small median projection. Legs developed; proximal half of femur I bearing 5 strong spines on anteroventral surface followed by series of small spines towards apex, where two strong apical spines are present; posteroventral surface with three strong spines, one apical; femora II and III with strong spaced spines on ventral surfaces. Pulvilli present on four tarsal segments, claws symmetrical and specialized, with two rows of small spines on ventral surface. Tegmen not reaching beyond apex of abdomen.

**Abdomen.** Tergal modification a tall triangular structure between two humps. Below that, a pyramid-shaped hump (Fig.30). Supra-anal plate round with cerci short; cerci with row of cilia on each segment (Fig. 31). Subgenital plate asymmetrical with apical cleft, with left style in dorsal view long, filiform and sclerotized; right style absent (Fig. 32). Internal genitalia with left phallomere with median structure shaped as sclerotized cleft (Fig. 33); median sclerite developed as a spine with sclerotized apical curvature (Figs. 34, 35). Right phallomere with curved apex and a small thorn near the apex; lateral shaft of phallomere with spines (Fig. 36)

**Material examined.** Holotype ♂, Brazil, São Paulo, Campos do Jordão, X/1954. P.H. Saldanha col.

**Diagnosis.** *Poeciloderrhis minoris* sp. n. is small (17.1 mm) when compared with the other described species. It has short wings, similar to the wings of *Poeciloderrhis santosi* (Rocha e Silva & Lopes, 1976), but can be distinguished from it in the tergal modification that is similar to *P. caracensis* sp. n., general coloration and genital parts: the right phallomere is wider apically and the apical thorn at the apex of the median sclerite is reduced.

**Etymology.** The *minoris* is from the Latin minor, referring to the small size (17.1 mm) of this species when compared to the other described species.

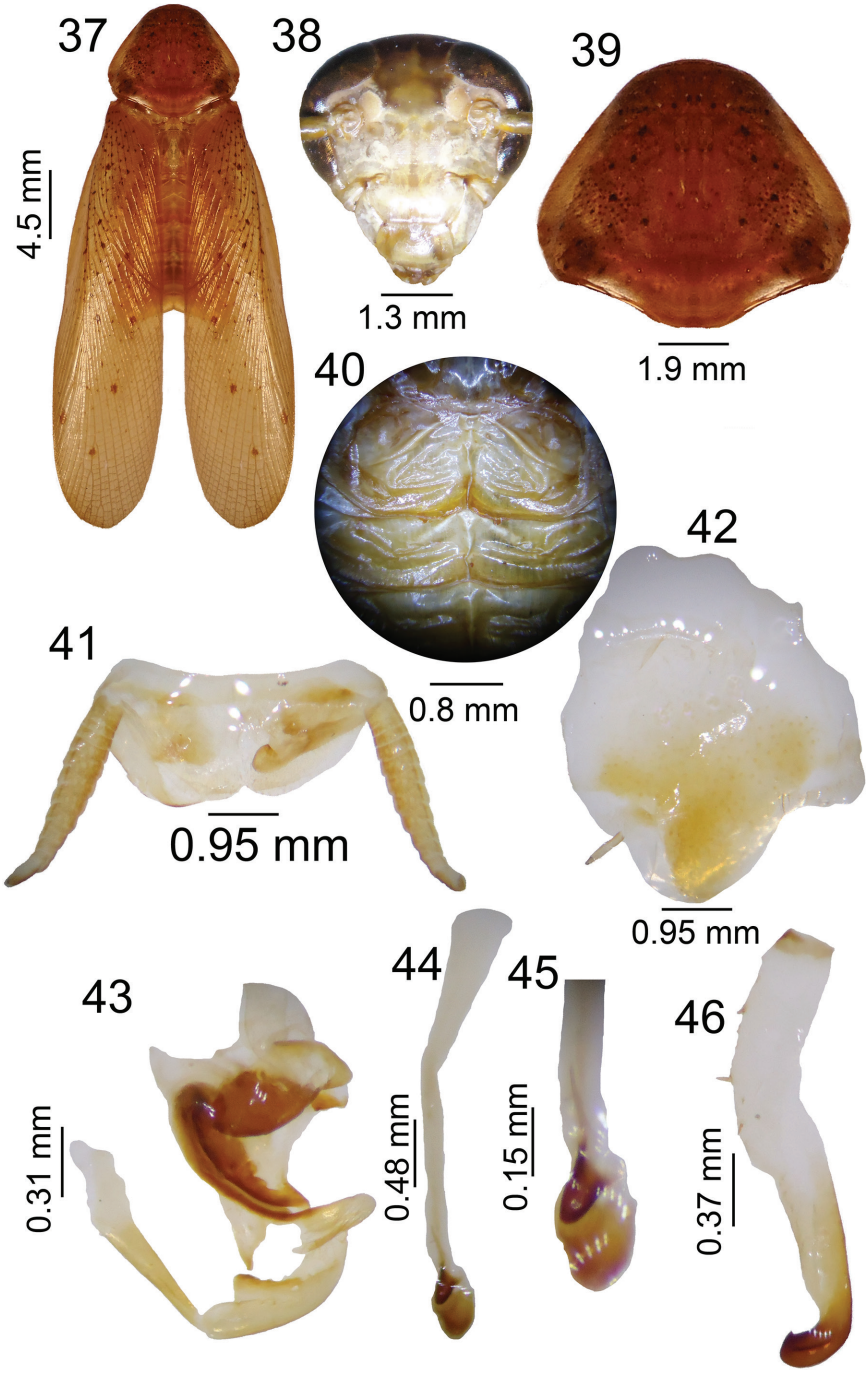
### ***Poeciloderrhis tijucana*** **sp. n.**

http://zoobank.org/F58D23FE-B4D5-4595-A7A6-657E9318E3F0
Figures 37–45

**General coloration.** Shiny light brown (Fig. 37). Head with vertex, interocular space between ocelli brown; other regions light brown. Maxillary palps with apical segment brown, cilia golden. Eye brown (Fig. 38). Pronotum light brown, with dark brown punctations (Fig. 39); tegmen light brown, with dark brown punctations. Legs light brown with spine, pulvilli, arolia and claws dark brown. Abdomen light brown.

**Dimensions (mm).** Total length: 33; total length of pronotum: 7.0; width of pronotum: 8.25; length of tegmen: 28; width of tegmen: 7.9.

**Head.** Triangular with rounded edges, vertex slightly exposed; interocular space about 1.0 mm. Antennae long, slender, and tomentose, reaching beyond apex of cerci.




**Figures 37–46.** *Poeciloderrhis tijucana* sp. n. male **37** habitus; **38** head, ventral view; **39** pronotum, dorsal view; **40** tergal modification in 1st tergite and 2nd; **41** supra-anal plate, dorsal view; **42** subgenital plate, ventral view; **43** left phallomere, dorsal view; **44–45** median sclerite, dorsal view; **46** right phallomere.

Eyes positioned antero-laterally; maxillary palps with first and second segments reduced, the latter 0.46 mm, third segment 25% larger than fourth and 10% larger than fifth, which is a little more dilated and very tomentose.

**Thorax.** Pronotum ample, pentagonal, convex, with curved margins, base bearing small median projection. Legs developed, femur I bearing 7 strong spines on anteroventral half, followed by series of small spines towards apex, where two strong apical spines are present; posteroventral surface with three strong spines, one apical; femora II and III with strong spaced spines on ventral surfaces. Pulvilli present on four tarsal segments, claws symmetrical and specialized, with two rows of small spines on ventral surface. Tegmen not reaching beyond apex of abdomen.

**Abdomen.** Tergal modification with two latero-apical humps converging toward thorax on first segment and small median hump on second tergite (Fig. 40). Supra-anal plate round with cerci reaching over apex of plate and short apical cleft (Fig. 41). Subgenital plate asymmetrical with apical cleft, with one long, filiform style and another inconspicuous one (Fig. 42). Genitalia with left phallomere with median structure shaped as sclerotized cleft (Fig. 43); median sclerite round apically and sclerotized on pre-apical region, with prepucium membranous bearing small spines (Fig. 44, 45). Right phallomere with curved apex and a small apical spine (Fig. 46).

**Material examined.** Holotype ♂, Brazil, Rio de Janeiro, Tijuca. No date and collector information.

**Etymology.** This species is named after the type locality, Tijuca, in Rio de Janeiro.

**Diagnosis.** This species is close to *P. ferruginea* in size, differing in: the coloration of the tegmina being more intense in *P. ferruginea*, ventral view, the subgenital plate having the right style small but distinct in *P. ferruginea*, and in the median sclerite having a sharp apex in *P. ferruginea*.

## Acknowledgments

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RESEARCH ARTICLE

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# *Mestus cruciatus*, a new delphacid species from southwest China with some remarks on the genus (Hemiptera, Fulgoromorpha, Delphacidae)

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## Abstract

A new delphacid (Hemiptera, Fulgoromorpha, Delphacidae) species, *Mestus cruciatus* **sp. n.** is described based on specimens from Yunnan Province, China. Habitus photos and illustrations of male genitalia are provided. The *Mestus* species and phylogenetic arrangement of this genus is discussed. A key to the species of *Mestus* is also provided.

## Keywords

Auchenorrhyncha, Fulgoroidea, planthopper, taxonomy, distribution, new species

## Introduction

The Oriental planthopper genus *Mestus* was established by Motschulsky (1863) with *Mestus morio* as the type species from Sri Lanka. It is a small genus in the Delphacini of Delphacinae with two species currently recognized, *M. morio* Motschulsky and *M. tungpuensis* Yang (Motschulsky 1863; Metcalf 1943; Fennah 1973–75; Yang 1989). It is distributed in Sri Lanka, the Philippines and south China (Taiwan). Recent identification of material in the collections of NWAFU has led to the discovery of a new species of this genus from Yunnan Province (southwest China) and it is described here.

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## Materials and methods

The specimens examined in this study including type material are deposited in the Entomological Museum, Northwest A&F University, Yangling, Shaanxi, China (NWAFU). The genital segments of the examined specimens were macerated in 10% KOH and drawn from preparations in glycerin jelly with the aid of a light microscope. Line diagrams were drawn using an OLYMPUS PM-10AD microscope. Photographs were taken with an automontage QIMAGING Retiga 4000R digital camera (CCD) stereozoom microscope. The terminology in this paper follows that of Ding (2006). Measurements of the body length were from the apex of the vertex to the posterior tip of the abdomen. All measurements are in millimeters (mm).

## Taxonomy

### Genus *Mestus* Motschulsky, 1863

*Mestus* Motschulsky, 1863: 111; Distant 1906: 489; Fennah 1973–75: 85; Yang 1989: 161; Ding 2006: 396.

**Type species.** *Mestus morio* Motschulsky, 1863 by original designation.

**Diagnosis.** The genus *Mestus* Motschulsky is readily separated from other genera in the Delphacini of Delphacinae by the vertex with apices of submedian carinae feebly developed, by the median frontal carina distinct but feeble at base, by the post-tibial spur without teeth along posterior margin, by the caudal margin of pygofer strongly produced near base, by the pygofer with a single process on the midventral margin, and by the aedeagus with teeth subapically on both sides.

**Description.** Head including eyes nearly as wide as pronotum. Vertex quadrate, anterior margin rounded, apices of submedian carinae and base of median frontal carina feebly developed. Angle of fastigium obtuse. Y-shaped carina with common stem distinct. Antennae cylindrical, short. Spinal formula of hind leg 5-7-4, post-tibial spur cultrate, concave on inner surface without teeth along posterior margin. Male pygofer in profile wider ventrally than dorsally, laterodorsal angles roundly produced, caudal margin near base strongly produced posteriorly, in posterior view the pygofer with a single process on the midventral margin, lateroventral margins not well defined. Parameres widely divergent apically. Diaphragm of pygofer broad, dorsally produced and incised in middle. Suspensorium ring-like ventrally. Aedeagus tubular, not twisted at base, subapex bearing teeth on both sides. Anal segment deeply sunk into the dorsal emargination of pygofer, caudoventral angles each produced in a spinose process.

**Remarks.** After being established by Motschulsky (1863), the genus *Mestus* was subsequently studied by Melichar (1903) and Distant (1906). However, the placement of this genus was unclear and was not treated in Muir's phylogeny of the family Del-

phacidae because Muir did not agree with the original description of the type species (Muir 1915). Thereafter, Muir (1917) thought Melichar had confused *Anectopia mandane* Kirkaldy with *Mestus morio* Motschulsky, just as Fennah (1973–75: 85) stated: "he [Melichar] was wrong in interpreting *Anectopia mandane* Kirkaldy as *M. morio.* Motschulsky describes *M. morio* as having a strong median frontal carina, and his figure shows that the tegmina are not ornamented. *Anectopia mandane*, by contrast, has no median carina on the frons…". The diagnosis of the type species, especially the male genital characters, became more identifiable after the work of Fennah (1973–75), Meanwhile, Fennah reconfirmed and treated *M. testaceus* Motschulsky and *Anectopia atrata* Muir as junior synonyms of *M. morio* Motschulsky, respectively. This study agrees with Fennah, who suggested *Anectopia atrata* Muir was a junior synonym of *M. morio* Motschulsky because the illustrations of *Anectopia atrata* (see Muir 1917, Figs 22, 22a, 22b) meet the definition of the genus *Mestus*.

The genus *Anectopia* Kirkaldy was established by Kirkaldy (1907). Muir (1915) checked its type species and placed this genus in the Delphacini of Delphacinae with two species (*A. mandane* Kirkaldy, 1907 and *A. igerna* Kirkaldy, 1907) known so far. Although *Anectopia* lacks a redescription after its establishment, the genus *Mestus* studied here differs from *Anectopia* in the post-tibial spur not having fine teeth along the posterior margin based on the works of Kirkaldy (1907), Muir (1915) and Fennah (1973–1975).

*Mestus* was once placed in Araeopini of the Araeopinae by Metcalf (1943); later it was assigned to the Tropidocephalini of the Delphacinae (Fennah 1973–75). This genus is currently recognized as a member of the Delphacini within Delphacinae (Asche 1985; Yang 1989; Ding 2006). From the keys of Yang (1989) and Ding (2006), the diagnosis of this Oriental genus is rather distinct and easily distinguished from other genera in the Delphacini by the post-tibial spur cultrate, solid, without teeth along posterior margin. Particularly in the key of Yang (1989), this genus is similar to two tropidocephaline genera: *Malaxa* Muir and *Tropidocephala* Stål. However, the post-tibial spur alone is not a sufficient indicator for tribal placement and for separating *Mestus* from other related genera, and there are many Delphacini that lack teeth along posterior margin (e.g., all of the former Alohini), features of the male genitalia are a better indication which should be considered for these genera. *Mestus* bears no obvious similarities with *Malaxa* or *Tropidocephala*. Furthermore, the composition and phylogeny of the Tropidocephalini needs to be reinvestigated.

Yang (1989) described *M. tungpuensis* based on "coleopterous" adults in Taiwan. According to the work of Bourgoin et al. (2015), the term coleopterous is useless to describe the tegmen precisely and has little morphological value. Therefore, the members of the genus *Mestus* have two wing forms, brachypterous and macropterous. The macropterous form of *Mestus* was described by Muir (1917) from the Philippines (*Anectopia atrata*, a synonym of *M. morio* as noted above). In the Chinese fauna, only the brachypterous form has been found so far. The wing polymorphism and biogeography of this genus need to be studied further.

**Distribution.** China (Taiwan, Yunnan), Sri Lanka, Philippines.

## List of species and synonyms in *Mestus* Motschulsky

1 *Mestus morio* Motschulsky, 1863 synonyms: *Mestus testaceus* Motschulsky, 1863, synonymized by Melichar 1903: 105; *Anectopia atrata* Muir, 1917, synonymized by Fennah 1973–75: 85.
2 *Mestus tungpuensis* Yang, 1989

## Key to species of the genus *Mestus* (males)

1 Medioventral process of pygofer widening in basal third then tapering to acuminate apex (Fennah 1973–75, Fig. 15); in posterior view the parameres lack teeth medially along inner margins (Fennah 1973–75, Figs 15, 16; Muir 1917, Figs 22, 22a) ..... ***M. morio* Motschulsky**
– Medioventral process of pygofer simple, not widening in basal third (Figs 8–11; Yang 1989, Figs 67G, F); in posterior view the parameres have distinct teeth medially along inner margins (Figs 8, 9, 12, 17; Yang, Figs 67D, L)... 2
2 Male anal segment has two processes long, overlapped near bases (Figs 8, 18); caudoventral protrusion of pygofer near base well developed, subquadrate, extending to the same level as apex of medioventral process in profile (Fig. 9); aedeagus broadened in basal 1/3, ventral margin in profile almost straight medially (Figs 12, 14) ..... ***Mestus cruciatus* sp. n.**
– Male anal segment with two processes short and separated, not overlapped near base (Yang 1989, Fig. 67D), caudoventral protrusion of pygofer near base moderate, not extending to the same level as apex of medioventral process in profile (Yang 1989, Fig. 67E); aedeagus in profile slightly broadened in middle, ventral margin arched medially (Yang 1989, Fig. 67I)..... ..... ***M. tungpuensis* Yang**

## *Mestus cruciatus* sp. n.

http://zoobank.org/2FE82B05-6733-4BE2-A101-0A16AE495B1A
Figures 1–19

**Description.** Brachypterous: Total length (from apex of vertex to the tip of abdomen): male (n=16) 2.40–2.75 mm, female (n=15) 2.65–2.88 mm; tegmina length: male (n=16) 1.85–1.90 mm, female (n=15) 1.88–1.98 mm.

*Color*. General color of male dark brown (Figs 1, 2). Vertex, frons and genae blackish brown (Figs 1, 5, 6). Eyes grayish black (Figs 1, 2, 5, 6). Antennae pale brown (Figs 1, 2, 5, 6). Pronotum, mesonotum, tegmina and abdomen dark brown (Figs 1, 2, 5); in some specimens the posterior margin of pronotum and scutellum brown. Postclypeus blackish-brown except apex and median carina yellow (Fig. 6). Longitudinal veins of forewing speckled with black brown granules (Figs 1, 2, 19). Legs yellowish brown

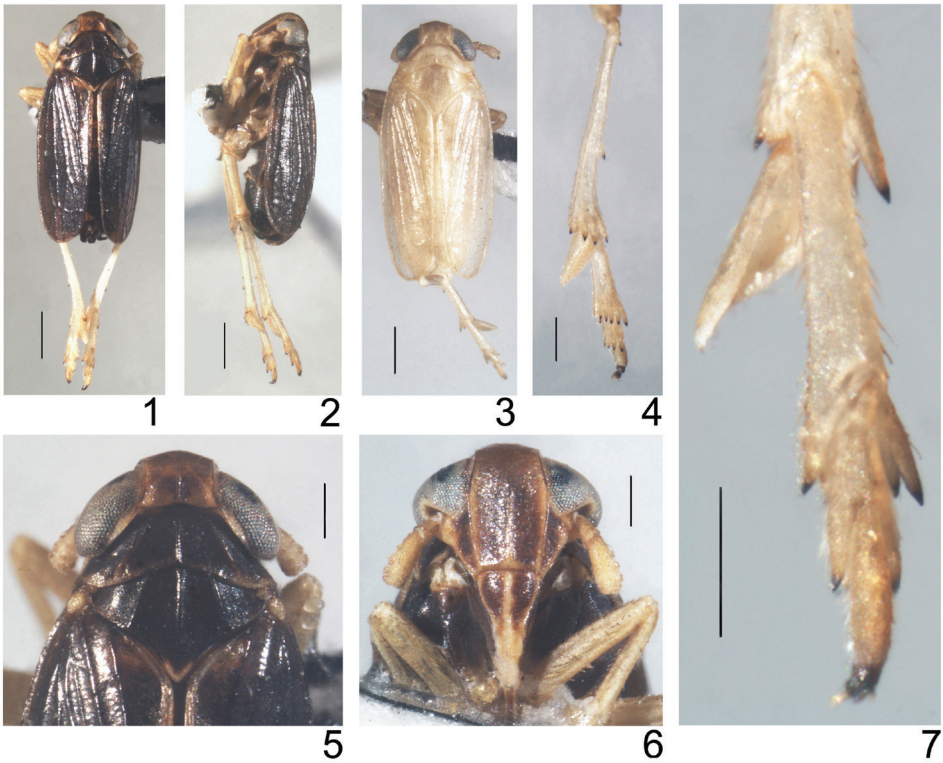


**Figure 1–7.** *Mestus cruciatus*, sp. n. **1** male adult, dorsal view **2** male adult, left lateral view **3** female adult, dorsal view **4** metatibia, metatarsus and post-tibial spur **5** head and thorax, dorsal view **6** frons and clypeus **7** metatarsus and post-tibial spur. Scale bars = 0.5 mm (Figs **1–3**); 0.2 mm (Figs **4–7**).

except fore- and middle coxae brown, apices of spines on tibiae and tarsi of hind legs black (Figs 4, 7). General color of female beige (Fig. 3). Tegmina semitransparent (Fig. 3). Ovipositor brown to blackish brown.

*Structure*. Vertex at about 1.32 times as broad as long in midline, slightly narrower at apex than at base (about 0.97: 1), anterior margin rounded, slightly projecting in front of eyes, lateral margins concave in dorsal view, submedian carinae originating from near 1/3 base of lateral carinae and feeble at apex (Figs 1, 5). Y-shaped carina with lateral arms faint, basal compartment shallowly concave, wider at base than greatest length (about 1.95:1) (Fig. 5). Fastigium rounded (Fig. 2). Frons longer in midline than maximum width about 1.61:1, widest at level of ocelli, lateral carinae slightly convex medially, median carina feeble at base (Fig. 6). Postclypeus wider at base than frons at apex (about 1.16:1), post- and anteclypeus together approximately 0.89× the length of frons (Fig. 6). Rostrum almost reaching meso-trochanters. Antennae terete, apex reaching to near the middle of postclypeus, scape longer than wide at apex (about 1.51:1), pedicle nearly twice the length of scape (Fig. 6).

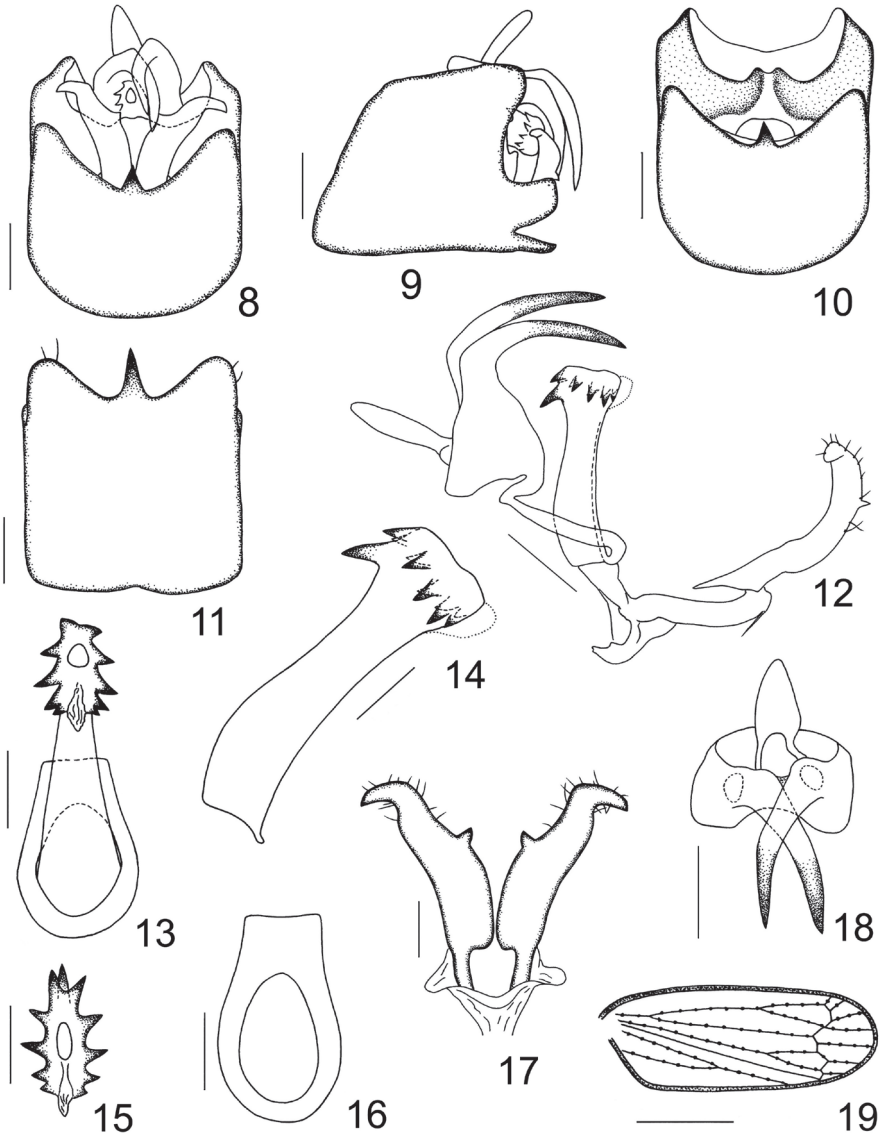


**Figure 8–19.** *Mestus cruciatus* sp. n. **8** male genitalia, posterior view **9** male genitalia, left lateral view **10** male pygofer, posterior view **11** male pygofer, ventral view **12** anal segment, aedeagal complex, connective and parameres, left lateral view **13** aedeagus, ventral view **14** aedeagus, left lateral view **15** apex of aedeagus, caudodorsal view **16** suspensorium, posterior view **17** parameres, posterior view **18** anal segment, caudodorsal view **19** tegmen. Scale bars = 0.2 mm (Figs **8–12**, **18**); 0.1 mm (Figs **13–17**); 0.5 mm (Fig. **19**).

Pronotum in midline slightly shorter than length of vertex (about 0.85:1), lateral carinae slightly curved, not reaching posterior margin of pronotum (Figs 1, 5), Mesonotum medially ca. 1.14 times longer than vertex and pronotum together, lateral carina almost straight, reaching posterior margin, median carina obscure before apex of scutellum (Figs 1, 5). Tegmina almost reaching or slightly surpassing apex of abdomen, longer than widest part about 2.48:1, widest near middle (Figs 1–3, 19). Spination of apex of hind leg 5 (3+2) (tibia), 7(5+2) (basitarsus) and 4 (2nd tarsomere) (Figs 4, 7). Hind tibiae 0.93–1.07 mm long, bearing 2 lateral teeth, post-tibial spur (0.33–0.38 mm) about 0.76× length of metabasitarsus, without identifiable teeth along posterior margin (Figs 4, 7).

*Male genitalia*. Pygofer in profile wider ventrally than dorsally, dorsolateral angle roundly produced, caudoventral margin near base with a well-developed, subquadrangular process, reaching the same level as medioventral process in profile (Fig. 9); in posterior view pygofer subquadrate, lateroventral margins excavated, medioventral process simple, spine-like in ventral view (Figs 8, 10, 11). Suspensorium ventrally ring-like, dorsally broad (Fig. 16). Dorsal margin of diaphragm produced, incised and membranous medially, in profile surpassing end of pygofer (Figs 9, 10). Parameres reaching the level of anal segment, sinuate, convergent at bases and then divergent distally, apices narrowed and strongly curved laterad, in posterior view each has a small tooth medially along inner margin (Figs 8, 9, 12, 17). Aedeagus moderate, in profile broadened dorsally in basal 1/3, ventral margin almost straight medially, at apex has a membranous tag on ventral side; in dorsocaudal view the aedeagus armed with approximately ten teeth circling the apical orifice, another bigger tooth, if present, shifted basally on the dorsal side (Figs 12–15). Male anal segment collar-shaped, laterocaudal margin with a long spinous process, overlapped near bases (Figs 8, 9, 12, 18).

**Species examined.** Holotype. ♂ (brachypterous, NWAFU), China, Yunnan Province, Weixi County, 13-VIII-2010, coll. Meng Zhang. Paratypes. 15♂♂, 15♀♀ (brachypterous, NWAFU), same data as holotype.

**Etymology.** This specific name alludes to the two overlapped processes near bases of the anal segment.

**Host plant.** Unknown.

**Discussion.** *Mestus cruciatus* sp. n. differs from *M. tungpuensis* Yang in having the caudoventral protrusion of pygofer near base well developed, extending to the same level as apex of medioventral process in profile; the aedeagus broadened dorsally in basal 1/3, ventral margin in profile almost straight medially. It differs from *M. morio* Motschulsky in having the medioventral process of pygofer simple, not widening in basal third; the inner margin of parameres each with tooth medially in posterior view. Furthermore, the new species differs from both species in having the lateroventral processes of male anal segment overlapped near bases.

**Distribution.** Yunnan Province (in southwest China).

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DATA PAPER

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# A geographic distribution database of the Neotropical cassava whitefly complex (Hemiptera, Aleyrodidae) and their associated parasitoids and hyperparasitoids (Hymenoptera)

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## Abstract

Whiteflies (Hemiptera, Aleyrodidae) are represented by more than 1,500 herbivorous species around the world. Some of them are notorious pests of cassava (*Manihot esculenta*), a primary food crop in the tropics. Particularly destructive is a complex of Neotropical cassava whiteflies whose distribution remains restricted to their native range. Despite their importance, neither their distribution, nor that of their associated parasitoids, is well documented. This paper therefore reports observational and specimen-based occurrence records of Neotropical cassava whiteflies and their associated parasitoids and hyperparasitoids. The dataset consists of 1,311 distribution records documented by the International Center for Tropical Agriculture (CIAT) between 1975 and 2012. The specimens are held at CIAT's Arthropod Reference Collection (CIATARC, Cali, Colombia). Eleven species of whiteflies, 14 species of parasitoids and one species of hyperparasitoids are reported. Approximately 66% of the whitefly records belong to *Aleurotrachelus socialis* and 16% to *Bemisia tuberculata*. The parasitoids with most records are *Encarsia hispida*, *Amitus macgowni* and *E. bellottii* for *A. socialis*; and *E. sophia* for *B. tuberculata*. The complete dataset is available in Darwin Core Archive format via the Global Biodiversity Information Facility (GBIF).

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**Keywords**
Aleyrodid, *Manihot esculenta*, hymenopterous parasitoids, hyperparasitism, tritrophic interaction, CIAT's Arthropod Reference Collection (CIATARC)

## Introduction

Whiteflies (Hemiptera, Aleyrodidae) are represented by more than 1,500 herbivorous species around the world (Hodges and Evans 2005, Evans 2007, 2008). Some of them are notorious pests of cassava (*Manihot esculenta*), a primary food crop in the tropics (Lebot 2009). Particularly destructive is a complex of Neotropical cassava whiteflies whose distribution remains restricted to their native range (Trujillo et al. 2004, Bellotti et al 2005). Despite their importance, neither their distribution, nor that of their associated parasitoids, is well documented (Evans 2008, Aliaga 2012, da Silva Alonso et al. 2012, Pietrowski et al 2014, Silva et al. 2014, Plantwise 2015 and Global Biodiversity Information Facility 2015). This paper therefore reports observational and specimen-based occurrence records of Neotropical cassava whiteflies and their associated parasitoids and hyperparasitoids. The dataset consists of 1,311 distribution records documented by the International Center for Tropical Agriculture (CIAT).

## Data published through GBIF

http://www.gbif.org/dataset/c6f4c2de-3b71-4ebd-9c98-c21537548f07

## Project details

**Project title:** Management of RTB Critical Pest and Diseases under Changing Climates, through Risk Assessment, Surveillance and Modeling.

**Project personnel:** Aymer Andrés Vásquez-Ordóñez (Data Manager, Data Publisher), Nicolas A. Hazzi (Data Manager, Data Publisher), Juan David Escobar-Prieto (Data Manager, Data Publisher), Dario Paz-Jojoa (Data Manager, Data Publisher), Rodrigo Zúñiga (Data Manager), Soroush Parsa (Principal Investigator, Data Publisher).

**Whiteflies and parasitoids collectors:** Collectors who have more than 30 records include: Bernardo Arias, Jose A. Castillo, Claudia M. Holguin, José María Guerrero B., Gerardino Perez Francisco Rendon and Harold Trujillo.

**Funding:** This project was supported by the Roots, Tubers and Bananas (RTB) Research Program of the Consultative Group on International Agricultural Research (CGIAR).

**Design descriptions:** The purpose of this dataset is to broadly and openly share geographic distribution data for the cassava whitefly complex and their associated parasitoids and hyperparasitoids. Prior to this contribution, no records were found of these

arthropod species in cassava at the Global Biodiversity Information Facility (2015). To bridge this gap, this paper submits 1,311 distribution records (whiteflies: 841; parasitoids: 466; hyperparasitoids: 4), documented by the International Center for Tropical Agriculture (CIAT) between 1975 and 2012. More than half of these records correspond to specimens preserved at CIAT's Arthropod Reference Collection (CIA-TARC). Most of the whitefly records correspond to *Aleurotrachelus socialis* Bondar and *Bemisia tuberculata* Bondar (Fig. 1A). In turn, most parasitoid records belong to *Encarsia hispida* De Santis, *Encarsia* sp. and *E. sophia* (Girault & Dodd) (Fig. 1B). This dataset should be of particular interest to whitefly biologists, cassava entomologists and national plant protection organizations (NPPOs) in tropical countries.

## Taxonomic coverage

### General taxonomic coverage description

Most records were identified to the species level (whiteflies: 97%; parasitoids and hyperparasitoids: 73%) by expert entomologists. Experts identifying more than 20 records were Gregory A. Evans, María del Pilar Hernández, Sueo Nakahara and Louise M. Russell. Whitefly records belong to nine genera and eleven species (Table 1), whereas parasitoid records belong to eight genera and 14 species (Table 1). The dataset also includes four records of the genus *Signiphora* (Table 1), considered a genus of whitefly hyperparasitoids (Evans 2007).

## Taxonomic ranks

**Kingdom:** Animalia
**Phylum:** Arthropoda
**Class:** Insecta
**Order:** Hemiptera, Hymenoptera
**Family:** Aleyrodidae, Aphelinidae, Ceraphronidae, Encyrtidae, Eulophidae, Platygastridae, Signiphoridae
**Genus:** *Aleuroctonus*, *Aleurodicus*, *Aleuroglandulus*, *Aleuronudus*, *Aleurothrixus*, *Aleurotrachelus*, *Amitus*, *Anagyrus*, *Aphanogmus*, *Bemisia*, *Encarsia*, *Eretmocerus*, *Euderomphale*, *Metaphycus*, *Paraleyrodes*, *Signiphora*, *Tetraleurodes*, *Trialeurodes*
**Species:** *Aleuroctonus vittatus* (Dozier), *Aleurodicus dispersus* Russell, *Aleurodicus flavus* Hempel, *Aleuroglandulus subtilis* Bondar, *Aleurothrixus aepim* (Goldi), *Aleurotrachelus socialis* Bondar, *Amitus fuscipennis* MacGown & Nebeker, *Amitus macgowni* Evans & Castillo, *Bemisia tabaci* (Gennadius), *Bemisia tuberculata* Bondar, *Encarsia americana* (DeBach & Rose), *Encarsia bellotti* Evans & Castillo, *Encarsia cubensis* Gahan, *Encarsia desantisis* Viggiani, *Encarsia guadeloupae* Viggiani, *Encarsia hispida* De Santis, *Encarsia luteola* Howard, *Encarsia nigricephala* Dozier,

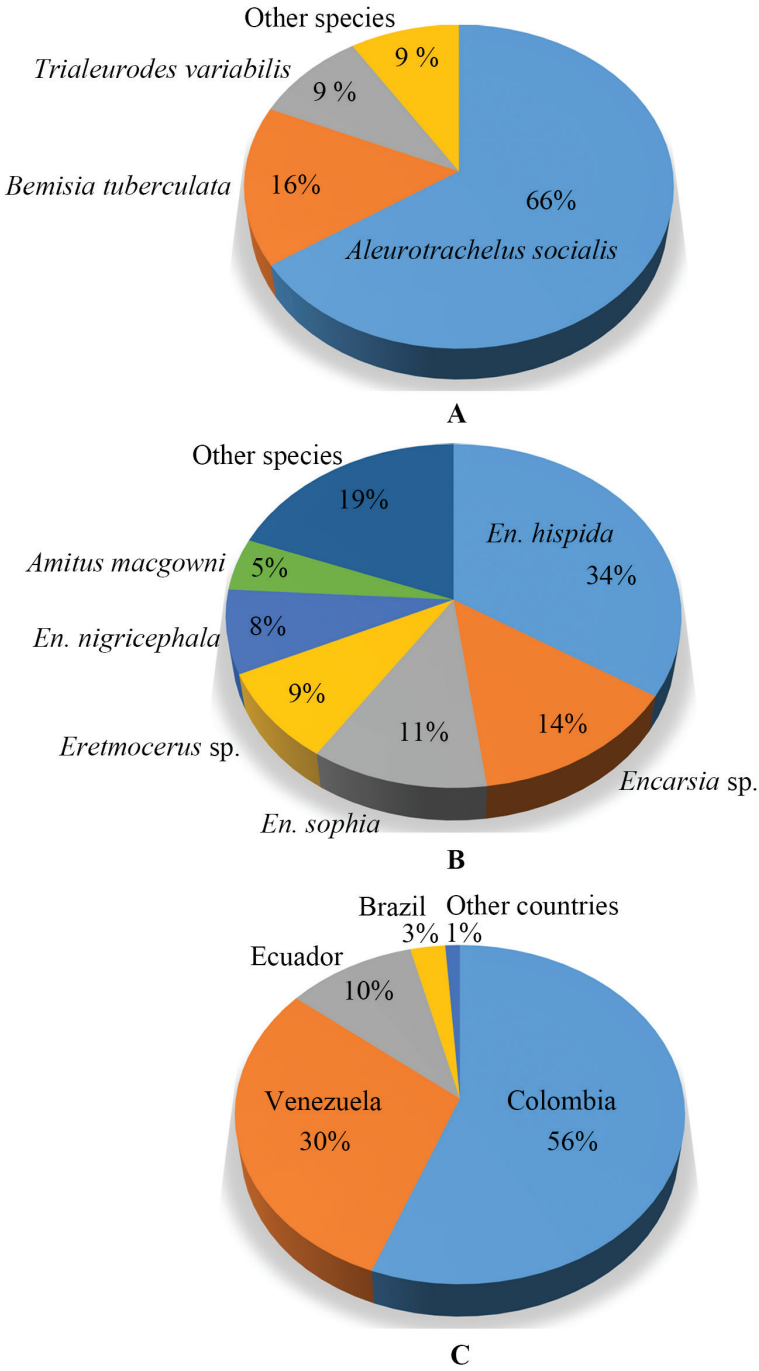


**Figure 1.** Percentage of occurrence records by Neotropical whitefly species (**A**), by parasitoids (**B**) and by country origin (**C**) in the CIAT's Arthropod Reference Collection database (N=1,311).

**Table 1.** Neotropical cassava whiteflies or parasitoids associated with the parasitoids and hyperparasitoids of the CIAT's Arthropod Reference Collection database. Ad: *Aleurodicus dispersus*, Asp: *Aleurodicus* sp., Asu: *Aleuroglandulus subtilis*, Am: *Aleuronudus melzeri*, Aa: *Aleurothrixus aepim*, As: *Aleurotrachelus socialis*, Alsp. *Aleurotrachelus* sp., Bt: *Bemisia tabaci*, Btu: *Bemisia tuberculate*, Bsp: *Bemisia* sp., Tvap: *Trialeurodes vaporariorum*, Tsp: *Tetraleurodes* sp., Tva: *Trialeurodes variabilis*, Trsp: *Trialeurodes* sp., Eh: *Encarsia hispida*, n: number of host for each species.

| Hymenoptera | | Whitefly species | | | | | | | | | | | | | | Eh | n |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Family** | **Species** | **Ad** | **Asp** | **Asu** | **Am** | **Aa** | **As** | **Alsp** | **Bt** | **Btu** | **Bsp** | **Tvap** | **Tsp** | **Tva** | **Trsp** | | |
| Aphelinidae | *Encarsia* sp. | | × | × | × | | × | | × | × | | | | × | × | | 8 |
| | *Encarsia americana* | | | | | | × | | | | | | × | | | | 2 |
| | *Encarsia bellottii* | | | | | | × | | | | | | | × | × | | 3 |
| | *Encarsia cubensis* | | | | | | × | | | | | | | | | | 1 |
| | *Encarsia desantisi* | | | × | | | | | | | | | | | | | 1 |
| | *Encarsia guadeloupae* | | | × | | | | | | | | | | | | | 1 |
| | *Encarsia hispida* | | | | | | × | × | × | × | | | × | × | × | | 7 |
| | *Encarsia luteola* | | | | | | | | × | | | | | | | | 1 |
| | *Encarsia nigricephala* | | | | | | | | × | | | | | | | | 1 |
| | *Encarsia pergandiella* | | | | | | | | | × | | × | | × | | | 3 |
| | *Encarsia sophia* | | | | | | × | | × | × | × | | | | | | 4 |
| | *Encarsia tabacivora* | | | | | | | | × | | | | | | × | | 2 |
| | *Eretmocerus* sp. | | | | | | × | | × | × | | | | × | | | 4 |
| Ceraphronidae | *Aphanogmus* sp. | | | | | | × | | | | | | | | | | 1 |
| Encyrtidae | *Anagyrus* sp. | | | | | × | | | | | | | | | | | 1 |
| | *Metaphycus* sp. | | | | | | × | | | × | | | | | | | 2 |
| Eulophidae | *Aleuroctonus vittatus* | × | | | | | | | | | | | | | | | 1 |
| | *Euderomphale* sp. | | | | | | × | | | × | | | | | | | 2 |
| Platygastridae | *Amitus* sp. | | | | | | × | | | × | | | | × | | | 3 |
| | *Amitus fuscipennis* | | | | | | | | | | | | × | | | | 1 |
| | *Amitus macgowni* | | × | | | | × | × | | | | | | | | | 3 |
| Signiphoridae | *Signiphora* sp. | | | | | | ×[1] | | | | | | | | | × | 2 |
| | *Signiphora aleyrodis* | | | | | | | | | ×[1] | | | | | | | 1 |
| **Total species by host** | | 1 | 2 | 3 | 1 | 1 | 13 | 2 | 7 | 9 | 1 | 1 | 3 | 6 | 4 | 1 | |

[1] This is a hyperparasitoid case (see taxonomic coverage).

*Encarsia pergandiella* Howard, *Encarsia sophia* (Girault & Dodd), *Encarsia tabacivora* Viggiani, *Signiphora aleyrodis* Ashmead, *Tetraleurodes ursorum* (Cockerell), *Trialeurodes similis* Russell, *Trialeurodes vaporariorum* (Westwood), *Trialeurodes variabilis* (Quaintance)

**Common name:** whitefly (for Aleyrodidae)

## Spatial coverage

**General spatial coverage:** Most of the distribution records belong to South America (Brazil, Colombia, Ecuador and Venezuela) and Central America (El Salvador, Guatemala, Honduras, Nicaragua and Panama). Colombia and Venezuela are the best represented countries, followed by Brazil and Ecuador (Fig. 1C). There are also seven records of whiteflies from Asia (Lao and Thailand). The distribution maps of principal whiteflies and their parasitoids are shown in Figure 2.

**Coordinates:** 17.95751 and -25.38936 latitude; -89.86917 and 104.72175 longitude

**Temporal coverage:** 1975-2012

## Natural collections descriptions

**Collection name:** CIAT's Arthropod Reference Collection (CIATARC)

**Specimen preservation method:** Specimens are preserved in microslides (whiteflies, parasitoids and hyperparasitoids), tissue beds on dried vials (parasitoids), 70% ethyl alcohol (parasitoids and hyperparasitoids), or in 35 mm plastic slide mounts (whiteflies). These samples are deposited within cabinet drawers maintained at 21.0 ± 0.4 °C and 47.6 ± 8.6% relative humidity. They are sorted numerically by species and country of origin.

**Curatorial unit:** 1601 with an uncertainty of 0.

## Methods

**Method step description:** The dataset integrates two data flows: observational records and specimen-based records, identified either to genus or to species. The former were digitized from field diagnostic forms recorded by personnel extensively trained in identification of whiteflies and parasitoids identification. These identifications, however, were likely conducted on site without mounting and preserving samples. Alternatively, these observations may correspond to properly-mounted but lost specimens. In either case, we are significantly confident on these identifications due to relatively clear macroscopic differences in our focal taxa (Caballero 1994, Fernández and Sharkey 2006). Still, conservative users of our database may prefer to rely only on genus-level

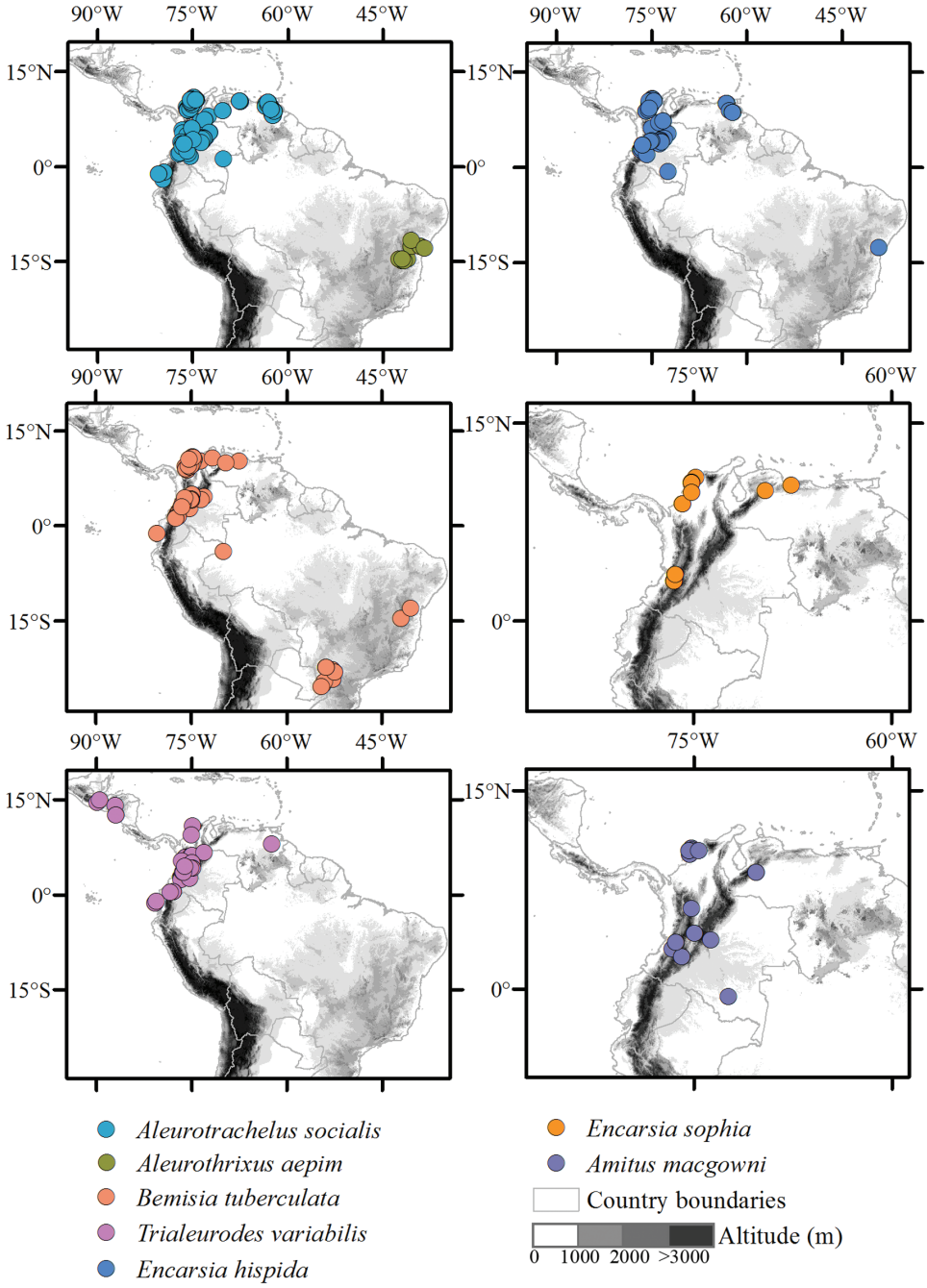


**Figure 2.** Geographic distributions of Neotropical cassava whitefly species (maps on the left) and their associated parasitoid species (maps on the right) in the CIAT's Arthropod Reference Collection database.

identifications of these records. On the other hand, the specimen-based records belong to verifiable samples properly-preserved at CIATARC. Guidelines of Martin (1987) and Hodges and Evans (2005) were followed for whitefly slide preparations, and Noyes (1982) for parasitoid and hyperparasitoid preparations. Unique accession numbers were assigned to all records.

All biodiversity data available (i.e. specimen, species identification, name of determiner, sex, locality, date, habitat, host, collector and observations) were digitized in a Microsoft Excel 2010 spreadsheet adopting the Darwin Core Archive format v1.2 (Wieczorek et al. 2012). We updated locality fields (e.g., district, municipality) using the most current names and classifications of administrative divisions used by each country (e.g. http://www.dane.gov.co/Divipola/ for Colombia, http://www.inec.gob.ec/estadisticas/?option=com_content&view=article&id=80 for Ecuador, etc. [accessed 14 November 2014]). Based on their locality names, we then geocoded the records using Google Maps (https://maps.google.com/), Geolocate (http://www.museum.tulane.edu/geolocate/), GeoNames (http://www.geonames.org/) or with georeference indicated in scientific articles (Calderón et al. 1994, Eiszner et al. 1996, Navia Estrada et al. 2006, Cuadros et al. 2011, Gutiérrez R. et al. 2011). GPS coordinates were converted to decimal degrees. The dataset with metadata was uploaded to the Integrated Publishing Toolkit (IPT) of the Colombia node of Global Biodiversity Information Facility (GBIF) (http://www.gbif.org/dataset/c6f4c2de-3b71-4ebd-9c98-c21537548f07).

**Sampling description:** The records in the dataset have been documented in three ways:

1) Records from CIAT's initial field explorations to document pests in cassava (CIAT 1974, 1985; 0.7% records, between 1975-1989).
2) Records documented during the "Biological Control of Whiteflies by Indigenous Natural Enemies for Major Food Crops in the Neotropics Projects" and participation in "Global Whitefly IPM Project" led by CIAT, Instituto Nacional de Investigaciones Agropecuarias (INIAP), Centro Nacional de Investigaciones Agropecuarias (CENIAP), Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA), The University of Florida and Corporación Colombiana de Investigacion Agropecuaria (Corpoica) (CIAT 1995, 2002, Bellotti et al. 1996, 1999, 2000, 2005, Bellotti 2001, Arias and Bellotti 2002, CIAT et al. 1998, Castillo 1996, López-Ávila et al. 2001, Hernandez and Bellotti 2002, Holguín et al. 2002, Hernández et al. 2004, 2009, Trujillo et al. 2004, Herrera et al. 2006; 95.7% records, between 1990-2007).
3 Records from other sources; including field inspections and collections conducted during routine farm visits by CIAT personnel, and specimens submitted to CIATARC by fellow institutions and researchers (Adriano Muñoz and Gerardino Perez, pers. comm. November 29, 2014; 2.6% records between 2008-2012).

The records resulted from one of two sampling methods. The first method was designed to identify parasitoids associated with dominant whitefly species on farmers' fields. One middle-canopy leaf infested with whiteflies was collected from each of 40-100 randomly-selected plants per field. A disc of 2.54 $cm^2$ was excised from the

leaf lobe with the highest density of whitefly pupae. The single most abundant whitefly species per disc was identified and individuals not belonging to that species were eliminated by puncturing them with a needle. The disc samples were then individually placed in 25-ml glass vials and held for 2–3 days at 24.5 ± 4 °C and 70 ± 5% relative humidity under laboratory conditions until parasitoids emerged (Bellotti et al. 1999, 2000, Trujillo et al. 2004). The second method corresponds to opportunistic collections during routine farm visits by CIAT personnel, when leaves infested with whitefly pupae would be collected in vials with 70% alcohol and submitted to the CIATARC for subsequent identification (Herrera et al. 2006). All formally-submitted samples were mounted and are preserved at the CIATARC. The database does not indicate which sampling method was used for each record.

**Quality control description:** Record validation and cleaning was incorporated at several steps of the documentation process, following guideless by Chapman (2005a, b). The scientific names on labels were checked with a taxonomic thesaurus developed by Aymer Andrés Vásquez-Ordóñez, Juan David Escobar-Prieto and Dario Paz-Jojoa. This thesaurus compiled all known synonyms and spelling variants of the scientific names used for our focal species. Scientific names were assigned in accordance to current taxonomic trends (whiteflies: Evans 2008; parasitoids and hyperparasitoids: Woolley 1988, Polaszek et al. 2004, Evans 2007, Johnson 2007, 2015, Noyes 2014; associated plants: Tropicos 2014). Geographic coordinates were verified using the "Check Coordinates" function in DIVA-GIS (Hitmans et al. 2001). For this last step, we relied on the Global Administrative Unit Layers (GAUL) shape file developed by the Food and Agriculture Organization of the United Nations (FAO 2015), and official shape of administrative division of Brazil, Colombia, Ecuador and Venezuela (IBGE 2007, INEC 2011, SIGOT 2011, IVIC 2007).

## Datasets

### Dataset description

**Object name:** Darwin Core Archive cassava whiteflies complex and their associated parasitoids and hyperparasitoids: data of the CIAT's Arthropod Reference Collection of International Center for Tropical Agriculture (CIAT).
**Character encoding:** UTF-8
**Format name:** Darwin Core Archive format
**Format version:** 1.0
**Distribution:** http://www.gbif.org/dataset/c6f4c2de-3b71-4ebd-9c98-c21537548f07
**Publication date of data:** 2015-05-15
**Language:** English
**Licenses of use:** This dataset [Neotropical cassava whiteflies complex and their associated parasitoids and hyperparasitoids of CIAT's Arthropod Reference Collection (CIATARC)] is made available under the Creative Commons Zero (CC0) 1.0.

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# Two new fossil genera and species of Cerocephalinae (Hymenoptera, Chalcidoidea, Pteromalidae), including the first record from the Eocene

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## Abstract

Cerocephalinae (Chalcidoidea, Pteromalidae) is a small group of parasitoid wasps characterized by a number of derived diagnostic features. Their hosts are endophytic beetles. So far, 43 species of Cerocephalinae have been described, including one fossil species from the Miocene. In this study, we add two new genera and species from Baltic and Dominican amber to the fossil record. *Tenuicornus dominicus* **gen. et sp. n.** is the second genus described from Dominican amber, and *Pteropilosa lailarabanorum* **gen. et sp. n.**, described from Baltic amber, represents the oldest record of the subfamily, pushing the minimum age of Cerocephalinae back to the Eocene. Diagnostic characters of both species are discussed in comparison with other Cerocephalinae. An updated key to extant and fossil Cerocephalinae is presented.

## Keywords

*Tenuicornus*, *T. dominicus*, *Pteropilosa*, *P. lailarabanorum*, Miocene, Baltic amber, Dominican amber

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## Introduction

Cerocephalinae is one of the smaller, yet most distinctive subfamilies of Pteromalidae (Hymenoptera, Chalcidoidea). Cerocephaline wasps are comparatively easy to recognize by a prominence in the intertorular area that can be a longitudinal carina or a tooth-like structure of varying size, by typical wing vein length ratios, and by two spurs on the hind tibia. Including the fossil record, only 43 species of Cerocephalinae in 14 genera have been described (Noyes 2014). All species are assumed to be parasitoids of small endophytic beetles (Bouček 1988), which makes them potentially potent biological control agents. Members of the genera *Cerocephala* and *Theocolax* have hereby proven to be effective against pests like *Stegobium paniceum* Linnaeus, 1758, *Rhyzopertha dominica* Fabricius, 1792 and other crop-feeding beetles (Flinn and Hagstrum 2002, Adarkwah et al. 2014).

Recent studies (Munro et al. 2011, Heraty et al. 2013) support the monophyly of Cerocephalinae, but their phylogenetic placement within Chalcidoidea still poses a problem. Pteromalidae is recognized as a polyphyletic assemblage (e.g., Krogmann and Vilhelmsen 2006, Heraty et al. 2013), but the phylogenetic relations among the pteromalid subfamilies and the remaining Chalcidoidea are unresolved. Among these, Cerocephalinae have not been studied intensively. A phylogeny of the taxa of Cerocephalinae has never been established, and only few taxonomic studies (e.g., Hedqvist 1969, Bouček 1988, 1993, Krogmann 2013) have been published since Gahan's (1946) first comprehensive revision of the group.

Cerocephalinae stand out as particularly underrepresented in the fossil record, with only one representative from Dominican amber, *Dominocephala vibrissae* Krogmann, 2013, known so far. In this study, two additional fossils representing two new genera and species are described. One of the new genera was found in Dominican amber (same as *Dominocephala vibrissae*), which is estimated to be 20–15 million years old (Iturralde-Vinent and MacPhee 1996). The other genus was found in Baltic amber, which is estimated to be 56–34 million years old (Szwedo and Sontag 2009). The latter taxon now represents the oldest record of the subfamily Cerocephalinae. Both genera are compared to extant members of Cerocephalinae and an updated key to the genera of this subfamily is given.

## Material and methods

Terminology follows Gibson (1997) with additions from Krogmann (2013). Descriptions of surface sculpture follow Harris (1979). Images for Figures 1 and 2 were taken with a Keyence VHX 600 digital microscope using incident light. Images for measurements were taken with a Leica DXM 1200 digital camera attached to a Leica MZ 16 APO microscope and processed using Auto-Montage (Syncroscopy) software. All images were edited with Adobe Photoshop CS3 and figure plates assembled with Adobe Illustrator CS3.

## Systematics

### Subfamily Cerocephalinae Gahan, 1946

**Diagnosis.** Intertorular area with prominence that can be a carina or tooth-shaped (also referred to as inner antennal process (iap)). Fore wing disc bare or with setae reduced to setal bases (pilose only in *Pteropilosa* gen. n.), with marginal fringe, fore wing always with thickened juncture between marginal vein and submarginal vein (parastigma), marginal vein elongate, postmarginal and stigmal vein shortened, postmarginal vein usually shorter than stigmal vein. Mesonotum with complete notauli. Hind tibia with two spurs.

### Key to extant and fossil genera of Cerocephalinae

This key is modified after Krogmann (2013) and includes the two new fossil genera described herein.

1 Antenna with five funicular segments in females and six funicular segments in males ..... **2**
– Antenna with six funicular segments in females (Fig. 1D) and seven funicular segments in males ..... **4**
2 Antenna shortened, with all funicular segments transverse; fore wing without a tuft of erect setae on parastigma (apterous species occur)..... ..... ***Choetospilisca*** **Hedqvist, 1969** [USA, Brazil, India]
– Antenna of normal size, with all funicular segments longer than or about as long as wide; fore wing with or without a tuft of erect setae on parastigma.... **3**
3 Fore wing with a tuft of erect setae on parastigma..... ..... ***Theocolax*** **Westwood, 1832** (in part) [Cosmopolitan]
– Fore wing without a tuft of erect setae on parastigma (as in Fig. 2E)..... ..... ***Acerocephala*** **Gahan, 1946** (in part) [USA, Samoa]
4 Fore wing disc distinctly pilose (Fig. 1B) ..... .....***Pteropilosa*** **gen. n.** [fossil, Eocene Baltic amber]
– Fore wing disc bare, setae (if present) reduced to setal bases..... **5**
5 Head, pronotum and mesoscutum sculptured; fore wing without a tuft of erect setae on parastigma..... **6**
– Head dorsally and mesoscutum entirely smooth and polished; pronotum usually polished but sometimes partly sculptured; fore wing with or without a tuft of erect setae on parastigma ..... **10**
6 Mandibles enlarged and conspicuous, at least 1/3 as long as head capsule... **7**
– Mandibles of normal shape and dimensions, less than 1/3 as long as head capsule..... **9**
7 Mandibles without a basal process.....***Muesebeckisia*** **Hedqvist, 1969** [Brazil]

– Mandibles with a basal process ..... **8**
8 Mandibles with two distinct teeth ... ***Gnathophorisca*** **Hedqvist, 1969** [Brazil]
– Mandibles with three distinct teeth ..... ***Gahanisca*** **Hedqvist, 1969** [Brazil]
9 Antenna inserted at level of ventral margin of eye ..... ***Neosciatheras*** **Masi, 1917** [Seychelles]
– Antenna inserted much higher than ventral margin of eye ..... ***Sciatherellus*** **Masi, 1917** [Seychelles]
10 Mandible elongate and conspicuous, 1/3 to 3/4 as long as head capsule .... **11**
– Mandible of normal size, far less than 1/3 as long as head capsule ..... **13**
11 Head with row of conspicuously elongate setae extending dorsally from the lower facial process; fore wing without a tuft of erect setae on parastigma ..... ***Dominocephala*** **Krogmann, 2013** [fossil, Miocene Dominican amber]
– Head without a row of conspicuously elongate setae; fore wing with or without a tuft of erect setae on parastigma ..... **12**
12 Mandible two-dentate; fore wing with a tuft of erect setae on parastigma ..... ***Paralaesthia*** **Cameron, 1884** [Panama]
– Mandible four-dentate; fore wing without a tuft of erect setae on parastigma ... ***Acerocephala*** **Gahan, 1946** (in part) [USA, Samoa]
13 Antenna inserted distinctly below level of ventral margin of eye; head in dorsal view parallel-sided ..... ***Theocolax*** **Westwood, 1832** (in part) [Cosmopolitan]
– Antenna inserted at or slightly below level of ventral margin of eye; head in dorsal view not parallel-sided ..... **14**
14 Fore wing with a tuft of erect setae on parastigma ..... **15**
– Fore wing without a tuft of erect setae on parastigma ..... **16**
15 Antenna with all funicular segments transverse, i.e., shorter than wide; propodeum with median carina ..... ***Paracerocephala*** **Hedqvist, 1969** [Zaire]
– Antenna with all funicular segments longer than wide or at least as long as wide; propodeum without median carina ..... ***Cerocephala*** **Westwood, 1832** [Cosmopolitan]
16 Antenna with all funicular segments longer than wide, cylindrical, almost parallel-sided ..... ***Laesthiola*** **Bouĉek, 1993** [USA]
– Funicular segments different; most funicular segments shorter than wide or as long as wide ..... **17**
17 Face deeply impressed, with long setae lateral to the impression of face; intertorular prominence nail-like and positioned distinctly above toruli (Fig. 2C, D) ..... ***Tenuicornus*** **gen. n.** [fossil, Miocene Dominican amber]
– Face convex, without long setae lateral to the impression of face; intertorular prominence variable in shape but never nail-like and positioned at level of or below toruli ..... ***Neocalosoter*** **Girault & Dodd, 1915** [Southern Hemisphere, Neotropics, Nearctic, Philippines]

***Pteropilosa* gen. n.**
http://zoobank.org/224D6EC0-9AB4-41E0-9558-6430B75D62B1

**Type species.** *Pteropilosa lailarabanorum* sp. n.

**Material.** Female holotype, preserved in Eocene Baltic amber (56-34 Ma). Holotype deposited in the amber collection of the State Museum of Natural History, SMNS collection number BB-2815.

**Diagnosis.** Funicle of female 6-segmented with funicular segments 3-6 distinctly transverse, i.e., shorter than wide (Fig. 1D); toruli positioned near upper margin of eyes (upper third of eyes); intertorular prominence tooth-shaped, positioned slightly below level of toruli; shape of head almost round (Fig. 1D). Fore wing pilose (Fig. 1B); marginal vein less than four times as long as stigmal vein; parastigma without a tuft of erect setae (Fig. 1B). Mesosoma sculptured and irregularly imbricate with short and transverse strigulate lines; frenal line present (Fig. 1C).

**Etymology.** The generic name *Pteropilosa* is composed of two parts. The first being *Ptero-*, which is derived from the old-Greek "pteryx", meaning "wing"; the last letters *-pilosa* are derived from the Latin "capillosus", meaning "hairy". It can be roughly translated as "hairy wings", referring to the most striking unique feature of this new genus. The generic name is feminine in gender.

***Pteropilosa lailarabanorum* sp. n.**
http://zoobank.org/6C7DCAE6-9192-49F3-B4DC-77A9F0DCF4A3

**Diagnosis.** See genus.

**Description.** Female: total body length 1.62 mm; length of head 0.32 mm, of mesosoma 0.64 mm, of metasoma 0.86 mm. Body without metallic luster. *Head*: height 0.35 mm. Shape of head round (globose) and head smooth, without sculpture; no depression on face; mandibles small (not measurable). Eyes rather big and slightly egg-shaped, 0.22 mm high and 0.19 mm wide. Intertorular prominence tooth-shaped and positioned between toruli, but slightly below level of toruli. *Antennae*: inserted well above ventral margin of eyes (in upper third of eyes); scape length 96 µm, pedicel length 48 µm, pedicel rather short and stout; funicle 6-segmented. First funicular segment wider than long, F2 longer than wide. F3-F6 wider than long, distally broadened club-like (F1: length: 33 µm × width: 37 µm; F2: 40 µm × 38 µm; F3: 47 µm × 56 µm; F4: 48 µm × 69 µm; F5: 48 µm × 71 µm; F6: 54 µm × 77 µm); all funicle segments with sensilla. Clava egg-shaped, 0.14 mm long and 81 µm wide. *Wings*: fore wing disc pilose, without fuscous band. Elongate admarginal setae absent. Fore wing length 1.19 mm and width 0.33 mm; submarginal vein 0.42 mm long, marginal vein 0.33 mm and postmarginal vein 76 µm long, stigmal vein curved, 76 µm long; stigma slightly thickened and uncus visible. Hind wing length 0.98 mm and width 0.23 mm, only two hamuli visible. *Legs*: length of hind tibia 0.24 mm, hind femur 0.35 mm, hind trochanter 46 µm, hind coxa 0.15 mm. The other legs cannot be measured due to the

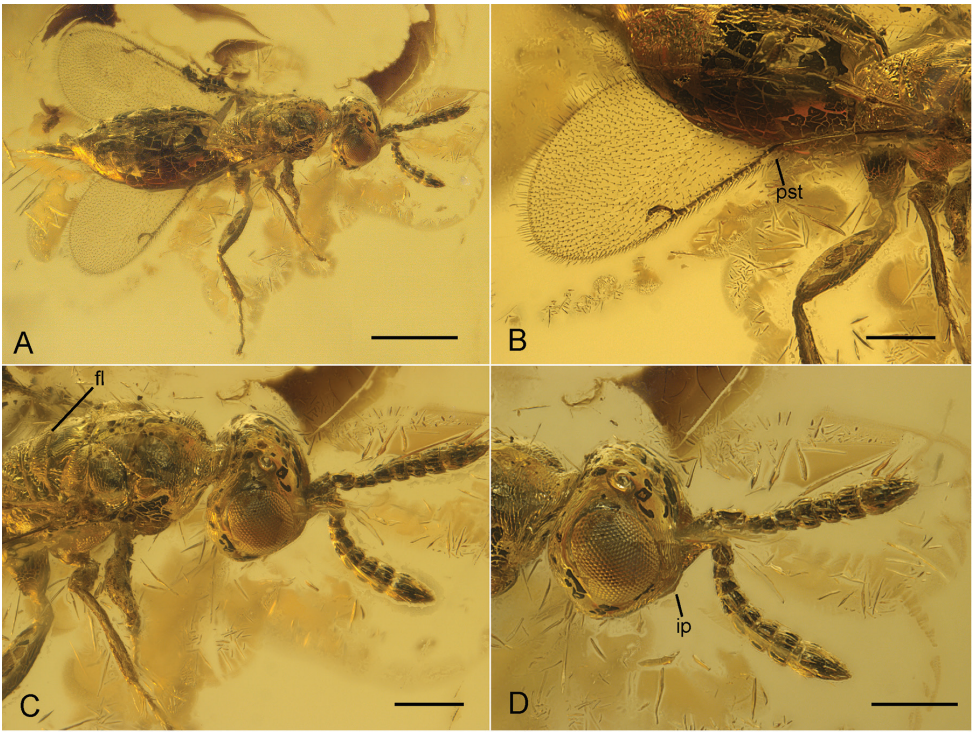


**Figure 1.** *Pteropilosa lailarabanorum* gen. et sp. n. in dorsolateral view, showing general habitus and diagnostic characters. **A** General habitus **B** Fore wing with distinct pilosity on disc, with comparatively short marginal vein, and without a tuft of erect setae on the parastigma (pst) **C** Head and mesosoma, showing surface sculpture on pro-, and mesonotum, and distinct frenal line (fl) **D** Head and antennae, showing tooth-shaped intertorular prominence (ip) positioned slightly below insertion of antennae; antennae inserted well above ventral margin of eyes, segments 3–6 of the 6-segmented funicle distinctly transverse. Scale: 500 µm (**A**); 200 µm (**B–D**).

position of the specimen within the amber. *Mesosoma*: pronotum, mesoscutum and mesoscutellum completely reticulated. Frenal line clearly visible and foveolate; frenum 0.55 times as long as mesoscutellum. Length of pronotum 0.25 mm, of mesoscutum 0.13 mm, of mesoscutellum 50 µm, of frenum 29 µm. Axillae large, medially connected. Metanotum with distinct foveae; lateral panel of metanotum wide and smooth. Metascutellum thin; not reaching anterior margin of metanotum. Propodeum coarsely reticulated. *Metasoma*: petiole ($Mt_1$) small, transverse, hardly recognizable. Metasomal tergites $Mt_2$ to $Mt_9$ smooth, $Mt_2$: 0.23 mm, $Mt_3$: 42 µm, $Mt_4$: 0.15 mm, $Mt_5$: 0.13 mm, $Mt_6$: 67 µm, $Mt_7$ 0.10 mm, $Mt_{8/9}$: 70 µm. Ovipositor 0.12 mm (top view) exerted beyond end of gaster.

**Taxonomic remarks.** Following the latest available identification key of Krogmann (2013), *Pteropilosa lailarabanorum* would be determined as *Sciatherellus*. However, there are distinct differences between the two genera. In addition to the pilose fore wings which are unique in *Pteropilosa* (Fig. 1B), *Sciatherellus* differs from *P. laila-*

*rabanorum* in having six antennal funiculars that broaden distally, with F3-6 distinctly transverse (Fig. 1D). In contrast, no funicular segment in *Sciatherellus* is wider than long. The fore wings of *Sciatherellus* also possess two prominent dark transverse bands that are absent in *Pteropilosa*, and the stigmal vein is straight in contrast to that of *P. lailarabanorum*, which is distinctly curved (Fig. 1B). The main differences between *Pteropilosa* and *Neocalosoter* are the pilose wings, the sculptured mesosoma, and the position of the toruli. In *Pteropilosa*, the antennae are inserted distinctly above the lower margin of the eyes, at around 2/3 of the height of the eyes (Fig. 1D). In the description of *Neocalosoter* (by Girault and Dodd in Girault 1915), it is stated that the antennae in this genus are "inserted at mouth border", i.e., below the lower margin of the eyes. However, the position of the toruli in *P. lailarabanorum* is not unique within Cerocephalinae. *Sciatherellus*, *Dominocephala*, *Muesebeckisia*, and *Gnathophorisca* also have the antennae inserted above the lower margin of the eyes. *Muesebeckisia* and *Gnathophorisca* are easily distinguishable from *Pteropilosa* by their enlarged and conspicuously thickened mandibles. Furthermore, *Muesebeckisia* and *Gnathophorisca* share a fuscous band on the fore wing, which is absent in *P. lailarabanorum*. The recently described fossil genus *Dominocephala* can be distinguished from *P. lailarabanorum* by the elongate mandibles and the set of multiple setae on the lower facial process, both of which are not found in *P. lailarabanorum*. *Dominocephala* also features a fuscous band on the fore wing not present in *P. lailarabanorum*.

**Etymology.** Named after Laila and Raban Ohlhoff, the grandchildren of the private donor.

***Tenuicornus* gen. n.**
http://zoobank.org/917FEC30-8E65-4848-982D-58982C4558C6

**Type species.** *Tenuicornus dominicus* sp. n.

**Material.** Female holotype, preserved in Lower Miocene Dominican amber (20-15 Ma). Holotype deposited in the amber collection of the Senckenberg Forschungsinstitut und Naturmuseum Frankfurt am Main, Germany, collection number SMF Be 2395.

**Diagnosis.** Funicle of female 6-segmented and clavate with F1–F2 longer than wide and F3–F6 wider than long and distally broadening; scape elongate (1/3 of total antennal length) (Fig. 2D). Face deeply impressed with one distinct seta at each side of lateral margin of the impression anterior to mandibular articulation; seta long and thickened, slightly clavate in shape (Fig. 2C). Inner antennal process (iap) very thin and nail-like, located above level of toruli at upper margin of facial impression. Position of iap distinctly above ventral margin of eyes, on level with middle of eyes (Fig. 2C, D). Fore wing without a tuft of erect setae at parastigma. Wing disc bare, without setal bases. Marginal vein four times as long as stigmal vein (Fig. 2E). Prepectus large and triangular. Mesonotum almost completely polished (Fig. 2B). Exerted part of ovipositor long, approximately 1/4 of gaster length (Fig. 2A).

**Etymology.** The first letters of the generic name *Tenui-* are derived from the Latin word "tenuis", meaning "thin" or "sharp". The last letters *-cornus* of the generic name are derived from the Latin word "cornus", meaning "horn". The generic name is male in gender and refers to the thin inner antennal process.

***Tenuicornus dominicus* sp. n.**
http://zoobank.org/8968FC81-D138-43FB-AA79-CD15E283D82C

**Diagnosis.** See genus.

**Description.** Female: total body length 2.07 mm; length of mesosoma 0.92 mm, of metasoma 1.02 mm. Body without metallic luster. *Head*: height 0.39 mm, width 0.38 mm. Face deeply impressed. Shape of head cuboid; mandibles not visible, hidden in facial depression. Margin of facial depression with rough surface and with a thickened seta on each side (length of setae 85 µm). Inner antennal process (iap) positioned distinctly above level of toruli; nail-like, 0.11 mm long, with basis wider than apex, orientated anteroventrally. Eyes large and egg-shaped, 0.25 mm high and 0.2 mm wide. *Antennae*: inserted at ventral margin of eyes; scape long and slightly curved, length 0.25 mm; pedicel length 75 µm, rather short and stout; funicle 6-segmented with first two funicular segments longer than wide (F1: length: 71 µm × width: 52 µm; F2: 68 µm × 60 µm) and F3-F6 wider than long, distinctly broadening distally, club-like (F3: 59 µm × 72 µm; F4: 60 µm × 74 µm; F5: 58 µm × 80 µm; F6: 52 µm × 86 µm). Clava egg-shaped: 97 µm long and 77 µm wide. *Wings*: fore wing long and slender (length 1.53 mm and width 0.55 mm); submarginal vein 0.57 mm long, marginal vein 0.38 mm long, postmarginal vein 0.11 mm long, stigmal vein 99 µm long; stigma slightly thickened and uncus visible. Wing disc bare, setal bases absent. Elongate admarginal setae present. Hind wing length 1.27 mm and width 0.27 mm, three hamuli present. *Mesosoma*: pronotum and anterior part of mesoscutum with slight traces of strigulate surface sculpture; mesonotum otherwise polished. Notauli foveolate. Length of pronotum 0.37 mm, length of mesoscutum 0.22 mm, length of mesoscutellum 0.22 mm; no frenal line. Axillae medially connected. Mesopleuron (in lateral view) height 0.29 mm, width 0.36 mm. Prepectus enlarged and triangular in shape (0.14 mm × 0.17 mm). Length of metanotum 39 µm; length of propodeum 72 µm. Propodeum without a median carina or plicae. *Legs*: coxae strong and stout. Femora and tibiae long and slender ($Fe_1$: 0.45 mm; $Fe_2$: 0.32 mm; $Fe_3$: 0.41 mm; $Ti_1$: 0.39 mm; $Ti_2$: 0.49 mm; $Ti_3$: 0.42 mm). *Metasoma*: petiole ($Mt_1$) short and transverse, hardly visible. Metasomal tergites $Mt_2$ to $Mt_9$ smooth, $Mt_2$: 0.28 mm, $Mt_3$: 0.17 mm, $Mt_4$: 0.15 mm, $Mt_5$: 0.16 mm, $Mt_6$: 0.11 mm, $Mt_7$ 60 µm, $Mt_{8/9}$: 71 µm. Ovipositor 0.23 mm (top view) exerted beyond end of gaster.

**Taxonomic remarks.** The two genera that are most similar to *Tenuicornus* are *Neocalosoter* and *Cerocephala*. *Tenuicornus* runs to *Neocalosoter* in the key of Krogmann (2013) but differs from this genus in various features: *Tenuicornus* possesses a head that is deeply impressed (convex in *Neocalosoter*), the dark transverse bands on

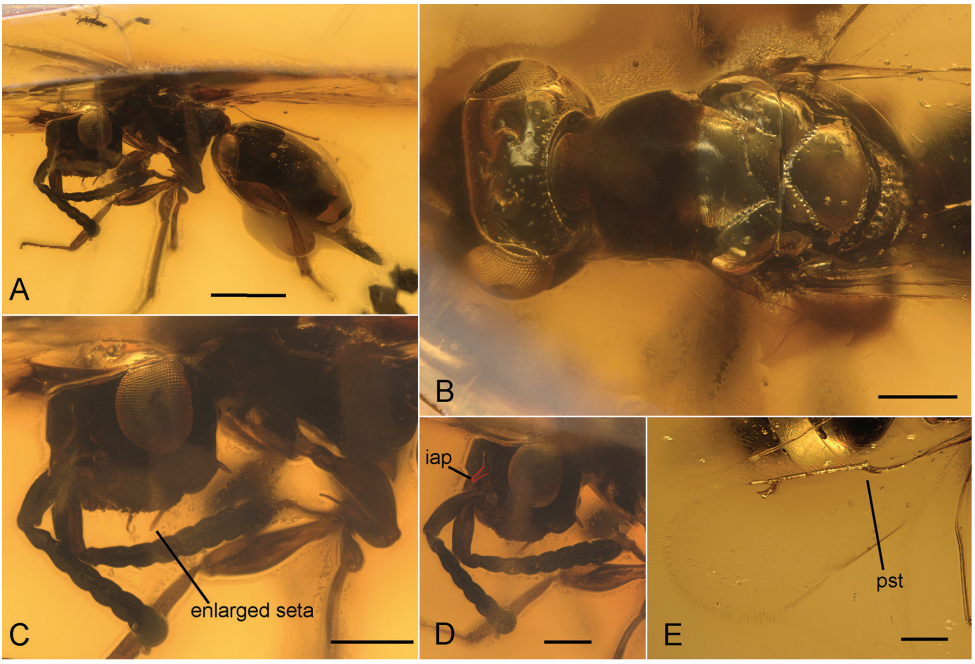


**Figure 2.** *Tenuicornus dominicus* gen. et sp. n., showing general habitus and diagnostic characters. **A** General habitus in frontolateral view, showing rather long exerted part of the ovipositor **B** Head and mesosoma in dorsal view, mesosoma with polished mesonotum, foveolate notauli, and absent frenal line **C** Head in frontolateral view, with deep facial impression and enlarged setae at each side of lateral margin of the impression **D** Head and antennae in frontolateral view, at slightly different angle than **C**, with nail-shaped inner antennal process (iap) visible and highlighted with a red line; antennae inserted at ventral margin of eyes, with long scape, and 6-segmented, clavate funicle **E** Fore wing without a tuft of erect setae at parastigma (pst) and without pilosity or setal bases on wing disc. Scale: 500 µm (**A**); 200 µm (**B–D**).

its fore wing are absent, and the propodeum has no traces of a median carina or plicae (Fig. 2B). The tentative similarity between *Tenuicornus* and *Cerocephala* is based on the deeply impressed face. However, *Tenuicornus* differs from *Cerocephala* by the absence of a tuft of setae on the parastigma on the fore wings (Fig. 2E), one of the most distinct characters for the generic classification of Cerocephalinae. *Tenuicornus* further differs from *Cerocephala* by the shape and position of the inner antennal process. In *Tenuicornus*, the process is shaped like a nail and positioned above the level of the toruli at the upper margin of the facial depression (Fig. 2C). In *Cerocephala*, the process is broader and stouter and positioned at or slightly below the level of the toruli. Furthermore, *Cerocephala* is described to have all funicular segments longer than wide (Westwood 1832), while in *Tenuicornus* only the first two funicular segments are longer than wide. The funicular segments three to six are wider than long (Fig. 2D).

**Etymology.** The name *dominicus* is derived from the amber deposit in which the fossil was found.

## Discussion

*Pteropilosa lailarabanorum* features a variety of characters that are unique within Cerocephalinae. The most striking of these characters is the wing pilosity (Fig. 1B). In some genera of Cerocephalinae, such as *Cerocephala* (in part), *Neosciatheras*, and *Gnathophorisca*, there are still setal bases present, but no distinct pilosity. It is plausible to assume that pilose wings represent the ground plan character state for Cerocephalinae and that the pilosity has been reduced in crown-group lineages. This loss might already have happened before the Miocene. While *Dominocephala* still possesses setal bases, they are completely lost in *Tenuicornus* (Fig. 2E). Also, the presence of a distinct frenal line in *Pteropilosa* (Fig. 1C) most likely represents a plesiomorphic character state (see Krogmann and Vilhelmsen 2006) and has consequently been reduced in Miocene and extant Cerocephalinae. The same seems to apply to the strong surface sculpture of the mesonotum of *Pteropilosa* (Fig. 1C). In all other cerocephaline taxa, the mesonotum is polished or only partly sculptured.

Since both fossils were found without syninclusions (in contrast to *Dominocephala*), it is impossible to speculate about the host species of the newly described genera. However, the short and stout ovipositors and the overall similarity of body size and appearance with extant taxa of Cerocephalinae suggest that both genera are, like all known extant representatives, parasitoids of endophytic beetles.

Although all three known fossils are expected to be parasitoids of endophytic beetles, there are already hints of differential host specialization. The ovipositor of *Tenuicornus* is further exserted beyond the end of the gaster than in the other two fossils, which might serve as an indicator that this genus has a different host biology than *D. vibrissae* and *P. lailarabanorum*.

All three known cerocephaline fossils are females. This is most likely connected to the association with wood-boring beetles, which represent the vast majority of known cerocephaline hosts. Females visit trees for oviposition and have a much higher chance of being trapped in resin than males. Members of the family Ptinidae, a common host group of Cerocephalinae (Adarkwah et al. 2014), are closely associated with resin-producing trees and rank among the four most abundant beetle families in Baltic amber (Bukejs and Alekseev 2015). Other known hosts for Cerocephalinae are ambrosia beetles (Curculionidae: Platypodinae), which are diverse and common inclusions in Dominican amber (Peris et al. 2015) and were found as syninclusions of *D. vibrissae* (Krogmann 2013).

*Tenuicornus* has a very conspicuous single thickened and enlarged seta on each side of the facial impression (Fig. 2C). Similar structures were found on the face of *D. vibrissae* and the extant *Choetospilisca tabidoides* Hedquist, 1969. In *D. vibrissae*, a row of elongate setae extends dorsally from the lower facial process. *Choetospilisca tabidoides* features a set of long setae that cover the area between the toruli and the mandibles. Although the amount of setae varies, the position is similar, i.e., all setae are positioned at the most frontal position of the face. In this prominent position, they might serve as a sensory organ for the location of hosts in wood or other plant parts.

The description of *Pteropilosa* pushes the minimum age of Cerocephalinae from the Miocene to the Eocene and hints to an earlier host shift to endophytic beetle parasitoids than previously thought (Krogmann 2013). The occurrence of two morphologically distinct genera in Dominican amber shows that Cerocephalinae had already significantly diversified by the Miocene. Future examination of unstudied material and understudied amber Lagerstätten might further change or complement our view on the evolution of Cerocephalinae as well as of other Chalcidoidea groups.

## Acknowledgements

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# Notes on the ant genus *Cataglyphis* Foerster, 1850 (Hymenoptera, Formicidae) in the Arabian Peninsula with description of a new species and a key to species of the *C. pallida*-group

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## Abstract

*Cataglyphis fisheri* **sp. n.** is described and illustrated from the United Arab Emirates, Oman and Kingdom of Saudi Arabia based on the worker caste. It belongs to the *C. pallida*-group which is recorded for the first time from the Arabian Peninsula. *Cataglyphis fisheri* **sp. n.** is similar to *C. pallida* Mayr, 1877 from Kazakhstan. Differential diagnosis between these two species is given and a key to the species of the *C. pallida*-group is presented. *Cataglyphis laylae* Collingwood, 2011 is treated as a junior synonym of *Cataglyphis saharae* Santschi, 1929. *Cataglyphis flavobrunnea* Collingwood & Agosti, 1996 is redescribed and a lectotype for this species is designated.

## Keywords

Synonymy, new designation, taxonomy, lectotype, Arabian Peninsula, Middle East, Palearctic region, Formicinae, key

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## Introduction

The ant genus *Cataglyphis* Foerster, 1850 currently includes 108 valid species and subspecies (http://www.antwiki.org/, accessed 15 August 2015) distributed in the desert areas of the Palearctic Region ranging from South Palearctic to Ghana, East to North China and India (Brown 2000). Members of the genus are among the commonest ants of the desert ecosystems of the Arabian Peninsula and Central Asia, where they build their crater nests directly in the ground (Brown 2000, Sharaf and Aldawood, unpublished data) and feed on dead insects (Lenoir et al. 2010). Their role in the desert ecosystem is important as they have been reported pollinating flowering plants (Herrera et al. 1984) and contributing to the dispersal of seeds (Hulme 1997; Boulay et al. 2007).

The worldwide revision of the genus by Santschi (1929) is out of date, but a comprehensive reclassification of the genus and its species groups was presented by Agosti in 1990. Many regional faunal treatments are available: Israel (Emery 1925), Iraq (Pisarski 1965), former European U.S.S.R. (Arnol'di and Dlussky 1978), Iberian Peninsula (Collingwood 1978), Kingdom of Saudi Arabia (KSA) (Collingwood 1985), Turkmenistan (Dlussky, Soyunov and Zabelin 1992), Bulgaria (Atanasov and Dlussky 1992), Armenia (Arakelian 1994), Central Europe (Seifert 1996), Portugal (Collingwood and Prince 1998), Asia species key (Radchenko 1998), Northwest China (Chang and He 2002), Egypt (Sharaf 2006), North and Central Europe species key (Seifert 2007) and Morocco (Cagniant 2009). Many *Cataglyphis* species are polymorphic, dimorphic or have variation in worker size. This makes it necessary to be cautious when making identifications and, even more, so when treating a single worker as representing a new species.

The Arabian species of *Cataglyphis* were first treated by Collingwood (1985), who recorded 18 species from the KSA describing two new species *C. asiriensis* and *C. minima* from the Asir Mountains of southwestern KSA. Subsequently, Collingwood and Agosti (1996) reviewed the genus for the entire Arabian Peninsula providing a key to species. The 26 recorded species included six new species, *C. acutinodis*, *C. flavobrunnea*, *C. harteni*, *C. holgerseni*, *C. opacior* and *C. shuaibensis*. A myrmecofaunal list of the United Arab Emirates (UAE) (Collingwood et al. 2011) reported 20 species and described an additional new species, *C. laylae* Collingwood for the Peninsula.

In the present paper a new species, *C. fisheri*, is described from the UAE based on the worker caste. A new lectotype designation for *C. flavobrunnea* Collingwood & Agosti, 1996 is presented with redescription of the worker caste. *Cataglyphis laylae* Collingwood, 2011 is shown to be a junior synonym of *C. saharae* Santschi, 1929.

## Materials and methods

### Measurements and indices

All measurements are in millimeters and follow standard measurements of Agosti (1990).

**Measurements**

| | |
|---|---|
| **Eye length (EL)** | Maximum diameter of eye. |
| **(F1)** | Length of first funicular segment. |
| **(F2)** | Length of second funicular segment. |
| **Head length (HL)** | Length of head proper, excluding mandibles, measured from mid-point of anterior clypeal margin to mid-point of posterior head margin, in full-face view. |
| **Head width (HW)** | Maximum width of head in full-face view, measured below eyes. |
| **Metanotum height (MH)** | Maximum distance from line spanned between anteriormost and posteriormost part of mesosoma and lowest part of metanotum, measured at a right angle to this line. |
| **Mesosomal length (ML)** | Diagonal length of mesosoma in profile from point at which pronotum meets the cervical shield to posterior base of metapleuron. |
| **Median ocellus size (OS)** | Diameter of the ocelli. |
| **Ocelli distance (OD)** | Distance between the two basal ocellus. |
| **Propodeum height (PH)** | Maximum distance from a line spanned between anteriormost and posteriormost part of mesosoma and most raised part of propodeum, measured at a right angle to this line. |
| **Pronotal width (PW)** | Maximum width of pronotum measured in dorsal view. |
| **Petiole height (PTH)** | Maximum height of petiolar measured in lateral view from highest (median) point of node to ventral outline. |
| **Scape length (SL)** | Maximum straight line length of antennal scape excluding basal constriction or neck to condylar bulb. |
| **Total length (TL)** | Outstretched body length from mandibular apex to gastral apex. |

**Indices**

| | |
|---|---|
| **Cephalic index (CI)** | HW × 100/HL. |
| **Eye index (EI)** | EL × 100/HW. |
| **Funicular index (FI)** | Length of first funicular segment × 100/Length of second funicular segment. |
| **Propodeum index (PI)** | PH × 100/MH. |
| **Scape index (SI)** | SL × 100/HW. |

### Abbreviations of depositories

**KSMA** King Saud University Museum of Arthropods, King Saud University, College of Food and Agriculture Sciences, Plant Protection department, Riyadh, Kingdom of Saudi Arabia.
**MHNG** Muséum d'Histoire Naturelle de la Ville de Genève, Geneva, Switzerland.
**NHMB** Naturhistorisches Museum Basel, Basel, Switzerland.
**WMLC** World Museum Liverpool, Liverpool, United Kingdom.

In the original description of *Cataglyphis flavobrunnea* Collingwood and Agosti fixed the holotype from Oman and listed nine paratype specimens from Oman, The KSA, The United Arab Emirates and Yemen. Extensive searches in WMLC and NHMB did not succeed in finding the holotype specimen but nine specimens matching the paratypes data from the KSA were located. As recommended by the International Commission of Zoological Nomenclature, we designate a lecotype in this study to unequivocally ascertain the identity of the species

## Results and discussion

***Cataglyphis fisheri* Sharaf & Aldawood, sp. n.**
http://zoobank.org/9C54C443-0729-42AE-9B3A-E7CA294879E9
Figures 1–3

**Material examined.** United Arab Emirates, Baynounah, "sandy desert" (Sheiekh Zayed city), 23°38'40"N 53°37'12"E, 8.iii.1995, (C. A. Collingwood leg.), next to *Zygophyllum* plants, King Saud Museum of Arthropods (KSMA), College of Food and Agriculture Sciences, King Saud University, Riyadh, Kingdom of Saudi Arabia.

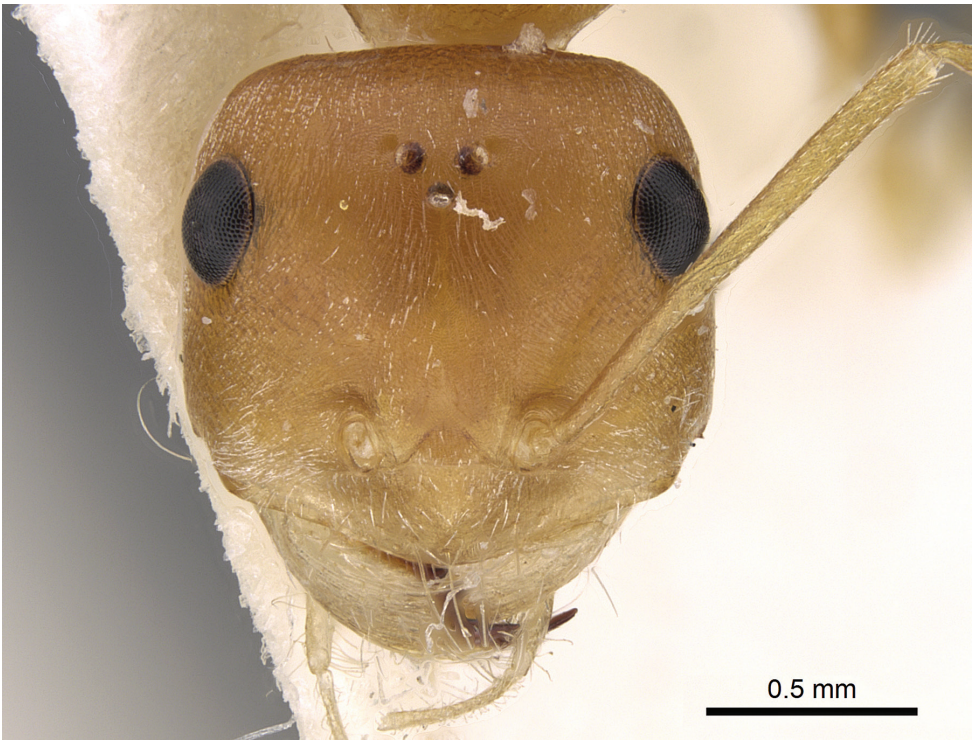
**Paratypes.** 1 worker, United Arab Emirates, Rhatam, 11.xi.1993, (C. A. Collingwood leg.), (KSMA); 3 workers, Oman desert, 30.ii.1997, (M. D. Gallagher leg.), (code 8907) (WMLC); 1 worker, Saudi Arabia, Riyadh Province, Rawdhat She'al, 22.40318°N, 46.59209°E, 596m, 13.iv.2015, PT (Aldhafer et al. leg.) (KSMA); 4 worker, Saudi Arabia, Riyadh Province, Rawdhat She'al, 22.41559°N, 46.58806°E, 602m, 18.x.2015, PT (Aldhafer et al. leg.) (KSMA); 7 worker, Saudi Arabia, Riyadh Province, Rawdhat She'al, 22.4279°N, 46.57547°E, 612m, 18.x.2015, PT (Aldhafer et al. leg.) (KSMA); 2 worker, Saudi Arabia, Riyadh Province, Rawdhat She'al, 22.42496°N, 46.57556°E, 606m, 18.x.2015, PT (Aldhafer et al. leg.) (KSMA).

**Holotype worker.** TL 5.00, F1 0.26, F2 0.15, HL 1.24, HW 1.16, MH 0.20, PH 0.22, SL 1.27, ML 1.80, OS 0.07, OD 0.08, EL 0.28, PW 1.00, PTH 0.50, CI 94, EI 24, FI 173, PI 110, SI 109.

**Paratype.** TL 3.12–5.75, F1 0.17–0.30, F2 0.10–0.17, HL 0.87–1.32, HW 0.72–1.17, MH 0.10–0.17, PH 0.15–0.25, SL 0.97–1.25, ML 1.37–2.00, OS 0.07,

**Figures 1.** Body in profile of *Cataglyphis fisheri* sp. n. (Holotype worker), CASENT0906454. Photographer: Cerise Chen, www.AntWeb.org

**Figures 2.** Body in dorsal view of *Cataglyphis fisheri* sp. n. (Holotype worker), CASENT0906454. Photographer: Cerise Chen, www.AntWeb.org




**Figures 3.** Head in full-face view of *Cataglyphis fisheri* sp. n. (Holotype worker), CASENT0906454. Photographer: Cerise Chen, www.AntWeb.org

OD 0.07-0.08, EL 0.20–0.35, PW 0.55–0.95, PTH 0.22–0.42, CI 77–90, EI 25–34, FI 113–220, PI 125–208, SI 90–144 (11 measured).

**Worker. Head.** Head distinctly longer than broad (CI 83–94), with straight posterior and lateral margins; posterior ocelli located at the level of posterior margin of eyes; scapes when laid back from their insertions surpass posterior margin of head by less than ¼ of its length. **Mesosoma.** Propodeal dorsum in profile distinctly low, nearly at same level as petiolar node. **Petiole.** Petiole an upright or slightly inclined scale, with the anterior face meeting the posterior face with a narrowly rounded margin angle. **Pilosity.** Third maxillary palp with erect hairs not longer than 1.5× maximum diameter of third segment; area behind the lateral clypeal margins with dense white pubescence, anterior clypeal margin with abundant long, curved, hairs; mesosomal dorsum with a few scattered hairs, two pairs each on the mesonotum and propodeum, petiole bare, gaster bare except for a few short hairs on apex, posterior margin of head with single pair of erect hairs. **Sculpture.** Cephalic dorsum faintly sculptured; median cephalic surface in front of ocelli feebly but distinctly longitudinally striated, striae curving outward to lateral margins in front of eyes; mandibles faintly but distinctly longitudinally striated, mesosoma and petiole faintly sculptured, general appearance dull. **Colour.** Uniform yellow, mandibular teeth brown.

**Table 1.** Differential diagnosis between *C. fisheri* sp. n. and *C. pallida*.

| ***C. fisheri* sp. n.** | ***C. pallida*** |
|---|---|
| Posterior margin of head in full-face view straight and with five hairs. | Posterior margin of head in full-face view convex and without hairs. |
| Head and mesosoma with few pubescence. | Head and mesosoma with abundant pale pubescence. |
| Median cephalic surface in front of ocelli feebly but distinctly longitudinally striated, the striae curving outward to lateral margins in front of eyes. | Cephalic surface unsculptured. |
| Ocelli larger and set closer together | Ocelli smaller and set apart from each other. |
| OS 0.07, OD 0.07–0.08 | OS 0.04, OD 0.10 |
| Scape shorter, SL 0.97–1.25, SI 90–144 | Scape longer, SL 1.30, SI 173 |

**Etymology.** This species is named in honor of Dr. Brian Fisher, Department of Entomology, California Academy of Sciences, San Francisco, California, U.S.A.

**Affinities.** *Cataglyphis fisheri* is a member of the *C. pallida*-group as defined by Agosti (1990), which is recorded here for the first time from the Arabian Peninsula. Although Collingwood and Agosti (1996) reported 265 species or morhospecies from the entire Arabian Peninsula, a large number of ant specimens remained unidentified. *Cataglyphis fisheri* was among those specimens. The workers cannot be identified from the key to Arabian species compiled by Collingwood and Agosti (1996) because material was not included in the study. However, *C. fisheri* is similar to the Palearctic species *C. pallida* Mayr, 1877 described from Kazakhstan. A differential diagnosis of the two species is summarized in Table 1.

In the key to Arabian species (Collingwood and Agosti 1996), *C. fisheri* will run to couplet 12 that also includes the much larger *C. sabulosa* Kugler, 1981. *Cataglyphis fisheri* sp. n. can be readily separated by the upright or slightly inclined petiole with a dorsal rounded node, the lower propodeal profile and the absence of body pubescence whereas *C. sabulosa* has a squaminode petiole with a convex anterior surface and straight posteriorly, a higher propodeal profile and the body covered with white silvery pubescence. The drawing of *C. sabulosa* in Collingwood (1985) is incorrect.

## Key to species of *C. pallida*-group

1 Colour uniform brown or dark brown; mesosoma massively constructed; in profile propodeal dorsum high, meeting declivity in a distinct obtuse angle (Figure 4) Kazakhstan (type locality), Afghanistan, China, Iran, Turkmenistan..... ***emeryi* (Karavaiev, 1911)**

– Colour uniform pale yellow or orange yellow; mesosoma elegantly or smoothly constructed; in profile propodeal dorsum making a continuous curve into the declivity (Figure 5)..... **2**

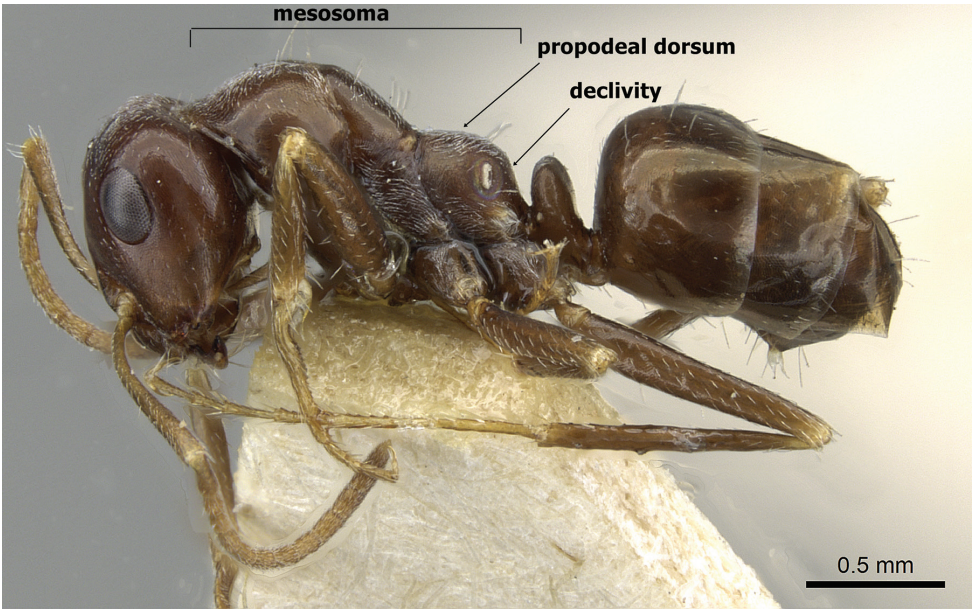



**Figure 4.** *Cataglyphis emeryi* body in profile, (Syntype worker), CASENT0911110, Photographer: Zach Lieberman.

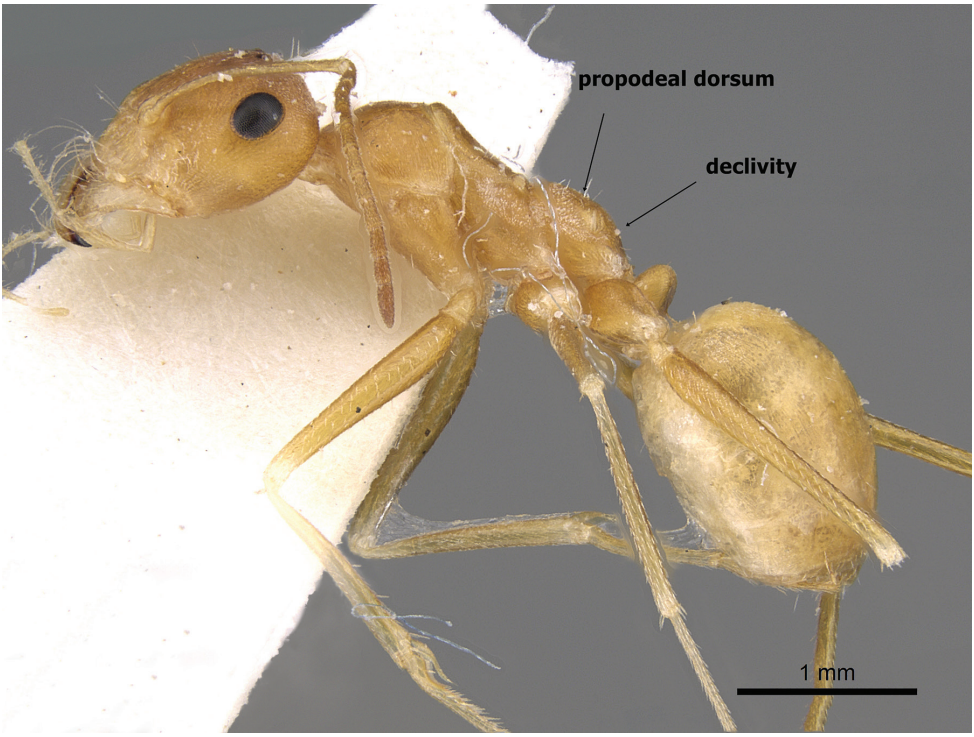



**Figure 5.** *C. fisheri* sp. n. (Holotype worker), body in profile, CASENT0906454, Photographer: Cerise Chen.

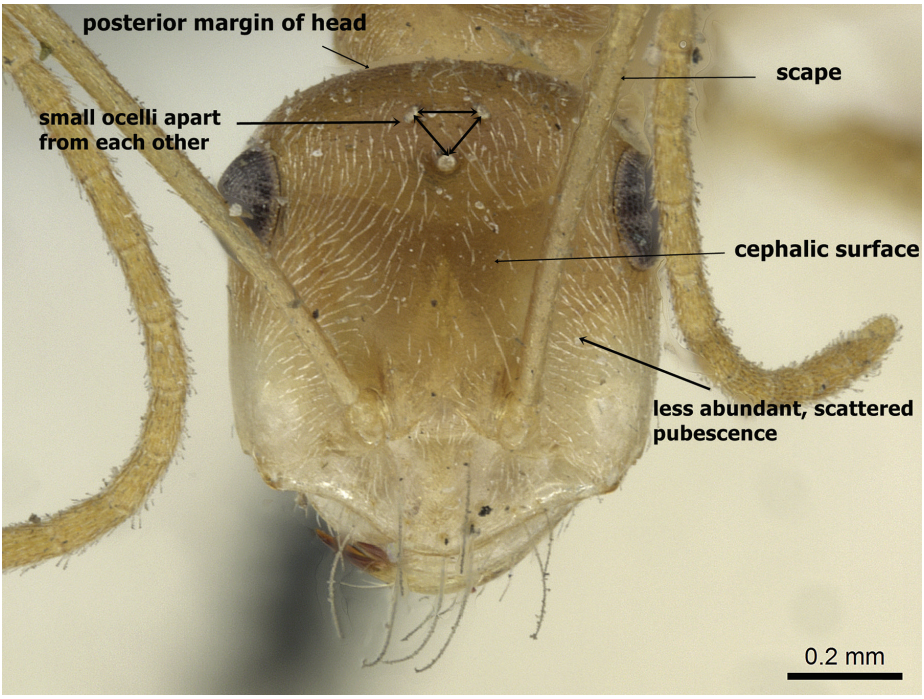



**Figure 6.** *C. pallida*, head in full-face view, CASENT0911112, Photographer: Zach Lieberman.

**Figure 7.** *C. fisheri* sp. n. (Holotype worker), body in profile, CASENT0906454, Photographer: Cerise Chen.

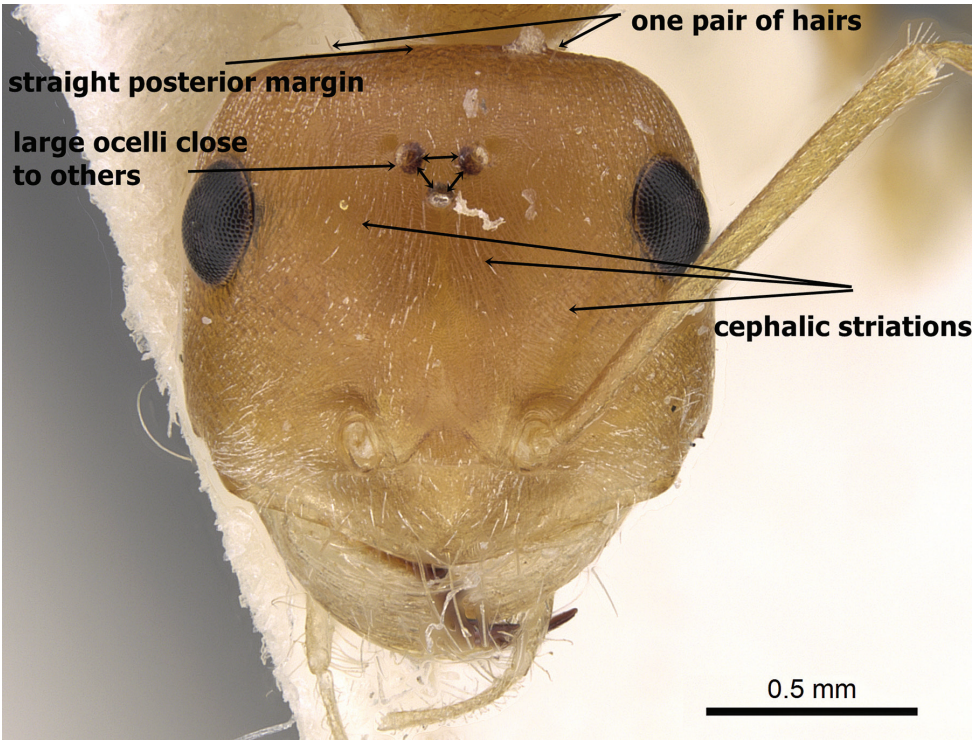



**Figure 8.** *C. pallida* (Cotype), head in full-face view, CASENT0911112, Photographer: Alexandra Westrich.

2 Ocelli smaller and set apart from each other (OS 0.04, OD 0.10) (Figure 6); posterior margin of head in full-face view convex and without hairs (Figure 6); cephalic surface unsculptured (Figure 6); body colour pale yellow (Figure 7). Kazakhstan (type locality), Afghanistan, China, Kyrgyzstan, Turkmenistan ..... ***pallida* Mayr, 1877**

– Ocelli larger and set closer together (OS 0.07, OD 0.07–0.08); posterior margin of head in full-face view straight and with a single pair of hairs (Figure 8); median cephalic surface in front of ocelli feebly but distinctly longitudinally striated, the striae curving outward to lateral margins in front of eyes (Figure 8); body colour orange yellow. Kingom of Saudi Arabia .....***fisheri* sp. n.**

## *Cataglyphis flavobrunnea* Collingwood & Agosti, 1996

Figures 9–12

*Cataglyphis flavobrunneus* Collingwood & Agosti, 1996: 378, fig. 41 (w.), Saudi Arabia: Jeddah, 7.v.l978 (W. Buttiker) (NHMB), http://www.antweb.org/specimen/casent0249838 [one paratype worker is designated here as lectotype]. [new designation].

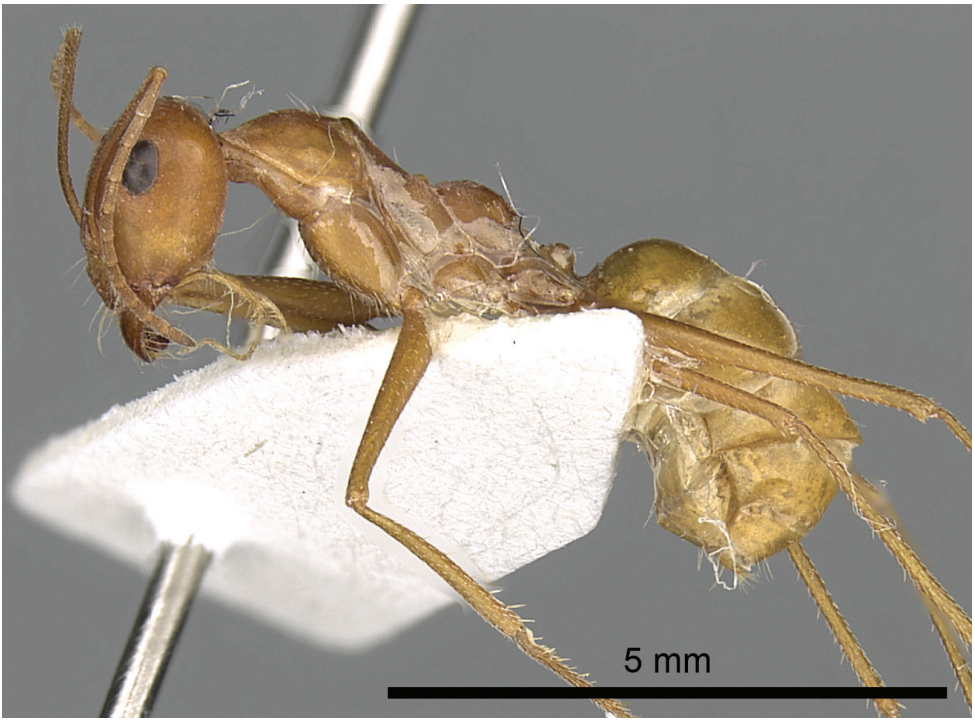



**Figure 9.** Body in profile of *Cataglyphis flavobrunnea* (paralectotype worker), CASENT0249838.

**Description. Major head** HW = HL (CI 100), minor the same with a shallowly convex posterior margin and nearly straight sides; first funicular segment 1.35× longer than second. **Mesosoma.** Metanotal spiracle distinctly raised. **Petiole.** Petiole in profile smoothly rounded but slightly assymetrical with the anterior more rounded and posterior near flat. **Pilosity.** Propodeal dorsum with two pairs of erect hairs; pronotum and mesonotum each with a single pair of erect hairs; posterior margin of head bare; gaster with sparse scattered and very short hairs; all body pubescence whitish or pale. **Sculpture.** Cephalic, mesosomal and petiolar surfaces finely punctate and dull, gaster smooth and shining. **Colour.** Head, mesosoma, petiole, coxae and femora brownish, antennae, tibiae and tarsi yellowish brown, gaster uniform dirty yellow.

**Measurements.** TL 8.81; HL 1.92; HW 1.82 (major HL = HW = 2.31 Antweb scale); SL 2.21; FS1 0.38; FS2 0.28; PW 1.20; EL 0.53; Indices: CI 95 (Antweb image 100); EI 29; SI 121.

**Material examined.** Saudi Arabia, Jeddah, 7.5.1978, (W. Buttiker Leg.), 9 workers, major available on http://www.antweb.org/specimen/casent0912239, and minor on http://www.antweb.org/specimen/casent0249839, (NHMB).

**Remarks.** The original description of *C. flavobrunnea* indicated differential diagnosis of this taxon with *C. laevior* of the *C. bicolor*-group, *diehlii*-complex (Agosti, 1990). However, examination of the newly designated lectotype and the remaining

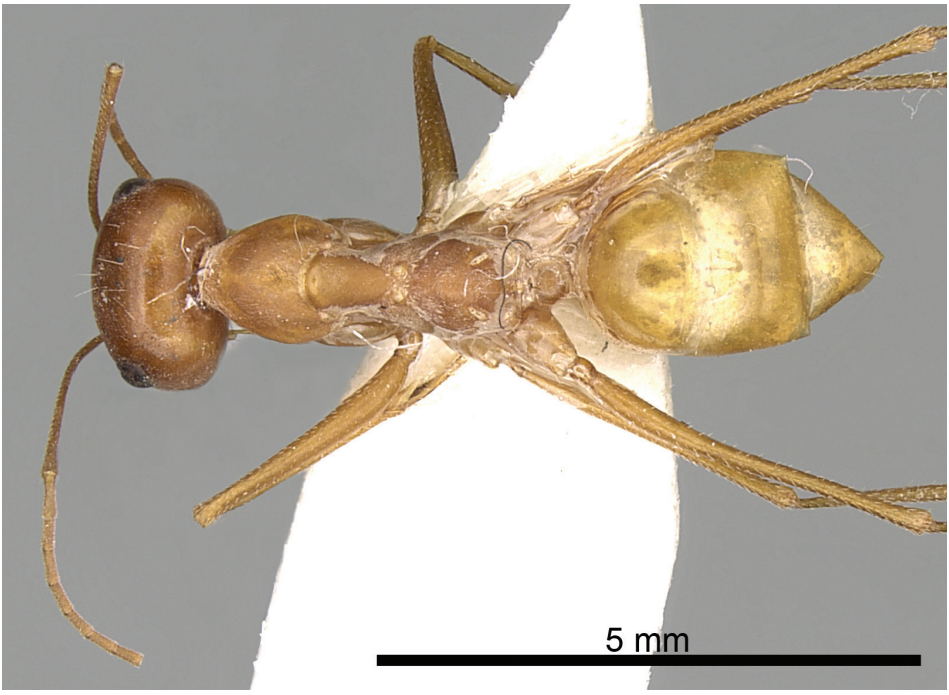



**Figure 10.** Body in dorsal view of *Cataglyphis flavobrunnea* (paralectotype worker), CASENT0249838.

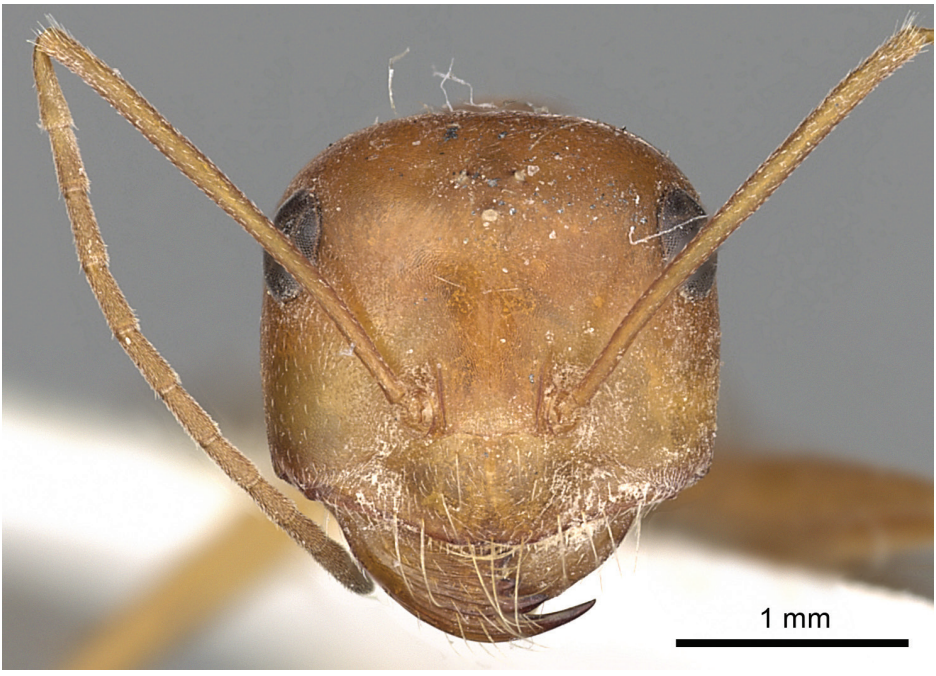



**Figure 11.** Head in full-face view of *Cataglyphis flavobrunnea* (paralectotype worker), CASENT0249838.

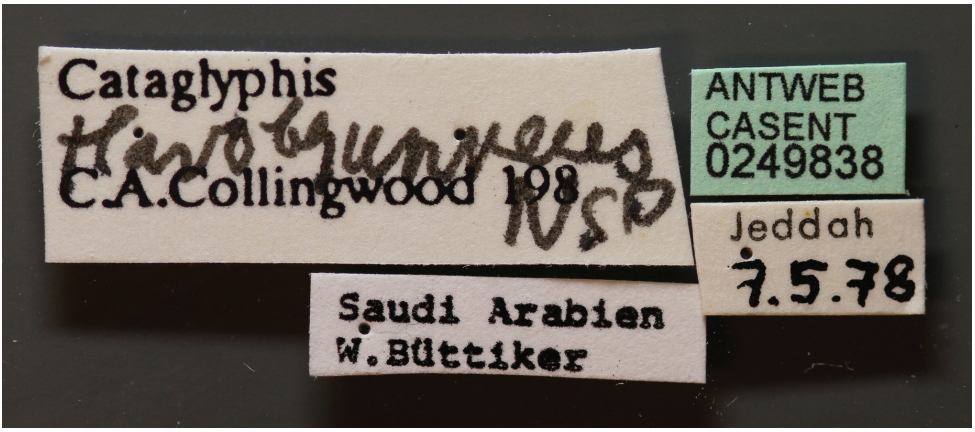



**Figure 12.** Specimen label. Photographer: Ryan Perry, www.AntWeb.org

11 paratypes indicates that the species are very different (casent0104615). *Cataglyphis flavobrunnea* has a uniformly brownish body and yellowish gaster whereas *C. laevior* has yellowish brown body and dark brown gaster. The head and mesosoma of *C. flavobrunnea* has dense white pubescence, whereas *C. laevior* lacks pubescence on the head and mesosoma. Collingwood and Agosti (1996) mentioned that head *C. flavobrunnea* is smooth and polished, but the head of the Lectotype is dull and is finely granulate.

### ***Cataglyphis saharae*** **Santschi, 1929**

Figures 13–16

*Cataglyphis bicolor* st. *saharae* Santschi, 1929: 48, fig. 3 (w.) (holotype worker), Algeria: Biskra, (NHMB), http://www.antweb.org/specimen/CASENT0912226 [Image of the type specimen examined]. Elevated to species: Collingwood, 1985: 291.

*Cataglyphis laylae* Collingwood, 2011: 458, pl. 96-103 (w.), United Arab Emirates: Al-Ain [24°13'N 55°46'E], iii.1995, (MHNG), http://www.antweb.org/specimen/CASENT0264538-D01 [holotype presumably lost, paratypes examined], Syn. n.

**Remarks.** The brief original description did not adequately diagnose this taxon from other members in the *C. bicolor*-group. It was mentioned that *C. laylae* is similar to *C. nigra* (André, 1882) and *C. savignyi* (Dufour, 1862) and presented a single distinguishing character, the slender petiole. An examination of several paratypes showed that *C. laylae* Collingwood, 2011 is a junior subjective synonym of *C. saharae* Santschi.

**Material examined.** United Arab Emirates, Al-Ain Zoo, 9.v.1995, 24°13'N, 55°46'E, 280 m (C. A. Collingwood leg.) (8 paratype workers) (KSMA), United Arab Emirates, Sweihan, iv.1995 (C. A. Collingwood leg.) (1 paratype worker), United Arab Emirates, Sweihan, iii.1995 (C. A. Collingwood leg.) (5 paratype workers), United Arab Emirates environmental desert, 3.iii.2005 (1), United Arab Emirates, Sharjah

**Figure13.** Body in profile of *Cataglyphis saharae* (holotype worker), CASENT0912226.

**Figure14.** Body in dorsal view of *Cataglyphis saharae* (holotype worker), CASENT0912226.

**Figure15.** Head in full-face view of *Cataglyphis saharae* (holotype worker), CASENT0912226.

**Figure 16.** Specimen label. Photographer: Zach Lieberman, www.AntWeb.org

desert park, iii. 2006 (1), United Arab Emirates, Al Ain, v. 1995 (Pitfall trap) (1), United Arab Emirates, Sharjah desert, 15.i.2004 (2) 22 workers with no data, all the materials collected by C. A. Collingwood (WMLC).

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# First cavernicolous trechine beetle discovered in Guilin karst, northeastern Guangxi (Coleoptera, Carabidae, Trechinae)

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## Abstract

A new subgenus and new species of anophthalmic trechine beetles, *Oodinotrechus* (*Pingleotrechus*) *yinae* **subgen. n., sp. n.**, is described and illustrated from a limestone cave called Chaotianyan in southern part of Guilin karst, northeastern Guangxi Zhuang Autonomous Region. The new taxon is very different from the Maolan-Mulun congeners belonging to the nominate subgenus *Oodinotrechus* (*s. str.*) Uéno, 1998, in several important character states including pronotal structure, elytral chaetotaxy and male genitalia. It is the first record of a cavernicolous trechine beetle in Guilin karst, and in the eastern part of Guangxi. In addition, a distribution map for the genus *Oodinotrechus* Uéno, 1998, is provided.

## Keywords

Ground beetle, subterranean, new subgenus, new species, China

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## Introduction

Many karstic landscapes and limestone caves are distributed in southern China, the largest karstic area in the world (Waltham 2009; Lu 2012). Guilin is one of the most famous karstic wonders in China and is listed in the World Heritage as part of South China Karst (UNESCO 2015). Guilin karst ranges from 110°09' to 110°42'E and 24°40' to 25°40'N, with total area of 7104 $km^2$ in which 3752 $km^2$ are carbonate rocks and represented mainly by Fenglin landscapes (Zhu 1988).

However, the cave fauna of the Guilin karst is not well-known. Wang and Cao (1998) reported the fauna in several caves in Guilin area, which is rather poor comparing to Mulun karst (Deharveng et al. 2008). Regarding Coleoptera, only one beetle species belonging to the family Pselaphidae was recorded in Guilin karst (Nomura and Wang 1991).

The anophthalmic cavernicolous trechine genus *Oodinotrechus* Uéno, 1998, was erected to contain the single species, *O. kishimotoi* Uéno, 1998, found in a cave in Maolan karst of southernmost Guizhou Province. So far, it is known by only the holotype, a male exemplar (Uéno 1998). Then, a second species, *O. liyoubangi* Tian, 2014, was discovered in several caves in Mulun karst, Huanjiang County, northernmost Guangxi (Tian 2014). Mulun karst is connected to Maolan karst to the south, and both karsts share the most beautiful karstic forest in southern China and have similar cave fauna.

During two visits in the limestone cave called Chaotianyan, Pingle County, southern part of Guilin karst, a number of exemplars of a quite small sized beetle belonging to *Oodinotrechus* were collected. Further study confirmed that it is a new species and the first troglobitic trechine found in Guilin karst. Because of its striking characteristics which are so different from other congeners occurring Maolan-Mulun karst, a new subgenus named *Pingleotrechus* subgen. n. is established to accommodate this new species. To date, *Oodinotrechus* contains three species and ranges from southernmost Guizhou / northernmost Guangxi to northeastern Guangxi (Fig. 1).

## Materials and methods

The beetles for this study were collected by hand or by using an aspirator, and kept in 55% ethanol before study. Dissections and observations were made under a Leica MZ75 dissecting microscope. Dissected genital pieces, including the median lobe and parameres of aedeagus, were glued on small paper cards and then pinned under the specimen from which they were removed. Digital pictures were taken using a Canon EOS 40D camera, and then processed by means of Adobe Photoshop CS5 software.

Length of body is measured from apex of right mandible (in opened position) to elytral apex.

**Abbreviations of other measurements used in the text are as following:**

**HLm** length of head including mandibles, from apex of right mandible to occipital suture

**HLl** length of head excluding mandibles, from front of labrum to occipital suture
**HW** maximum width of head
**PL** length of pronotum, along the median line
**PW** maximum width of pronotum
**PfW** width of pronotum at front
**PbW** width of pronotum at base, measured between hind angles
**EL** length of elytra, from base of scutellum to elytral apex
**EW** maximum width of combined elytra

**Abbreviations for the specimens' depository are as following:**

**IOZ** National Museum of Zoology, Institute of Zoology, Chinese Academy of Sciences, Beijing
**MNHN** Muséum National d'Histoire Naturelle, Paris
**SCAU** South China Agricultural University, Guangzhou
**ZUBM** Biological Museum of Zhongshan University, Guangzhou

## Taxonomic treatments

***Pingleotrechus* subgen. n.**
http://zoobank.org/B33BD019-3F0F-4CA7-8767-D0FA758DEC91

**Type species.** *Oodinotrechus yinae* sp. n. (Cave Chaotianyan, Pingle County)

**Diagnosis.** Similar to the nominate subgenus *Oodinotrechus* (*s. str.*) Uéno, 1998, but smaller and slenderer; body, in particular head and elytra, longer; head narrower, genae only slightly expanded laterally; pronotal base with sides much in advance of nearly straight medial part, without a gap submedially on each side between pronotum and elytra; scutellum visible from above; elytra slenderer, with two dorsal pores on 3$^{rd}$ and 4$^{th}$ striae, respectively; umbilical setae 5 and 6 widely separate, distance between them almost triple as that between setae 4 and 5; an additional striole running inside and forming a crescent with apical stria; aedeagus short and stout, without sagittal aileron.

**Remarks.** *Pingleotrechus* subgen. n. is similar to *Oodinotrechus* (*s. str.*) Uéno, 1998, occurring in Maolan-Mulun karst, in many aspects, *viz.* short and stout body, short legs and antennae, entire frontal furrows, tridentate right mandible, well-defined labial suture, two pairs of supraorbital setigerous pores present on head, campanulate pronotum, ciliate elytral margin, presence of two dorsal pores on elytron, and unmodified protarsi in male. However, *Pingleotrechus* is different from the nominate subgenus in many characters as follows: body smaller and slenderer; head slightly expanded laterally (versus strongly expanded); second dorsal pore situated on 4$^{th}$ elytral stria (versus on 5$^{th}$ stria); umbilicate setigerous pores of the middle group (pores 5 and 6) widely separated (versus very close to each other); an additional, inner, apical striole, present

(versus absent); male genitalia stouter, without sagittal aileron (versus with a large sagittal aileron).

**Etymology.** Refers to Pingle County, the locality of the type species.

**Distribution.** China (northeastern Guangxi) (Fig. 1).

### *Oodinotrechus* (*Pingleotrechus*) *yinae* sp. n.

http://zoobank.org/0094B29C-B668-495F-9325-952D4E85B0F2

Figs 1–3, 5–6

**Diagnosis.** A small, short and stout beetle, anophthalmic and depigmented, with short appendages, fore body distinctly shorter than elytra, head short and narrow, with two pairs of supraorbital setae, mentum and submentum separated by clear labial suture, pronotum broad and campanulate, both lateromarginal setae present, elytra serrate and ciliate, shoulders distinct, 5$^{th}$ and 6$^{th}$ pores of the marginal umblicate series widely separated, a crescent-form structure present on apical part of each elytron.

**Description.** Length: 4.0–4.8 mm; width: 1.3–1.7 mm. Habitus as in Fig. 2.

Depigmented; yellowish to reddish dark brown, very shiny, palps and tarsi light yellow.

Genae with several sparse and short setae, frons and vertex glabrous; a pair of suborbital setae present between mentum and prosternum; disc of pronotum with four erect setae each side of median line; propleura and mesosternum glabrous, pro- and metasterna with a few setae medially; elytra, prosternum and abdominal ventrites sparsely pubescent, entire legs pubescent. Microsculpture formed by faintly engraved transverse meshes on head and elytra, moderately transverse on pronotum.

Head anophthalmic, subquadrate, distinctly longer than wide, HLm/HW=1.74–1.79, HLl/HW=1.22–1.29; frons depressed and almost flat, vertex slightly convex, frontal furrows long and deep. Genae slightly expanded laterally, distance between anterior and posterior supraorbital pores almost as great as minimum distance between frontal furrows. Mentum bisetose, with medial tooth simple and blunt. Submentum with a row of 6 setae. Palps slender, 3$^{rd}$ maxillary palpomere as long as 4$^{th}$ while 2$^{nd}$ labial palpomere longer than 3$^{rd}$. Antennae short and subfiliform, extended to about basal 1/3 of elytra and pubescent from 2$^{nd}$ antennomere; 1$^{st}$ antennomere with several additional setae near apex, slightly longer than 2$^{nd}$, 3$^{rd}$ longest; antennomeres 4–10 decreasing gradually in length, 11$^{th}$ as long as 4$^{th}$.

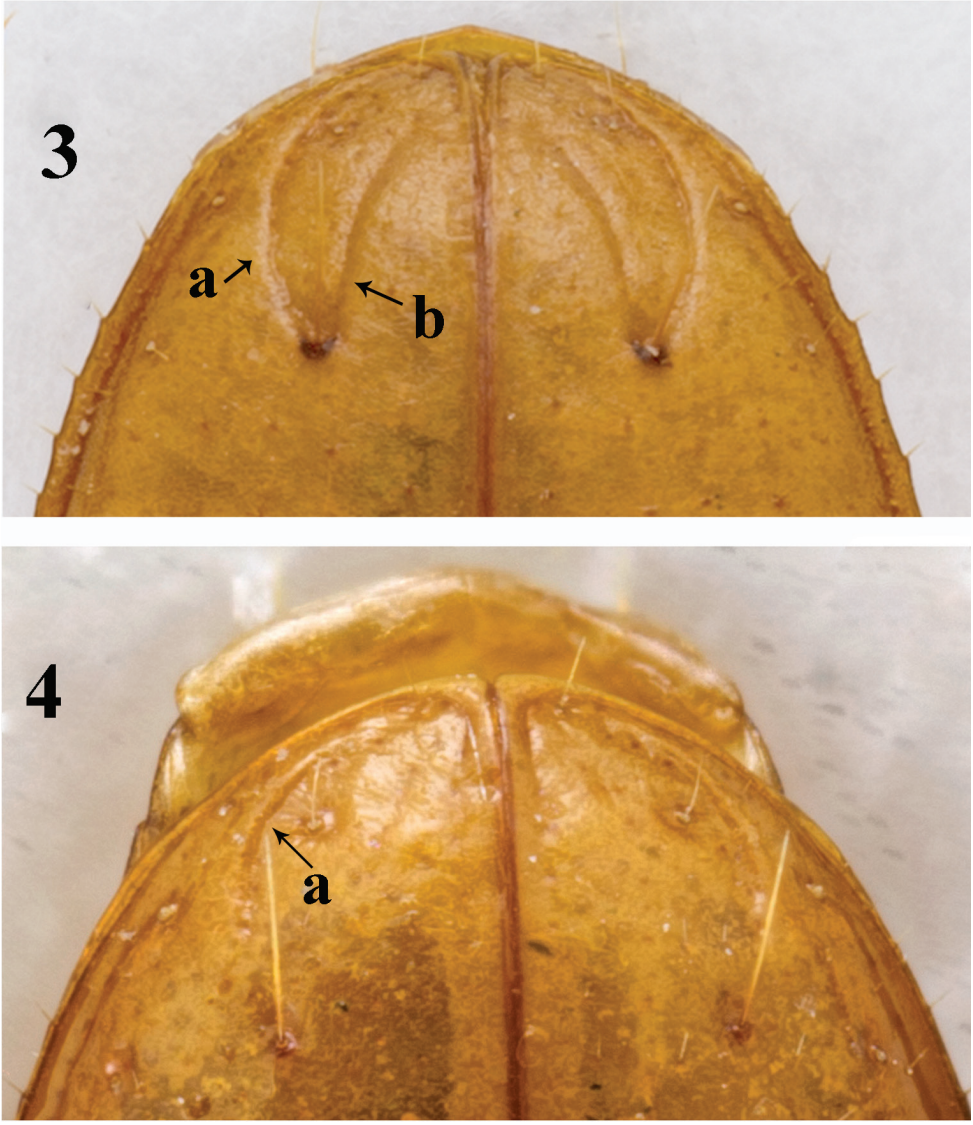
Pronotum transversely campanulate, PW/PL=1.40–1.47, as long as head, widest just before hind angles, which are widely obtuse and not denticulate; sides gently and gradually converging apicad in a smooth arc; fore angles are rounded off; anterior margin nearly straight. Base nearly straight, markedly wider than apex, PWb/PWf=1.67–1.71, with sides in advance of median part and oblique towards hind angles; lateral margins widely expanded and reflexed; anterolateral seta a third from apex, posterolateral seta just in front of hind angle. Disc moderately convex. Median

**Figure 1.** Distribution of the genus *Oodinotrechus* Uéno, 1998 ★ *O.* (*O.*) *kishimotoi* Uéno ● *O.* (*O.*) *liyoubangi* Tian, 2014 ■ *O.* (*Pingleotrechus*) *yinae* subgen. n., sp. n. **a** map of China, showing the location of Guangxi Zhuang Autonomous Region.

line fine and deep. Both frontal and basal transverse impressions well-marked, basal foveae indistinct.

Scutellum large, visible from above. Elytra longer than forebody, EL/(HLm+PL)=1.32–1.39, longer than wide, EL/EW=1.54–1.79, with unbordered base, rounded shoulders and narrowed apex; widest about 1/3 from base; lateral margin serrate and ciliate throughout. Disc moderately convex, distinctly depressed at base and along suture. Parascutellar striole absent. 1$^{st}$ stria distinct, 2$^{nd}$ and 3$^{rd}$ faint but traceable; apical striole long and well-marked. Intervals flat, 2$^{nd}$ wider than any other. Basal setigerous pore present, anterior dorsal pore on 3$^{rd}$ stria about 1/6 from base, second pore on 4$^{th}$ stria a little behind middle; preapical pore distinct, inserted at anterior end of apical striole about 1/4 from apex, where 3$^{rd}$ and 4$^{th}$ striae anastomosed. Umbilicate setigerous pores subdivided into subhumeral group (setae 1–4, closely spaced), middle group (setae 5 and 6, widely separated) and preapical group; seta 5 much closer to 4$^{th}$ than to 6$^{th}$, 6$^{th}$ closer to 7$^{th}$ than to 5$^{th}$; distance between 5$^{th}$ and 6$^{th}$ about three times greater than between 5$^{th}$ and 4$^{th}$, preapical pore equidistant from suture and from apex of elytra. Apical stria (Fig. 3a) and an additional, inner, striole (Fig. 3b) rising from preapical pore and forming a crescent combined; this additional striole gently curved inwards behind and not quite reaching stria 1.

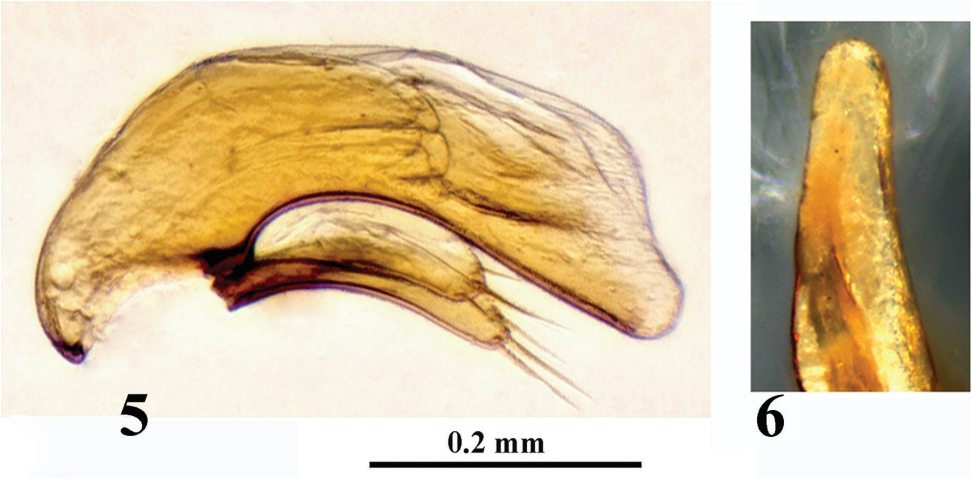
**Figure 2.** *Oodinotrechus* (*Pingleotrechus*) *yinae* subgen. n., sp. n. Habitus, holotype, male (chaetotaxy indicated by small white round points on left part of the body) (photos Xinhui Wang).




**Figures 3–4.** *Oodinotrechus* species, apical part of elytra **3** *O.* (*Pingleotrechus*) *yinae* subgen. n., sp. n. **4** *O.* (*O.*) *liyoubangi* **a** apical stria **b** additional striola.

Protibia straight, without longitudinal external sulcus. Protarsomeres 2–4 nearly moniliform. 1st tarsomere slightly shorter than or as long as, or longer than 2–4th combined in protarsi, mesotarsi, and metatarsi, respectively.

Male genitalia (Figs 5–6): Aedeagus moderately sclerotized; median lobe small, short and stout, moderately arcuated in lateral view; ventral margin deeply concave in median portion, then gently and almost straight towards apex, which is rather broad, not tube-like. Basal portion very large, with a large basal orifice, sagittal aileron absent.




**Figures 5–6.** *Oodinotrechus* (*Pingleotrechus*) *yinae* subgen. n., sp. n., aedeagus **5** median lobe and parameres, lateral view **6** apical lobe of median lobe, dorsal view (photos Xinhui Wang).

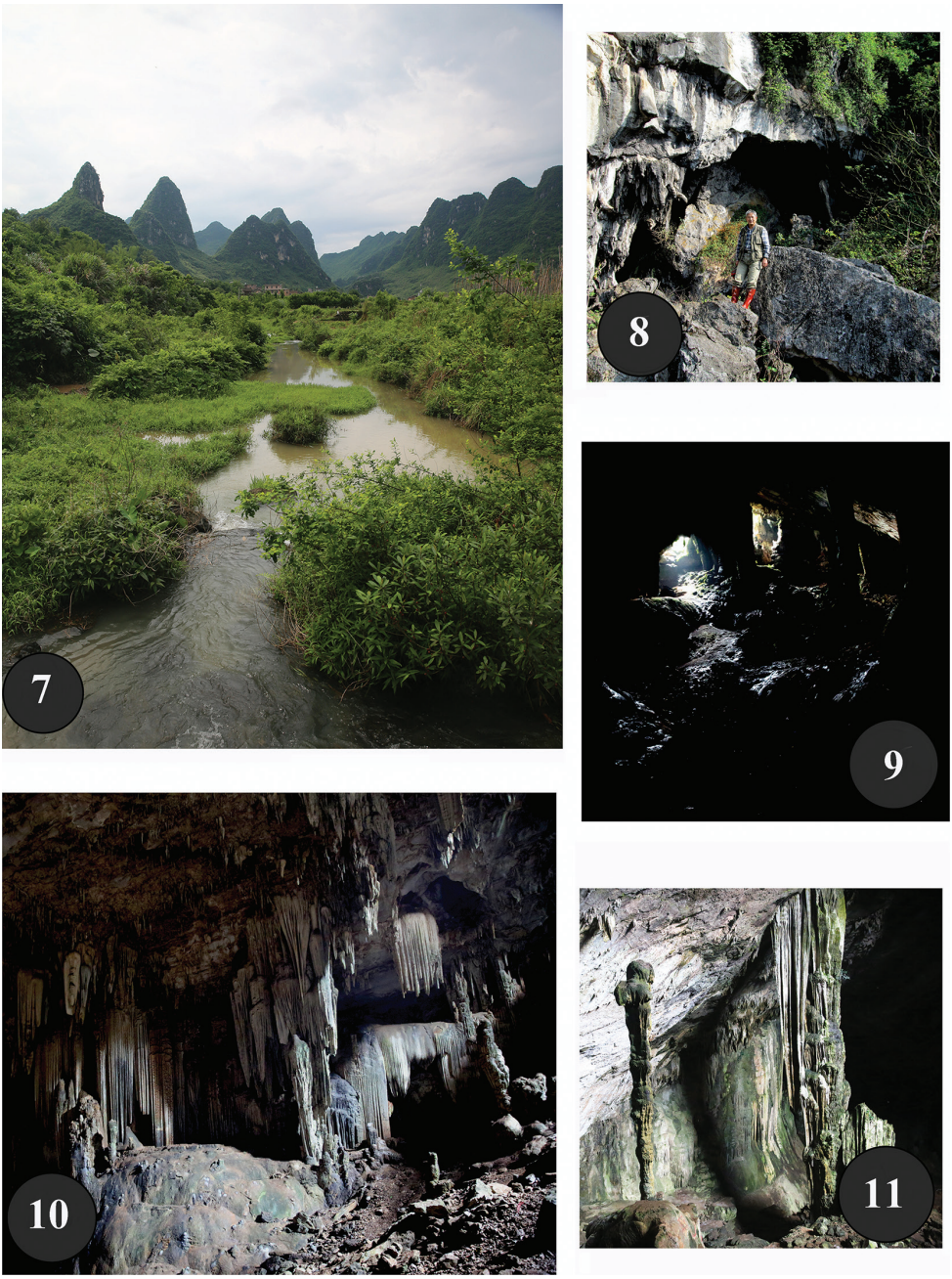
Dorsal orifice wide and long. Inner sac armed with an indistinct copulatory piece, about 1/3 as long as aedeagus. Apical lamella in dorsal view rather long and thin, not parallel-sided, gently narrowed towards apex which is rounded at tip. Parameres short and narrow, right slightly longer than left, both are broadly rounded at apex and bearing three and four long setae, respectively.

**Etymology.** This new species is named in honor of Ms. Haomin Yin, an active member in our cave biological study team.

**Distribution.** Northeastern Guangxi (Fig. 1). Known only from cave Chaotianyan, the type locality. The cave Chaotianyan is located in Letang village (Fig. 7), Ertang, Pingle County, at the southern part of Guilin karst. It opens in a subway of a hill, at about 60 m above foot, with a big entrance (Fig. 8). There is a large hall after the entrance, decorated by different deposits (Figs 9–11). It is a long cave according to the villagers, but detailed information is still not available. The beetles were collected in a dark and wet area under stone, not far from the entrance.

It is an interesting discovery to find an *Oodinotrechus* species in Guilin karst, northeastern Guangxi, because cave Chaotianyan, the type locality of *O. yinae* sp. n. is approximately 300 km away from the Maolan-Mulun karsts in the bordering areas between southernmost Guizhou and northernmost Guangxi where other two species of *Oodinotrechus* are found. However, in the Letang area there is a Fengchong landscape (Fig. 7), rather than Fenglin landscape which is dominant in other parts of the Guilin karst (Zhu 1988).

**Materials examined.** Holotype: male, Guangxi: Guilin: Pingle: Ertang: Letang: cave Chaotianyan, 110°45’501"E / 24°37’075"N, 5-XII-2011, Mingyi Tian, Weixin Liu & Haomin Yin leg, in SCAU. Paratypes: 3 males and 4 females, same data as holotype; 6 males and 4 females, same cave, 29-IV-2013, Mingyi Tian, Weixin Liu, Haomin Yin & Feifei Sun leg. All are deposited in SCAU, except one male paratype in each of IOZ, MNHN and ZUBM, respectively.




**Figures 7–11.** The type locality of the cave Chaotianyan and its surroundings **7** Fongchong landscape in Letang area **8** cave opening **9–11** a hall and deposits inside the cave (photos Mingyi Tian).

**Key to species of the genus *Oodinotrechus* Uéno**

1 Body smaller and slenderer, head slightly expanded laterally; second dorsal pore situated on 4th elytral stria, umbilical setae 5 and 6 widely separated; elytra in apical quarter with a crescent formed by apical striole proper and an additional, inner, striole; aedeagus stouter, without sagittal aileron (*Pingleotrechus* subgen. n.) ..... ***O.* (*P.*) *yinae* sp. n.**

– Body mostly larger and stouter, head distinctly expanded laterally; second dorsal pore situated on 5th elytral interval; umbilical setae 5 and 6 set close to each other; only apical striole present; aedeagus slenderer, with a large sagittal aileron (*Oodinotrechus* (s. str.)) ..... **2**

2 Scutellum at least partly visible from above; basal margin near hind angle nearly straight; apex of the median lobe of aedeagus parallel-sided in dorsal view; both parameres bearing four long setae at apices ..... ***O.* (*O.*) *liyoubangi* Tian**

– Scutellum invisible from above; basal margin near hind angle emarginate, apex of the median lobe of aedeagus slightly expanded and gradually narrowed in dorsal view, parameres each bearing two or three long apical setae ..... ..... ***O.* (*O.*) *kishomotoi* Uéno**

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# Resolution of taxonomic problems in Australian Harpalini, Abacetini, Pterostichini, and Oodini (Coleoptera, Carabidae)

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## Abstract

Taxonomic changes are made for several problematic Australian Carabidae in the tribes Harpalini, Abacetini, Pterostichini, and Oodini. Examination of types resulted in the synonymy of *Veradia* Castelnau, 1867 with L*economerus* Chaudoir, 1850; *Nelidus* Chaudoir, 1878, *Feronista* Moore, 1965, and *Australomasoreus* Baehr, 2007 with *Cerabilia* Castelnau, 1867; and newly combining *Fouquetius variabilis* Straneo, 1960 in the genus *Pediomorphus* Chaudoir, 1878; *Australomasoreus monteithi* Baehr, 2007 in the genus *Cerabilia* Castelnau, 1867; and *Anatrichis lilliputana* W.J. Macleay, 1888 in the genus *Nanodiodes* Bousquet, 1996. *Cuneipectus* Sloane, 1907 is placed in Pterostichini Bonelli, 1810, which is a senior synonym of Cuneipectini Sloane, 1907.

## Keywords

Ground beetles, classification, Australia, New Zealand

## Introduction

In a continuing effort to make the faunal list of Australian carabid beetles as accurate as possible, I sought out and studied type specimens for a number of historically problematic taxa. Results of my study require a number of adjustments to recognized taxa.

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## Methods

Institution codens used here for material examined: Australian National Insect Collection (ANIC) CSIRO, Canberra; Essig Museum of Entomology (EMEC), Berkeley; Museo Civico di Storia Naturale "Giacomo Doria" (MCSN), Genova; Muséum National d'Histoire Naturelle, (MNHN), Paris; Museum of Comparative Zoology (MCZ), Harvard; Naturhistorisches Museum Basel (NMB), Switzerland; Queensland Museum (QM), Brisbane; and Western Australian Museum (WAM), Perth.

## Results and Discussion

### Harpalini Bonelli, 1810

*Lecanomerus* Chaudoir, 1850; type species, *Lecanomerus insidiosus* Chaudoir, 1850.
= *Veradia* Castelnau, F.L. Laporte de, 1867; type species *Veradia brisbanensis* Castelnau, F.L. Laporte de, 1867. **syn. n.**
*Lecanomerus brisbanensis* (Castelnau, 1867). **comb. n.**

**Material examined.** Holotype, male [MCSN]. Type locality Brisbane. A female specimen, "26.49S 151.58E [29°49'S / 151°58'E] Yarraman QLD State F. No. 282, 31 Mar. 1982, R.A. Barrett, M. Lenz, L. Miller"//"Rotten log" [ANIC].

**Notes.** Originally this species was placed by Castelnau (1867) near *Moriodema* Castelnau, 1867, a Moriomorphini taxon, which was then considered to be within Pterostichini. Subsequently it was moved to Harpalini by Chaudoir (1880) and according to Chaudoir it did not differ from *Hypharpax* W.S. Macleay, 1825. Sloane (1898) agreed with the placement in Harpalini, but deferred on the generic assignment and its possible similarity to *Hypharpax*. Straneo (1941) thoroughly reviewed the pertinent literature and studied the type specimen of *Veradia brisbanensis*. He concurred with the placement in Harpalini and suggested there were similarities with *Nemaglossa* Sloane, 1920 (=*Lecanomerus* Chaudoir, 1850, not *Nemaglossa* Solier, 1849), *Euthenarus* Bates, 1874 and *Diaphoromerus* Chaudoir, 1843 (= *Notiobia* (*Anisotarsus*) Chaudoir, 1843). These taxa fall in three different tribes of Harpalini and Straneo pointed out that without access to Australian material for comparison that he could not make a decision regarding the status or relationships of the genus and species. Moore et al. (1987) maintained the genus in Harpalitae incertae sedis, accurately reflecting the uncertainty of the placement of the taxon at that time.

I examined the holotype and confirm that it has typical Harpalini character states, e.g. single supraorbital seta and no elytral plica, and does not have any character states that would place it in any other tribe. Additionally the male has the front and middle tarsomeres expanded with spongy ventral pads, the penultimate labial palpomere is

bisetose, the posterior lateromarginal seta of pronotum is absent and the angular base of stria 1 is absent. This combination of character states is consistent with placement of this taxon in subtribe Pelmatellina and is identical to the state combination found in many Australia *Lecanomerus* species. Based on this evidence, *Veradia* is considered a junior synonym of *Lecanomerus*.

A search in the holdings of the ANIC and QM did not yield any additional specimens of this species beyond the single female, but at least six very similar looking *Lecanomerus* species were found. Each was distinctly different, but all are very likely closely related based on their general similarity. How many of these are currently named species cannot be assessed without recourse to the types.

## Abacetini Chaudoir, 1873

### *Pediomorphus variabilis* (Straneo, 1960), comb. n.

= *Fouquetius variabilis* Straneo, 1960

**Material examined.** Holotype, male [NMB]. Type locality Katherine, Northern Territory. Examined images only.

**Notes.** Straneo (1960) discusses at length his sense that *Holconotus* Schmidt-Goebel, 1846 (= *Fouquetius* Maindron, 1906) and *Pediomoprhus* Chaudoir, 1878 are closely related and that *Pediomorphus macleayi* Sloane, 1900 could be a species of *Holconotus*. Moore (1965) confirmed that *P. macleayi* is a true *Pediomorphus*. Straneo's conclusions are based on very limited material and he did not discuss characters that allow for clear placement of species in these two genera. Among other characteristics, *Pediomorphus* has distinctly expanded penultimate labial palpomeres not found in *Holconotus*, while the elytral lateral bead is distinctly, finely serrate in *Holconotus* and smooth in *Pediomorphus*. The type specimen of *Pediomorphus variabilis* has clearly expanded penultimate labial palpomeres and smooth elytral lateral beads. Given the new combination, *Holconotus* is removed from the Australian faunal list.

## *Cerabilia* Castelnau, 1867

*Cerabilia* Castelnau, 1867; type species, *Cerabilia maori*, Castelnau, F.L. Laporte de, 1867.
= *Zabronothus* Broun 1893; type species, *Zabronothus striatulus* Broun, 1893.
= *Nelidus* Chaudoir, 1878; type species, *Nelidus australis* Chaudoir, 1878. **syn. n.**
= *Australomasoreus* Baehr, 2007; type species, *Australomasoreus monteithi* Baehr, 2007. **syn. n.**
= *Feronista* Moore, 1965; type species, *Feronista amaroides* Moore, 1965. **syn. n.**

***Cerabilia australis* (Chaudoir, 1878), comb. n.**

= *Nelidus australis* Chaudoir, 1878

**Material examined.** Holotype, male [MNHN], type locality given as Paroo River area (QLD or NSW), but probably erroneous. See below.

***Cerabilia monteithi* (Baehr, 2007), comb. n.**

= *Australomasoreus monteithi* Baehr, 2007

**Material examined.** Holotype, male [QM]. Type locality Bulburin State Forest via Many Peaks, Qld. An additional 12 specimens from the type locality [EMEC, QM].

**Notes.** *Cerabilia*, sensu Will (2011) includes Australian species placed in *Feronista* by Moore et al (1987) and *Cerabilia* species from New Zealand and New Caledonia. Baehr (2007) described *Australomasoreus monteithi* as a Masoreini, but he clearly noted that this placement was both anomalous for the species' characteristics and biogeography. Study of the type and additional material for both morphology and DNA data (Will unpubl.) clearly places this species in *Cerabilia*.

*Cerabilia australis* is known only from the holotype specimen and was reported as coming from the Paroo River area. However, this specimen is unlike any Australian species of carabid and is very similar to *Cerabilia* species from New Zealand. It may in fact be a synonym of one of the described New Zealand species, but until their types are studied this cannot be established. The Australian *Cerabilia* species are all restricted to the higher elevation rainforests in the northeastern coastal region. The Paroo River runs through the semi-arid inland region of southwestern Queensland and northwestern New South Wales and is both geographically and environmentally distant from any location where *Cerabilia* has been found in Australia. Likely the type locality was erroneously reported.

**Pterostichini Bonelli, 1810**

**= Cuneipectini Sloane, 1907. Syn. n.**

*Cuneipectus* Sloane, 1907; type species, *Cuneipectus frenchi* Sloane, 1907.

**Material examined.** Holotype, *Cuneipectus frenchi* [ANIC] and three additional specimens [ANIC, MCZ]; ten specimens of *Cuniepectus foveatus* Sloane, 1915 [EMEC].

**Notes.** Sloane described a new tribe for *Cuneipectus* suggesting that it belonged "at the beginning of the Trigonotomid series of the subfamily Harpalinae", i.e. as sister to a group Pterostichini. Subsequent authors have placed it between Harpalini and

Chlaeniini (Csiki 1931), near chaetogenyines, chlaeniines, oodines, and licinines (Callistitae sensu Erwin and Sims (1984) and Erwin (1985, 1991)) in Licininae (Lorenz 2005) in Pterostichitae (Moore et al. 1987) or Pterostichini (Lawrence and Slipinski 2013). Moore (1965) did not include *Cuneipectus* in his treatment of Australian Pterostichinae. Aside from the original description, there has not been a discussion of the characteristics of *Cuneipectus*. Its variable placement, non-inclusion in Moore's (1965) treatment and frequent association with Chlaeniini and Licinini by various authors apparently stems from the species being described as having a single supraorbital setae in combination with the presence of an elytral plica. However, supraorbital seta number is variable, with some individuals having one and others two above each eye. Other characteristics are typical of Australian Pterostichini, including the presence of the spermathecal gland duct diverticulum (sgd) in the female (Liebherr and Will 1998). The sgd is typical in many pterostichines including Australian taxa like *Prosopogmus* Chaudoir, 1865 (Will 2011), *Paranurus* Tshitshérine, 1901 (Liebherr and Will 1998) and *Trichosternus* Chaudoir, 1865 (Will unpubl.). The sgd is not known to be present in any Chlaeniini or Licinini. Additionally, preliminary analyses of DNA data (Will unpubl.) consistently places *Cuneipectus* with Australian Pterostichini. Based on this evidence, *Cuneipectus* is placed in Pterostichini and Cuneipectini is synonymized.

**Oodini LaFerté-Sénectère, 1851**

*Nanodiodes lilliputana* (W.J. Macleay, 1888)
= *Anatrichis lilliputana* W.J. Macleay, 1888

**Material Examined.** Syntypes [ANIC], type locality, King Sound, Western Australia. Additional material in ANIC and WAM examined.

**Notes.** *Nanodiodes* Bousquet, 1996 was proposed by Bousquet (1996) to replace *Nanodes* Habu, 1956 and he moved all species that where included by Moore et al. (1987) in *Anatrichus* LeConte, 1853 into this genus except for *Anatrichis lilliputana*, which Bousquet had not studied. Although some subsequent catalogs (e.g., Lorenz 2005) treated this species as *Nanodiodes lilliputana*, there is no indication that the character states were confirmed. I examined the syntypes and found the following: submentum with pairs of setae at the lateral edge; mesocoxa with a posterior seta and; metatrochanter without a seta. This combination is consistent with *Nanodiodes*, confirming that it shares the putative synapomorphic character states with species currently included in that genus. *Anatrichis* is therefore not found in the Australian fauna.

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material critical to this communication. I also thank Nadine Guthrie, Department of Parks and Wildlife, Western Australia for examining specimens of Oodini and Dr. Eva Sprecher-Uebersax of the Naturhistorisches Museum, Basel for taking and sending images of the type of *Fouquetius variabilis*. I thank Geoff Monteith, Queensland Museum for the extremely helpful suggestions and corrections in his review of the manuscript.

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# Two new species and one new record of *Parakiefferiella* Thienemann, 1936 from China (Diptera, Chironomidae)

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## Abstract

Two new species of the genus *Parakiefferiella* Thienemann, 1936 (*P. fasciata* Liu & Wang, **sp. n.** and *P. liupanensis* Liu & Wang, **sp. n.**) are described as adult males from China. *Parakiefferiella tamatriangulata* Sasa is recorded from China for the first time. A key to the known adult males of *Parakiefferiella* from China is presented. The generic diagnosis of male *Parakiefferiella* given by Cranston et al. (1989) is emended.

## Keywords

Chironomidae, *Parakiefferiella*, new species, key, taxonomy

## Introduction

The genus *Parakiefferiella* was erected by Thienemann in 1936, with *P. coronata* (Edwards, 1929) as type species. According to Cranston et al. (1989), it can be separated from other orthoclad genera by the following combination of characters: eyes bare, without dorsomedial extension; acrostichals absent but scutum with median tuft of microtrichia, sometimes on hump; wing membrane without setae, with fine punctation; squama bare; transverse sternapodeme gently curved, with developed oral projections. Virga strongly developed. Gonostylus with more or less well pronounced curve

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or bend and slight or absent crista dorsalis. Larval stages of the genus are found in both running and standing waters. Adults fly during spring and summer, rarely in large numbers.

The genus is probably quite speciose. Tuiskunen (1986) described four new species and redescribed eight species from Fennoscandian region. Moubayed (1991, 1994) and recently Moubayed-Breil and Langton (2004) described three additional species: *P. pyrenaica* Moubayed, 1991 (France); *P. wuelkeri* Moubayed, 1994 (western Europe and north Africa); *P. normandiana* Moubayed-Breil & Langton, 2004 (France, Germany and England). According to the catalog of Japanese Orthocladiinae (Yamamoto 2004), ten valid species were record in Japan. Nine species were reported in the Russian Far East by Makarchenko and Makarchenko (2010). To date, 44 species of the genus have been recorded worldwide, of which 33 are Palaearctic, seven are Nearctic, three are Oriental, four are Neotropical and four are Afrotropical (Ashe and O'Connor 2012; Ree, Nam and Jeong 2012).

So far, three species of the genus (*P. bathophila* (Kieffer, 1912), *P. coronata* (Edwards, 1929) and *P. tipuliformis* (Tokunaga, 1940)) were recorded in China (Wang 2000). The species *P. tipuliformis* (Tokunaga, 1940) from Taiwan province previously placed in *Spaniotoma* (*Smittia*) by Tokunaga (1940) was transferred to *Parakiefferiella* by Sasa and Kikuchi (1995). The species diagnostic characters fit the genus *Parakiefferiella*. Moreover, *P. coronata* (Edwards, 1929) was recorded just as larval stage (Wang 2000).

Based on specimens from China, two new species are described in this paper, and a key to the species of *Parakiefferiella* in China is provided.

## Materials and methods

Morphology and terminology follow Sæther (1980). The material examined was slide-mounted following the procedures outlined by Sæther (1969). Measurements are given as the range followed by the mean. Color is described as observed in specimen preserved in alcohol. The specimens examined in this study are deposited in the College of Life Sciences, Nankai University, China (BDN).

## Taxonomy

### *Parakiefferiella* Thienemann, 1936

**Emended diagnosis.** Based on the material examined and references, the generic diagnosis of male *Parakiefferiella* (Cranston et al. 1989) must be emended as follows: antenna with 12–13 or occasionally with five (*P. gynocera* (Edwards, 1937)) or ten (*P. fasciata* Liu & Wang, sp. n. and *P. liupanensis* Liu & Wang, sp. n.) flagellomeres; wing anal lobe weakly to moderately developed (*P. bathophila* (Kieffer, 1912)); R and $R_1$ with few setae, occasionally all veins bare (*P. fasciata* Liu & Wang, sp. n. and *P.*

*liupanensis* Liu & Wang, sp. n.); anal point with 2–8 basal setae, sometimes bare (*P. fasciata* Liu & Wang, sp. n.).

***Parakiefferiella fasciata* Liu & Wang, sp. n.**
http://zoobank.org/4FC0DE0C-3F8D-4746-938E-DBD5E5188AB6
Figs 1–7

**Type material.** Holotype: ♂ (BDN. No.1165), China, Shandong Province, Yantai City, Kunyu Mountain, 37°30'10"N, 121°23'40"E, 24.viii.1987, sweeping net, Wang XH. The specimens were sealed with Canada balsam on slides. Paratypes: 3 ♂♂, data as holotype.

**Diagnosis.** The adult male can be distinguished from known species of the genus by the following combination of characters: anal point lacking keel, very broad at base, rounded apically, without basal setae; virga consisting of four spines; antenna with ten flagellomeres, AR 0.47–0.50; tergites III and VIII dark brown, others tergites pale yellow; HR 1.98–2.06; HV 2.65–3.00.

**Description.** Male imago (n = 4). Total length 1.04–1.09, 1.07 mm. Wing length 0.71–0.72, 0.71 mm. Total length/wing length 1.45–1.56, 1.47. Wing length/length of profemur 3.24–3.29, 3.26.

*Coloration.* Head brown. Thorax brown with dark spot. Tergites (Fig. 4) III and VIII dark brown, others tergites pale yellow.

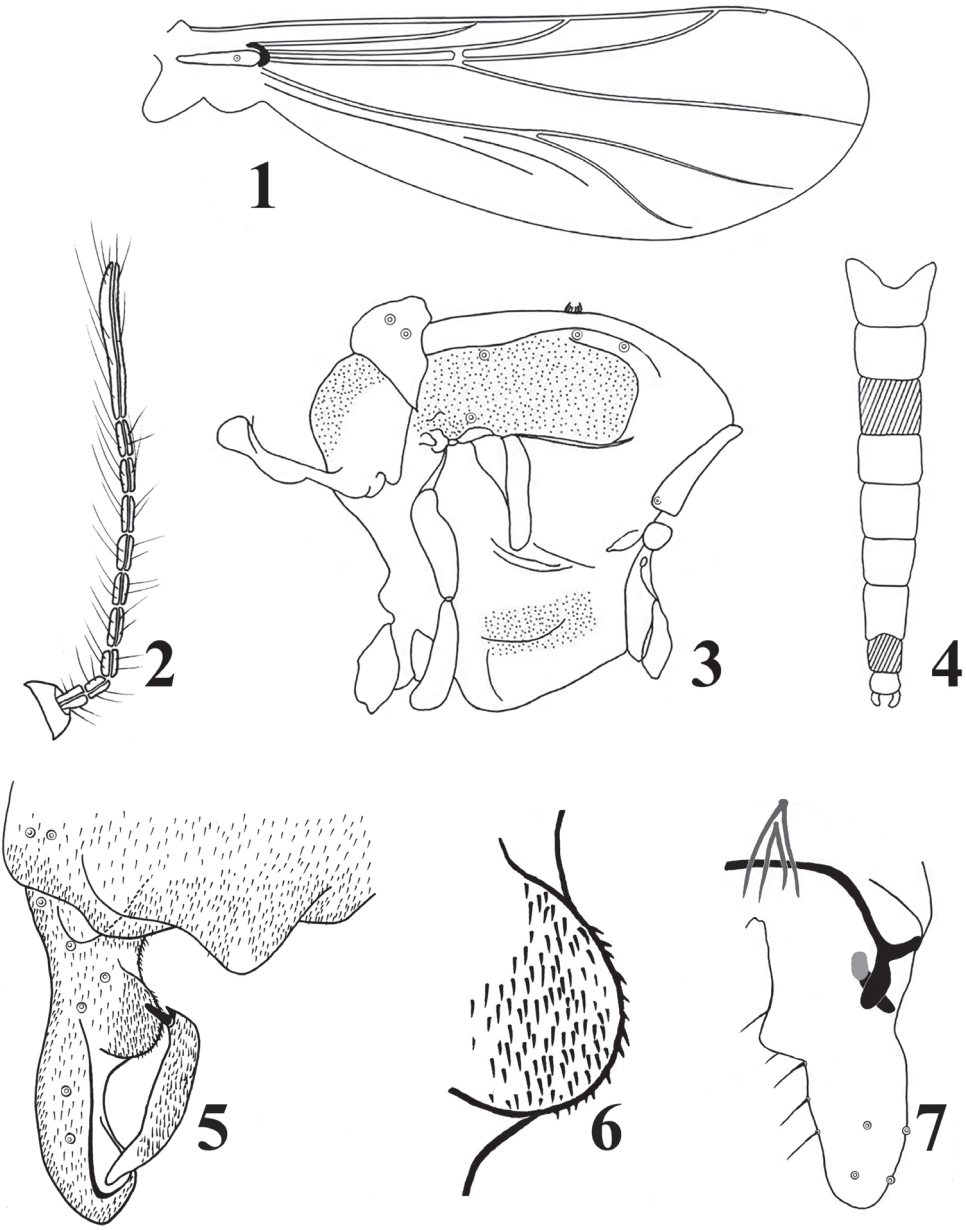
*Head.* Antenna (Fig. 2) with ten flagellomeres. AR 0.47–0.50, 0.49. Ultimate flagellomere 137–144, 140 μm long. Inner vertical 1. Clypeus with four setae. Tentorium 55–72, 66 μm long, 5–7, 6 μm wide. Palpomere lengths (in μm): 10–12, 11; 14–19, 16; 26–29, 28; 43–48, 47; 88–96, 92. L: $5^{th}/3^{rd}$: 3.26–3.55, 3.43

*Wing* (Fig. 1). Anal lobe reduced. VR 1.12–1.21, 1.17. Costal extension 40 μm long. Brachiolum with one seta. All veins bare. Squama bare.

*Thorax* (Fig. 3). Antepronotal lobes developed. Antepronotum with one lateral seta. Dorsocentrals 2–4, 3; one prealars. Scutellum with 2–6, 5 setae. Mesonotum with a tuft of hairs.

*Legs*. Spur of fore tibia 24–25, 24 μm long; spurs of mid tibia 9–12, 11 μm and 12–14, 13 μm long; spurs of hind tibia 9–10, 9 μm and 20–22, 21 μm long. Hind tibial comb with 9–12, 11 spines, 19–38, 30 μm long. Width at apex of fore tibia 17–19, 19 mm, of mid tibia 19–20, 19 mm, of hind tibia 21–24, 23 mm. Lengths (in μm) and proportions of legs as in Table 1.

*Hypopygium* (Figs 5–7). Anal point triangular and hyaline, very broad at base, with rounded apex and without basal seta. Laterosernite IX with 2–4, 3 setae. Phallapodeme 20–24, 23 μm long. Transverse sternapodeme 48–54, 53 μm long. Virga consisting of four spines, 20 –35, 25 μm long. Tergites III and VIII bearing colored bands. Gonocoxite 72–74, 73 μm long, outer margins concave medially. Superior volsella absent; inferior volsella rounded and very large, occupying nearly half of the total length of gonocoxite, lacking dorsal setae and densely covered with microtrichia (Fig. 6); ventral




**Figures 1–7.** *Parakiefferiella fasciata* Liu & Wang, sp. n., male. **1** wing **2** antenna **3** thorax **4** abdomen tergites coloration **5** hypopygium (dorsal view) **6** inferior; **7** hypopygium (ventral view).

margin strongly swollen medially. Gonostylus 36–38, 37 μm long, anterior margin nearly straight, posterior margin slightly curved in dorsal view. Megaseta 5–7, 7 μm long. Crista dorsalis reduced, slightly visible in lateral view. HR 1.98–2.06, 2.01. HV 2.65–3.00, 2.75.

**Table 1.** Lengths (in μm) and proportions of legs of *Parakiefferiella fasciata* Liu & Wang, sp. n. (n = 4)

| | $P_1$ | $P_2$ | $P_3$ |
|---|---|---|---|
| fe | 216–220, 219 | 288–300, 293 | 240–258, 256 |
| ti | 247–264, 254 | 240–249, 243 | 276–282, 278 |
| $ta_1$ | 120–130, 121 | 108–120, 112 | 124–139, 131 |
| $ta_2$ | 57–67, 59 | 57–67, 62 | 60–68, 66 |
| $ta_3$ | 48–52, 49 | 43–48, 47 | 67–76, 71 |
| $ta_4$ | 29–31, 30 | 29–31, 30 | 40–43, 41 |
| $ta_5$ | 31–36, 34 | 30–33, 32 | 33–38, 34 |
| LR | 0.45–0.52, 0.48 | 0.41–0.44, 0.43 | 0.45–0.51, 0.48 |
| BV | 3.33–3.53, 3.43 | 3.61–3.87, 3.73 | 3.07–3.10, 3.09 |
| SV | 3.86–4.00, 3.98 | 4.89–5.00, 4.90 | 3.88–4.13, 4.01 |
| BR | 2.50–2.75, 2.71 | 3.08–3.25, 3.12 | 3.50–3.75, 3.54 |

**Etymology.** The specific name is from Latin *fasciata*, referring to different colored bands in its tergites.

**Remarks.** The new described species is distinguished from all other *Parakiefferiella* species by the following unusual combination of characters: antenna with ten flagellomeres; tergites III and VIII with colored bands; anal point lacking both dorsal setae and keel; absence of dorsal setae on inferior volsella, which is bearing only microtrichia.

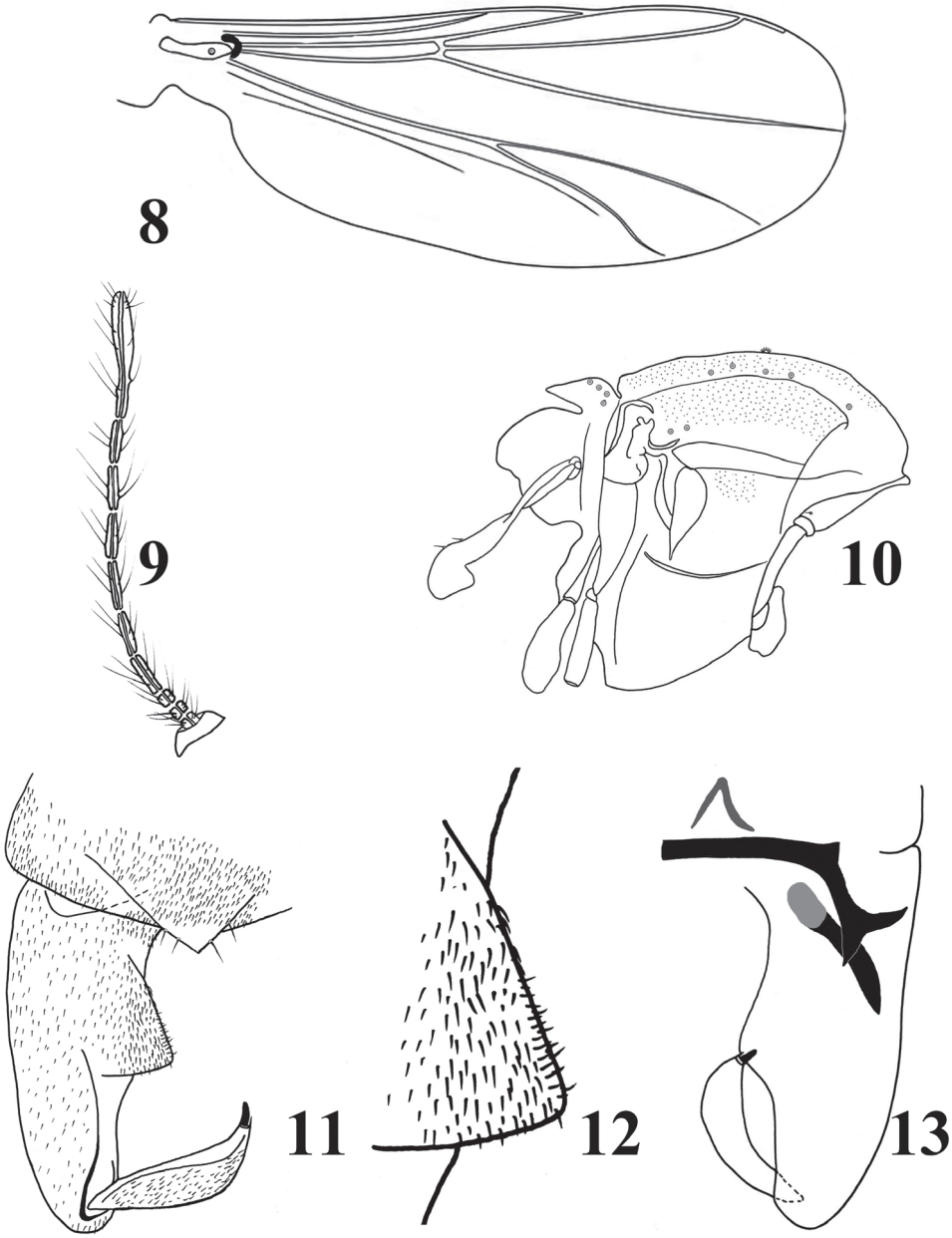
While the new species close related to *P. coronata* (Edwards, 1929; Makarchenko and Makarchenko 2010). However, the new species differs from the latter on the basis of following characters: (1) the antenna of the new species with ten flagellomeres, whereas *P. coronata* has 13 flagellomeres; (2) the superior volsella of *P. coronata* is large, whereas in the new species it is absent; (3) the new species has abdomen pale yellow with tergites III-VIII dark brown, whereas *P. coronata* has abdomen dark with tergites IV, VI-VII shiny.

Female and immature stages unknown.

***Parakiefferiella liupanensis* Liu & Wang, sp. n.**
http://zoobank.org/816E951D-6283-4643-9640-C9EDC141A97E
Figs 8–13

**Type material.** Holotype: ♂ (BDN. No.1168), China, Ningxia Hui Autonomous Region, Liupan Mountain, Erlong river, 35°38'40"N, 106°31'40"E, 6.viii.1987, sweeping method, Wang XH. Paratypes: 4 ♂♂, as holotype.

**Diagnosis.** The adult male can be distinguished from known species of the genus by the following combination of characters: anal point obtuse triangular with pointed and hyaline apex, lacking keel and bearing four setae placed laterally (two on each side); antenna with ten flagellomeres; all of the veins bare; inferior volsella square with




**Figures 8–13.** *Parakiefferiella liupanensis* Liu & Wang, sp. n., male. **8** wing **9** antenna **10** thorax **11** hypopygium (dorsal view) **12** inferior **13** hypopygium (ventral view).

rounded inner margin, not projected, occupying about half of the gonocoxite length, lacking dorsal setae and covered with microtrichia; ventral margin swollen medially; AR 0.33–0.37; HR 2.20–2.28; HV 2.36–2.43.

**Description.** Male imago (n = 5). Total length 1.20–1.25, 1.23 mm. Wing length 0.78–0.85, 0.81 mm. Total length/wing length 1.45–1.47, 1.46. Wing length/length of profemur 3.38–3.58, 3.45.

*Coloration of preserved specimens.* Head and tergites brown. Thorax brown with dark spot.

*Head.* Antenna (Fig. 9) with ten flagellomeres. AR 0.33–0.37. Ultimate flagellomere 108–115, 112 μm long. Temporal seta one, including one outer vertical. Clypeus with 3–4 setae. Tentorium 62–72, 69 μm long, 7–9, 8 μm wide. Palpomere lengths (in μm): 12–14, 13; 24–26, 25; 28–34, 31; 28–36,32; 52–54, 53. L: $5^{th}/3^{rd}$: 1.61–1.83, 1.81.

*Wing* (Fig. 8). Anal lobe moderate reduced. VR 1.02–1.18, 1.14. Costal extension 40 μm long. Brachiolum with one seta. All of the veins bare. Squama bare.

*Thorax* (Fig. 10). Antepronotal lobes developed. Antepronotum with one lateral seta. Dorsocentrals 5–7, 6; acrostichals absent; two prealars. Scutellum with four setae. Mesonotum with a tuft of hairs.

*Legs*. Spur of fore tibia 12–21, 18 μm long; spurs of mid tibia 9–12, 11 μm and 12–14, 13 μm long; spurs of hind tibia 9–10, 9 μm and 20–22, 21 μm long. Hind tibial comb with 9–12, 10 spines, 19–38, 23 μm long. Width at apex of fore tibia 19–22, 20 mm, of mid tibia 12–22, 17 mm, of hind tibia 18–22, 21 mm. Lengths (in μm) and proportions of legs as in Table 2.

*Hypopygium* (Figs 11–13). Anal point obtuse triangular with pointed and hyaline apex, lacking keel and bearing 4 setae placed laterally (2 on each side). Laterosernite IX with 2–4, 3 setae. Phallapodeme 19–21, 20 μm long. Transverse sternapodeme, straight 44–48, 46 μm long. Virga consisting of two spines, 20 –25, 23 μm long. Gonocoxite 79–82, 80 μm long. Superior volsella absent; inferior volsella square, occupying about half of the gonocoxite length, lacking dorsal setae and covered with microtrichia (Fig. 12); ventral margin swollen medially. Gonostylus 36–38, 37 μm long, narrowed apically, distinctly bent and curved inward in dorsal view; crista dorsal

**Table 2.** Lengths (in μm) and proportions of legs of *Parakiefferiella liupanensis* Liu & Wang, sp. n. (n = 5)

| | $P_1$ | $P_2$ | $P_3$ |
|---|---|---|---|
| fe | 236–242, 239 | 264–272, 268 | 239–248, 241 |
| ti | 288–302, 298 | 216–241, 232 | 252–272, 265 |
| $ta_1$ | 141–153, 145 | 108–120, 109 | 132–137, 136 |
| $ta_2$ | 98–116, 111 | 60–64, 63 | 72–80, 74 |
| $ta_3$ | 72–76, 74 | 50–54, 52 | 74–79, 76 |
| $ta_4$ | 36–40, 38 | 26–31, 29 | 36–48, 43 |
| $ta_5$ | 31–36, 34 | 30–33, 31 | 33–38, 36 |
| LR | 0.49–0.53, 0.51 | 0.45–0.50, 0.49 | 0.48–0.52, 0.50 |
| BV | 2.62–2.72, 2. 65 | 3.61–3.66, 3.63 | 2.85–2.89, 2.87 |
| SV | 3.50–3.66, 3.61 | 4.69–4.77, 4.71 | 3.73–3.84, 3.79 |
| BR | 1.25–1.75, 1.50 | 2.50–2.75, 2.60 | 3.40–3.75, 3.60 |

absent. Megaseta 5–7, 7 μm long. Without crista dorsalis. HR 2.20–2.28, 2.23. HV 2.36–2.43, 2.41.

**Etymology.** The specific name refers to the Liupan Mountain where the species was collected.

**Remarks.** The new species can easily be separated from other related *Parakiefferiella* species by the following characters: antenna with 10 segments; anal point square, lacking keel and bearing four setae laterally; inferior volsella without dorsal setae and covered with microtrichia.

*P. liupanensis* Liu & Wang, sp. n. is closely related to *P. bathophila* (Kiffer, 1912). However, the new species differs from the latter on the basis of the following characters: (1) the antenna of the new species with ten flagellomeres, whereas *P. bathophila* possesses 13 flagellomeres; (2) the hypopygium of *P. bathophila* with triangular superior volsella, whereas in the new species it is absent; (3) the anal point of the new species obtuse triangular, not tapered apically, whereas *P. bathophila* gradually tapered to apex; (4) the shape of inferior volsella in the new species square, without dorsal setae, whereas *P. bathophila* triangular, with dorsal setae.

Female and immature stages unknown.

### *Parakiefferiella tamatriangulata* Sasa,1981

*Parakiefferiella tamatriangulata* Sasa, 1981: 94; Sasa and Arakawa 1994: 99.

**Specimens examined.** 1 ♂, Liaoning Province, Dandong City, Fengcheng County, 40°51'00"N, 124°07'00"E, 25.iv. 1992, Sweeping net, Wang JC.

**Diagnostic characters.** Total length 2.06–2.29 mm. Wing length 1.02–1.37 mm. AR 0.38–0.53. Anal lobe reduced. Laterosernite IX with five setae. Phallapodeme 36–38μm long. Transverse sternapodeme 74–81 μm long. Anal point small, triangular and with pointed apex, bare and hyaline excepting the basal portion with microtrichia. Inferior volsella semicircular, bearing dorsal setae. Gonostylus 6 μm long, narrowed apically, distinctly bent and curved inward in dorsal view. Megaseta 10 μm long. HR 2.18. HV 1.56.

**Remarks.** The Chinese specimens mainly agree with the original description by Sasa (1981), but they have higher AR (0.53) than the specimens from Japan (0.38–0.48).

**Distribution.** China (Palaearctic China: Liaoning Province), Japan.

### Key to known adult males of the genus *Parakiefferiella* in China

1 Tergites banded ..... **2**
– Tergites unicolor..... **3**
2 Tergites III and VIII dark brown, others pale yellow; all veins bare..... ..... ***P. fasciata*** **Liu & Wang, sp. n.**

– All tergites with a narrow dark band on caudal margin; veins very delicate and colorless ..... ***P. tipuliformis*** **(Tokunaga)**

3 Antenna with 13 flagellomeres; inferior volsella triangular or semicircular, bearing dorsal setae ..... **4**

– Antenna with 10 flagellomeres; inferior volsella square lacking dorsal setae... ..... ***P. liupanensis*** **Liu & Wang, sp. n.**

4 Anal lobe developed; inferior volsella large, roughly triangular..... ..... ***P. bathophila*** **(Kieffer)**

– Anal lobe reduced; inferior volsella semicircular..... ***P. tamatriangulata*** **Sasa**

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# Musculature of the male genitalia in *Rivellia* (Diptera: Platystomatidae)

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## Abstract

The musculature of male genitalia was studied hitherto only in two species of Tephritidae, one species of Platystomatidae, one species of Pallopteridae, and three species of Ulidiidae of the superfamily Tephritoidea. The split of the hypandrium from one structure into three (the hypandrium and two lateral sclerites) is traced. The hypandrial origin of the lateral sclerites of the hypandrial complex is shown based on the localization of muscle attachment sites. The subepandrial origin of the inner lobes of the surstyli is also confirmed.

## Keywords

Tephritoidea, Platystomatidae, male genitalia, sclerites, musculature, body size

## Introduction

The signal flies (Tephritoidea: Platystomatidae) include nearly 1300 described species of more than 120 genera occurring predominantly in the Paleotropics, with a few genera and species in the Holarctic and Neotropic regions (V.A.Korneyev, unpublished

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data). They are a sister group to the Pyrgotidae + Tephritidae lineage, sharing with them numerous synapomorphies, including the structures of male genitalia, such as the phallus stored in rest in a membranous pocket under the 5th tergite of abdomen, glans clearly separated from the remaining part of distiphallus, lateral (outer) surstyli fused to epandrium, phallapodeme and adjusting structures of hypandrium forming a "fultella", etc. (Korneyev 1999).

The male postabdomen in Platystomatidae consists of modified segments 6–8 (pregenutal segments) and derivatives of segments 9–11 forming the genitalia and cerci. In the superfamily Tephritoidea, the musculature of the male genitalia has been studied in representatives, shown in Table 1.

**Table 1.** Representatives of the superfamily Tephritoidea, in which the musculature of the male genitalia has been studied.

| Species | Family | Reference |
|---|---|---|
| *Ceratitis capitata* (Wiedemann, 1824) | Tephritidae | Hanna (1938), Valdez-Carrasco and Prado-Beltran (1990) |
| *Campiglossa hirayamae* (Matsumura, 1916) | Tephritidae | Sueyoshi (2006) |
| *Rivellia basilaris* (Wiedemann, 1830) | Platystomatidae | Sueyoshi (2006) |
| *Temnosira trichaeta* Ozerov, 1993 | Pallopteridae | Sueyoshi (2006) |
| *Timia erythrocephala* Wiedemann, 1824 | Ulidiidae | Galinskaya and Ovtshinnikova (2015) |
| *Ulidia ruficeps* Becker, 1913 | Ulidiidae | Galinskaya and Ovtshinnikova (2015) |
| *Physiphora alceae* (Preyssler, 1791) | Ulidiidae | Galinskaya and Ovtshinnikova (2015) |

There are different views on the homology of some genital sclerites in the superfamily Tephritoidea. Different terminology is therefore used for some structures in a few cases, where morphology of Platystomatidae genitalia is considered: outer and inner surstyli (McAlpine 1973, 1999) or **lateral and medial surstyli** (White et al. 1999, Korneyev 2001); **lateral sclerites of hypandrium** (McAlpine 1973, White et al. 1999), gonites and vanes of fultella (Korneyev 1987), gonocoxites and vanes of phallapodeme (Korneyev 1999); decasternum or 10th sternite (Korneyev 1987), ventral plate of proctiger, derivate of 10th sternum (Ovtshinnikova 1989, 1994, 2000), **subepandrial sclerite** (Cumming et al. 1995) etc. Here, we provisionally follow terminology of White et al. (1999), with some reservations.

Study of the musculature is helpful not only in specifying the functions of genital sclerites, but also for revealing homology of some poorly traced structures (Ovtshinnikova 1989, 1993, Ovtshinnikova and Yeates 1998; Galinskaya and Ovtshinnikova 2015). Recently, the musculature of the male genitalia was described for three species of the tribe Ulidiini (Galinskaya and Ovtshinnikova 2015) of the family Ulidiidae, which is a basal group to Platystomatidae + Pyrgotidae + Tephritidae lineage (Korneyev 1999).

In this paper, the musculature of male genitalia is described in *Rivellia* (Platystomatidae), continuing comparative study of morphology of the Tephritoidea.

## Methods

The terminology of the genital sclerites mainly follows White et al. (1999), Kameneva (2000), Galinskaya (2012), and Sinclair (2000).

Musculature of the male genitalia was studied by manually dissecting material (preserved fresh in 70% alcohol) with microknives in water under a Leica MZ9[5] stereomicroscope. The illustrations were obtained using the image capture function of the Leica MZ9[5] trinocular head and subsequently processed.

The male genital muscles of Tephritoidea were classified into several groups: muscles of the epandrial complex, muscles of the hypandrial complex, tergosternal muscles, and pregenital muscles. The muscles are designated by numbers following the classification previously accepted by Ovtshinnikova (1989).

List of abbreviations: **cerc** – cerci; **epand** – epandrium; **bph** – basiphallus; h**ypd** – hypandrium; **l scl** – lateral sclerite of hypandrium; **l sur** – lateral surstylus; **m sur** – median surstylus; **phapod** – phallapodeme; **sbepand scl** – subepandrial sclerite; **sec scl** – secondary sclerotisation of hypandrial membrane; **sur** – surstylus; **8 stgst** – 8 syntergosternite; **M1–M19** – muscles.

## Results

### Platystomatidae
### General plan of male genitalia

Male genitalia are similar to those in Tephritidae: hypandrium U-shaped, with membranous fold posterior of basiphallus, but without epiphallus, metaphallic plate, or a sclerotized bridge connecting posteromedial cornu of hypandrium; phallapodeme firmly fused to paired sclerotized bars, forming V- or Y-shaped "fultella" (term of Griffiths 1972), flexibly joined to the paired bar-like sclerites called "lateral sclerites of hypandrium" (McAlpine 1973) posteriorly fused to hypandrium and laterally connected to hypandrium by membrane; they are sometimes considered to be walls of modified, rudimentary gonites (Korneyev 1987) or gonocoxites (Korneyev 1999); in *Rivellia*, the left sclerite is completely fused with hypandrium (Korneyev 1985, Sueyoshi 2006), whereas in genera related to *Platystoma*, and in a few examined Scholastinae and Plastotephritinae both sclerites are symmetrical and free anteriorly (Korneyev 1985, 2001, Whittington 2003) membranous bottom of hypandrium allied to basiphallus in most "Higher Tephritoidea," including Platystomatidae usually with a pair of small rounded sclerites (bearing fields of 8 trichoid mechanoreceptive sensilla), sometimes considered to be rudiments of parameres (Korneyev 1987) or gonopodites (Korneyev 1999). Epandrium dorsally setose, with lateral (or outer) surstyli fused to it without a seam, and connected either anteroventrally (Scholastinae, Plastotephritinae, *Rivellia* and related genera – see McAlpine 1973, Korneyev 1985, Hara 1989, Whittington 2003, Sueyoshi 2006, Galinskaya and Shatalkin 2013) or posteroventrally (*Platystoma*

and related genera – see Hara 1987, Korneyev 2001). Ventrally of epandrium, a V-, X-, or H-like sclerite, the subepandrial sclerite (Cumming et al. 1995), sometimes referred as 10th sternite or decasternum (e.g., Korneyev 1987) or, in its medial part, as "plate-like", "transverse" or "bacilliform sclerite" (Sueyoshi 2006) is located between the hypandrium and cerci; Ovtshinnikova (1989, 1994) considered this sclerite to be a possible derivative of 10th sternum and Cumming et al. (1995) considered this sclerite to be a possible derivative of sclerotized intersegmental membrane of the 10th sternum. Its posterolateral lobes often form a pair of finger-like projections, called medial (inner) surstyli, bearing setae, including pair or subapical, dentate, thickened prensisetae; in Scholastinae and Plastotephritinae inner surstylus usually short, with prensisetae basal, whereas in most Platystomatinae, including *Platystoma*, *Rivellia* and related genera, the prenisetae are subapical, closer to apex of lateral surstylus (McAlpine 1973, Hara 1989, Korneyev 2001). Phallus consists of a basal ring-like, sclerotized basiphallus, flexibly joined to paired posterior arms of the phallapodeme, and a long tubular and coiled distiphallus, apically bearing a clearly expressed glans, well separated by a fold. Cerci usually large and apically widened (see McAlpine 1973, Korneyev 2001, Galinskaya and Shatalkin 2013)[1].

## Musculature of the male genitalia

### *Rivellia alini* Enderlein, 1937

**Material.** 3 males: Russia, Primorsky Krai, Ussuri District, Kamenushka, 4 August 2013 (T.V. Galinskaya).

**Description.** Lateral sclerite of hypandrium separated from hypandrium at right side; left sclerite completely fused with hypandrium. Subepandrial sclerite consisting of the elongate bifurcated medial part and elongate postero-lateral lobes. Lateral surstylus long, apically curved. Cerci paired, long, sclerotized, ventrally connected to subepandrial sclerite (Figure 1).

Platystomatidae have same set of muscles as in Ulidiidae, differing from them by the degree of development, shape, and their attachment sites (Figures 2, 3).

Muscles of the hypandrial complex: *M1*, *M2*, and *M23*. Strong, wide, and short phallapodeme retractors *M1* connect the anterior part of hypandrium with grooves on the Y-shaped phallapodeme arms. Strong, wide, and long phallapodeme protractors *M2* are attached to the distal half of the lateral surfaces of the unpaired phallapodeme lobe and to the inner surface of hypandrium at left and to the lateral sclerite at right side.

Ejaculator compressors *M23* strong and long, surrounding ejaculator apodeme. Their contraction pumps semen into the phallus.

Tergosternal muscles. Tergosternal muscles *M5* long, fan-shaped, connecting lateral parts of the epandrium anterior margin with lateral parts of anterior margin of

1 The short characteristic of genital structures was kindly compiled by Valery A. Korneyev.

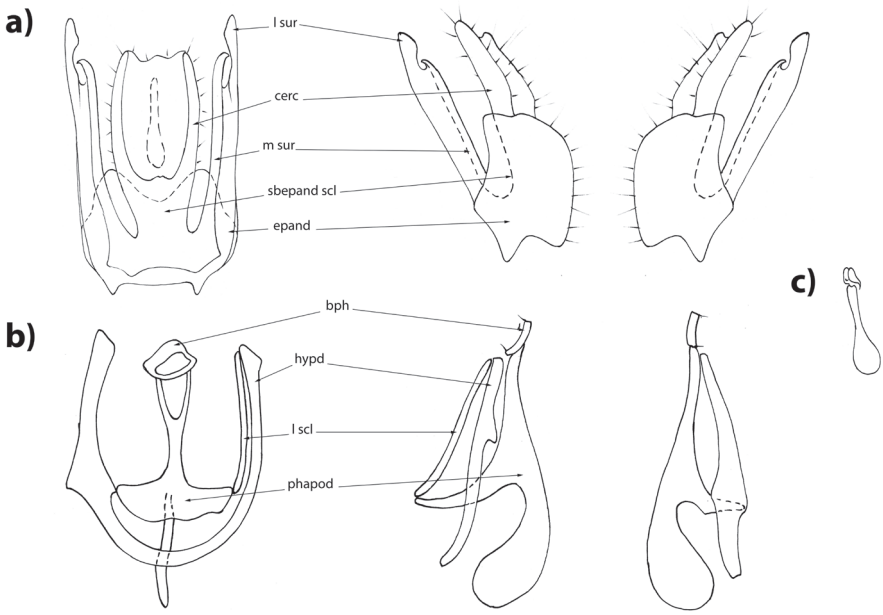


**Figure 1.** Male genitalia of *Rivellia alini* Enderlein, 1937. **a** epandrium in ventral, right lateral and left lateral views **b** hypandrium in dorsal, right lateral and left lateral views **c** ejaculatory apodeme.

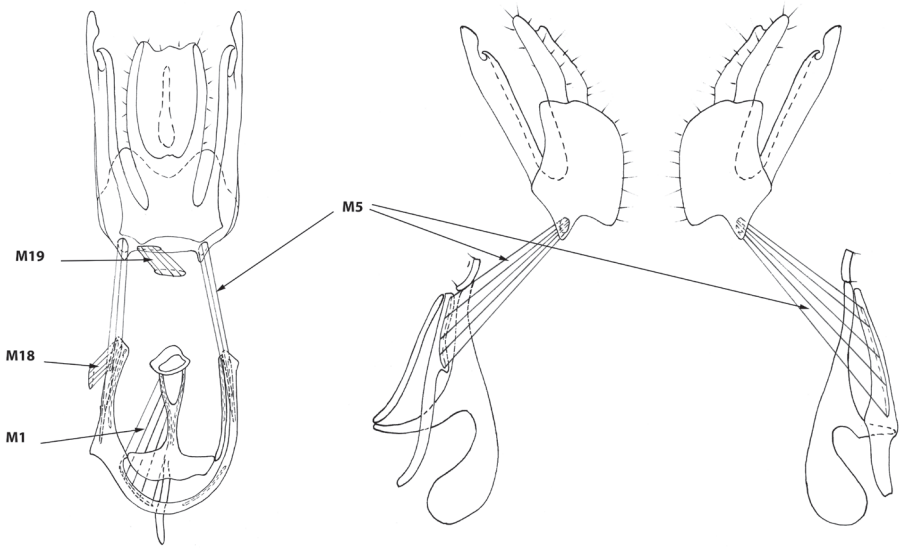


**Figure 2.** Male genitalia of *Rivellia alini* Enderlein, 1937. Epandrium and hypandrium in inner, right lateral and left lateral views.

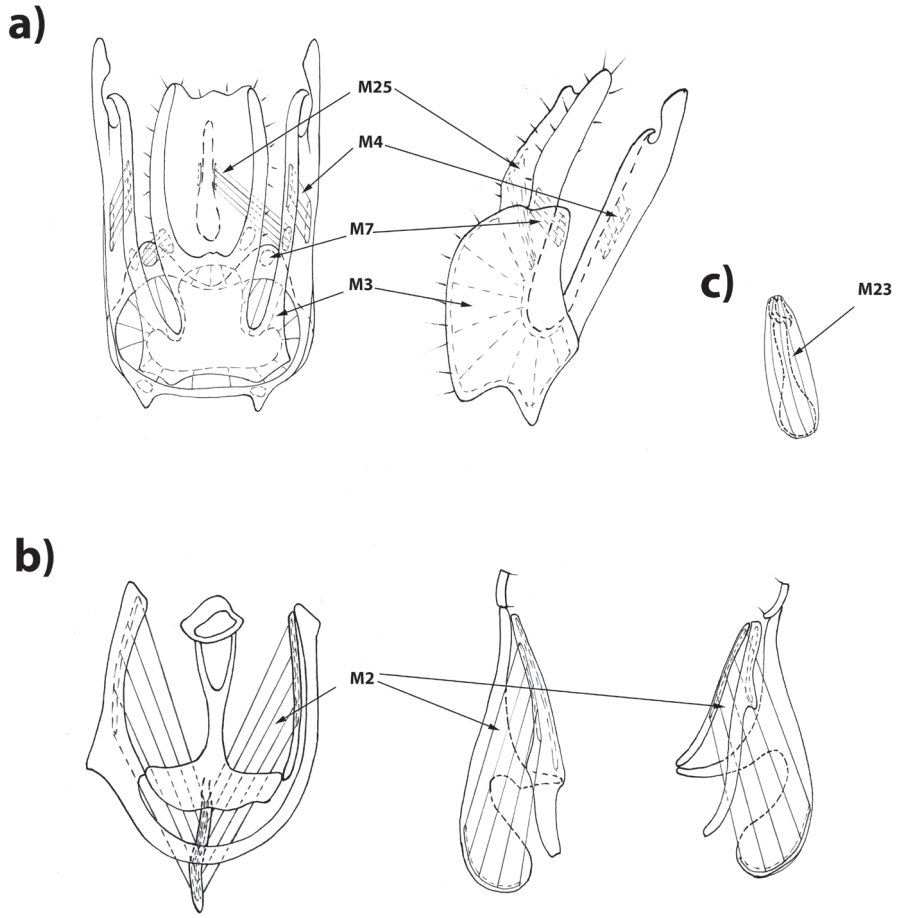


**Figure 3.** Male genitalia of *Rivellia alini* Enderlein, 1937. **a** epandrium in ventral and left lateral views **b** hypandrium in dorsal, left lateral and right lateral views **c** ejaculatory apodeme.

hypandrium (in contrast to Ulidiidae, in which these muscles are attached to the distal margin of the hypandrium). These muscles draw hypandrium to epandrium. During copulation, epandrium clasps female's ovipositor while the hypandrium is retracted into the male's abdomen by contraction of these muscles.

Muscles of the epandrial complex: *M3*, *M4*, *M7,* and *M25*.

Subepandrial sclerite adductors *M3* strong, connecting the inner surface of the epandrium (occupying a considerable part of it) to the inner surface of anterior part of the subepandrial sclerite as a wide bundle.

Adductors of surstyli *M4* short, fine, poorly visible, extending from the middle of long posterolateral lobe of the subepandrial sclerite (medial surstyli) to the middle of lateral part of at inner surface of the (lateral) surstylus.

Cercus retractors *M7* short, fine, extending from the inner surface of the basal part of the epandrium to the basal cercal lobes.

The long and fine poorly visible retractors of anal integument *M25* connect the median part of medial surstyli with the basal part of the rectum.

Pregenital muscles: *M18*[2] and *M19*. The unpaired adductor of the hypandrium *M18*[2] extends from the distal part of syntergosternite 8 to the left hypandrial arm. The strong fan-shaped unpaired epandrial retractor *M19* obliquely extends from the distal part of syntergosternite 8 to the left part of the basal margin of the epandrium.

## Discussion and Conclusions

Our results were compared with musculature of male genitalia of *Rivellia basilaris* (Wiedemann, 1830) studied by Sueyoshi (2006). In this species he studied muscles of epandrial complex and tergosternal muscles and revealed three pair of muscles: *M42+43* (=*M4* sensu Ovtshinnikova), *M31* (=*M3*), *M34* (=*M5*). We confirmed his results and expanded the area of the study.

Comparisons of descriptions revealed homologies and the following correspondence between numbers of homologous muscles (Galinskaya and Ovtshinnikova 2014) (Table 2).

**Table 2.** Homologous muscles of Tephritoidea from different articles.

| Number of muscle in current research | Numbers of homologous muscles | Muscle complex |
|---|---|---|
| *M1* | *MUS1* (Hanna 1938) and *M41* (Sueyoshi 2006) | Hypandrial complex |
| *M2* | *MUS2* (Hanna 1938) and *M35–37* (Sueyoshi 2006) | Hypandrial complex |
| *M23* | *MUS* (Hanna 1938) | Hypandrial complex |
| *M5* | *M34* (Sueyoshi 2006) | Tergosternal complex |
| *M3* | *M31* (Sueyoshi 2006) | Epandrial complex |
| *M4* | *M42+43* and *M44* (Sueyoshi 2006) | Epandrial complex |
| *M7* | *MC* (Sueyoshi 2006) | Epandrial complex |

Analysis of the attachment sites of muscles has shown that in all studied families paired phallapodeme muscles *M2* are attached with one end to the distal half of the lateral surface of the unpaired lobe of phallapodeme, and with the other end it is attached either to the the inner surface of the hypandrial arms (in Ulidiidae; only on the left side, in *Rivellia* ); they are attached to the lateral sclerites in some Tephritidae and (only on the right side) in *Rivellia*. Thus, the attachment of *M2* muscles to the lateral sclerites confirms their hypandrial origin.

It can be noted that the attachment sites of the subepandrial sclerite adductors *M3* and surstyli adductors *M4* are constant and these muscles are thus clearly distinguished

from each other. These muscles are synergistic, and when they contract during copulation, the surstyli grasp and hold the female ovipositor, as they do in most other cyclorrhaphan flies, including those considerably different in the structure of the surstyli and subepandrial sclerite.

Comparative analysis shows that studied *Rivellia* displays similar sets of muscles of the male genitalia, close to the plan of structure fundamental for Cyclorrhapha, possibly as a result of reduction of or lacking some of the muscles (Ovtshinnikova 1989), and differs from this fundamental plan in the split of muscle *M3–4* into two pairs and presence of muscles of the anal integument *M25,* which is also typical of the family Syrphidae. We have also noted asymmetry in the muscles of genitalia.

In this paper we confirmed the hypandrial origin of lateral sclerite and or medial surstylus is a lobe derived from the bacilliform sclerite.

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